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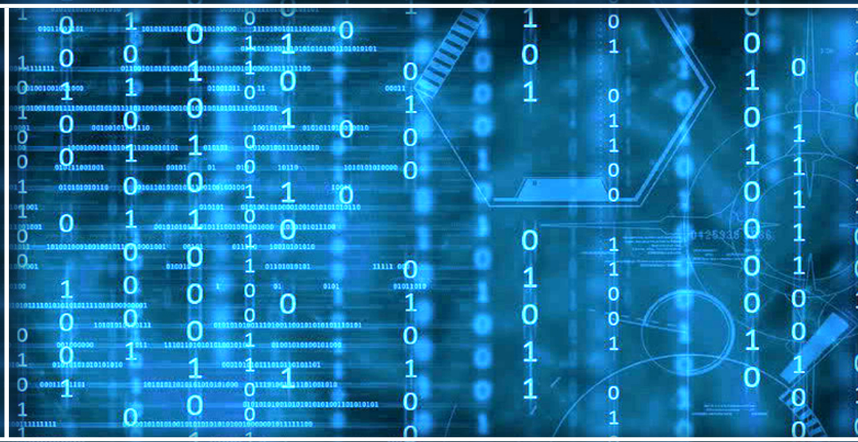

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Editorial Preface

From the Desk of Managing Editor…

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

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

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

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

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

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

Thank you for Sharing Wisdom!

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Teaching Software Testing using Data Structures

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***Abstract*—Software testing is typically a rushed and neglected activity that is done at the final stages of software development. In particular, most students tend to test their programs manually and very seldom perform adequate testing. In this paper, two basic data structures are utilized to highlight the importance of writing effective test cases by testing their fundamental properties. The paper also includes performance testing at the unit level, of a classic recursive problem called the Towers of Hanoi. This teaching approach accomplishes two important pedagogical objectives: (1) it allows students to think about how to find hidden bugs and defects in their programs and (2) it encourages them to test more effectively by leveraging data structures that are already familiar to them.**

Keywords*—Software Testing; Data Structures; Abstract Data Type (ADT); Unit Testing; Performance Testing; Stacks; Binary Search Tree; Towers of Hanoi

I. Introduction

In general, software testing is a hugely neglected area in the software development life cycle. This is evident in students' approach to testing. Students often perform very little testing to find bugs or defects in their software projects. Even though these projects are group oriented, consisting of at least two members, testing is rarely ever an automated, planned or systematic activity. Inadequate testing is a major issue in the software development field and bugs and defects account for huge losses and rework when testing is neglected. At the course level, it is important to motivate students to take a responsible approach to software development by integrating proper testing with the aim of finding and correcting bugs and errors.

Data Structures [8] is a common course that is offered in most Computer Science, Computer Engineering and Software Engineering degree programs. However, software testing is not always a required course. The idea behind testing may seem simple to most students. However, in general, students only manually test their programs using inputs they know will always produce a correct output, instead of trying to break, find bugs or flaws in the logic of their programs [1,2,3,4,]. This phenomenon is known as confirmation bias [3] in software testing. It may be due to the fact that, finding bugs or defects, means that they will need to spend more time to optimize their programs, and time is something students are typically short of.

One of the goals of this paper is to share a relatable teaching approach that will enable students to write automated tests by considering the fundamental properties and constraints of a problem. It introduces a straight forward approach to unit testing by utilizing common data structures that are often used in programming and software development. By using data structures, along with well-known problems that are introduced earlier in the curriculum or in a prerequisite course, students can seamlessly learn the principles and application of software testing without the added burden of learning new unfamiliar content. The rest of the paper is organized as follows. Section 2 presents a fundamental overview of Stacks and Binary Trees. Section 3 explains how to test the fundamental properties and constraints of a stack, and binary search tree. Section 4 presents the Towers of Hanoi which is a classic recursive problem to illustrate performance testing at the unit level. Section 5 concludes, after discussing future work.

II. Using Data Structures for Software Testing

As stated earlier, software testing is not always a required course in most degree programs. However, it is a fundamental aspect of software development and is typically introduced briefly in the later stages of most Software Engineering courses.

Often times, students become overwhelmed with the software testing tools they need to learn to conduct automated testing. They often struggle with the concept of testing to find bugs rather than just testing to show that their software is operating perfect on a given set of inputs. To address this issue, a wide variety of software testing problems are given to students, and it becomes immediately apparent that they do not quite understand the fundamental properties or dynamics of testing to find bugs. A natural approach is to utilize Abstract Data Types (ADT) to teach them this type of testing [8].

Abstract Data Types [8] are taught in Data Structures, and most students learn about ADTs in the previous semesters to aid and develop their programming skillset and knowledge. It, therefore, makes perfect sense to utilize ADTs in teaching software testing, because doing so provides continuity and allows students to concentrate more on learning and applying testing principles.

Stacks are a last-in-first-out (LIFO) data structure. This fundamental property is easy for students to understand and test. In a stack, the element which is placed (inserted or added) last, is accessed (removed) first. Similarly, Binary Search Trees (BST) have a fundamental property which states that all elements in the left sub-tree must be less than the root, and all the nodes in the right sub-tree must be greater than or equal the root node. The Towers of Hanoi is a recursive problem that students are introduced to in Data Structures. This

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problem involves moving a given number of disks from peg A to peg C using peg B as auxiliary, where the disks can be moved successfully from one peg to another in a minimum number of steps. Because of the fundamental constraints of these two data structures, and the nature of the Towers of Hanoi problem, in particular, they allow students to better understand how to effectively create test cases, and to ensure that their constraints are enforced. This exercise will be explained further in Section 3.

III. The Software Testing Approach

Students are first introduced to testing at the unit level [6] using Eclipse[1] and JUnit[2]. These tools allow them to develop automated test methods and test classes [7, 8]. Unit testing is a software development process in which the smallest testable parts of a program are individually and independently analyzed for proper operation. Unit testing focuses more on finding bugs in objects, functions and classes. In particular, students are taught how to test Stacks and Binary Search Trees to ensure that their fundamental properties are not violated. They are also introduced to performance testing at the unit level.

A. Stacks

The dynamics of a stack are relatively simple [8]. Stack operations may involve initializing the stack, using it, and then de-initializing it. A stack has two basic primary operations: (a) **push()** – pushing (storing) an element on the stack; and (b) **pop()** − removing (accessing) an element from the stack. Additionally, other supporting operations that must be defined to efficiently use a stack are:

- **peek()** − get the top data element of the stack, without removing it.
- **isFull()** − check if the stack is full.
- **isEmpty()** − check if the stack is empty.

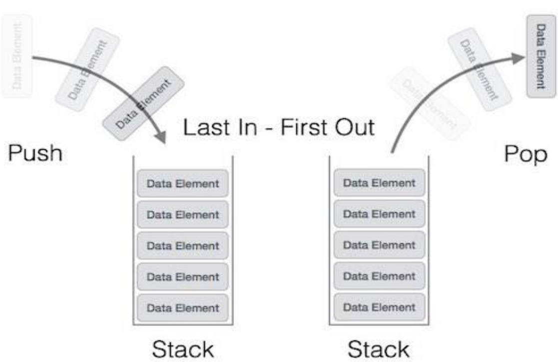

Fig. 1. Example of stack dynamics

Fig. 1 shows the basic idea behind a stack. A new element is always added at the top of the stack using the push() operation. The element at the top of the stack is always removed with the pop() operation.

B. The Stack Test

Students are asked to create a test that will effectively test the properties of a stack. This is simple to test; it involves adding a bunch of elements on a stack, and ensuring that they are removed in the correct order.

[1] http://www.eclipse.org

[2] http://junit.org/junit4/

For example, if 1, 2, 3 and 4 are pushed unto a stack one at a time, and if the stack is popped (the element at the top of the stack, is removed first, one at a time) until it is empty, then this means the stack is adhering to its fundamental LIFO property. This process is illustrated in Fig. 2.

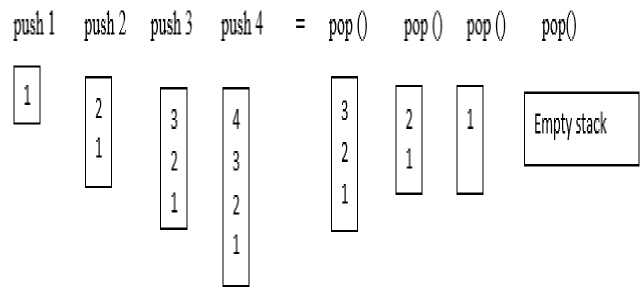

Fig. 2. Stack Unit Test

In this example 1 was pushed on the stack first; this means that 1 will be the last item to be popped from the stack. Similarly, 3 was the third element to be pushed on the stack. Therefore, 3 must be the second element to be popped from the stack. The last element that was added to the stack is 4. Thus, the first pop operation should remove an element with the value 4. In other words, the sequence and value of elements added must adhere to the LIFO constraint. In the example given, notice that each element holds a unique value to better illustrate the basic dynamics of this test. If the first pop operation removed an element with a different value, then clearly the stack is not adhering to its fundamental LIFO constraint.

C. Binary Search Tree (BST)

A Binary Search Tree [8] is a finite set of elements that is either empty or partitioned into three disjoint subsets. The first subset contains a single element called the root of the tree. The other two subsets are themselves binary search trees, called left and right sub-trees of the original tree. A left or right sub-tree can be empty; each element of a binary tree is called a node. Fig. 3 illustrates a binary search tree.

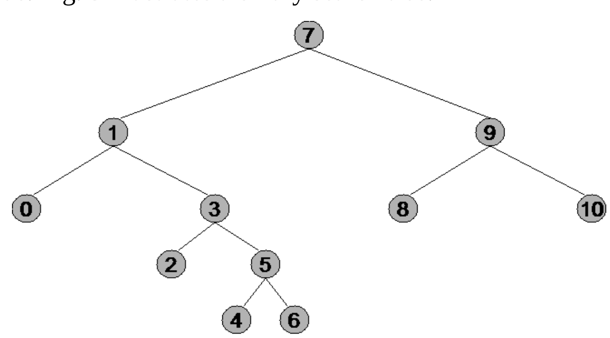

Fig. 3. Binary Search Tree

The fundamental properties of a binary search tree are: (i) all the nodes in the left sub-tree must be less than the value of the root node; and (ii) all the node values in the right sub-tree must be greater than or equal to the value of the root node.

Traversal [8] is a process that visits all the nodes in the BST in a particular order. Note that any node can be a root of the entire tree or a sub-tree. There are three (3) ways to traverse a BST; they are:

- Preorder traversal algorithm:
  - Visit the root
  - Traverse the left sub-tree in preorder
  - Traverse the right sub-tree in preorder
- Postorder traversal algorithm:
  - Traverse the left sub-tree in postorder
  - Traverse the right sub-tree in postorder
  - Visit the root
- Inorder traversal algorithm:
  - Traverse the left sub-tree in inorder
  - Visit the root
  - Traverse the right sub-tree in inorder

D. *The Binary Search Tree Test*

Students are asked to create a test that will effectively test the properties of a BST. A simple way to test the BST property (where all nodes in the left sub-tree must be less than the root; and all nodes in the right sub-tree must be greater than or equal to the root node) is to perform an inorder traversal on the binary search tree.

For example, given the BST in Fig. 3, an in order traversal would visit each node as follows: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Notice that all the node values (0, 1, 2, 3, 4, 5, 6,) in the left sub-tree are all less than the value (7) in the root node. Similarly, all the node values (8, 9, 10) in the right sub-tree are greater than or equal to the root node value (7). Therefore, doing an in order traversal is a simple and effective way to test that a given tree is actually a Binary Search Tree.

The stack and binary search tree examples are just two of many ADTs that can be used to teach the fundamentals of testing at the unit level to uphold fundamental constraints.

IV. Performance Testing at the Unit Level

In unit testing [5], sometimes the performance of a given method or class is tested to determine its efficiency in solving a problem. Exhaustive testing is expensive (and time consuming). Therefore, evaluating the efficiency of a solution can be used as a performance test at the unit level. Recursion [8] is a topic that is covered in Data Structures. Essentially, recursion is used where a large problem can be broken down into smaller repetitive "sub-problems". A recursive method calls itself to perform those sub-problems, and eventually the method will come across a sub-problem so trivial, that it can handle it without recalling itself. This is known as a base case, and it is required to prevent the method from calling itself repeatedly without ever stopping.

The Towers of Hanoi [8] is a classic problem that is solved using recursion. The basic problem is as follows. Given three pegs and a stack of N disks, where each disk is a little smaller than the one beneath it, the goal is to transfer all N disks from one of the three pegs to another, while adhering to two important constraints:

- You can only move one disk at a time
- You can never place a larger disk on top of a smaller one

Fig. 4 provides an example that illustrates this problem. There are 3 disks on peg A and the goal is to move all of them to peg B while adhering to the two important Towers of Hanoi constraints mentioned above.

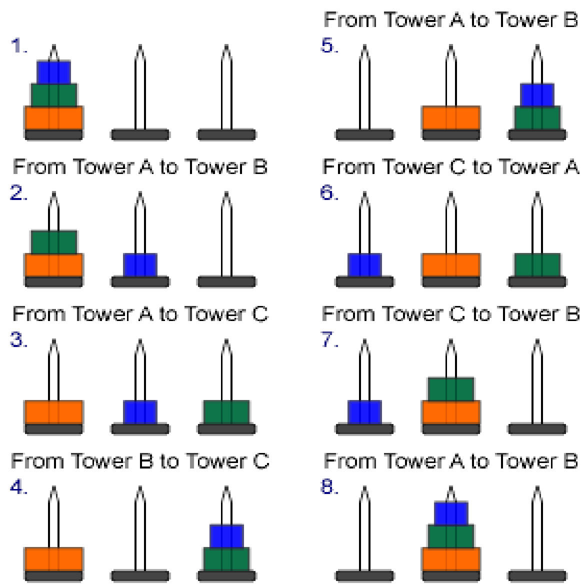

Fig. 4. Binary Search Tree

A. *The Tower of Hanoi Test*

Given the nature of the Towers of Hanoi problem, its performance can be evaluated, since N disks can be moved from one peg to another peg, using a minimum number of moves. Given N disks, one can mathematical find the least number of moves to achieve this goal. Students were asked to write a test that will verify that the least number of moves are used to move a stack of 3 disks from peg A to peg B using peg C as auxiliary.

Additionally, in order to define a recursive solution, students must find the base case and the recursive call [8]. The base case specifies when the function ends to avoid an infinite loop. The recursive call is defined to break the problem into smaller, yet, identical steps, to solve the bigger problem. Students would have to define the following in order to solve the Towers of Hanoi problem recursively:

1) Base case:

- When the number of disks N, equals 1.

2) Recursive call:

- Move N-1 disks from peg A to peg C, using peg B as auxiliary

In Fig 4, two disks are moved from peg A to Peg B, as shown in steps 2, 3, and 4.

- Move the remaining disk from peg A to peg B

In Fig 4, we move the remaining disk from peg A to peg B, as shown in step 5.

- Move the N-1 disks from peg C to peg B, using peg A as auxiliary.

In Fig 4, two disks are moved from peg C to Peg B, as shown in steps 6, 7, and 8.

By means of mathematical induction, the minimum number of moves required to solve the Towers of Hanoi problem is $2^n - 1$, where n is the number of disks.

This means that students would have to figure out that the minimum number of moves to transfer 3 disks from peg A to peg B is 7. This test presents a practical example of testing the performance/efficiency of a method or class by using the Towers of Hanoi example, which is a classic problem that is taught in most Data Structures course.

V. Future Work and Conclusion

Future work entails identifying, and developing, additional relatable examples that can be used to teach software testing at other testing levels-including at the integration, and system testing levels. Additionally, finding techniques and relatable exercises that help students understand code coverage in terms of data path, and input partition coverage, are also important.

Software testing is a very important activity that requires more relatable teaching strategies to help students learn how to effectively test their programs. Testing does not get enough attention in the software development life cycle and so, naturally, students do not spend enough time to fully understand the problems they are solving at a fundamental level. As a result, this negligence propagates into how they test their code.

Using the three examples in Sections 3, it was demonstrated that effective testing can be achieved by utilizing some of the basic topics covered in a typical Data Structures course. This approach focuses on understanding constraints and the fundamental properties associated with solving a particular problem. The aim is to encourage students to invest the minimum time to fully understand a problem in order to create test cases that will effectively find bugs and defects, which are the primary goals of software testing. Additionally, we extended the scope of unit testing to include performance testing of a recursive method, which was applied to Towers of Hanoi problem.

By using data structures, along with well-known problems that were introduced to students earlier in the curriculum or in a prerequisite course, they can seamlessly learn the principles and application of software testing without focusing on learning new unfamiliar content. Furthermore, students often utilize the same data structures to implement software programs in other upper level courses and internship projects. Therefore, teaching automated software testing with ADTs, provides students with a second opportunity to master their skills and knowledge in software development and testing.

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Deep Learning Approach for Secondary Structure Protein Prediction based on First Level Features Extraction using a Latent CNN Structure

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***Abstract*—In Bioinformatics, Protein Secondary Structure Prediction (PSSP) has been considered as one of the main challenging tasks in this field. Today, secondary structure protein prediction approaches have been categorized into three groups (Neighbor-based, model-based, and meta predicator-based model). The main purpose of the model-based approaches is to detect the protein sequence-structure by utilizing machine learning techniques to train and learn a predictive model for that. In this model, different supervised learning approaches have been proposed such as neural networks, hidden Markov chain, and support vector machines have been proposed. In this paper, our proposed approach which is a Latent Deep Learning approach relies on detecting the first level features based on using Stacked Sparse Autoencoder. This approach allows us to detect new features out of the set of training data using the sparse autoencoder which will have used later as convolved filters in the Convolutional Neural Network (CNN) structure. The experimental results show that the highest accuracy of the prediction is 86.719% in the testing set of our approach when the backpropagation framework has been used to pre-trained techniques by relying on the unsupervised fashion where the whole network can be fine-tuned in a supervised learning fashion.**

Keywords—Secondary structure protein prediction; secondary structure; fine-tuning; Stacked Sparse; Deep Learning; CNN

I. Introduction

Bioinformatics implicates the technology of using the computer aid based system for many reasons such as storage, retrieval, manipulation, and distribution of information. Biological macromolecules such as DNA, RNA, and proteins, are the most related branch of the bioinformatics which is related to the information distribution systematic. The emphasis here is on using the computers aid system to solve these issues since most of the task genomic data analysis are highly repetitive and mathematically complex, computers aid system here is essentially using in mining genomes in terms of information gathering and knowledge building [1]. Although, protein structure prediction methods are classified under the bioinformatics category.

Bioinformatics is a board filed that takes in many other fields and disciplines such as information technology, biology, biochemistry, statistics, and mathematics [2].

Bioinformatics category for protein prediction is depends on the main types of protein structure which are divided into four main types, Primary, Secondary, Tertiary and Quaternary structures. Primary structure is the first type of protein structure which consisting of 20 different types of amino acids. This structure provides foundation information about all the other suture types. The second type of protein structure is the Secondary structure. This type describes and illustrates the arrangement of the connection and attaches within the amino acid groups. It consists of three different structures which are (H, E, and C) [3]. Protein Secondary Structure Prediction (PSSP) Tertiary structure which is the third structure type, provides useful information about protein activity, relationship, and function [3]. That has been done by protein folding which is a prediction of the Tertiary structure. This information can be predicted from linear sequence protein process method which is an unsolved and ubiquitous problem. This approach invites research from many fields of study such as computer science, molecular biology, biochemistry, and physics. The disinfectant information of the Secondary structure use in many proteins folding prediction approaches which is also used in many different area of bioinformatics application [4]. Proteome and gene annotation which is the determination of protein flexibility are the main scientific applications that applied in this area because when searching in a database with peptide mass tags, there is a lack of flexibility in the search programs. In another word, if a single mistake is made during the searching in the assignment of a y- or b-ion which can be possibly happen quite frequently, the amino acid sequence will be incorrect that means the database searching process will bring up irrelevant proteins items. Sub cloning of protein fragments for expression is another application area of this approach which is the assessment of evolutionary trends among organisms [3] [4]. In other hands, Protein Secondary Structure Prediction (PSSP) is an active and significant reach area for many useful applications these days which includes protein integral and analysis [4].

In past years, multi-layer neural networks have been one the popular deep learning approaches. The idea of constructing the network with several levels of nonlinearity to solve more complex problems is not new. [3] However, it is difficult in practice, particularly for deep architectures which have an optimization issue where the expected gain beyond one or two hidden layers is difficult to get [5]. In general, autoencoder is an unsupervised approach of the neural network that also relies on a back-propagation learning approach [5]. By giving only unlabeled training dataset $\{x_1, x_2, \ldots x_n\}$, where $x_i \in R^d$, the autoencoder neural network attempts to learn the identity function of the data samples $f_{W,b}(x) \approx x$ by setting the outputs equal to the inputs, i.e. $y_i = x_i$. If some constraints have been added on the structure of the autoencoder, like limit number of hidden neurons or average rate of firing, the learned identity function will reveal the interesting underlying structure of the data. For example, the activations of the deepest hidden layer can be extracted as new features corresponding to the compressed representation of the input muck like the principal component analysis (PCA) [6].

In this paper, the stacked sparse autoencoder model is introduced and explained after defining the multi-hidden-layer sparse autoencoder model and the stacked Pre-training Method in the second section 2. Then it is followed by section 3 where the CNN model is explained. Finally, in section 5, the summary and discussion of the experimental results.

A. Our Approach Motivation

In this paper, a latent approach using supervised and unsupervised machine learning methods for secondary structure of protein prediction is proposed. A Deep Learning approach using Convolutional Neural Network (CNN) [7] is used as a main structure to build our Latent Deep Learning model for protein prediction. The proposed model relies on an unsupervised learning approach, Stacked Sparse Autoencoder [8] network structure for both 3-state SS first level feature structure detection and prediction using soft-max classifier. Then, compare the results with the latent model by using two training frameworks. The Latent Deep Learning Approach (LDLA) that is proposed for secondary structure of protein prediction relies on using the first level of proteins features that already have been extracted to construct new convolutional filters that will have used in the convolutional layer in the Deep Conditional Neural Network structure (CNN) [7]. Our Latent Deep Learning approach learns not only the complex sequence-structure but also captures the relationship of the models SSlabel correlation through adjacent residues.

The combination between the Deep Learning and Stacked Sparse Autoencoder produces a new data dimension which has been extracted from the first level of the sparse autoencoder network. Those features are used to build convolutions filters that use later in the convolutional layer in the Deep Learning structure. The proposed system implementation differs from Cheng's method [9] instead of using just a typical Deep Learning network, a Latent Deep Convolutional Network (CNN) after some filters has been learned by applying sparse autoencoder. The implementation of the Latent Deep Learning Approach is done by relying on a convolutional filter that construction by using sparse autoencoder as a preprocessing and feature extraction step, which can capture longer-range sequence information than Cheng's method. Our experimental results show that our implementation has greatly achieves the state-of-the-art, especially on those structures whose types are significant challenging to predict.

TABLE. I. SECONDARY STRUCTURE ASSIGNMENT

3 state classes	Abbreviation	DSSP class
α-helix	H	H
310 helix	G	H
β-sheet (E)	E	E
Isolated β _ ridge	B	E
π – helix	I	C
Turn	T	C
Bend	S	C

B. Background and motivation

Today, secondary structure of protein prediction can be classified to three classes. The classified classes are model-based, neighbor-based, and meta predicator-based [2]. The first approach (neighbor-based) predicts the secondary structure by depending on sequence identifying of similar sequence. The second approach (model-based) implements an advanced machine learning model to learn and build a decent model for sequence structure detection [3]. The third model is the meta predicator-based approach which depends on a combination the results of the neighbor model-based approach because basically this model is a method used to make a prediction by integrating the prediction results of several methods [5]. Obviously, the most useful and successful model-based approach is proposed by PSIPRED [4] which was based on using neural network as a learning model [5] and support vector machine [6] that has been tested and showed a decent performance results [7].

C. Dataset

In this paper, the SCRATCH protein predictor dataset is used an a large scale protein dataset. This dataset consists of primary and secondary structure of protein data (SSpro) with 3 classes. The SSpro data has server homologous protein's secondary structure information. The recent and current accuracy that has been achieved in this data set is about 79% correctly classified, and override about 92% correctly classified [10].

D. Secondary Structure Classes Assignment

Given the 3D atomic coordinate of a protein structure, there are several methods to assign its secondary structures including a dictionary of secondary such as the structure of proteins (DSSP) [6] and Structural Identification (STRIDE) [7]. The secondary structure assignment of each residue is not perfectly well-defined, which means that these methods often disagree on their assignments. For example, DSSP and STRIDE differ on approximately 5% of residues [8]. This inconsistency justifies the need for a certain and standard assignment techniques (methods) that could be used to provide alternate definition of protein amino-acid boundaries. The method was adopted here is DSSP as the standard algorithm and the most frequently used for secondary structure definition method. The Neural Network (NN) is trained to predict a three-category (H, E and C) of the secondary structure assignment which has been reduced from the eight-category assignment which is produced by using DSSP method that has been shown in Table1.

II. RELATED WORKS

Little work has been done on secondary structure protein prediction using "SSpro-3 classes" sets [10].

Christophe et al. [11]: This paper presents an approach of training model to predict the secondary structure of protein prediction. This work depends on the distinction of the sequence similarity from the sequence profiles at the input stage and an additional structure based similarity. Multi-class prediction approach has been proposed using SSpro8 and SCCpro20. This work achieved about 79 and 80%. The accuracy of SSpro rises to 92.9% (90% for ACCpro).

Jian Zhou et al [12] in this work, the uniquely architecture of prediction model depends on the low-level labels structured has been proposed. The secondary structure of each amino acid has been trained and tested in this model. This model achieved about 66.4% Q8 accuracy on the dataset.

III. PROPOSED SYSTEM

The proposed Latent Deep Learning Approach (LDLA) for secondary structure of protein prediction has is shown in Fig.1. A Latent Deep Learning model relies on the Stacked Sparse autoencoder to detect and extract the first level of proteins features, and the main approach of Deep Learning using (CNN) structure. In this approach, a combination method is proposed between the Sparse Autoencoder to extract the first level of protein features and use those features to construct accurate filters that will have used in the convolutional layer with the original protein data to learn more features than relies just on the random or initialized filters for the convolutional layers in the main Deep Learning Structure. In this case, the Stacked Sparse Autoencoder Approach that is shown in Fig.2 is applied using soft-max classifier for secondary structure protein prediction, and compare the results with our Latent Deep Learning Approach using also sot-max classifier.

In this proposal, two different learning frameworks is used. The first one is without using the fine tuning for the trained data, and the other one is the backpropagation framework which is used to pre-trained the whole network in an unsupervised fashion to fine-tuned the data in a supervised learning fashion.

IV. STACKED SPARSE AUTOENCODER APPROACH

The predatory layer-wise approach for pre-training the Deep Neural Network works by training each layer in turn. In this section, how autoencoder can be "stacked" in a layer-wise fashion for pre-training which is the initializing of the weights of a Deep Neural Network (DNN) is illustrated and described. Typically, a stacked autoencoder consisting of multiple layers of sparse autoencoder which is the outputs of each layer have been connected to the inputs of the successive layer [13]. A Multi-hidden-layer sparse autoencoder is putting and crooking together many of the simple neurons. In this case, the output of neurons can be represented as input of another layer.

To train this type of network, it needs to train set of our data samples $(x(i), y(i))$ where$y(i) \in R2$. This type of network is more accurate and useful if there are multiple outputs (multi-class) that are going to classify and predict. Assume that the fixed training number set of the data sample

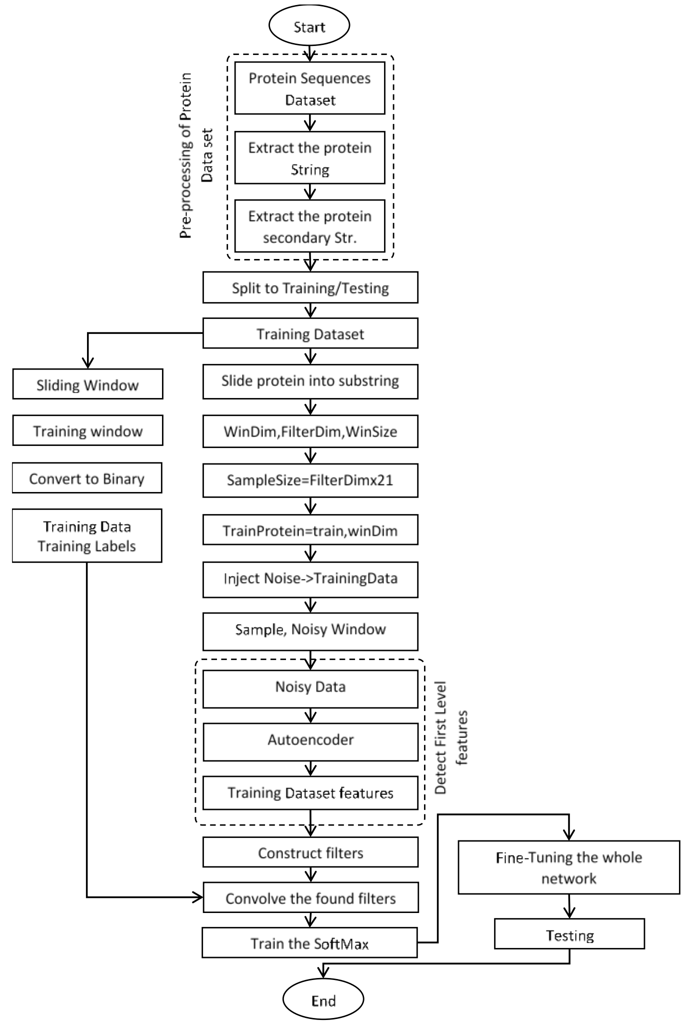

Fig. 1. The proposed Approach Latent Deep Learning Structure for secondary structure of protein prediction using a laten CNN structure

$\{(x(1), y(1)) \ldots (x(m), y(m))\}$ of m training examples, in this case the model can be trained using batch gradient descent approach. In more detail, for a single training data sample (example) (x, y), is proposed the cost function (objective) with respect to multi-hidden layer to be as given in Eqs.(1):

$$(\mathrm{w,b}) = \frac{1}{\mathrm{N}}\left(\sum_{i=1}^{N} J(W_1, b, x_i, \hat{x}_i)\right) + \frac{\lambda}{2}\left(\sum_{l=1}^{m_l-1} \|W_l\|_F^2\right) + \beta\left(\sum_{l=1}^{h_n-1} KL(p\|\hat{p}_j)\right) \tag{1}$$

where $\mathrm{J(W_I,b;x_I,\hat{x}_i)}=\frac{1}{2}\left\|\mathrm{x_i}-\hat{\mathrm{x}}_{\mathrm{i}}\right\|_2^2$ is the squared error term and $\hat{\mathrm{x}}_{\mathrm{I}}$ is the output of the autoencoder. The second term $\mathrm{l_2}$ is a regularized term that has been used for weight decay term. This term tends to reduce the magnitude of the weights and helps to jump the over-fitting situation where $\hat{\rho}_{\mathrm{j}} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i=1}}^{\mathrm{N}}\left[\phi(\mathrm{h_j})\right]$ is the average of the activation of hidden unit, and $\mathrm{h_j}$ is a sparsity term ρ , which is equal to 0.05 in the experiment. In this model, denotes the desired activation extent of each hidden neuron $\mathrm{h_j}$.

$\mathrm{KL}\left(\rho \| \widehat{\rho}_j\right)$ by using the Kullback-Leibler (KL) function. This function divergence between two Bernoulli random parameters with means ρ and $\widehat{\rho}_j$ respectively as it given in Eqs (2):

$$\mathrm{KL}\left(\rho \| \widehat{\rho}_j\right) = \rho \log \frac{\rho}{\widehat{\rho}_j} + (\text{“}1\text{-}\rho\text{”}) \log \frac{1-\rho}{1-\widehat{\rho}_j} \qquad (2)$$

It is a measurement of how different two distributions are. If the average activation $\widehat{\rho}_j$ of hidden unit h_j deviates a lot. from the desired ρ, $\mathrm{KL}\left(\rho \| \widehat{\rho}_j\right)$ will add big penalty on the objective function to make $\widehat{\rho}_j$ small in the next iteration. By taking partial derivative on objective function $J(W, b)$ with respect to W_l and b_l, the update rule for, the update rule for W_l and b are the following [13]. Multi-hidden-layer Sparse Autoencoder approach process steps are described in the next algorithm (1).

Algorithm (1): Stacked Sparse Autoencoder

1. **While**
2. Implemt a feedforward pass approach.
3. Compute the activations for the layers L_2, L_3 until the output layer L_{n_l}, activation function $\phi(\cdot)$ is activation function.
4. **For** the output layer, take $\delta_{n_l} = -(x - \hat{x})\phi'(net_{n_l})$, where net_{n_l} is the net activation energy of each neuron of output layer
5. **For** $l = n_l - 1, n_l - 2, \ldots, 2,$ additional with – $l = \frac{n_l+1}{2}$,
6. **Take** $\delta_l = (w_l^T \delta_{l+1}) \cdot \phi'(net_l)$,
   $$\delta_{\frac{n_l+1}{2}} = \left(W^T_{\frac{n_l+1}{2}} \delta_{\frac{n_l+3}{2}} + \beta\left(-\frac{\rho}{\hat{\rho}} + \frac{1-\rho}{1-\hat{\rho}}\right)\right) \cdot \phi'\left(net_{\frac{n_l+1}{2}}\right) \quad (3)$$
   where $\frac{n_l+1}{2}$ is the deepest layer whose outputs are the new features it needed.
7. **Compute** the gradients of W_l and b_l,
   $$\nabla_{W_l} J(W, b; x, \hat{x}) = \delta_{l+1} \cdot net_l^T + \lambda W_l \quad (4)$$
   $$\nabla_{b_l} J(W, b; x, \hat{x}) = \delta_{l+1} \quad (5)$$
8. **Update** the parameters:
   $$W_l^{t+1} = W_l^t + \eta \frac{1}{N} \sum_{i=1}^{N} \nabla W_l^i + \lambda W_l \quad (6)$$
   $$b_l^{t+1} = b_l^t + \eta \frac{1}{N} \sum_{i=1}^{N} \nabla b_l^i \quad (7)$$
9. **End For**
10. **End For**
11. **Repeat** from 1 until converge

The stacked pre-training method is to train each layer one by one as a one hidden layer autoencoder. First, it trains the first layer on the raw input data to gain parameters and output $W_1^{initial}$ and h_1 as it shown in Fig.3 then trains the second layer using the previous output h_1. Then train of the second layer using the previous output h_1 as input and desired output of this second hidden layer h_2 to get $W_2^{initial}$ as it shown in Fig.4, which repeat for subsequent layers by using the output of each layer as input for the subsequent layer to initialize $W_l^{initial}$ [14].

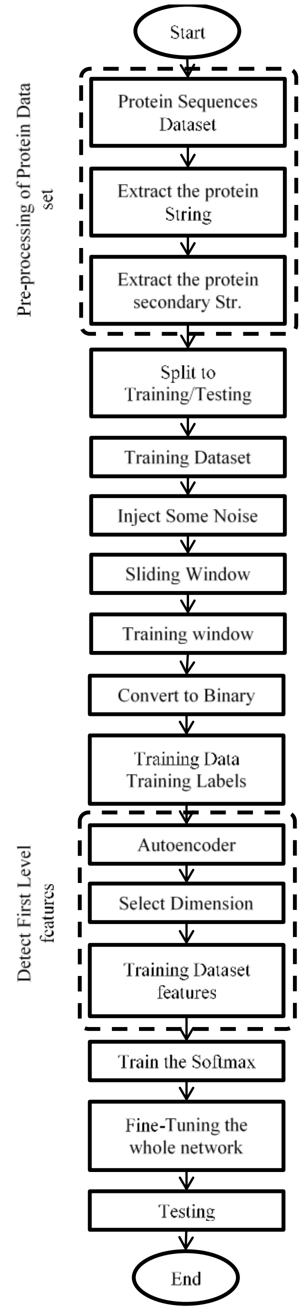

Fig. 2. The proposed Stacked Sparse Autoencoder Network Approach for detect and extract the first level of portions features, using softmax classifier to predict the secondary structure of proteins prdection

V. Deep Learning Approach using Laten CNN Structure

Deep Learning approach using Convolutional Neural Networks (CNN) is a set of biologically-inspired variants of MLPs. This approach has been proposed and produced by Hubel and Wiesel [6]. The main idea of this approach is depending on the visual context which contains significant cells. These cells represent small sub-rejoins of the original visual context. Those cells demonstrate as local filters overcome the input space to extract the strong local relation and correlation in the original space [15]. Moreover, two types of cells have been significantly used (simple and complex cell). Simple cell is maximally respond to a specific edge-like patterns within their receptive field. In the other hand, the complex cells which have larger receptive fields and are locally invariant to exact the position of the pattern. This kind (complex cells) being the most powerful visual processing system in existence, that seems natural to emulate its behavior [16].

Practicality, the CNNs, local filter hi scanned the whole entire data and replicated across the whole entire visual field. These local filters unit share the same parameters (weight vector and bias) and form a feature map [5]. The CNN, s feature map is acquired by repeating using a function across sub-regions of the entire data. In the other words, this process is done by convolution of the input data with a specific linear filter (line detector as an example) by adding a bias term and then applying a non-linear function. If the k-th is denoated as a feature map at a specific layer as hk, whose filters are determined by the weights wk and bias bk, then the feature map hk is gained as follows as given in the following Eqs (8):

$$h_{ij}^k = tanh\big((W^k * x)_{ij} + b_k\big) \quad (8)$$

By recalling the following definition of convolution process for a 1D signal as given in the following Eqs (9) [16].

$$\mathrm{O[n]} = \mathrm{f[n]} \times \mathrm{g[n]} = \sum_{u=-\infty}^{\infty} \mathrm{f[u]g[v]} = \sum_{u=-\infty}^{\infty} \mathrm{f[n\text{-}u]g[u]} \quad (9)$$

which can be extended to the 2D as given in the following Eqs (10) [16]:

$$O[m,n] = f[m,n] \times g[m,n] = \sum_{-\infty}^{\infty} f[u,v]g[m-u,n-v] \quad (10)$$

From the 2D form above, each hidden layer is composed of multiple feature maps such as, $\mathrm{h^{(k)}}, \mathrm{k} = 0..\mathrm{k}$. This can be weighted as w of a hidden layer which can be represented as a 4D tensor flow. The 4D tensor consists of combination of destination elements [17]. However, in 4D tensor the feature map, source feature map, source vertical position, and source horizontal position are the common destination elements. Moreover, the biases b also can be represented as a vector that containing of one element for every destination feature map [15].

The Deep Learning design requires two main operations. The main one is the convolution operator which is the main workhorse for implementing a convolutional layer in the CNN structure [15]. According to the mini-batches of (training sample) of input data, the shape of the tensor is constructed. In other words, mini-batch size, several input feature maps, image height, and data width are main category of the tensor design in the CNN structure. A 4D tensor is corresponding to the weight matrix W which is a significant technique of the tensor to determine the number of feature maps at layer m. and the number of the feature maps at layer m-1, filter height, filter width [17].

The second operation of the CNN structure is the Max-pooling. This operation takes the input data (sub-region) into a set of non-overlapping regions. For each sub-region, the outputs are the maximum value. The main reason of using the

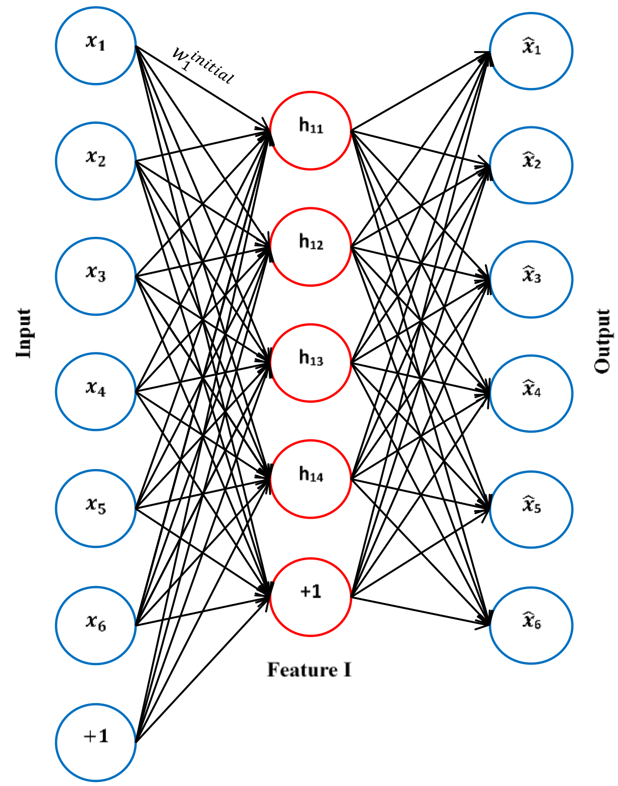

Fig. 3. Stacked sparse autoencoder network weights initialization example of the first level weights w^1

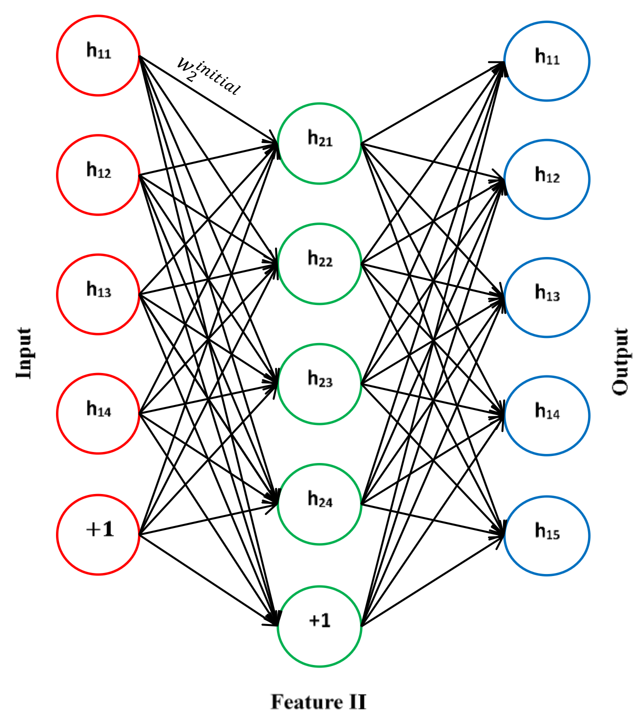

Fig. 4. An example of the first level of the stacked sparse autoencoder structure

max-pooling is to it reduces computation for upper layers on the architecture. Also, it provides a form of translation invariance. In the max-pooling layer, there are 8 directions in which one can translate the input image by a single pixel [16]. For example, if the max-pooling i s done over by a 2x2 region, 3 out of these 8 possible configurations will produce the same output at the convolutional layer [18]. In our design, the Full model of the Deep Learning consists of two convolution layer and two max-pooling layers with one fully connected layer. The lower layers are collected by alternating convolution and max-pooling layers and the upper layers are fully-connected which corresponds to a traditional MLP (hidden layer with logistic regression). The fully connected layer operates on 4D tensors technique which can be flattened to a 2D matrix of the feature maps, to be convenient with the MLP main implementation.

VI. Experimental Results

In terms of measuring the performance of the prediction model, the statistical method of k-fold cross validation is used in this approach. In supervised learning, a certain amount of labeled data is available for training the prediction model. The performance of a prediction model depends on its efficiency on detecting the labels of unlabeled data. To estimate performance, one can set aside some of the labeled data for testing, making sure that the test data is not also used for training. Where the available data is limited, then the process of training on part of the labeled data and testing on the remaining part can be repeated to improve the estimate of accuracy.

A. Evaluation Criteria

The evaluating performance of Protein secondary structure prediction system is calculated by using Q3 measurement, which is defined as the ratio between the numbers of correct recognition decision to the total number of attempts.as it is given in equation (11).

$$Accuracy = \frac{Number\ of\ correct\ attempts}{Total\ number\ of\ attempts} \qquad (11)$$

B. Stacked Sparse Autoencoder prediction Results

Fig.5 shows the sparse autoencoder prediction on the testing dataset. It’s clear to see that the sparse autoencoder has predicted about (67%) ‘C’ as a true positive (TP) which is correctly predicted, about (43 %) for correct prediction for class ‘E’, and it has been satisfied about (65 %) on class ‘H’.

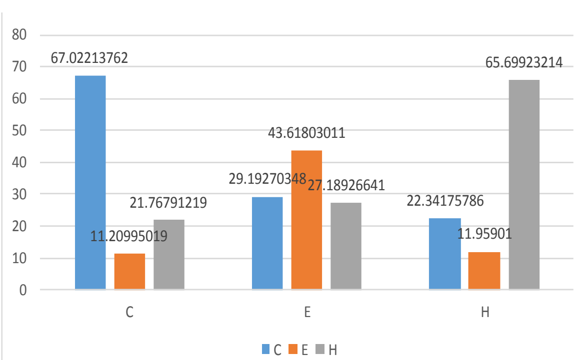

Fig. 5. Stacked Sparse Autoencoder approach performance results

Although, Fig.6 shows the different accuracy result when the fine-tuning approach has been applied in this approach that has been shown in Table.2. it’s clear enough to notice that this approach has been increased about (7.047%) on training set, and (2.283%) on testing set.

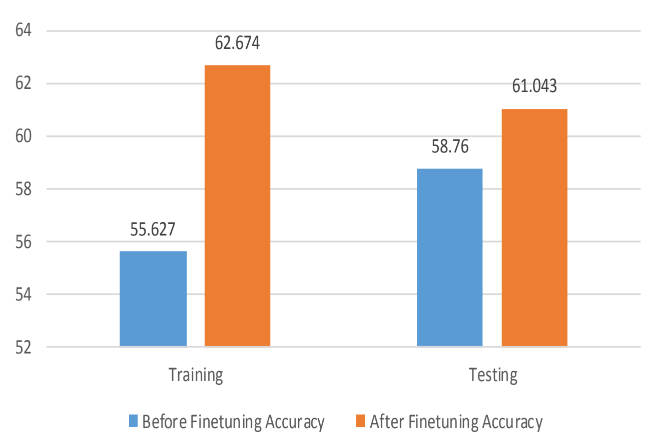

Fig. 6. Sparse Autoencoder performance results with/without fine-tuning

TABLE. II. Stacked Sparse Autoencoder Approach Performance Results

Approach	Training	Testing
Before Finetuning Accuracy	55.627	58.76
After Finetuning Accuracy	62.674	61.043

The overall performance results of Stacked Sparse Autoencoder for secondary structure of protein prediction is illustrated in Fig.7 which illustrates the difference in the prediction accuracy result using fine tuning is better that using the same approach without tuning the trained data.

C. Latent Deep Learning using Prediction Results

In this section, it explores the performance of our Latent Deep Learning approach depends on constructed filter from the previous approach (Stacked Sparse Autoencoder for first level features detection and extraction) to convolve the new features with the original proteins data using Convolutional Neural Networks (CNN) structure. In this approach, two training frameworks are used. The first one is Deep Learning approach without a fine tuning, and the second one is with fine tuning. Matlab program language is used to design and implementation of those two structures.

1) Our Deep Learning Approach-without Fine Tuning

Fig.7 shows the Latent Deep Learning approach prediction result using forward pass approach (without fine-tuning) on the Training dataset. It’s clear to notice that the Deep Learning has predicted about (66.073%) ‘C’ as a true positive (TP) which is correctly predicted, about (26.972 %) for uncorrected prediction for class ‘E’, and (20.104 %) uncorrected prediction for class ‘H’, so it has been correctly predicted about (41.981 %) for class ‘E’, and (70.671 %) for class ‘H”.

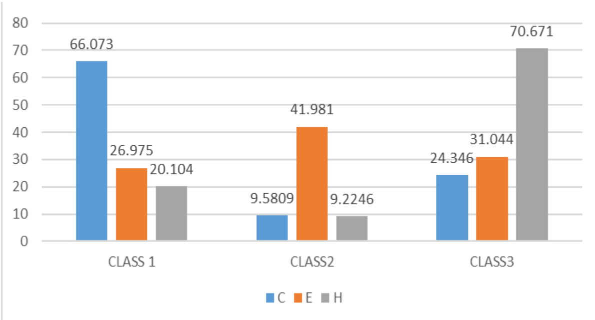

Fig. 7. Our Deep Learning Approach without fine-tuning performance results for the testing dataset

Fig.8 shows the Latent Deep Learning prediction result on the testing dataset. It's clear to notice that the Deep Learning approach has predicted about (67.37 %) 'C' as a true positive (TP) which is correctly predicted, about (28.638%) for uncorrected prediction for class 'E', and (21.898%) uncorrected prediction for class 'H'. Although, it has been correctly predicted about (43.496 %) for class 'E', and (67.14 %) for class 'H".

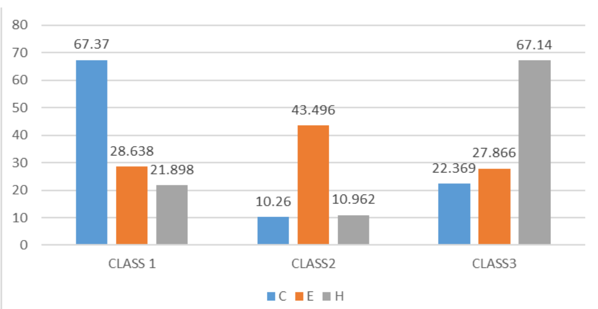

Fig. 8. Our Latent Deep Learning Approach without Fine-tuning performance results for the testing dataset

2) Our Deep Learning Approach-with Fine Tuning

Fig. 9 shows the Deep Learning with fine tuning results (backpropagation approach) on the training dataset.

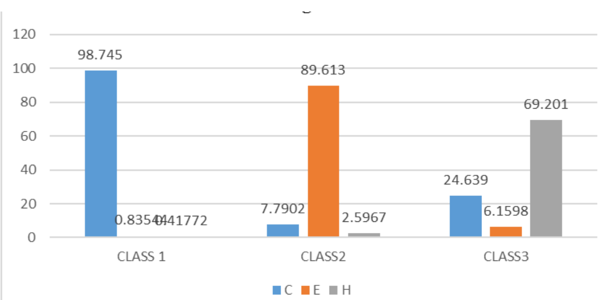

Fig. 9. Our Deep Learning with Fine-tuning performance results for the training dataset

It's clear to see that this approach has predicted about (98.745 %) 'C' as a true positive (TP) which is correctly predicted, about (0.835%) for uncorrected prediction for class 'E', and (0.41772%) uncorrected prediction for class 'H'. Although, it has been correctly predicted about (89.613 %) for class 'E', and (69.201%) for class 'H".

Finally, Fig.10 shows the Deep Learning approach with fine tuning prediction result on the testing dataset. This approach has predicted about (99.923 %) 'C' as a true positive (TP) which is correctly predicted, about (0.05159%) for uncorrected prediction for class 'E', and (0.27%) uncorrected prediction for class 'H'. Although, it has been correctly predicted about (99.876 %) for class 'E', and (71.139%) for class 'H".

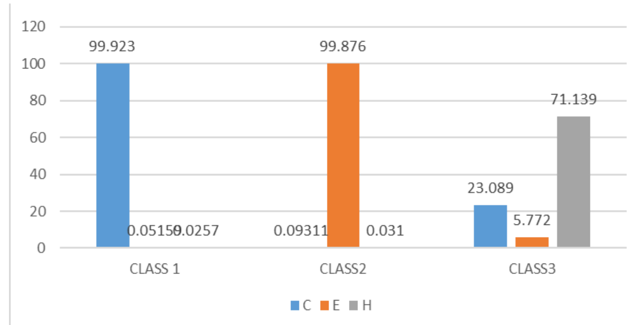

Fig. 10. Our Deep Learning (CNN) with Fine-tuning performance results for the testing dataset

A. Latent Deep Learning Model Comparison with Other Approaches

In term of evaluate our Latent Deep Learning approach for secondary structure of protein prediction against the "state-of-the-art" and other approaches that have been discussed in (Section. II), Table 3 shows that we achieved 90.3126% Q8 accuracy on the test set sequences using SCRATCH protein predictor dataset which consists of primary and secondary structure of protein data (SSpro) with 3 classes. As it shown in Table 3, The machine learning and structural similarity methodology that has been proposed by Christophe [11] achieved (84.51%) Q8 accuracy. This approach provides a sequence-based structural similarity methods which systematically combining the protein profile in such grows dataset using machine learning methods and sequence-based. in this case, the structural similarity seems to be the best strategy, and this is one of the reasons why it has been chosen because this approach provides separate modules for each one of these three tasks [11]. In contrast, since protein structures are more conserved than protein sequences this model has small improvements since this approach capable of detecting remote structural similarity, not readily visible in the sequences alone. However, Table 3 shows that the second approach that use Deep Supervised and Convolutional Generative Stochastic Network for protein secondary structure prediction, which is proposed by Jian Zhou et al [12] has achieved 72.1 ± 0.6% Q8 accuracy on the same dataset. This approach proposed a Deep features extractor model by using a 3-layer convolutional structure. Starting with $\{80 \times \text{conv5}\} - \{\text{pool5} - 80 \times \text{conv5}\} - \{\text{pool5}{-}80{\times}\text{conv4}\}$. This model suggests the combination of convolutional and supervised generative stochastic network which is applied well suited for low-level structured prediction that is sensitive to local information, while being informed of high-level and distant features. In contrast, one limitation of this approach is that the current architecture may not be optimal to capture the spatial organization of protein sequence in some cases, especially for structures that formed by long-range interactions.

TABLE. III. STACKED SPARSE AUTOENCODER APPROACH PERFORMANCE RESULTS

Approach	Q8 Accuracy
Christophe [11]	84.51%
Jian Zhou [12]	72.1%
State-of-the-art [19]	0.649%
Our Approach	**90.3126%**

Latent Deep Learning approach proposes a combination between the Deep Learning and Stacked Sparse Autoencoder. This combination produces a new data dimension which has been extracted from the first level of the sparse autoencoder network. Those features are used to build convolutions filters that use later in the convolutional layer in the Deep Learning structure which is a powerful complement to classical machine learning tools and other analysis strategies. In this approach, a new technique of learning the low-level features is produce to build the convolutional kernel that are used later in the convolutional layer inside the Latent Deep Learning structure. This method jump out the other limitation on the previous approaches by using a powerful structure that capable of detecting the remote structural similarity of the protein sequence depending on the structure feature extraction where the readily protein features are visible in the sequences alone. Although, this approach has more capability to capture the spatial organization of protein sequence since it uses the original low-level features itself (constructed kernels) to extract the portion sequence features in the latent Deep Learning Approach.

VII. CONCLUSION

First level features detection is the main contribution and a new approach that has been used to predict the protein secondary structure. In this approach, two machine learning approaches and a combination between them have been proposed and used in this paper. The first one is the unsupervised learning approach based on using Sparse Auto-encoder network structure, and the semi-supervised learning approach based on using Deep Learning neural network structure. The first approach using sparse autoencoder has been achieved about (65.627%) in training set, and about (72.674%) in the testing set without using the fine-tuning approach. The highest accuracy of the same approach is used in the fine-tuning approach which is 86.760% in training set and 71.043% in the testing set. The highest accuracy is (86.719%) in the testing set of the Deep Learning approach, and (85.853%) on the training set when the fine-tuning approach uses, but without that the Deep Learning approach has been satisfied (70.575%) in training set and (79.33%) in the testing set. In the conclusion, the Deep learning methods are a powerful complement to classical machine learning tools and other analysis strategies. However, this paper presents a proposed system that implements a combined structure between semi-supervised and convolutional architecture to learn hierarchical representation on full-sized data. Finally, the fine-tuning approach of the whole network gives a better result, which brings the network’s hidden weights W and biases b to a descent area of the parameter space to comprise a better startup point of the weight than random initialization.

For further works and development of the protein sequence and structure relies on the Latent Deep Learning structure. An adaptive and dynamic architecture will be proposed to better model the long-range interactions in a protein. This adaptive will changes the connectivity adaptively based on input of the low-level of the portion features which may further improve the quality of representation in of the Q8 accuracy in the future.

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3D Human Action Recognition using Hu Moment Invariants and Euclidean Distance Classifier

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***Abstract*—This paper presents a new model of scale, rotation, and translations invariant interest point descriptor for human actions recognition. The descriptor, HMIV (Hu Moment Invariants on Videos) is used for solving surveillance camera recording problems under different conditions of side, position, direction and illumination. The proposed approach deals with raw input human action video sequences. Seven Hu moments are computed for extracting human action features and for storing them in a 1D vector which is constringed as one mean value for all the frames' moments. The moments are invariant to scale, translation, or rotation, which is the robustness point of Hu moments algorithm. The experiments are evaluated using two different datasets; KTH and UCF101. The classification process is executed by calculating the Euclidean distance between the training and testing datasets. Human action with minimum distance will be selected as the winner matching action. The maximum classification accuracy in this work is 93.4% for KTH dataset and 92.11% for UCF101.**

Keywords*—*human action recognition; Hu moment invariants; surveillance camera; Euclidean distance

I. Introduction

Human motion analysis is an important field of research in computer vision with many applications including surveillance footage, scene realization, user-interfaces, automatic activity recognition and augmented reality. Over the past years, human action recognition in videos has been popularized to have many real-world applications [1]. Thus, human action recognition has found applications across different scientific fields including information technology, artificial intelligence, image processing, acoustics classification, communication, computer diagnosis, and data mining [2].

However, the assortment of realistic video data has given rise to different challenges for action recognition. It has been a challenging problem in the computer vision analysis. The shape descriptors of moment invariants are important in computer vision. There are two types of shape descriptors: contour-based shape descriptors and region-based shape descriptors. Regular moment invariants are part of the most popular and are highly classified as contour-based shape descriptors [3], [4].

Generally, the human action recognition process includes two steps: feature extraction, and classification process. In this paper, we focus on recognizing different human action from video clips of KTH and UCF101 datasets including various environment backgrounds (outdoor, indoor, different views with difference clothes, gender). The video clips are recorded using surveillance camera that is stable with changes of recording conditions like side, position, direction and illumination. These conditions cause the problem of distinguishing the action accurately. To overcome this problem and to improve the recognition accuracy, Hu moments approach introduced by Hu [3] has been used in this work, where the values are invariant with respect to the scale, translation, and rotation. Moment invariants were chosen because they are one of the most important and most used methods in the object recognition field. The shape descriptors of Hu moments feature have been continuously developed and are a powerful tool for image recognition applications.

Seven-moment invariants have been calculated for each frame of KTH and UCF101 video clips, and they are stored as a 1D vector. To constringe our results, we compute the average value of these moments for each frame, and the final average of all these sub-averages has been calculated, which represents the dominant feature of that video clip. These calculations are repeated for the testing dataset also. Euclidean distance is the appropriate method for the classification process to measure the minimum distance between the final average of both the training and testing datasets for each class. Minimum distance indicates the closer human action of testing dataset to human action class of the training data.

The organization of this paper is as follows: *Section IV, A*, a database of different human actions is formed from each dataset. *Section VI, A*, the HMIV is trained based on that database by applying Hu moment invariants algorithm designed for feature extraction. *Section VI, B* a test dataset is applied on the proposed system utilizing the Euclidean distance classifier EDC to recognize the human action. *Section VI, C*, a comparison between the proposed HMIV and spatial-temporal SURF (ST-SURF) technique has been taken into consideration.

II. Literature Review

Human action recognition in video is a significant and challenging problem in computer vision and machine learning. Some of researchers focus on developing the recognition accuracy as in [5] and [6] by using huge and complex benchmark datasets as presented in [7]-[11]. Many different algorithms are used to achieve the best accuracy in the recognition process.

An adaptive multiple kernel learning approach applied in [12] to get the minimum mismatch between distributions from YouTube and consumer videos. While in [13], they used saliency thresholding concept to remove features from non-salient regions, and the remaining features contribute equally to the final representation measures. On the other hand, the moment technique itself implemented successfully in object detection presented in [4] and [14], also in trademark identification existed in [15] as pattern recognition. In general, the basic contribution of researches consisted of using Geometric Invariant Moment (GIM) to recognize objects of captured images.

Many specialized algorithms have been advanced for human action recognition. Computer vision applications include the task of detecting harmonization between two images with the similar scene or entity. [16]. For action recognition in video, both patio and temporal features are needed to represent the actions, while only spatial features, such as SIFT and SURF are needed for object scene recognition on a still image [17]. In action recognition's state-of-the-art, the BoW models are widely used since they have shown the effectiveness of local appearance based descriptors [18], [19].

In comparison with other approaches, Bag of visual word selection is still in its infancy. To extract video descriptors, many researchers have been investigating in tracking major parts of human bodies then extracting features from these regions [20]. However, they needed to setup many hypotheses. These considerations and hypothesis are often demanding. However, methods based on spatiotemporal features are promising for action recognition. Some of them were based on the extraction of low-level optical flows from cuboids [21]. This method gave good results in terms of feature selection and good classifications accuracy [21]. Besides, in [22] a spatiotemporal descriptor called ST-SURF was presented. That work was based on a combination of the speed up robust feature and the optical flow. In [23], the authors presented an algorithm for human action recognition from videos. His method was based on a combination of two feature types extracted from Aligned Motion Images (AMIs). AMIs is a technique for capturing the motion of all video's frames in one image. In addition, [24] was also based on aligned motion images (AMIs), but using three different sorts of AMIs, aligned motion history image (AMHI), aligned motion energy image (AMEI), and aligned gait energy image (AGEI).

It is worth to mention that the proposed work in this paper has been compared with the state-of-art [22], in terms of feature extraction, classification technique, and evaluated accuracy results.

III. Hu Moments Theory

The moment invariants were first introduced by Hu [3]. Hu moments algorithm is chosen to extract image features since the generated features are rotation scale translation. Geometric Moment GM was successfully applied in aircraft identification, texture classification and radar images for optical images matching [25].

Basic terms in the construction of the invariant moments have two steps. First, consider an image that has a gray function $f(x,y)$ having a bounded support and a finite nonzero integral. Second, geometric moment m_{pq} of the digital sampled $M \times M$ image $[f(x,y)]$, which can be computed using (1) [4].

$$m_{pq} = \sum_{x0}^{x=M-1} \sum_{y=0}^{y=M-1} (x)^{p} \cdot (y)^{q} \; f(x,y), \tag{1}$$

p,q = 0,1,2,3,….., where p,q are non-negative integers and (p+q) is called the order of the moment.

The moments of f (x, y) are translated by an amount (a, b), which is calculated by (2).

$$\mu_{pq} = \sum_{x} \sum_{y} (x+a)^{p} \cdot (y+b)^{q} \; f(x,y). \tag{2}$$

Consequently, the central moment μpq can be calculated from (2) by replacing a = - $\bar{x}$, and b = - $\bar{y}$ as

$$\bar{x} = \frac{m_{1,0}}{m_{0,0}}, \bar{y} = \frac{m_{0,1}}{m_{0,0}},$$

$$\mu_{pq} = \sum_{x} \sum_{y} (x-\bar{x})^{p} \cdot (y-\bar{y})^{q} \; f(x,y), \tag{3}$$

The central moment of the image is invariant to translation, while the scaling invariance can be achieved by normalizing the moments of the scaled image by the scaled energy of the original image that can be computed as stated below.

$$\eta_{pq} = \frac{\mu_{pq}}{\mu^{\gamma}{}_{00}}, \; \gamma = \frac{p+q}{2} + 1,$$

where γ is the normalization factor.

In fact, Hu defined seven values, calculated by normalizing central moments completed order three that are invariant to object scale, position, and orientation. In terms of the central moments, the seven moments are given as shown in (4) [26].

$$\left.\begin{aligned}
&M_1 = \eta_{20} + \eta_{02} \,,\\
&M_2 = (\eta_{20} - \eta_{02})^2 + 4\eta^2{}_{11} \,,\\
&M_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2,\\
&M_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \,,\\
&M_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right] +\\
&\qquad (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})\left[(\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2\right],\\
&M_6 = (\eta_{20} - \eta_{02})\left[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] +\\
&\qquad 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}),\\
&M_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})\right] +\\
&\qquad (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})\left[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} - \eta_{03})^2\right].
\end{aligned}\right\} \tag{4}$$

IV. PROPOSED TECHNIQUE

The proposed HMIV approach aims to detect a specific human action from videos of *N* frames. It includes extracting the features of the training and testing datasets using HMI algorithm. The extracted features of each action for both training and testing datasets are constringed to one magnitude, representing the distinctive features of that action. The classification process is the next step which depends on the Euclidian distance classifier between the training and testing datasets. Eventually, the human action of the minimum distance value would be selected as a matching action. Fig. 1 shows the block diagram of HMIV approach.

A. Data Acquisition

Data have been acquisition using KTH and UCF101 datasets. For each action, different recording conditions are covered, indoor, outdoor, various outfits, and gender. The input data is represented as frames sequences. In other words, the input is considered as 3D characteristics; (Height) × (Width) × (Number of frames). Fig. 2 shows the two used datasets.

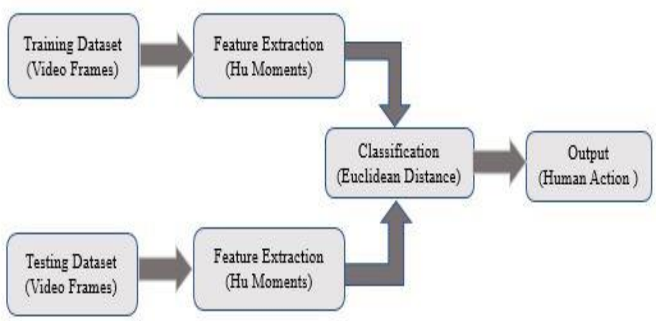


Fig. 1. Block diagram of the proposed HMIV approach

a. KTH dataset

b.UCF 101 dataset

Fig. 2. Two datasets including different human actions under various conditions

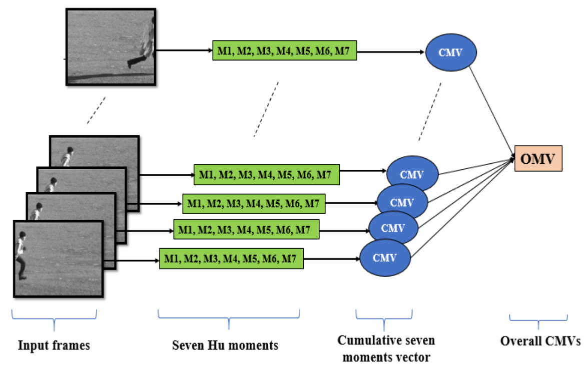


Fig. 3. Structure of feature extraction process

B. Feature Extraction

Features extraction process is a method of image transformations, which is capable to transfer high-dimension feature to the low-dimension feature vector. In another word, the feature extraction accomplishes dimensional compression, while preserving the essential information, which is most characteristic and necessary to the image [27]. Features selection and extraction are an outstanding process amongst the most significant strides in image recognition, which could impact on coming recognition process stages [28].

Indeed, feature extraction process includes computing seven Hu moments for each frame, and all moment's values are concatenated into a 1D vector.

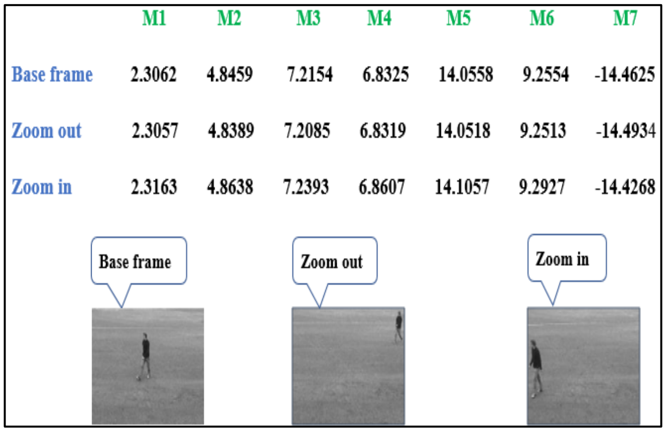
Under those circumstances, we calculated a vector of seven Hu moments for each frame. To address this issue, the average of those moments are computed as cumulative moments value (CMV) as shown in (5). To be able to accomplish accurate and fast calculation in the proposed algorithm, an average of all cumulative Hu moments values (CMVs) are constringed as overall moments value (OMV) for all the target frames carry out by (6). In fact, OMV grantees the dominant features that extracted from all the input frames for a specific human action. Fig.3 illustrates features extraction process.

$$\mu_{i,j} = \frac{\sum_{k=1}^{K} M_{i,j,k}}{K}, \qquad \forall i, \forall j, \tag{5}$$

where $\mu_{i,j}$ denotes the cumulative moments values, *i* is the number of human action's classes, and *j* represents numbers of frames.

$$\omega_i = \frac{\sum_{j=1}^{J} \mu_{i,j}}{J}, \qquad \forall i, \tag{6}$$

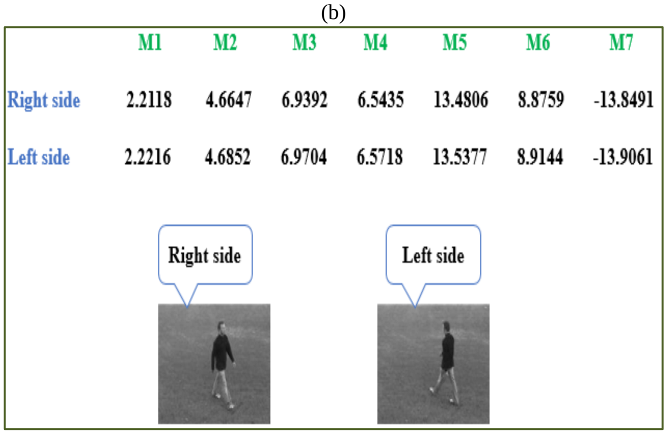
where ω_i symbolizes the overall moments value for each action, while *J* is the number of frames.



	M1	M2	M3	M4	M5	M6	M7
Base frame	2.3062	4.8459	7.2154	6.8325	14.0558	9.2554	-14.4625
Zoom out	2.3057	4.8389	7.2085	6.8319	14.0518	9.2513	-14.4934
Zoom in	2.3163	4.8638	7.2393	6.8607	14.1057	9.2927	-14.4268

(a)

(b)



	M1	M2	M3	M4	M5	M6	M7
Right side	2.2118	4.6647	6.9392	6.5435	13.4806	8.8759	-13.8491
Left side	2.2216	4.6852	6.9704	6.5718	13.5377	8.9144	-13.9061

(c)

Fig. 4. The power of Hu moment invariants identification

C. *Hu moments analysis on human action*

In human actions situation, it is essential to deal with an effective and valuable concepts in motion representation are based on HMI. For an instant, video sequences of walking action are taken, obviously, the HMI have such stationary values with a minor disparity in digits. As shown in Fig. 4 (a), it is back clearly that any individual moment of the base frame (M1 or M2 or … M7) almost preserves the same value in the zoom out and zoom in camera shot, even though the tracking person has various scaling. The zoom in and zoom out frames confirm the robustness of HMI; their moments are nearly identical (Fig. 4 (b)). Besides, the different positions (right or left) almost have no fluctuations on moments values individually (Fig. 4 (c)). For example, M1 in right side frame is 2.2118, which is just near to M1 value of the left side frame 2.2216). That highly demonstrates the efficiency of HMI theory on preserving the extracted features. In addition, person rotation could alter the image function more or less. Nonetheless, the moment invariants save varying while the person is rotated. Indeed, the theory strength relies on (4) entities, which cover all the possible recording conditions from the surveillance camera.

D. *Classification Process*

The distance measurement or similarity between images is an essential and an open issue in the computer vision and machine learning. The most commonly used distance is Euclidean distance, which converts images into vectors according to the gray levels of each pixel, and then compares intensity differences pixel by pixel. Deriving the Euclidean distance between two data points involves computing the square root for the sum of the differences squares between corresponding values, as described in [29].

Many applications in machine learning have commonly used the Euclidean distance, for an instance, K-Nearest Neighbor, K-Means Clustering, and the Gaussian kernel. Calculating the Euclidean distance can be significantly enhanced by taking benefit of the distinct instructions for performance matrix multiplications [30].

The Euclidean distance can be written in terms of a matrix multiplication that requires some reworking of the distance equation. In this work, recognition of human actions basically depends on Euclidean distance concept, which is easy to apply and less computational complexity. The classification process is performed using a convenient Euclidean distance classifier (EDC).

A similarity metric is based on the EDC, which computes the differences between OMV of the testing dataset and OMVs for different action classes of the training dataset, as adopted in (7):

$$D_{optimum} = \min\left(\sqrt{\left((\omega)_{Testing} - (\omega_i)_{Training}\right)^2}\right), \tag{7}$$

where $D_{optimum}$ is the minimum distance between the testing and training actions.

Fig. 5 demonstrates the proposed classification strategy. As described in *Section VI. B*, OMV for each action of the training dataset have been computed. Subsequently, OMV for the testing dataset has been calculated. The classifier EDC uses (7) to find the minimum difference value between the testing and training OMVs for each action. The action with the minimum value $D_{optimum}$ would be recognized as the closed action. Actually, $D_{optimum}$ refers to a severe convergence between the training action features and the testing one.

V. SURF VS. HMI

SURF algorithm (Speeded Up Robust Features) has been presented in [16]. It is needed for object scene recognition on a still image, and for extracting spatiotemporal features from videos. SURF can select a set of features from a dataset [17].

These features are tested to examine their ability for classifying a human action.

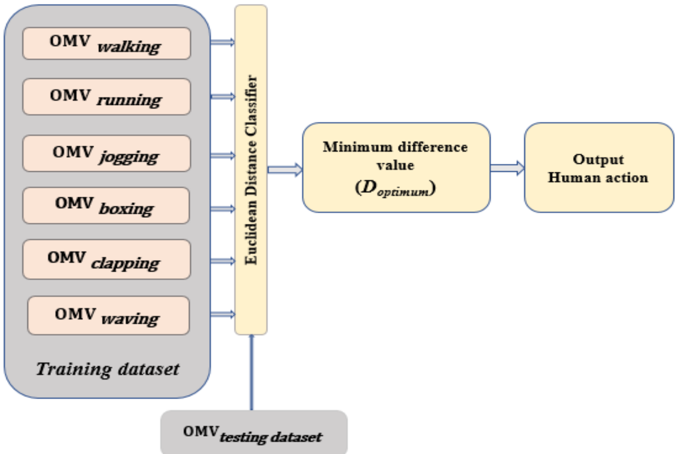


Fig. 5. Block diagram of classification process

The SURF detector includes Hessian-based detectors, which are more steady and repeatable than their Harris-based counterparts. Also, common calculations, like the different of Gaussian (DoG), provide a high speed at a low cost in terms of lost accuracy. In contrast, SURF descriptor defines a spreading of Haar wavelet responses inside the interest point neighborhood [16].

As a part of this research, an explicit comparison between SURF algorithm presented in [22] and our proposed HMIV has been introduced. The work in [22] goaled for detecting human actions based on SURF method. The procedures were summarized in three steps. First, video sequences were segmented in frame packets and a group of interest points. Second, the interest points ST-SURF (Spatial-temporal SURF) were localized and extracted from all training videos. After that, the extracted ST-SURFs were gathered via K-means clustering algorithm. The video clips were characterized as a K-bins histogram of the quantized descriptors “bag of spatiotemporal visual words” BoSTVW. Lastly, an SVM (support vector machine) classifier was trained by means of these histograms. The results of ST-SURF were evaluated using KTH and UCF sports datasets.

On the other hand, the proposed HMIV in this paper aims for human actions recognition; it is built depending on the HMI algorithm for the interest feature extraction, and Euclidean distance classifier EDC for the classification process. This model serves a surveillance camera system that is used to record various videos of human actions under different environments (indoor and outdoor), and different conditions of side, position, direction and illumination. In fact, HMI have an effective efficiency of maintaining their probative values, even though there are various changes in scale, translation, and rotation. Further, EDC classifier is easy to apply, it computes the difference between OMV from each training and testing action. As result, the minimum difference value indicates the winner human action. The datasets in this work are KTH and UCF101.

TABLE I. HU MOMENTS FOR WALKING ACTION FRAMES OF KTH DATASET

Hu moments	M1	M2	M3	M4	M5	M6	M7
Fram1	2.5380	0.3045	0.9058	0.5306	0.4355	0.1829	-15.6406
Fram2	2.5381	0.3046	0.9061	0.5308	0.4359	0.1832	-15.6409
Fram3	2.5381	0.3046	0.9060	0.5308	0.4358	0.1832	-15.6408
Fram4	2.5385	0.3057	0.9079	0.5320	0.4384	0.1849	-15.6427
Fram5	2.5385	0.3060	0.9085	0.5322	0.4392	0.1853	-15.6439
Fram6	2.5384	0.3063	0.9096	0.5322	0.4398	0.1854	-15.6454
Fram7	2.5388	0.3083	0.9146	0.5340	0.4450	0.1883	-15.6513
Fram8	2.5388	0.3087	0.9155	0.5339	0.4453	0.1884	-15.6509
⋮				⋮			⋮
Fram48	2.5279	0.2827	0.8679	0.4999	0.3741	0.1413	-15.5974
Fram49	2.5277	0.2816	0.8662	0.4992	0.3726	0.1401	-15.5993
Fram50	2.5271	0.2797	0.8632	0.4975	0.3686	0.1374	-15.5986

VI. EXPERIMENTAL RESULTS

The experiments have been evaluated using two different datasets with gray and color resolutions. The proposed HMIV performance has been estimated under different surveillance camera recording conditions of a side, position, direction, illumination, and an environment. KTH dataset is one of the widely common used datasets, it is presented in [31]. While UCF101 datasets are obtained from [32]. The inputs of the proposed HMIV include six different human actions; walking, running, jogging, boxing, handwaving, and handclapping for KTH dataset. On the other hand, for the UCF 101 dataset, baseball pitch, basketball, bench press, biking, and balance beam are chosen. These actions are considered by way of a database for model training.

A. Training

In this stage, the model was trained using the HMI algorithm. During model training, the feature extraction process was executed for six different categories. Using HMI, many conditions should be considered, such as the various side, positions, illumination including person shadow to guarantee the performance. As mentioned in Section IV. B, at the end of this stage, the most important features were constringed as one dense value, which is OMV for each training action.

By way of example, Table I illustrates the moments for walking action frames of KTH dataset. It shows the effective power of HMI weights with person movement and action displacement. These weights represent the dominant features of frame images. As labeled in Table I, it is obvious that the moments of frame1 (M1, M2,…,M7) nearly keep the equivalent value for the rest frames, excepting minor differences in decimal digits. In addition, Fig. 6 shows an example of the salient HMI features of KTH actions, despite there is a clear convergence of their moment's values.

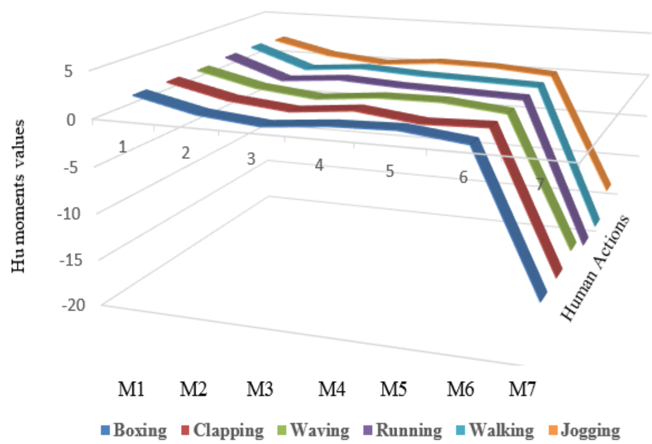


Fig. 6. Hu moment invariants for different human actions of KTH dataset

B. Testing and Results

For the proposed HMIV evaluation, comprehensive investigations have been implemented on KTH and UCF101 datasets. To realize greatest predictable classification accuracy, sets of human actions frames with different conditions and environments are tested. In a like manner of the training section, the testing dataset is processed under HMI algorithm for extracting action features and obtaining OMV. Subsequently, OMV of testing dataset is examined with all OMVs of training dataset classes, to figure out which action is the closest matching one. EDC would be prepared for that classification process by calculating the minimum difference value adopted as (6).

For evaluation purpose, the experimentation results are carried out using KTH and UCF101 datasets. It is verified that the designed HMIV displays promising results. As shown in two Figs. 7 and 8, confusion matrices include the classification accuracy for per human action. For KTH dataset in Fig. 7, jogging action has the maximum classification accuracy about 96%, compared with handwaving action accuracy which is the minimum among them about 88%. Overall, the KTH dataset reaches an aggregate classification accuracy of 93.4%. Moreover, a maximum classification accuracy in UCF101 basketball action reaches to 94.55%, while the minimum accuracy runs to 89.23% at bench press action. The aggregate classification accuracy arrives at 92.11% for the UCF101 dataset.

The classification error rate appears in Fig. 9 (a,b) for KTH and UCF101 respectively. By observing error results, for KTH dataset actions, handwaving has the maximum error value of about 0.12. In contrast, the minimum error has been recorded in jogging around 0.04. But regarding to UCF101 dataset actions, the maximum error value is noted in bench action for about 0.1077, while the minimum one is belonged to basketball action of 0.0564.

C. Comparative Studies

As described in section V, the designed descriptor using ST-SURF was compared with the proposed HMIV. Comparing with the results driven by the best classification accuracy result of the ST-SURF, the HMIV approach achieves 93.4% for KTH dataset better than the 88.2% reported using Spatiotemporal SURF (ST-SURF) presented in [22]. Besides, outperforming the accuracy results related to UCF dataset in HMIV is 92.11%, whereas in ST-SURF was 80.7% as illustrated in Table II.

VII. Conclusion

In this paper, our contribution toward exhibiting HMIV qualification is in the feature extraction stage according to SURF method. A MATLAB code of the *detectSURFFeatures* function is implemented on KTH dataset of walking action. It is important to mention that SURF method cannot recognize the action features when a part of the human body disappears or is hidden from view In contrast, HMIV captures the features of the same case. Fig. 10 confirms this status; SURF descriptor display no feature detect, while our proposed HMIV gives the ordinary seven moments.

The work of proposed HMIV in this paper has been compared with other state-of-the-art techniques. Table III clarifies the classification accuracy results of the human actions literature works in comparison with ours. Overall, the proposed HMIV demonstrates a considerably improved performance compared with other existing state-of-the-art methods.

In this paper, we present and demonstrate the advantage of the HMIV model for human actions recognition of video frames sequence. It gives a basic usefulness of solving surveillance camera recording problems, such as various position (right, left, forth and back), illumination (indoor, outdoor, shadow), and disorganized environment (gender, outfits). Environment changing highly effects on the feature extraction of human actions. It is worth to mention that the Hu moment invariants HMI have such a distinguished power on preserving the extracted features from images sequences. Two different datasets have been used in our approach, KTH, and UCF101 with various human actions. The designed descriptor is based on Hu moment invariants HMI algorithm. The proposed feature extraction process consists on computing seven moments as features that are invariants to scale, translation, and rotation. Then, the moments of each frame are mapped into a 1D vector space for each action class of the training and testing datasets. To reduce the dimension of feature vector into one intensive value, the average of vector's values is calculated as cumulative moments value (CMV).

Because datasets (training and testing) are as 3D input data, and each dataset has multi-actions, so we summarize CMVs into overall moments value OMV. Whereas OMV considers as the dominantly interesting features that extracted from all input frames for a specific human action. Afterward, the recognition process in this work is employed using an appropriate Euclidean distance classifier (EDC).

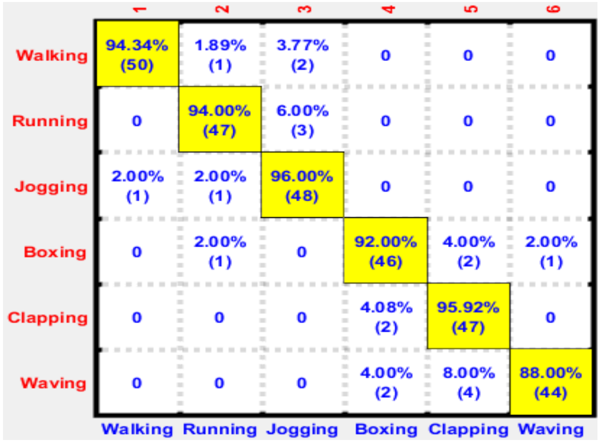


Fig. 7. Confusion matrices for classification accuracy per human action for KTH dataset

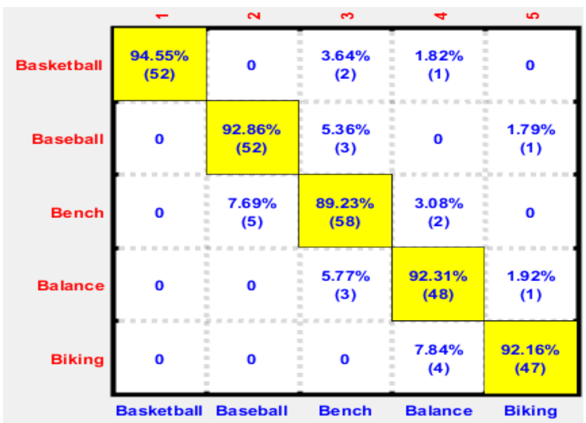


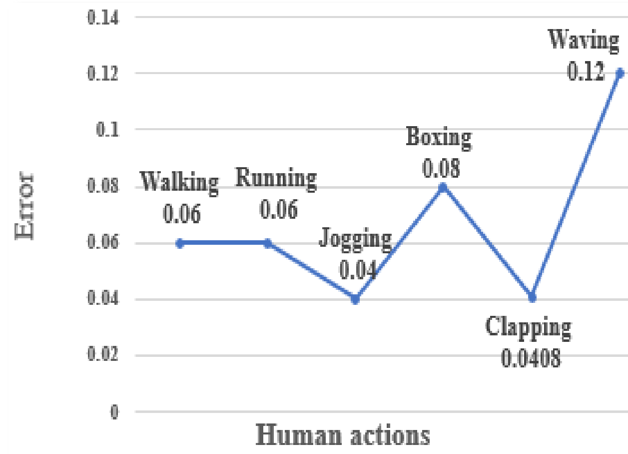
Fig. 8. Confusion matrices for classification accuracy per human action for UCF101 dataset

TABLE II. COMPARISON CLASSIFICATION ACCURACY OF PROPOSED HMIV AND ST-SURF

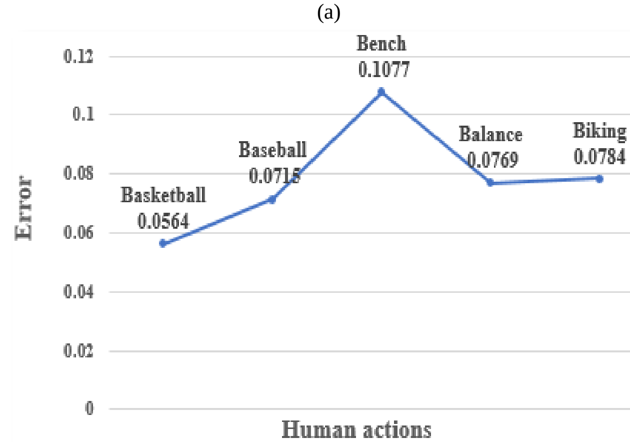
	KTH	UCF
ST-SURF	88.2 %	80.7%
HMIV	**93.4%**	**92.11%**

TABLE III. COMPARISON CLASSIFICATION ACCURACY OF PROPOSED HMIV WITH THE STATE-OF-THE-ARTS

KTH		
Schu¨ldt et al. [31]	Local SVM Approach	71.7%
Doll´ar et al. [33]	Sparse Spatio-Temporal Features	81.2%
Niebles et al. [34]	Unsupervised learning method	83.3%
Jhuang et al. [35]	A biologically-motivated system	91.7%
Ji et al. [36]	3D Convolutional Neural Network	90.2%
HMIV	**Hu Moment Invariants on Video**	**93.4%**
UCF sports		
Wang et al. [37]	Local spatio-temporal features	85.60%
Kovashka et al. [38]	Discriminative Space-Time Neighborhood Features for	87.27%
Arac et al. [39]	Lagrangian Descriptors	89.97%
HMIV	**Hu Moment Invariants on Video**	**92.11%**



(a)



(b)

Fig. 9. Error estimation of the proposed HMIV for: (a) KTH, and (b) UCF101 datasets

SURF	No features						
HMIV	M1	M2	M3	M4	M5	M6	M7
Features	2.3090	4.8449	7.2162	6.8397	14.066	9.2621	-14.517

Fig. 10. SURF descriptor shows no feature detect, but HMIV obtains moments features when a part of human body disappears

From the other point of view, we present a comparison between the proposed HMIV and ST-SURF (Spatial-temporal SURF), in terms of the used features extraction technique and classification accuracy. The proposed approach in this paper reaches to 93.4% for KTH dataset, which is better than 88.2% reported via ST-SURF. In addition, HMIV performs more improved than ST-SURF. The accuracy result correlated to HMIV for UCF dataset is 92.11%, however in ST-SURF had 80.7%.

As a future task, we are looking forward to investigating approaches for objects detection, EEG signal classification, and facial expression recognition.

VIII. Discussion

In this paper, human actions are recognized by the implemented HMI algorithm in features extraction and EDC classifier for the recognition process. They are commonly utilized in object recognition due to their discriminations strength and robustness. As has been noted in the confusion matrices, the average accuracy over each of the six actions for KTH and five sports actions of UCF101 datasets is satisfied. HMIV produced good results, in terms of an average classification accuracy of 93.4% for KTH dataset. However, less accuracy is observed in the handwaving action, which is 88%. It is obviously clear that handwaving is similar with handclapping action mostly (8% error ratio), while less similarity with boxing action (4%), because it basically depends on hands motions. In addition, HMIV approach highly discriminates the jogging action with best existing accuracy of 96%. This results due to the fact that the extracted features of this action have a lack of correspondence among other actions, except a small error ration of 2% with running and walking actions.

Besides, for UCF101 dataset has an average recognition accuracy of 92.11%. The bench action has the minimum accuracy of about 89.23%, there is some matching features with the baseball action with 7.69% error ratio. Whereas, basketball is the best recognized action having an accuracy of 94.55%. In other words, HMI algorithm with the EDC could highly capture its features accurately. Lastly but not least, comparing with results driven by the state-of-the-art existing methods.

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Learning Analytics in a Shared-Network Educational Environment: Ethical Issues and Countermeasures

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***Abstract*—The recent trend in the development of education across the globe is the use of the new Learning Analytics (LA) tools and technologies in teaching and learning. The potential benefits of LA notwithstanding, potential ethical issues have to be considered and addressed in order to avoid any legal issues that might arise from its use. As a result of this, Higher Education Institutions (HEIs) involved in the development of LA tools need to pay particular attention to every ethical challenges/constraint that might arise.**

This paper aims to identify and discuss several ethical issues connected with the practice and use of LA tools and technologies in analysing and predicting the performance of students in a shared network environment of HEIs. The study discusses the four ethical issues of Information and Communication Technology namely Privacy, Accuracy, Property and Accessibility (PAPA's Model) as well as other approaches to explain these future concerns. The paper also presents the empirical evidence of the views of students on the analytical use and storage of their data.

The results indicate that even though students have high trust in the privacy and security of their data being used by their institutions, more than half of the students have ethical concerns with the accessibility and storage of their data beyond a certain period. In the light of this, generalised strategies on ethical issues of the use of learners' data in an HEI shared networked environment are proposed.

Keywords*—Learning Analytics; Student's data; Emerging technologies; Ethical Issues; Higher Education

I. Introduction

Learning analytics is an emerging technology that is becoming of great use in various areas of education - from the pre-school level to the tertiary level education. Presently, some researchers have also identified its uses in healthcare education and in educational (serious) games [31, 22, 29, 6, and 23]. The adoption of LA technologies has been very dynamic and ever changing as the nature of ICT changes globally. Its importance and benefits are seen in all sections of education, from traditional face-to-face teaching to blended education and e-learning [2]. In the same empirical study, Ali et al. [2] investigated factors influencing adoption of LA tools and found that intuitive interfaces, students' learning interaction, perceived usefulness of the tools, sustainability of usefulness among others have great influence on adoption of the tools while the educator's pedagogical role has no influence. However, its implementation in the UK is still in the nascent stage, presently nearly half of the HEIs (47.2%) have not implemented LA while another 34% are just considering implementing it. In total, only about 18.9% have either fully or partially implemented it [14]. In predictive analytic use of LA in measuring students' performance, over 95% of HEIs are not using it at all with a mere 2.5% making adequate use of it. This low implementation rate has been attributed to the level of understanding of the possible benefits of LA in HEIs apart from the problem of the high cost of initial implementation. In total, only 22.6% of management in HEIs understand the short and long terms benefits of LA use in their institutions [14].

Therefore, one of the recurrent questions from this emerging area of education is how to increase the motivation to use it effectively in HEIs. However, the bulk of the responsibility for its use is on the major stakeholders - the administrators (Institution), the teachers and the students [12, 3]. These three major stakeholders have great responsibilities in the development and use of LA technology.

- **The Administrators:** Identify the technology, propose its use, provide an enabling environment, propose the implementation strategy and monitor the use of the tools. Other responsibilities revolve around administrative decision-making.
- **The Teachers:** decide on the importance, acceptance and adaptability/personalization of the tool to meet the interest and preference of the learner. The teachers assess the suitability of the tools and give feedback on how to improve the functionality and performance.
- **The Students:** determine the impact of the use of the tools on their learning and learning environment. The students give the necessary feedback on the advantages of the tools on their performance.

Other stakeholders include the course developer /researchers, computer/network administrators, technicians, data analysts. Therefore, LA implementation is human–centred and thus requires human cooperation for its effective adoption. Though the use of LA is not the panacea to all student problems, it may form a useful tool for identifying students at risk of failing.

However, ethical issues need to be considered with implementing LA tools especially now that HEs have systems that link students' demographic data with their educational performance data as well as their interaction with online learning resources to predict their future performance or even recommend material for them [29]. This is often referred to as longitudinal unique identification that helps connect data across platforms or systems [11]. HEs are a good example of such complex adaptive systems (CASs) where data, files, programs and other resources are collected and shared across different systems by different people [13, 16]. This is referred to as a shared networked environment. Hence, stakeholder involvement is necessary from the design stage to the implementation stage of LA tools with focus on unintended consequences and challenges that might arise with this emerging technology.

Learning Analytics, like any other emerging technology, poses new challenges emerging from the complexity of its uses, security, accessibility, privacy as well as other ethical issues. These ethical issues and other practical questions about Learning Analytics ethics are still unresolved [24, 7]. According to [24], the present legal framework in HE cannot handle properly the issues of ethics, security and privacy concerns that might arise within LA in the future. It will, therefore, be of great benefit to identify these challenges and find solutions to them at an early stage of development before they become more difficult to address later. Nevertheless, it should be noted that ethics in practice might be a bit difficult as there will always be a situation where the new framework may be found wanting in a real–world situation as technology progresses [10].

The unethical use of LA technologies by stakeholders (teachers, administrators, system administrators) as well as other system users will be increasingly invasive toward the lives of the learners and may further lead to serious problems such as exposure of confidential data to hackers, cyberbullies, or other criminals. In addition, the convergence of other disciplines (education, psychology, computing) in LA has made the coherent discourse on LA ethics difficult as well as making Mason's (1986) ethical model look outdated. Therefore, it is expedient to know the potential benefits and application of LA in HEIs but also to understand the potential ethical issues in HEIs and how to offer solutions to them.

Hence this study primarily investigates ethical issues associated with the implementation of Learning Analytical tools in HEIs. Three main research questions are proposed for the study;

- Q1- What are the main ethical concerns around the use of LA tools and technologies in HEIs.
- Q2- What are the views of learners on the ethical use of their data by HEIs?
- Q3 – What are the coping strategies to handle LA ethical issues in HEIs?

A good understanding of the LA ethical issues and the strategy to handle them will be of significant use to the various stakeholders in HEIs and the educational sector in general. The findings from the study might help to facilitate the development of a general policy framework for LA ethics in HE, facilitate training programs for students and other stakeholders as well as help in improving the design of LA tools and technologies to be more ethically complaint.

II. Theoretical Background

A. *Defining Learning Analytics, Learner Data and LA Tools*

There have been several definitions of LA that have emerged, however, the definition given by the Society of Learning Analytic Research (SOLAR) at the 1st Conference on Learning Analytics and Knowledge has been widely accepted. They defined LA as *"the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs"*. From this definition, it can be deduced that LA has no data of its own but exists to handle and analyse derived meta-data and other large datasets of learners for their benefit.

Another definition was given by Del Blanco et al. [8] who described LA as *"a discipline that gathered and analyzed educational data with different purposes such as seeking a pattern in the learning process and trends or problems in student performance"* while Greller and Drachsler [12] defined it as an academic domain *"that focused on learners, their learning processes, and behaviors"*. From all these definitions it can be seen that LA focuses on learners and the huge data collected about them for meaningful pattern discovery.

Learner data or student data can be defined as known or assumed information or facts, an observation about the learner collected for the purposes of analysis and decision making. It can also be described as the extraction and analysis of both static and dynamic learner data from different heterogeneous systems (databases) for use in the improvement of the learning process and the learning environment. Static data is from the university record systems while the dynamic data is from the systems such as the learning management system, virtual learning environment or social media. Learner data is an integral part of a learner's life and gives a clear picture about them, their past, present and the future and as such it is of great value to them. Alber [1] noted that learner data can be collected using formative assessment (quizzes, debate, question and answer), observation, summative assessment (projects and exams) and previous standardised test scores as well as cumulative files. However, the sources of learner data available to HEIs is continually increasing and this can be classified into five major groups:

- Demographic data: This data includes age, gender, place of birth, location, education, employment status.
- Behavioural data: This includes student interaction data from discussion forums, online activities, blogs etc as well as video and audio records of groups or individual activities.
- Assessment data: This includes data from coursework, assessment and examination.
- Financial data: This is the financial information store about the learner and it includes the sources of funding, fee status, tuition update, support allowances.
- Historical progression data: This is the information store about students after graduation and includes

degree type and class, employment data, location, forwarding address/contact, continuing education data, and alumni.

The diagram of common sources of learner data is presented in Figure 1

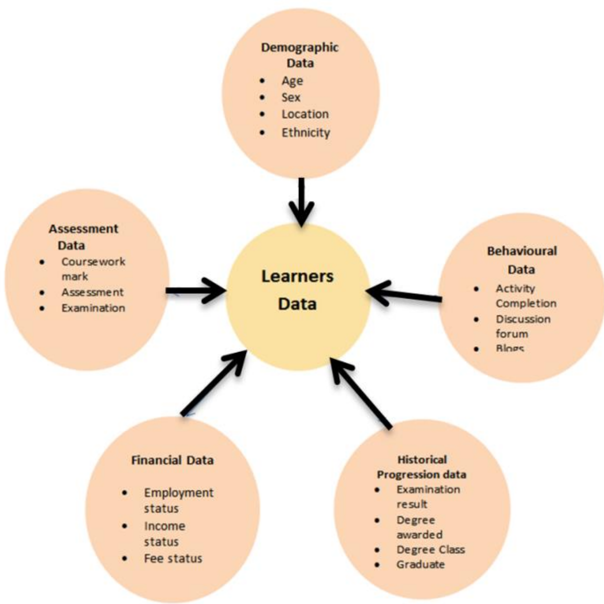

Fig. 1. Different sources of learner's data

While HEIs have always had access to data to work with, the increase in data being generated over time is unprecedented and associated technologies and analytic capabilities are trying to cope with the data increase [21]. In their study, Prinsloo et al [21] described LA as the "new black" box and learner data as the "new oil. They further explained that as there is an increase in learner data, there needs to be an understanding of the complexities of analysis of these data. This knowledge should facilitate the development of enabling technologies that will help gain an insight for the improvement of student performance, success and retention.

LA tools have been categorised variously by researchers. Siemens [24] grouped LA tools into two broad classes: **Commercial tools** developed by companies such as SPSS, NVivo and Stata and **Open Tools** such as Rapidminer, R, SNAPP and WEKA. Slater et al [26] also reviewed forty EDM/LA tools and categorised them into Data manipulation tools (MS Excel, EDM workbench, Structured Query Language), Algorithms analytical tools (Rapidminer, WEKA, SPSS,KEEL, Orange), Visualization tools (D3.js. D3.js, Tableau) and specialized tools such as Text mining, Coh-Metrix, WMatrix, Linguistic Inquiry and Word Count, LightSIDE. Other analytic tools that are more educational or system-specific include: Ellucian, Desire2Learn, Purdue University Signal for early warning about student performance, University of Maryland's "Check my Activity" tools for comparing learning activity of learners in LMS and Edith Cowan University's early warning tools called Connect for Success (C4S). A summary of all these tools was presented in a special study of LA tools and approaches by [4].

These LA tools used along with the learner data make analysis and assessment of students possible early in the semester without waiting for the tests or examination results at the end of the semester/year; ie. all the valuable information about students can be made available at the beginning or during the course of study so it can be used to assist their learning and learning environment. However, it should be noted that LA has no specific tools of its own but makes use of data mining tools for analysis and interpretation, which make it of great necessity to develop LA specific tools.

III. The Major Ethical Issues in the Implementation of LA in HEIs

Learning analytics is a recent trend in education data mining (EDM) that makes use of learners' data for learners' benefits. In HEIs, the benefits of its implementation are quite clear and such benefits have significant advantages for all the stakeholders. However, despite the laudable benefits of the implementation of LA tools in HEIs, there are still some ethical issues that might arise that need to be properly addressed.

Ethics has been defined by Bynum [5] as various concerns for the protection and advancement of central human values such as life, health, security, happiness, freedom, knowledge, resources, power and opportunity. It is the fundamental decision on what is 'good,' 'bad,' 'right,' 'wrong,' 'ought', before applying actions [27]. As such, it is not just good to understand the benefits of any new technologies but the ethical challenges that may arise from it. Though the issues of ethics in IT have been developed since the 1980s, its importance and application to the new age and emerging technologies needs to be revisited especially in this era of "Big data" in education. LA ethical issues are concerns on how the learners' data that are available to the users can have an impact on learners' lives and uphold their moral values. In this regard, the following question arises: "has the use of the learner's data benefitted the HEIs and makes the learner happy or otherwise? Therefore, to answer this question correctly, all potential ethical issues should be identified and addressed during the course of the design, development and implementation of the technology.

Willis, Campbell and Pistilli [30] in their article discussed these ethical issues using the Potter Box Ethical model to answer various questions that an administrator must address when using learner data. The Potter Box ethical Model/Concept is an ethical decision-making tool made up of four quadrants (steps):

- Provision of empirical definition (ie. defining the ethical dilemma using empirical information).
- Identification Values (involves prioritising the ethical issues).
- Identification and appeal to ethical value (involves identification and application of ethical principles or reasoning that will help in making an effective decision regarding the dilemma).
- Choosing loyalties (making a choice of where loyalties lie).

From this concept, different responsibilities and recommendations are made to the stakeholders that will enable them to make an effective ethical decision. However, this paper examines the ethical issues using Mason (1986) PAPA's Model and other approaches that describe the various vulnerabilities of people and organisation in the emerging ICT era. These are discussed below:

Property - This term applied not just to the concepts of software or technological ownership but also to Data ownership as well as the right to information and value of information. The data collected and stored in different databases of HEIs, the one collected through interaction with learning management system (via trackers, xAPI) and those collected through survey questionnaire do have issues of ownership. Who owns the data and the information derived from it and how can the information be used? Thinking of these issues brings about the following questions.

a) Who really owns the data? The student? The University? The System provider?

b) How can the data be used?

c) Who has access to learner data analysis?

d) What type of learner data is stored in that database?

e) How and for what duration can the data be stored?

f) Which geographical areas can the data be used?

g) Should students be able to see what the institution sees about them?

h) What happens to the data after students completion of their studies?

These and other related ethical questions need to be properly addressed. Though the issue of data ownership may sound legal, there is a moral ethical issue embedded within it as well. Presently the legal system has not been able to address the challenges of data ownership and copyright in the use of the learner's digital information [28].

Moreover, Property involves protection of intellectual property rights (IPR). The increase in data usage and new technologies have made protecting IPR challenging and this might have an impact on the ethical use of LA technologies. It also includes knowledge and skills possessed by the user of the technology. The lower the skills and knowledge, the lower efficiency and the safe use of the tools. Stronger IPR ensures that the tools and technologies (especially computer programs or algorithms) are not easily or cheaply reproducible and provide protection and security to the data. However, this might affect the rate of future development of such tools. In addition, students should know about the fundamental laws that protect them, their data, their works as well as the use of their data or materials by others.

Accuracy - This ethical issue mostly arises in LA implementation where there are complexity and multiplicity of databases to access for analysis. As learner data sources, complexity and variety increase, the issue of analysis and computation of accuracy may be adversely affected. Continual system input, processing, and system output, especially in a shared network and distributed databases using different LA tools, can often lead to missing data, errors in data as well as data mix-up or misplacement. Moreover, analytic software complexity can lead to inaccurate data being generated and used. Another major source of inaccuracy is in predictor selector and modelling which sometimes can involve complex statistical analysis. Therefore the question is how to ensure validity through the minimization of incomplete and inaccurate data. It is, however, important to note that, there might be legal issues involved when inaccurate or incorrect information about learners are used or distributed among systems.

Privacy – Privacy in the context of LA is ensuring the confidentiality of learners' information. Privacy protection is a widely accepted method of data protection and LA may pose privacy concerns as more data is being analysed especially where commercial tools are being used. One aspect of privacy is the inappropriate or unauthorised access to personal information. Every access to a database service by a stakeholder (user) means there is exchange of some information between the system and user as well as with various systems and even with the service provider. In addition, many commercial tool providers are looking for ways of making a profit from not just the students' data but also from the teachers' and universities' data and this is done through reselling of data to third parties [18].

In HEIs the following set of people has direct access to learner data: management, administration, student affairs and student counsellors, faculty and the students themselves. Hence, there needs to be an understanding by the learner of the type and extent of information they are implicitly or explicitly providing others access to. In as much as it might be viewed that all these people are helping the student to succeed, to some learners, it might mean an invasion of privacy. Unrestricted, unauthorised and privileged access to student data can lead to a breach of privacy, the source of which can be complicated to trace. Privacy breach in HEIs can also be the consequence of faulty protocol, database invasion as well as abuse by malicious users. This may involve divulging important confidential information about health status, marital status, personal information, private email correspondence and other information to a third party. Privacy issues usually occur during LA implementation due to lack of user control mechanisms over the networked environment as well as unauthorised access to data.

Accessibility – Accessibility in LA deals with authority and right to obtain learner data and the type of information one should have access to**.** The issue of accessibility relates both to the technology and the learner from which the data is derived. Learners should be aware and have access to the data and LA operation as well as the results of such operations performed on their data but presently this is not so. This often leads to lack of trust on the part of the learner. However, the issue of accessibility should be viewed from the learner's angle. Learners have the legal right to have access to their data, access the accuracy and correctness as well as being able to correct it when there is any mistake in the data held about them.

Trust – Trust enhances the implementation of LA as well as the technology acceptance of LA. The issues of trust by the learner in the use of their data is another major concern that might seriously affect LA as the data might be in the hands of the third parties. What about the situation of distrust in which the student may be unwilling to provide data or opt-out of the data being used for analysis? These and more questions need to be properly addressed. Trust is not just related to the tools or technologies but also to the users. Though the HEIs might give assurances about trust, the situation might arise where some elements within the shared networked system might mishandle and mismanage student data leading to security concerns and consequently, such trusts have to be periodically reviewed.

Security - There are various security issues that need to be considered during implementation and use of LA tools. A security breach or risk may be due to data location compromised, data loss, unauthorised access or unintended or inappropriate disclosures/exposure of data. In a networked environment, the challenges of breach of security are greater. This may be as a result of switching-related problems where, in most time, the confidentiality is breached.

IV. Survey Scenario of Learner Ethical Perception on the Use of Their Data

A. Materials and Methods

The study carried out a survey questionnaire using Survey Monkey in September 2016. The questionnaire emails were sent to students' mailboxes and non-probability sampling techniques was used in which every student have equal chance to respond as well as being selected. A total of 209 students at the University of the West of Scotland responded to the survey over a period of two weeks. The aim of the survey is to measure student perceptions on the use of their data and other the ethical issues relating to it. 77 participants (36.8%) were male and 132 (63.2%) were female while the modal age of participant ranges from 18 to 25 years. The questionnaire consisted of two main parts, first part collected demographic information while the second part was made up of six LA ethical-related questions, namely informed consent, security, awareness, trust, data accuracy and accessibility to data. The questionnaires responses were then analysed using SPSS version 22.0.

B. Results and Discussion

The survey was conducted based on the six questions in Table 1 using some of the items mentioned in Mason's four ethical issues of the information age [17]. A total of 151 students in level 8 to level 10 provided valid answers to the questionnaire for the study. The detailed results are presented in Table 2.

TABLE I. Questions on Ethical Perception and Consideration

Question
Q1 Are you aware of the ethics and data protection policy of the use of your data by your Institution?
Q2 Do you trust your tutors and the institution mechanism on the use and security of your personal information?
Q3 Do you ever think your personal information privacy might be breached or information used inappropriately by your institution?
Q4 Would you want your personal or analysed information to be kept for a longer period by the institution after your graduation?
Q5 Have you ever observed mistake or complained about the correctness of the personal information or data kept about you by the Institution?
Q6 Would you like to have access to analytical information stored about you by your Institution?

TABLE II. Percentage of Respondents to Each Question

Scale (%)	Q1	Q2	Q3	Q4	Q5	Q6
No	22.00	2.67	62.67	46.67	85.23	18.00
Neutral	18.67	17.33	27.33	39.33	6.04	27.33
Yes	59.33	80.00	10.00	14.00	8.72	54.67

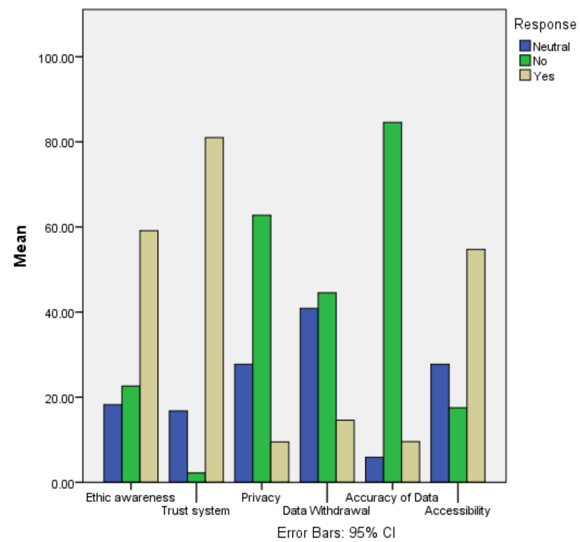

Fig. 2. Learners' Ethical Perception Results

Figure 2 shows that 33 students (more than 20%) are not aware of the ethics and data protection policy operating within the HEI and as such may not be aware of how their personal data might be used by the institution while another 28 students (18.5%) are not certain of whether such a policy actually exists or not. Though there is a sizeable number of students (90 students / 59.6%) that are aware of the data protection policy but the general result shows that there is an inadequate awareness on the ethical issues and their rights by the students and as such might not know when there is an abuse of their rights or misuse of their information.

For the second question, majority of the students (121 students / 80.1%) trust the institution's mechanism for the security of their personal information and thus believe that it cannot be hacked or their information used inappropriately. For the third question, 94 students (62.3 %) think their personal information is protected while only 15 students (9.9 %) believe it might be breached. However, the opinion of students on question 4 shows that 70 students (more than 46%) want their data and analysed information to be removed from the institutional databases and never to be used for further analyses after their graduation. In addition, nearly equivalent percentage (39.3%) of students are undecided on this, signifying that a significant number of the students are not aware of either the positive or negative ethical consequences of the post-graduation data storage. This further points to the problem of awareness of ethical rights and privileges as discussed above in question 1. It can be deduced that over 80% of students (about 120 students) want their data removed after graduation strongly suggesting that HEIs should formulate a policy that will ensure periodic appraisal of consent on approval (withdrawal) of data use. The respondents' judgment on the issue of accuracy of data as depicted by question 5 shows that 127 students (84.1%) have never observed any mistake in their data while 10% of the students have observed inaccuracies. This shows significantly meticulous data collection and processing methods in the university. Question 6 on the issue of student data accessibility shows that 83 of the students (nearly 55%) still have some ethical perception regarding data accessibility and would like to have more access to their personal data and analysed information stored about them by the university. Again, universities should encourage and permit this.

The general consensus from this study is that there is a need for an up-to-date and complete reference on the issues of ethics in the light of the general growth rate of new LA technologies and increase in the volume of learners' data. Learner's awareness of the ethical issues relating to them should be enhanced through regular training or the use of game based IT ethics and security training.

V. THE COUNTER MEASURES

Since the use of LA technologies is still at a nascent stage of development, the proper use of learner data for analysis and prediction must be a matter of great attention. Personal student data should be protected in order to avoid loss of confidentiality, trust, and integrity by the students. However, the bulk of the responsibility of dealing with ethical issues in HEIs lies with administration and Government. The following are the proposed strategies for protecting learner data from the design of the technology to deployment of the technology.

Design - Tools design approach and methodology can play a major part in dealing with issues ethics, security and privacy especially at present when the LA discipline is just emerging and there exists a lack a standardisation [24, 8]. There should be ethical considerations guiding the design, development, and deployment of LA technologies in a shared environment. Smart LA technology is a major solution to the problem of lack of LA specific tools and potential ethical issues that might arise in LA implementation. However, it should be noted that some HEIs have designed their own specific technologies but there are still many ethical issues relating to their use. Future design of LA tools should consider the various aspects of ethics for education in a shared environment, which should include supporting technologies that address the problem of privacy, security, and trust. Below are some suggested areas where ethical considerations should be made during the design.

a) Tools should have a section where data can be made anonymous; this is known as value sensitive design (protecting what a person considered of value or sensitive to him or her).In addition, data can be encrypted to prevent unauthorised access.

b) Development of an efficient system that streamlines the techniques used for heterogeneous databases.

c) Tools should be designed to improve the interoperability, extensibility and reusability of data within the system without breaching privacy [9].

d) Tools should be designed in such a way that incorrect or inconsistency of data entered is flagged or highlighted even in different databases e.g. age, race, gender.

e) Tools should be designed to be able to adapt to increasing data sources.

f) Generally, LA tools and systems should be designed in consultation with students in order to address the ethical issues correctly

g) The tool should be designed to align with the institutional ethics standards.

Centralised control - In order to ensure the security of learners' data, there should be a well monitored and centralised control of access to student database system. However, the level of access should be layered to avoid a breach. The following control mechanisms should be carried out in networked environment

a) Use of Certificate of Authority – This involves registering and attributing authorities to all users, making sure all valid users are assigned global unique identities in before implementing access authorisation control.

b) Access authorization control.

c) Access Authentication.

This can always be achieved using single and multiple sign-in procedures.

Privacy mechanisms - In a networked environment, privacy mechanisms should be designed and developed using specific data mining and other algorithms. The privacy mechanisms should cater for the LA domain with focus on these two categories of people who might have access to the system – genuine staff and malicious workers (including hackers). To address the issues of privacy, policy on data usage in LA should be clearly defined. This should include the extent of access to learner data by staff, the use of sensitive data (religion, ethnicity), sharing of data with external bodies, policy on anonymizing of data. Staffs who make use of a shared networked environment must understand their limitations, what they are allowed or forbidden to do. This should be well defined. In addition, to enhance privacy protection, the tool could prevent the execution of certain kinds of analyses where it would lead to the identification of individual students. In addition, staff who have no reason to use the LA tools should have no right to a system or databases where personal files and detail on students are held.

Reduced and restricted access - Reduced and restricted access should be enforced on all personnel that are not directly related to teaching and advising the student with their performance. Personal Identification Information (PII) can be implemented in order to get access to areas considered to be confidential and personal to students. There is a need to define a guiding principle of accessibility, who has access to a certain section of the network or database, and the kind of information that needs to be accessible to them. These questions can then be raised "which person or group of people should have more accessibility than others? And which criteria will be used in deciding the level of accessibility?" This should be properly defined for all users; needs-basis authorization should also be created while the proxy use of data is discouraged in all cases.

Informed consent and approval - To address ethical issues from the student's point of view, there should be transparency in the way learners' data are used. HEIs should always seek students' informed consent for collection and use of their data. This should include outsourcing the data to third parties, the right to opt out, withdraw from data collection, periodical renewal of consent to use data, consent to use data in a different way as well as protection of identity. The same process should also be applied to publicly available data about the students.

Policy framework development: Presently in the UK, only 10% of HEIs have adopted a code of practice or policy on the ethical use of data [14] and in order to avoid ethical breaches in the use of LA in a shared environment, new policies relating to IPR issues should be developed by HEIs. Just as many educational establishments have collaborated to develop standard e-learning content interoperability [8], similar collaboration should be geared towards establishing ethical standards for LA. The HEIs must put in place a well-defined access policy covering all stages of development. Without this, institutional change in the use of data may not come about. The policy should include guidelines and codes of conduct for staff using student data, including clear identification of who has access to learner data, the level of access, restriction. A good example of the policy is enumerated by Sclater in JISC's code of practice and rule of engagement for Learning Analytics. Developing a good policy framework in a shared environment will not only improve significantly the level of implementation of LA tools but also address various ethical issues that might act as a hindrance to its success.

In line with all these measures, institutions need to regularly organise conferences, workshop, and training for all academic, non-academic staff as well as students for proper understanding and knowledge about LA ethics and code of practice.

VI. Conclusions and Further Work

The uptake and use of LA is expanding and as such the ethical issues related to LA practice need to be considered and addressed.

With the increase in the use and acceptance of LA technologies, the risks and consequences of e unethical use of learner data may increase especially in a shared networked environment. The current ethical policy framework used in most HEIs may not be sufficient to effectively address the potential issues of the use of these tools as well as the legal consequences. In addition to this, students (learners) are becoming more aware of their legal rights in relation to the use of their data and if a proper ethical framework is not put in place, there might be serious problems.

Therefore, this paper has examined the ethical issues arising from implementing of LA technologies in such an environment and proposed the adoption of enhanced practices and policy frameworks from the design, development to the point of deployment of LA tools that will ensure that the rights and responsibilities of learners respected. In addition, the study proposes a framework that will address the issues of accessibility, post-graduation informed consent and security of learners' data and has suggested the establishment of ethical rules to guide the users and necessary sanctions applied when breached.

One contribution of this study apart from the opening of theoretical discussions on ethical issues of LA in a shared network environment of HEIs is the establishment of the learners' views on accessibility to their personal data and analytical information. The research has shown that most learners would like access to the data kept about them by the HEIs as well as have the right to withdraw consent for their data use after graduation. However, the study has a limitation in that it was performed at only one institution in Scotland and with a small dataset, therefore to be able to generalise the result of the study a larger sample should be used and the study should cover a representative sample of UK HEIs.

Future work needs to empirically address other open challenges of LA ethics (such as benefits and dangers of giving data ownership rights to any of the stakeholders) as well as develop a framework and a system that will integrate and support students' accessibility to LA tools and their data. Also, more empirical work should be performed on ethics of LA tools using a student-centric approach.

Finally, it must be noted that ethics is gradually becoming a reference discourse in Learning Analytics and as such a clearly articulated framework, policy and model should be developed for it.

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Dynamic Service Adaptation Architecture

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***Abstract*—This paper proposes a software architecture for dynamical service adaptation. The services are constituted by reusable software components. The adaptation's goal is to optimize the service function of their execution context. For a first step, the context will take into account just the user needs but other elements will be added. A particular feature in our proposition is the profiles that are used not only to describe the context's elements but also the components itself. An Adapter analyzes the compatibility between all these profiles and detects the points where the profiles are not compatibles. The same Adapter search and apply the possible adaptation solutions: component customization, insertion, extraction or replacement.**

Keywords—Adaptative service; software component; service; dynamic adaptation

I. Introduction

Software is executed in complex, heterogeneous, and highly interwoven computer infrastructures, in which a diversity of events may take place. Such events may be, for example, security threats, network problems, reduced performance in one of the servers, etc. In such situations, it is preferable to adapt the software to continue to provide the required functionality. The software adaptation can be considered as the possibility for man to reconfigure the software and then restart it; it may also be seen as the software's ability to reconfigure during execution [1]. The first case of adaptation is considered as static, while the second one is dynamic. It is possible to perform static adaptations or adjustments in cases where the system can be stopped to make the required manual adjustments. However, there are critical systems that cannot be stopped to implement the modifications, e.g. software that run power grids, and software used in the World Bank. In such situations, the software needs to dynamically adapt its behavior during execution in response to the changing conditions within its computer infrastructure support ([2], [3], [4]).

Such software programs are increasingly based on a service-oriented architecture and are implemented in dynamic and distributed large scale environments.

A service-based application should take into account different elements that interact with its functioning. It is well accepted that:

- Service-based applications are characterized by the use of heterogeneous and distributed components provided by third parties, a component is a binary composition unit with specified contractually interfaces and explicit context dependencies; it can be deployed independently and is subject to composition by third parties.
- The miniaturization of the devices and their mobility make them personal objects in their own right. Users then show a particular interest in being able to access a multitude of services and features from anywhere and any device.
- Users are also increasingly sensitive to the customization of the applications they use on their devices, such as adapting the GUI to the capabilities of the device, adapting the application to suit their preferences such as language, or adaptation depending on their movements or physical environment (brightness, temperature, etc.).

All these enumerated items are grouped in the concept of context of service. This context is variable; Dynamic availability of devices, network connectivity, location, and user preferences may change unpredictably during application execution. The adaptation of services to the context is an important problem whose solution varies over time.

Consider that a service application is built by assembling components. It is believed that the adaptation of this application is performed in its architecture by adding / removing / replacing its components.

This article is organized as follows: section 2 consists of a study of the existing domain and presents some models of components and some service architectures. After studying the weaknesses found in previous solutions, an illustrative example is used to present our proposal, in sections 3 and 4. The prototype implemented in this study, in order to validate the architecture, is described in section 5. Finally, the results obtained are exposed in the conclusion.

II. Study of the Existing Situation

Several studies, addressing the dynamic adaptation, are founded on component-based models. Recently, a component model has emerged in the industrial world, namely the Web service.

Basically, a Web service is a special software component that is searched, linked, and executed at runtime. It enables systems to interact through standard Internet protocols [5]. In order to reach their full potential, Web services can be combined to achieve specific functionalities. If the implementation of a Web service for business logic implies the use of other Web services, then this is called a composite service. In the case of web services, the assembly has a temporal dimension and is configured as a workflow assembly.

Research works ([6], [7], [8], [9]) targeted the evaluation of quality attributes of service orchestrations based on aggregation rules. These works share the same principle. The basic idea is to define the rules of aggregation for each workflow pattern and for each quality attribute. In most cases, the rules are defined for a couple of workflow patterns, often denoted as "composition patterns" ([7], [8]), except for "sequence" and "loop" patterns, which are considered individually.

Related works on the dynamic adaptation of service compositions can be classified into three groups. The first group supports the dynamic adaptation at the language level ([10], [11], [12], [13], [14]). This approach may harm the reasoning of adaptations with complex scripts and may be prone to error ([15]). The second group focuses on the low-level implementation mechanisms for self-adaptation ([15], [16], [17], [18]). This approach is not widely supported for the analysis of the variability inherent in the dynamic adaptation at the time of conception, and can impair the reasoning about adaptations with complex and error-prone scripts.

The third group carries on by using the reconfiguration transition system (RTS). Authors in [19] defined a transition graph model at the time of conception. The nodes of the graph represent the configurations of the system, and the arcs (edges) represent the reconfiguration transitions, which are the required operations to adapt a system from one configuration to another. However, the number of valid configurations may grow exponentially for a large number of variability points of the system due to the combination of characteristics. Therefore, the construction of such a diagram model may be impossible in a large number of areas.

III. Objective

The present study aims to provide a software architecture that enables the dynamic adaptation of services which are built by assembling components, depending on different use contexts.

In more detail:

The Evaluation of the behavior of each service in relation to its context of use, is done by analyzing the behavior of each component that constitutes the service.

Use a profile for each constituent of the service, which describes the component itself and the set of context elements.

An adapter analyzes the conformance between the different profiles of each component and the profiles of the context elements.

The adapter must then be able to identify the different incompatibilities, apply necessary modifications, with add, remove or replace one or more service components to remedy the problem of maladaptation.

As part of this first experiment, the context concerns the needs of users. The main characteristic of our proposal is that the behavior of each service with respect to its context of use is evaluated from the analysis of the behavior of each component making up the service. For this reason, profiles that describe not only the elements of context but also each component constituting the service are used. An Adapter analyzes the conformity between the different profiles of each component and the profiles of context elements. The adapter detects the mismatch points, then seeks the required changes and applies them to the different components of the service to restore this compatibility, by changing the configuration parameters, by adding, removing, or replacing components.

IV. Architecture for Dynamic Adaptation of Service

The proposed architecture consists of three parts, as illustrated in Figure 1:

- The modifiable part. This portion is composed mainly by the service, which consists of an assembly of components. The modifiable items include the components and the various interconnections between them.
- The monitoring part. This portion is represented by monitors which observe the resources and user profiles. These elements provide the necessary data for a complete description of the service, called meta-description of the service-context.
- The control part. This section is represented by an adapter which, from the description of the service-context, decides which modification is necessary in order to accommodate the service, and an assembler which executes what the adaptor decides. The adapter uses the existing components as adaptive solutions (by adding, modifying or removing components). These components are predefined by the application designer and grouped into a component-based set.

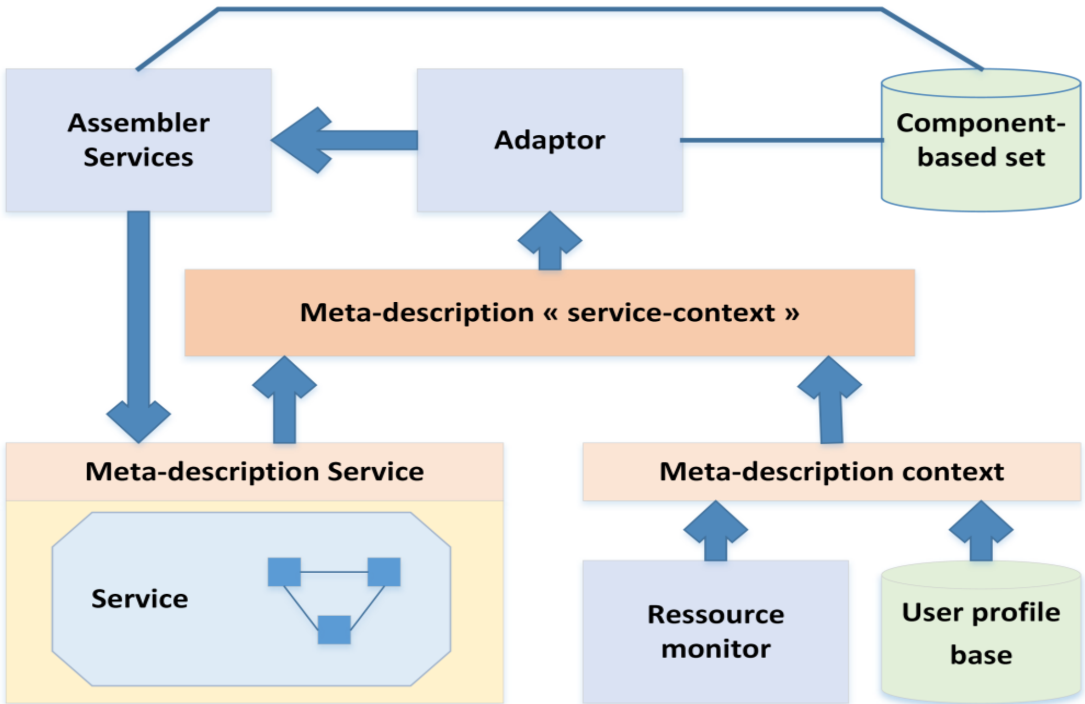

Fig. 1. Architecture for dynamic adaptation of service

A. *Illustrative example*

An electronic forum service or bulletin board system (BBS) allows a community of students to exchange information on scientific and cultural activities taking place within the university.

For practical reasons, the language of communication is the French language, and student members have the opportunity to write and read on the forum.

B. *Identify the Headings*

Figure 2 illustrates a perspective on the meta-description of the service-context that corresponds to the scenario presented in the illustrative example. Three different levels are found:

- The user plane (UP) which includes the physical elements of the context
- The arrangement scheme of components containing the architecture description language (ADL) of the service as well as the interface definition language (IDL) of the components.
- The ADLs describe the software architectures. The rewriting rules capture and combine the adaptations in the form of sets of rules (patterns) and facilitate their selection.
- The profiles plane combines the service profile and the context profile; it indicates the operation of the service.

a) The user plane – physical elements of context: The physical plane comprises the physical elements of the context. In this case, these elements are the users of the forum service. The elements found in this plane have projections in the profile plane. These projections constitute the meta-description of the context.

b) The compnent plane – Service, components, and assembly: The component plane includes service S in the form of an assembly of software components, which form the basis of the Bundles of the OSGI platform. In our example, this plane consists of:

- Component A to display messages posted to the forum,
- Component E to write a new message,
- Component F to represent the forum containing all the messages posted to the forum.

The HMI of service S is developed from a composition of the HMIs of components E and A. The component plane represents the syntactic part of the meta-description of the service. To describe the service in this plane, an architecture description language is used to determine the internal architecture of the service, the IDL descriptors and the interconnections, which are MANIFEST.MF files for the components. The HMI is also included in the interconnections (or connectors).

c) The profile plane - User profile, component profile, composition of profiles: The profile plane is essential for adaptation, because it represents the semantic part of the meta-description of the service-context. For the chosen example, this plane contains:

The profile service (PS) and the user profile (UP). The profile service (PS) results from the combination of profiles of components that make up the S Service, i.e. profile for writing a message (WP), profile for displaying a message (DP), and forum profile (FP). This plane contains the semantics of the service-context.

In our example, the user profile contains one single parameter, namely language = 'Ar' indicating a user who writes Arabic. The profile of a component indicates how this component operates with respect to the context parameters. The profile for a translation component Arabic – French is given next:

```
<profile>
    <component>Translation AR_FR</component>
    <point>
        <interface>Translation</interface>
        <method>translate</method>
        <argument>text</argument>
        <argtype>String</argtype>
        <precondition>langue = ‘AR’ </precondition>
    </point>
    <point>
        <interface>Translation</interface>
        <method>translate</method>
        <returntype>String</returntype>
        <function>=</function>
        <postcondition>langue = ‘FR’</postcondition>
    </point>
</profile>
```

This profile indicates the behavior of the component relative to the language; at the interface "Translation" of the component "Translation AR_FR", there is a pre-condition on the parameter "language" which requests the value "AR".

The returned value gives the value "FR". Therefore, this component changes the language. Thanks to the profile, the adapter can discover this fact.

The service profile, which is a composite component, results from the composition of the profiles of components W (write), D (display), F (forum); conventionally, F requires language = 'FR'.

d) Adaptation axioms of the service-context: Regarding the semantic part of the service-context, i.e. the one corresponding to the profile plane, there is a need to define the axioms (evidence or condition) that are verified to see if a service is adapted to its context. For the example under consideration, there is one axiom only. There is a need to adapt the service-context if the profile parameter values are contradictory. In our example, if the user writes in Arabic, there is a contradiction for the "language" parameter (Ar <> Fr) at the HMI of service S. In this case, the adaptation axiom is not verified.

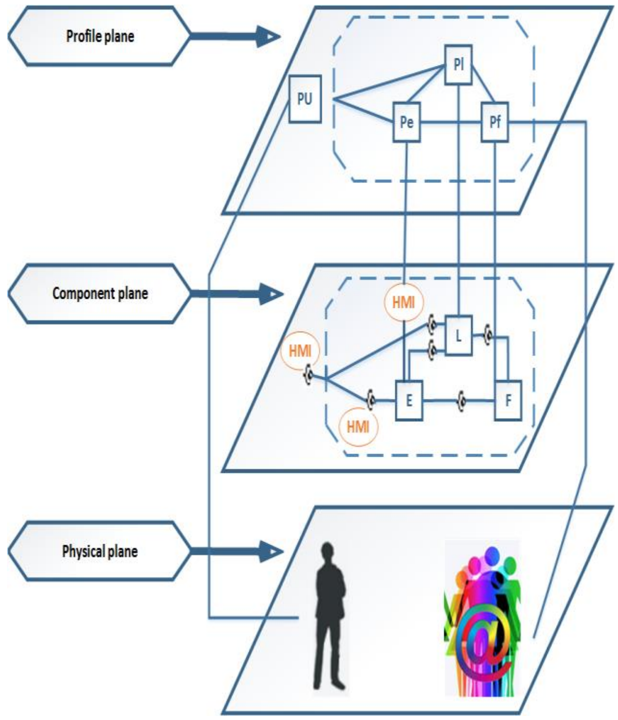

Fig. 2. Meta-description of the service-context - Various view planes

C. The adapter - Algorithm

The adapter should be able to adapt the service; its automation requires the use of dynamic formalisms and proceeds in three stages [20]:

- A technique is developed to detect in compatibilities,
- An abstract description of the properties of the adapted system, the mediator between components (adapter), or a simple correspondence between interfaces is provided; this is called the mapping of adaptation,
- The adaptation process is then generated automatically, using that Mapping with the interfaces of the components to be adapted. When the adapter is placed within the execution context, it allows correcting the system.

The Mapping of adaptation can be obtained automatically by using techniques from the field of semantic Web services [21]; It may also be provided by the software architect, and this is the case treated here.

An adapter is proposed here to perform the following operations:

a) Checking: The adaptation axioms are verified, for each parameter of the profiles; if they are all satisfied, it is an adapted service.

b) Searching for an adaptation solution: . If for at least one parameter, an axiom is not satisfied, an adaptation should be found:

- For each parameter that does not satisfy the axioms, the adapter builds a graph with nodes representing the component interfaces which have a relationship with that parameter and whose arcs are the interconnections,
- In this graph, the adapter locates the branches (chain of nodes) containing unequal values. For each branch, the adapter searches for components whose insertion in this branch helps restore the equal values.

c) applying the solution: if the adapter reaches that point, it can apply the solution obtained.

V. Prototype

The proposed architecture consists of three parts, as illustrated in Figure 1:

A – Display the forum

E - Write a message,

Proxy F - a local connector towards the remote component F - Forum.

Component T - Translation is dynamically added to the request of the adapter, using:

- The Wcomp platform [22] which offers a development environment based on software components; it allows creating dynamically the interconnections with ISL4Wcomp. The dynamic adaptation to Wcomp is done by the addition, removal, connection and disconnection of the software components during the execution of the application.
- The interaction language ISL4Wcomp [23] (Interaction Specification Language For Wcomp) is based on the interaction specification language (ISL) which enables to describe the interaction patterns between objects [24]. However, ISL4Wcomp tends to adapt these specifications in order to take into account the interactions that are based on messages or events in the components encountered in the assembly aspects.

The adapter finds the translation component T in the component directory. The search is carried out from the component profile while respecting the type of connections.

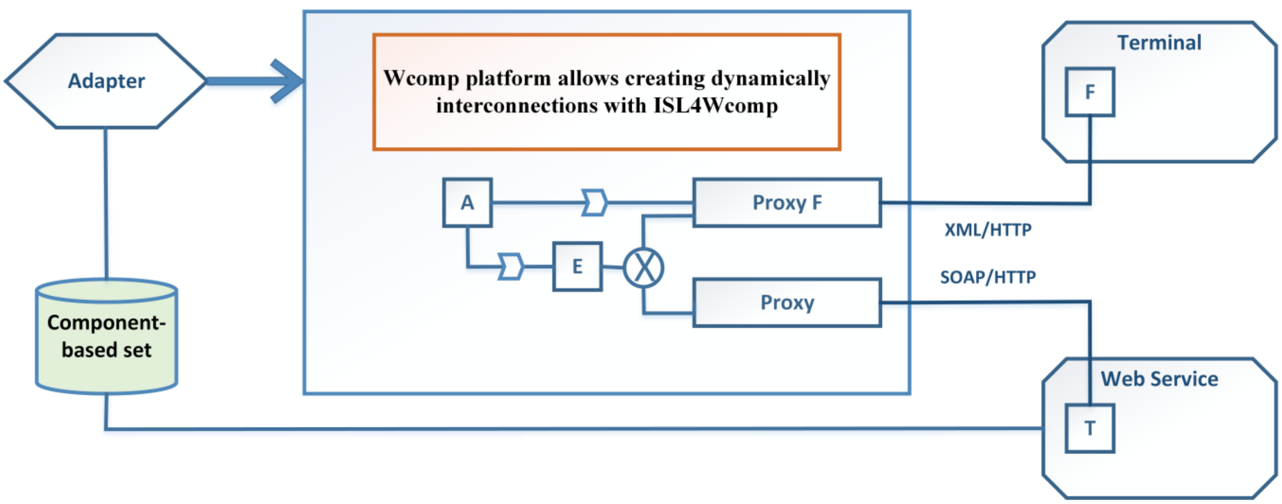

Fig. 3. Schematic of the prototype

VI. Conclusion

An architecture that allows the dynamic adaptation of services is developed in this article. Our proposal is based on the meta-description of the service-context in which we have a limited set of adaptation axioms that are based on the semantics of the service. It is not necessary to describe the different evolution rules; they can be found through the analysis of inadequacy cases, under the condition that each component is described with its profile.

To show that this architecture works, a prototype of forum service was proposed. This service was initially created for French-speaking users, but the proposed architecture enables adapting this service by dynamically adding a translation component if the user's language is not French.

The main weakness of the proposed architecture is its complexity. The suggested model still needs to be generalized and simplified so that the various profile parameters may combine in a simpler manner, while retaining the richness which is required to express the axioms of adaptation.

Despite these limitations and difficulties, the authors believe that the future of adaptation belongs to the semantic composition of services. To achieve this, the functioning of the service-context must be understandable both for the machine and the human services developer.

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A Comprehensive Insight towards Research Direction in Information Propagation

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***Abstract*—The concept of Information Propagation has been studied to illustrate the particular, discrete, and explicit behavior of the nodes in a complex and highly distributed and connected networks. The complex network structure exhibits various challenges towards information propagation due to the usage of diversified communication protocol and dynamic behavior in the context of uncertainty. This paper is first one of its kind, which reviews frequently addressed problems, the most significant research techniques, for addressing various research problems associated with the information propagation concerning to social network analysis, data routing behavior in the multi-path wireless networks, multimedia transmission, and security. This paper is useful for the various researchers, academicians, and industry having research interest into social network analysis, predictive modeling and information propagation analysis.**

***Keywords*—Information Propagation Prediction; Social Network Analysis; Predcitive Modelling; Information Propogation**

I. Introduction

With the advent of modernization in telecommunication and pervasive computing, there has been an enormous growth of data generation [1] [2]. Information is being generated using both voluntary and involuntary process. Voluntary process of information generation will be that is generated by a particular system or process or an individual, e.g. credit/deposit update of user's account in a bank, call logs generated by making calls, chat script of two individual over a network etc. Involuntary data is being generated by sensor or any particular data capturing unit. Normally, the process of information generation using involuntary process uses a particular schedule or duration during which the information is being recorded after being generated. However, for the voluntary process of information generation, there is no such schedule and the process could be extremely dynamic in nature [3] [4]. Hence, maximum complication and research problems could definitely arrive in the process of voluntary information generation. The challenges are i) predicting the time and node for information generation is not possible, ii) there exist uncertainty of applying certain storage models or applying analytical operation over the generated data, iii) it also effects the security features, iv) identifying or analyzing relationship among nodes in the network [5][6]. The existing size of information in the era of cloud is quite high dimensional and thereby performing sub-clustering on such higher dimensional data is still an open research problem. Although it has become two decades of using the internet, it is quite necessary to understand the true picture of information propagation over the complex networking structures [7] [8] [9]. There has been various break-through research works towards mining operation but in reality performing complex analytical operation towards complex data generated by the voluntary process in a social network is still an NP-hard problem [10]. At present, there are a various offering of multiple technologies with different communications protocols, which is striking factor influencing information propagation. The most difficult are to understand the traffic model or the underlying topology that governs information propagation of recent time.

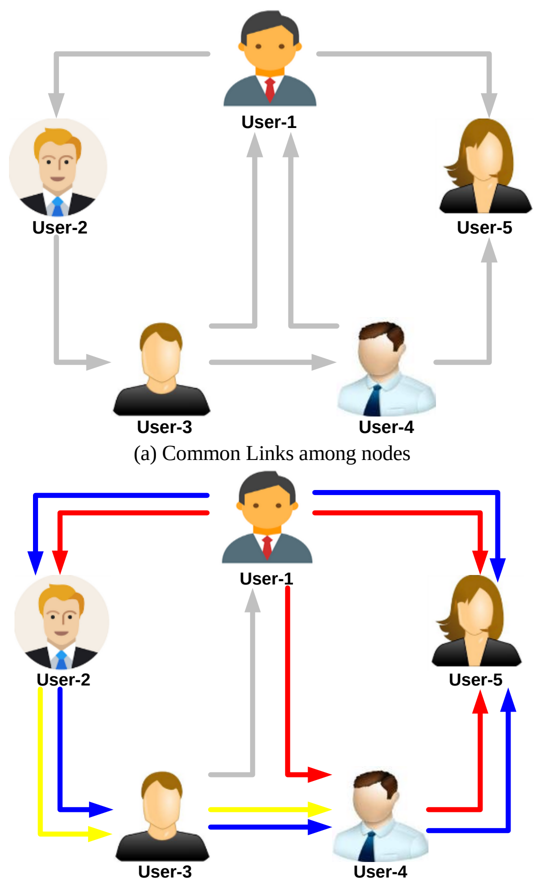
Another challenging issue in the area of the information propagation is to develop a generalized protocol that can perform exploration of the user-defined queries of the complex network. Although, the majority of the information extracted is in the form of the text, but all the information are not in textual format and may possibly differ. This could lead to another impediment towards information processing in complex networks. At present, graph and contents are used for performing analysis of the social network data but for the large and massive size of the data, such techniques are also becoming inapplicable [11][12]. This voluntary process leads to a generation of massive data which is uncertain in nature, is voluminous in size, and highly heterogeneous in its type. Such problem would definitely pose a significant level of impediment towards working on the upcoming complex forms of the network with more pervasiveness.

This research paper discusses the theoretical aspects of information propagation and attempts to highlight the progressive picture of its research work and its possible effectiveness. The information propagation is still in a nascent stage with respect to a voluntary process of data generation which requires further attention. This paper discusses various research problems being addressed by the existing researcher towards the domain of information propagation.

Section II discusses the information propagation followed by existing trends of research work in Section III. Various significant research techniques towards information propagation are discussed in Section IV followed by a discussion of the research gap in Section V. Finally, Section VI summarizes the contribution paper.

II. Information Propagation

There is a massive and infinite amount of information that flows over the World Wide Web (www) almost every second. Information propagation is one of the essential theories that act as a backbone for a maximum number of networks.



(a) Common Links among nodes

(b) Latent links among nodes

Fig. 1. Implication of Information Flow

Fig.1. (a) shows that there is a possible network communication existing among all the different types of users. However, just by observing this would mean the existing of links but doesn't give much discrete information about the type of the links [13]. The patterns of behavior among the communicating nodes are very different in a centralized system as well as in distributed system. To meet the demand of the existing customers, the majority of the enterprises are turning up their application from centralized to distributive so that it can be reached to maximum customers [14]. The presence of such links among the communicating nodes in Fig.1 (a) doesn't show any form of distinguishing behavior among the nodes. Therefore, information propagation assists in discretizing such forms of the communication links. Fig.1 (b) shows an unambiguous form of the links that were latent in nature. Hence more the dimensionality of data size is more and the probability that such links become more latent in nature [15]. Hence, exploring such latent links from the generalization links are the agenda of information propagation. The model of information propagation can be represented as the transmission of specific information from one node i to another node j for a given communicating environment and it is usually illustrated using abstract algebra using lattice. It was also observed that the theory of the information propagation is interpreted in the form of security policies in the communication channel. The information propagation represents the mechanism by which a data propagates throughput the networks and system. Maximum of the existing research techniques considers the challenges of enhancing the communication among the nodes and identifying the potential node for a specific job in a very dynamic environment. The message to be propagated would be in the form of a static web-page, a textual message shared in a social network, an address of a particular site, etc. The biggest challenging factor in this regard is to increase the influence of any particular node in a positive sense. The process of increasing the influence in information propagation targets to choose a certain quantity of nodes that has higher influence over other nodes for a given network [16] [17]. The another research challenge in information propagation is information diffusion [18]. These problems equally affect the structure of the link for a given network. However, it doesn't leverage any effects towards the information that are being exchanged among the nodes, which negates or weakens the present communication channel.

In the conventional network, it has been seen that the information diffusion considers the spreading of the influence among its adjacent nodes and grows exponentially over a period of time. However, as per certain studies, it was seen that probability has no dependencies towards neighborhood size [19]. It is the quantity of the inter-connected components with the nodes that affect the node's influential factor. The theory of information propagation has introduced certain algorithm e.g. PageRank algorithm [20], which is used at present by Google. Basically, Page Rank algorithm performs search optimization over a given link. It allocates a numerical weight to all the hyperlinked contents over the internet. The work carried out by Sargolzaei et al. [21] has elaborated discussed the problems pertaining to presently used technique to understand the node influence in information propagation. The authors have also discussed certain equivalent techniques related to PageRank and its possible enhancement in future. The implication of information propagation is quite high and is potentially needed in order to extract a lot of information within the given network. The next section will discuss the existing research trends towards information propagation.

III. Research Trends

This section discusses the existing research trends with an aid of certain statistics of research papers published and archived in last six years. It is explored that information propagation has various forms of associated implication towards different forms of research problems.

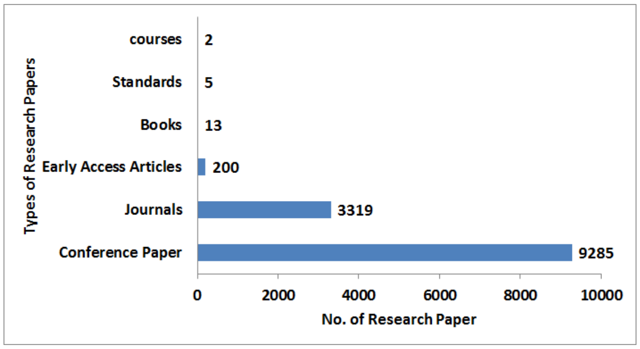


Fig. 2. Research trends on Information Propagation (source: IEEE Xplore)

It is noticed that there are 9285 conference papers and 3319 research journals published from 2010 to 2016 pertaining to various problems in information propagation. A closer look into this statistics shows that less number of standard implementation work being focused as visible by a lower number of journals as compared to the conference. Apart from this, there are 200 easy access articles, 5 standards, and 2 course related articles were published in this duration. In this, also did in-depth investigation towards understanding these trends to infer the various forms of research work that has been evolved over such period of time.

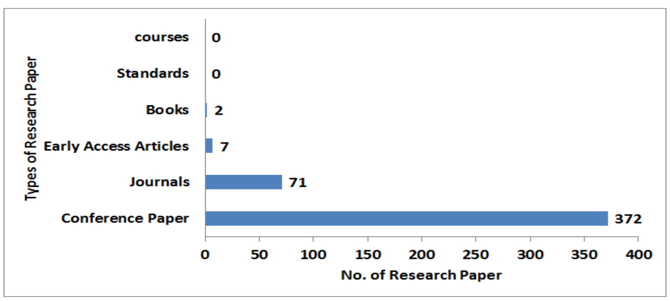


Fig. 3. Research trends on Social Network

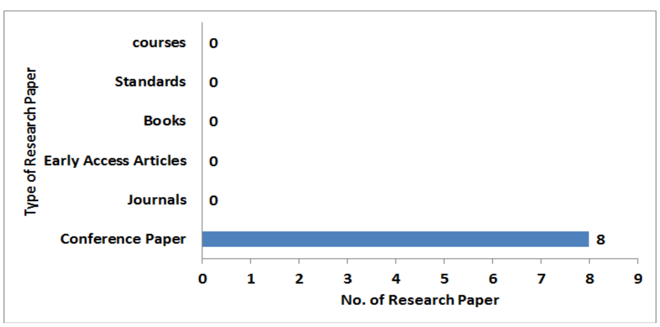


Fig. 4. Research trends on Adhoc Network

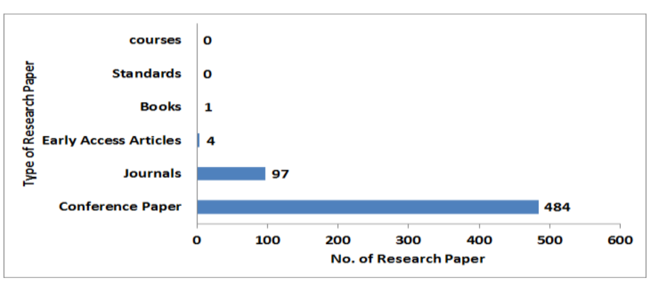


Fig. 5. Research trends on vehicle networks

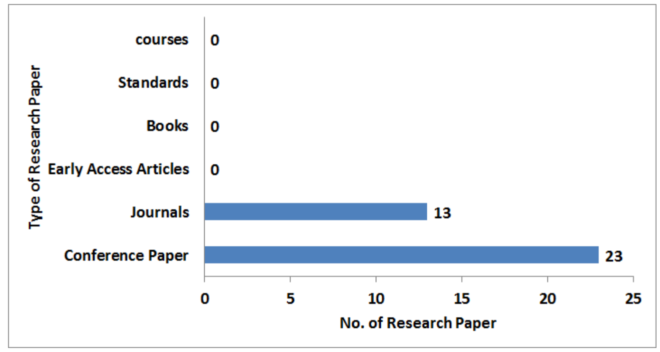


Fig. 6. Research trends on multimedia

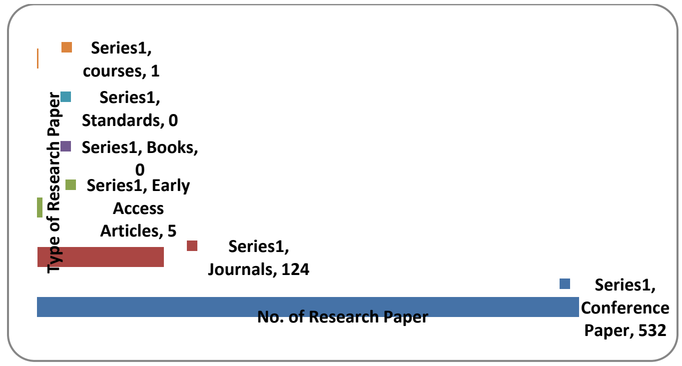


Fig. 7. Research trends on Security

Here find that there are 71 journals published for social network problems (Fig.3), 97 Journals towards vehicular network problems (Fig.5), 19 journals towards addressing multimedia problems (Fig.6), and 124 journals towards security problems (Fig.7). This statistics easily shows that although there are some numbers of studies towards wireless network but there are no journals stating implementation of dynamic web-based applications. From the security viewpoint also, there is quite a less number of implementation as compared to the massive progress being done on security algorithm in recent times. Information flow is normally studied with respect to the social network, but an implication of social network problems are less to be seen in existing research work. A similar trend can be also seen in other reputed publishers e.g. Springer, Elsevier, InderScience etc. By looking into the statistics of existing techniques, it can be inferred that Information Propagation is still theoretical and will need a further amount of investigation to explore better possibilities of enhancing the communication system in every respect. The next section discusses the recent research implementation techniques.

IV. Existing Research in Information Propagation

This section discusses the existing research work being carried out in information propagation. There are various forms of studies being carried out in this regard addressing to various problems. The easier way to understand information propagation in real-life is that of a transaction of email communication system. Studies on information propagation towards email-based communication system were carried out by Lejun et al. [22] using mathematical formulations with an aid of network-based attributes e.g. degree, density, betweenness, clustering coefficient, Eigenvector, etc. Similar attributes were used to find present work is better than existing mechanism. Various conceptualized model has also been presented in order to model in better shape. Usage of survival theory was seen in work done by Rodriguez et al. [23] in order to develop a new multiplicative model of information propagation. Usage of software component model for constructing architecture towards forecasting the reliability of the message flow was seen in the work of Brosh et al. [24]. Consideration of inter-contact time was adopted by Boldrini et al. [25] in order to investigate the instances of interaction among the nodes during information flow. Adoption of the neural network was found to have better classification usage in the proposed work of Latorre et al. [26]. Analysis of Information Propagation in Academic social network is done to identify the trend topics by S S Kumar et al. [27]. The model developed to capture the popularity of the video being propagated in Online Social Networks based on the sharing and viewing by the users of Subhankar et al. [28]. There are various such techniques that have been implemented during 2010-2016. Hence, for better illustration, this section will address the frequent area on which there are a significant amount of research work has been carried out toward information propagation.

A. *Studies on Social Network*

The information propagation is much studied in the context of a ocial network. The general concept of information theory finds its direct utility in analyzing social networks. Zhuang and Yagan [29] have investigated the impact of the physical network with an online social network in order to form a multilayered network. A clustering concept was introduced with arbitrary graph and the study outcome was evaluated with respect to epidemic size using varies cases of clustering. A similar idea of using physical and social network was also found to influence the cost of propagation. The concept of multilayer network was also seen in the work of Salehi et al. [30] where a modeling aspect of propagating the process is discussed. Reduction of such cost of propagation was found in the work of Guler et al. [31]. The uniqueness in the study was that the technique can identify the negative nodes existing in the path of information propagation and perform elimination of them. The study outcome was found to significantly minimize propagation complexity compared to existing techniques. Wong et al. [32] have presented a stochastic modeling that performs recommendation in the social network. The mechanism assists in giving recommendation of friend to the user. A unique diffusion model was presented by Niu et al. [33] where an analytical modeling was used to investigate the effect of multiple sources of influencing the node. The design completely uses Expectation Maximization approach in order to enhance the performance of information propagation. Zhang et al. [34] have presented a model that models the interactivity among the contagions. A co-competition modeling is presented in this work. Study towards the significant index of performance for monitoring propagation speed was carried out by Chou et al. [35]. The presented technique is essentially meant to be acted as a reference model in order to extract certain specific information pertaining to social network applications e.g. topological degree, rates of contact, the strength of social dynamics, etc. Cha et al. [36] have introduced a technique of investigating the characteristics of information propagators. Using twitter database, the authors have discussed the possible relationship among. There are various dynamics of the study concerned with the applicability of research work towards social network and each study has different forms of approaches. Also, will further classify the applicability of the existing techniques of information propagation towards various other implications of social networks:

- *Emotion Analysis*: The theory of information propagation also plays a significant when it comes to application performing emotional analysis. Normally, such application uses different forms of dictionaries and lexical database in order to extract certain degree of semantic information from the posts in social network. A unique cascading model is presented by Wang et al. [37] on the basis of emotional analysis in order to analyze the propagation probability of data pertaining to massive number of users. Dragoni et al. [38] have presented a framework for concept polarity as well as its linked uncertainty using fuzzy logic. A knowledge graph is developed using existing lexical resources, where the technique is used for propagating information pertaining to sentiments. Exactly similar approach of using fuzzy logic was also seen in the work carried out by Trung and Jung [39]. This technique performs analysis of sentiments from the social network with an aid of propagation modeling using fuzzy logic. Overgoor and Rosen [40] have also presented a simple modeling of sentiment analysis on the basis of online news in order to extract the information related to popularity.
- *Financial Analysis*: There has been a study related to information propagation also in the applications of finance-based. Normally, such application requires a highly safer and fault tolerant mechanism of propagating information. Toriumi and Komura [41] have presented a framework where an investment index has been designed on the basis of transfer entropy in information propagation. For this purpose, a cross-correlation technique is used to the stock prices and hence it generates a stock network. Financial analysis can be also carried out considering data from the financial news that bears various economics-related technicalities. Chang et al. [42] have extracted a significant feature of semantics from financial news using a neural network. Most recently Kaminski et al. [43] have presented a model that extracts correlation factor between posts of twitter and open source peer-to-peer money. The study basically computes the emotion from the post regarding bitcoin market. Similar work considering bitcoin network was also carried out by Decker and Wattenhofer [44]. Sprenger and Welpe [45] have investigated sentiments associated with stock-related tweets using a computational linguistics-based approach in financial information propagation.
- *Rumor Analysis*: Rumor detection and analysis is another frequently exploit research topic pertaining to social network analysis and information propagation.

One of the bigger challenges in this is to identify the extent of legitimate contents in the social post when the information propagation takes place in highly dynamic manner. Hamidian and Diab [46] have presented a technique to identify rumor from the twitter data using the feature of a latent vector. The authors have also used machine learning for this purpose. Tan et al. [47] have presented a propagation model for rumor where the emphasis is more on understanding its underlying patterns during information propagation. A mathematical modeling-based approach is used for this purpose for developing attributes for node interaction as well as for investigating the dispersion over the feasibility towards multiple states. Study towards rumor detection has been also carried out recently by Liu and Xu [48] where the authors have modeled information propagation in order to differentiate rumor-based messages. Wen et al. [49] have presented an analytical technique that can distinguish between positive and negative forms of information in social networks. Amoozgar and Ramezanian [50] have introduced a computational model for investigation the association between convergence of rumor and societal homogeneity in the process of information propagation. A similar form of study considering twitter data has been discussed by Jin et al. [51]. Krishna Kumar and Geetha Kumari [52] have used cognitive psychology in order to investigate the dispersion of rumor. With an aid of collaborative filtering property, the technique is also able to find the speed of rumor propagation. Luo et al. [53] have presented a technique to explore the source of rumor origination in social networks for a given observations that are quite limited. Wen et al. [54] have implemented a process of clarifying the rumor in order to discourage the spreaders of rumors. A similar cadre of research work towards eliminating the rumor is also carried out Krishnamurthy and Hamdi [55] where the authors have used acyclic graphs. Nel et al. [56] have discussed a model of rumor detection that uses clustering for detecting the similar publishing features.

B. *Studies on Wireless Network*

The studies on the information propagation are also carried out towards wireless network in different forms. The nature and characteristics of the network are quite essential when it comes to transmitting sensitive information. Most recently, Kim and Peeta [57] have used graph theory to model a communication system among the vehicles. A conceptual model is designed using integration of physical network for traffic flow, network layer, and virtual layer for inter-communication among the vehicles. A simulation-based approach has been used for this purpose. Liu et al. [58] have adopted a probabilistic approach for resisting the relay for message propagation in a mobile adhoc network. The authors have used Markov chain for message characterization and used simulation-based approach for evaluating their idea. Zhang et al. [59] have presented a technique for constructing an array of the virtual antenna using MIMO for performing information propagation. The investigation shows that speed of information propagation increases with increase in the density of the vehicle. Kim et al. [60] have presented a technique for communication among the vehicles in order to assists in the flow model of the traffic. The authors have developed an integrated traffic model using analytical modeling approach. Du et al. [61] have presented an investigation that computes delay of information propagation considered for vehicle-to-vehicle communication. The analysis of the study was carried out on multiple-way segments of the road in order to compute propagation delay on multiple scenarios. Study towards the delay of the information propagation is also carried out by Iyer and Vaze [62]. The author defines the speed of information propagation as a limit of the proportion of the spatial attribute from source to destination with respect to the duration consumed for successful delivery of information using multiple hops. The studies carried out by Wang et al. [63] have investigated on the speed of the information velocity when the data transmission takes place between two moving vehicles. The investigated have also focused on studying the underlying relationship among various traffic-based attributes e.g. direction, velocity, density, etc. Both dense and sparse network has been investigated considering bi-directional highway model using a traffic simulation tool. A similar study of a velocity of information speed during message transmission was studied by Han and Yang [64] considering the case study of cognitive radio networks of multihop type. The technique mainly used the maximum network for increasing the velocity of data transmission using the infinite plane. It also increases the velocity of message forwarding between the transmitter and receiver node. The problems associated with the dissemination of information are addressed by Li et al. [65] in connection with device-to-device communication. A constraint-based approach was formulated for constructing time and distance based limits. Pereira et al. [66] have introduced a diffusion-based data propagation model using the expectation-maximization algorithm. Baccelli et al. [67] have investigated the case study of delay tolerant network in order to further assess the characteristics of speed associated with information propagation among the vehicles. The authors find that speed of information propagation behaves in a different way when compared with certain thresholds. Using simulation-based study on multiple speed of a vehicle, the study characterizes the speed of information propagation. Similar study of speed of information propagation has been carried out by Jacque et al. [68]. Wang et al. [69] have used a specific routing technique called as most forward within radius used in the vehicular adhoc network for assessing the performance of speed of information propagation. The presented study also computes anticipated distance of transmission, the rate of packet loss, coverage etc. Xu et al. [70] have discussed the limits associated with the propagation of information in larger deployment scenario of the wireless network. A presence of higher limits of broadcast and unicast speed is found in presence of network noise. Zhang et al. [71] have presented a model where the speed of the vehicle is mapped with the constructed time-slots in order to derive an analytical modeling of information propagation associated with a mobile adhoc network. A simulation-based approach is used for assessing the presented study with respect to delay/gap as well as the logarithm of information speed using Poisson arrival model.

C. *Studies on Multimedia Propagation*

There has been a significant amount of research work towards multimedia transmission in last decades [72] [73] [74]. Such forms of research attempts deal with the retention of high data quality at the receiving side, reduces the complexities associated with information propagation. Usually, multimedia contents e.g. image, video, audio etc are quite heavier files when compared with other conventional files during information propagation. Transmitting such forms of heavy end data consumes maximum network resources and hence the information propagation is likely to be affected. Existing studies normally uses the performance parameters that centers around the quality of the multimedia contents e.g. peak signal-to-noise ratio, sensitivity, root mean square error, etc. Although, there are many such studies, but will discuss some of them with higher relevancy. An investigation was carried out towards sharing of the video by Li et al. [75] over social networks. The authors have investigated about the pattern of information propagation. Various forms of user's behavior, structures pertaining to typical propagation, etc were investigated in this study. Yang et al. [76] have presented a unique discussion of the unreliability problems associated with pairwise similarities. The authors have solved this problem using tensor product graph in order to regain the better amount of reliability using superiorly compressed video dataset. Yao et al. [77] discuss the problem associated with the re-ranking algorithm during retrieval process of image and video. The author uses the mutual exchange of the information in order to enhance the performance of visual search operation. Bracamonte and Poblete [78] have addressed the problem associated with image tagging which is one of the frequently used operations in the social network. This operation is mainly used for retrieving significant data. This technique introduces a graph-based mechanism that performs automatic tagging of the contents of multimedia. Apart from the above-mentioned studies, the majority of the studies are related to simple transmission of multimedia over certain forms of networks.

D. *Studies on Security*

Security is one of the potential demands for any forms of application and it is highly important in propagating information using secured channel. In past, there has been various significant studied being carried out towards evolving security systems using sophisticated cryptographic and encryption approaches [79]. Usage of public key cryptography is frequently used in wireless networks, which requires the secret key or certain level of passphrases to be propagated in a specific manner. Hence in this regard, this section will discuss some of the unique research attempts towards security pertaining to information propagation. Most recently, Haghighi et al. [80] have developed a novel model that performs the analytical operation in order to understand the dynamics related to data transmission in wireless sensor network. The technique uses both spatial as well as a geometrical constraint in order to have a better mapping of malicious objects e.g. worms in a sensor network. Gervais et al. [81] have investigated about proof of work blockchain associated with the usage of bitcoin and presented a quantitative modeling of assessing its security effectiveness. A new security model has been designed that using mining-based attributes for assessing the ability of secured information propagation. There is also a research work being carried out based on the transmission of malicious codes through short messaging services in a cellular network by Yun et al. [82]. A stochastic process is presented using analytical modeling using reputation, trust, and user-relationship in order to infer the malicious behavior in information propagation [83]. Patil et al. [84] and Teng et al. [85] have discussed a possible relationship between location and privacy. The authors have presented a collaborative modeling in order to protect privacy during the information propagation considering Bayesian attacks. The prime motive is to ensure location privacy during information propagation.

E. *Taxonomies of Existing Problems*

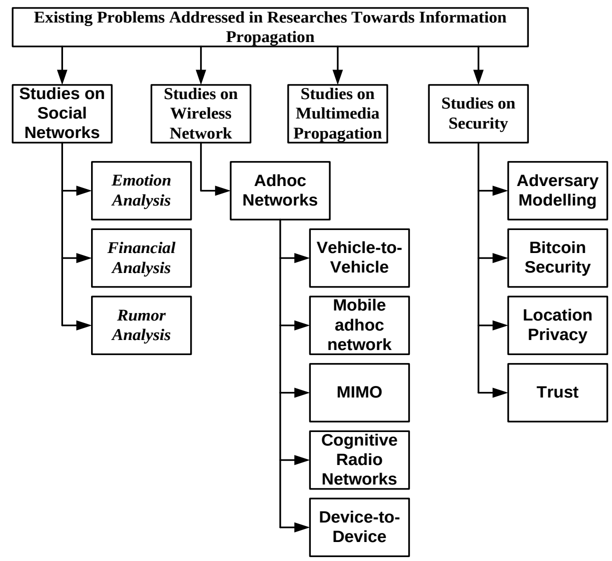


Fig. 8. Taxonomies of Existing Problems

Fig.8 shows the taxonomies of the various research problems addressed in the most recent times pertaining to the information propagation. A closer look into all these problems will show a common link i.e. the social network that offers a comprehensive platform for sophisticated exchanging of the significant information among the users in the most dynamic environment. The majority of the techniques offered using the backbone of the social network has also offered a potential structure representing the interactions among the users over network along with consideration of various network-based dynamics. The various phases of the content generation is the process of information propagation cannot be denied and it significantly affects the processing, production followed by distribution of the data from one to another end of the network. There is already various forms of the applications that area affected by such new advent of technologies e.g. online data sharing process among the communities, video-based information propagation, various dynamic services of multiple remote desktop connectivity, various virtualized-based applications over the cloud, patients details sharing using specific healthcare management etc. Hence, there are various applications that have been evolved due to the process of information sharing in most recent time. The next section will elaborate on the open-end research problems.

V. Research GAP

This section discusses the potential research gap explored in the area of information propagation by referring the discussion on the prior section. As it has been observed that:

- *Scattered Researched Form:* The concept of information propagation was not much focused on any particular problems. It can be seen that there are large number of studies being focused on adhoc network e.g. vehicle-to-vehicle, device-to-device, mobile adhoc network etc. Although, there are also studies carried out in other forms of wireless networks, but still the inclination of the problem is more on social network analysis and not on networking much. This creates an uneven balance in the research attempts for addressing the problems in information flow. Moreover, there are quite a few research implementations towards dynamic web-based networking system that may cause a serious impediment towards upcoming pervasive network. Moreover, from the viewpoint of problems associated with the social network, the existing studies towards information propagation doesn't deal with its inherent problems (e.g. computing the influential node, optimizing performance of social network) etc. Therefore, on that context, it can be said that there is less work towards social network problems using information propagation in recent times.

- *Studies towards Computing Potential Node:* Basically, the structure of the social network is highly dynamic in nature and finding one node or set of some nodes based on certain user-defined criterion is basically an NP-hard problem in information propagation. This pilot study toward existing approaches of exploring potential node in dynamic network finds that majority of the research techniques considers that significance value increases with maximization of degree of vertices. This leads to significance performance declination in large heterogeneous scale network. The existing approaches have also found usage of unconstrained and bound-constrained optimization problems towards exploring potential nodes in social network. However, such approaches are never stable as their fitness functions are more dependent on anticipated value of information diffusion. Finally, there is not much work towards aiming for reducing computational complexities in this regard with less evidence of any benchmarked model or research work till date.

- *Studies toward Optimization:* The problem considered in this part of the study is basically related to the enhancing the information dissemination performance in any dynamic networks. In an existing mechanism, various forms of business strategies are formed using ranking algorithms (e.g. Page Rank, etc). However, the biggest problems in using such applications are that they don't offer contextual information that is correlated with specific business need. This is basically because increasing the level of information diffusion is again an NP-hard problem on any dynamic network and the dissemination process can be hardly controlled or fine-tuned according to the business needs. Also, such problems are yet to receive attention and are worth to be considered as a novel optimization problem in information propagation.

VI. Conclusion

In the process of information propagation, the processes as well as all the communication factors are equally responsible for a node to be affected by its influential properties. However, normally presence of such massive and complex data gives rise to high-dimensional data where it is quite a challenging task to extract a dynamic pattern from a given set of multi-dimensional data during information propagation. The manuscript also discusses the various scenarios where information propagation is studied intensively by various researchers till date on the social network, wireless networks, multimedia transmission, and security. It is also seen that majority of the work carried out towards information propagation was on the social network and in wireless networks. The existing studies towards solving issues of the social network are also seen majorly focusing on rumor propagation, emotional analysis, and financial analysis. In reality, there is quite a less significant work carried out to extract the most potential node in a complex network. It was also studied that research techniques towards optimization are few to find in the line of information propagation. Therefore, future work will be carried out in the direction to address such problem.

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Visualizing Composition in Design Patterns

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***Abstract*—Visualization of design patterns information play a vital role in analysis, design and comprehension of software applications. Different representations of design patterns have been proposed in literature, but each representation has its strengths and limitations. State of the art design pattern visualization approaches are unable to capture all the aspects of design pattern visualization which is important for the comprehension of any software application e.g., the role that a class, attribute and operation play in a design pattern. Additionally, there exist multiple instances of a design pattern and different types of overlapping in the design of different systems. Visualization of overlapping and composition in design patterns is important for forward and reverse engineering domains. The focus of this paper is to analyze the characteristics, strengths and limitations of key design pattern representations used for visualization and propose a hybrid approach which incorporates best features of existing approaches while suppressing their limitations. The approach extends features which are important for visualizing different types of overlapping in design patterns. Stereotypes, tagged values, semantics and constraints are defined to represent the design pattern information related to attributes and/or operations of a class. A prototyping tool named VisCDP is developed to demonstrate and evaluate our proposed.**

***Keywords*—Design patterns; Visualization; Program Comprehension; Reverse engineering; Composition**

I. Introduction

Design patterns are proven solutions and they are composed with each other for the development of software applications [1, 2, 3]. The composition of design patterns [4, 5] when applied in an effective manner solves many generic and specific problems related to any object oriented programming domain. The visualization of pattern related information in UML diagrams and visualization of overlapping in recognized design patterns plays an important role for the program comprehension during forward as well as reverse engineering. The importance of composite visualization of design patterns is also highlighted by authors [32, 33, 34]. Mostly, design patterns are modeled using visual and formal languages such as UML [6], DPML [23], LePUS [26], RSL [31] etc. UML is a semiformal type of modeling language which is widely accepted by the academia and industry. It has a collection of visual notation techniques to build, specify, visualize, modify and document the visual models of software systems.

It is realized by Dong et al. [7] that standard UML is unable to keep track of the roles each modeling element plays in a design pattern and other design pattern related information. Therefore, some authors presented extended UML based design pattern specification and visualization approaches [3, 9, 13, 27, 28, 30]. The alternate visual and/or textual notations are also proposed to visualize the pattern related information in the software design. Porras et al. [8] concluded that all existing approaches are not capable to include all design pattern related information that is important for the comprehension of a software design. Therefore, it is important to carefully investigate all the notations. Authors in [8] presented a framework to compare the current and future notations based on participation, role and compositions of artifacts which play key roles in designing and composition of design patterns. They realized that different notations have their strengths and limitations. The limitations of existing notations provide opportunities to researchers for devise new notations that would further overcome identified limitations while combining the best features of current notations. We critically analyze state of the art design pattern representation approaches in the literature review Section 2.

The selection of an appropriate notation is important for designers, maintainers and reverse engineers. We selected Pattern: Role notation [3] and stereotype enhanced UML diagrams presented by Dong et al. [9] as baselines to propose our hybrid approach. These two notations are most representative and they are also used by other researchers [8]. Pattern: Role Notation is highly readable and informative, but it cannot represent the roles that an operation and attribute plays in a design pattern. This notation also cannot distinguish the multiple instances of the same design pattern. Stereotype enhanced UML diagrams are defined mainly by presenting a new UML profile for the representation and the visualization of the design patterns in their composed form. This approach represents the role each modeling element plays in a design pattern, but it is strongly textual thus text overload can considerably increase the size of the classes as well as make the classes harder to read. Furthermore, both these approaches do not focus on the visualization of different types of overlapping in design patterns which are important for the comprehension of software applications. When different roles (patterns, classes, operations, attributes) of a design pattern are reused in other patterns in the same application design, we call these roles overlapping. Such overlapping are very common in software applications as discussed by [4, 15, 16, 24, 25]. While analyzing results of different design pattern recovery tools, we recognized that proven composite patterns are present with different overlapping. For example, the Java AWT framework is composed of different patterns. Similarly, we found overlapping in different roles of Abstract Factory pattern and visitor pattern as mentioned in well know book by Gamma et al. [35]. Overlapping in design patterns give information about the level of coupling in different patterns and their roles. The detection and visualization of overlapped pattern roles are important for maintenance, comprehension and change impact analysis.

In order to overcome the limitations of design pattern visualization techniques [3, 9], this paper is intended to propose an approach that integrates the best features of Pattern: Role notation [3] and stereotype enhanced UML diagrams [9] while surpassing their limitations. Our approach extends new features for highlighting different types of overlapping and it is equally beneficial for forward and reverse engineering activities. The presented approach helps to visualize the following pattern related information in the recognized design patterns as contribution of this work:

- To visualize the role that a class, attribute and operation play in a design pattern;
- To visualize the multiple instances of a design pattern in class diagrams;
- To visualize One to one, one to many and many to many overlapping in design patterns;
- A proposed hybrid approach supplemented with prototyping tool VisCDP to support above mentioned claims;
- Evaluation and comparison of approach on a case study.

The rest of paper is structured as follows: We discuss state of the art on design patterns visualization approaches in Section II. Section III presents the comparison of existing approaches based on different attributes. A proposed hybrid approach used for visualization of composition in design patterns is laid down in Section IV. The prototyping tool used to validate concept of the proposed approach is discussed in Section V. Section VI discusses evaluation of approach with the help of a case study. Finally, we conclude and sketch future directions in Section VII.

II. Related Work

Design patterns are widely used in open source and industrial applications as they are known solutions to recurring problems [10]. Generally, the software developers come across with the certain kinds of problems repeatedly in their daily routines. They evaluate such problems and their context by referring to some existing design patterns and select a particular design pattern based on their needs and requirements. The reuse of a design pattern helps the software architect to reuse the knowledge that has already been documented and tested in order to improve the quality of their products. The visualization of design patterns information in large and complex software systems is decisive for the comprehension of software applications [21]. The better visualization of design patterns information enables better comprehension of examined applications [29]. Different authors proposed different approaches for the visualization of design patterns in software designs which are discussed as follows:

Smith [11] proposed a hierarchical approach called Pattern Instance Notation (PIN) to visually represent the composition of patterns. This notation provides a simple visualization approach which is not only for design patterns, but it is also for other abstractions of software engineering. A suitable graphical notation based on boxes and lines is devised in this approach, defining three modes namely collapsed, standard and expanded. The boxes are simple round corner rectangles having a pattern name in the center. Each box represents a specific design pattern instance. The pattern instances are connected to the different elements of a class through unidirectional arrows. PIN kept things simple and focus on the multiple design pattern instances and their roles. The proposed approach is still at infancy stages and work is in progress as mentioned by the author.

Dong et al. [9] presented a new UML profile for the representation and the visualization of the design patterns in their composed form. Few new stereotypes, their corresponding tagged values and constraints are defined in this extended UML notation to explicitly visualize pattern related information in any software design. UML meta-model is used to define such extension in UML profile. This new UML profile represents the role each modeling element (class, attribute, operation) plays in a design pattern. This approach also distinguishes the multiple instances of a design pattern. In addition, authors developed a tool called VisDP [12] for the dynamic visualization of design patterns information. Such information is displayed dynamically when the user moves the cursor on the screen. The applied approach is only limited to the visualization of design patterns information for forward engineering. Furthermore, authors did not focus on the visualization of different types of overlapping in the presented methodology.

Dong [13] proposed another new graphical notation that is an extension to UML. This approach provides a mechanism to visualize each individual pattern in the composition of design patterns by adding the tagged values. These tagged values contain the pattern and/or instance(s) and/or participant name(s) associated with the given class and its operations and attributes. The format of a tag is “pattern [instance]: role” = True/False. For example, if a class is tagged with notation “Adapter [1]: Adaptee” then the class plays a role of Adaptee in the first instance of the Adapter pattern. For the sake of simplicity only the participant name can be shown as it does not create any ambiguity. The author himself determined its limitation as the pattern related information is not as noticeable as the “pattern: role” notation with shading, but he consider it as a tradeoff. This approach provides a mechanism to determine one to one overlapping, but it does not focus on the other two types of overlapping.

Vlissides et al. [3] proposed a notation to explicitly visualize the pattern related information. In this notation, each class is tagged with a gray shaded box containing the pattern related information in the form of “pattern: role”. Each box, associated with a class, contains the pattern name and the role name that this class plays in the associated design pattern. If a class participates in more than one design pattern then all the design patterns in which this class participates will be presented in the same box. For the sake of simplicity, if the class role name is the same as of the design pattern then the design pattern name can be omitted. This notation is more scalable, highly readable and informative. However, the size of the original diagram can significantly be increased as each class has an associated gray box with it. This notation also does not represent the role that an attribute and operation play in a design pattern. There occur multiple instances of a design pattern in a class diagram, but this approach cannot distinguish the multiple instances of a design pattern. Moreover, Dong et al [9] identified the problems related to scanning and reading on the printed media because of gray backgrounds.

Schauer et al. [14] developed a prototype to make the program comprehension simple and efficient by recognizing design patterns and their visualization. For the visualization of design patterns, they proposed pattern enhanced class diagrams that use different colored borders to identify different patterns. This approach provides ease for identifying all the classes participating in a design pattern as this approach is strongly visual. However, this approach cannot identify the role a class, attribute and operation plays in a given design pattern. Moreover, it is really difficult to identify all the design patterns in which a class participates. Authors argue that they enhanced UML representation, but statistically it is difficult to measure improvement in the presented approach. The examples selected for experiments are very small and generalization of approach for large and complex systems is questionable.

Vlissides [3] presented an alternative notation that addresses the limitations of Venn diagram notation. In this notation, dashed ellipses are used to represent the design pattern names. Each ellipse (design pattern) is connected with its participating classes through dashed lines. These dashed lines contain the role names each class plays in a specific design pattern. This approach gives a major breakthrough over Venn diagram notation by specifying the role each class plays in a design pattern. However, the role that attribute or operation plays in a design pattern is not covered in this approach. In addition to this, the scalability issue arises as the system size grows. The design pattern information and the class structure get intermingled and the cluttered lines make it really hard to read and identify the required information [9 13].

Vlissides [3] introduced another intuitive approach to explicitly visualize the design patterns participating in a design diagram in the same report. To distinguish the design patterns from each other, all the classes participating in a design pattern are bounded with different shades of colors. Hence, all the classes participating in a design pattern are easily identified. This approach works well for small number of patterns in the system, but the scalability issue arises when the system size grows. It becomes very difficult to differentiate the overlapping among different design patterns when different classes participate in multiple design patterns. Moreover, this notation does not clearly depict role of different artifacts in the corresponding design patterns. The major focus of authors is to identify the boundary of each design pattern [9, 13].

The concept of composition of design patterns using formal specification is presented by Bayley et al. [4]. Authors applied idea of composition of patterns based on lifting and specialization operations on patterns. The meta-modeling notation GEBNF [16] is used for specification of composition in the design patterns. The applied approach has key focus on composition and formal verification of patterns which can be used for detection of design patterns, but it has no link with the visualization of design patterns during forward and reverse engineering phases which is a major focus of our approach. Composition of patterns is explained using Composite, Strategy and Observer design patterns.

Marie et al. [20] presented a design pattern visualization approach based on different pattern matching views. They used class view, pattern view and Abstract syntax view to represent and visualize information related with design patterns. User can compare candidate patterns with the specification. The experiments are performed on an Observer design pattern using JHotdraw [22] and generalization of composition with other patterns need investigation. The approach did not focus on visualization of operations and different types of overlapping in recognized design patterns. The approach is also limited to visualization for reverse engineering purpose.

III. COMPARISION OF EXISTING APPROACHES

UML and non-UML based notations are presented by different researchers for the specification and visualization of information related with design patterns. Non-UML based notations provide option of reasoning, verification and tool support, but they lack support for integration with other tools. These notations also have limitations to specify all features of design patterns. For example, LePUS is not cable to specify all GoF design patterns and their variants [26]. Standard UML based notations are also not capable to model all properties of design patterns, but still they are widely used due to integration of UML tools with other tools. While comparing different notations in this paper, we focus on UML based notations.

An empirical study conducted by Porras et al. [8] concluded that none of the existing notations fits all possible tasks. Therefore, it is important to carefully investigate all the notations. Authors suggested a framework to compare the current and future notations. The findings of study reflect that different notations have their strengths and limitations thus providing a ground to devise new notations that would further overcome identified limitations while combining the best of current notations. We compare the features of existing notations that are presented by different authors [3, 9, 11, 13, 14, 20] on the basis of attributes suggested by the existing framework [8] and by adding new attributes as indicated in Table 1. The major focus in our evaluation is visualizing different types of overlapping in the design of software systems.

Venn diagram-style pattern annotation and Pattern Enhanced Class Diagram are strongly visual approaches, but they do not specify the role each modeling element plays in a design pattern. They are just used to identify the boundary of a design pattern. UML Collaboration Notation is both visual and textual approach representing the role a class plays in a design pattern. However, the role that an attribute or operation plays in a design pattern is not covered in this approach. In addition to this, the scalability issue arises as the system size grows. The design pattern information and the class structure get intermingled and the cluttered lines make its comprehension really hard. Pattern: Role Notation also does not represent the role that an attribute and operation play in a design pattern. This approach is not able to distinguish the multiple instances of a design pattern.

Tagged Pattern Annotation, Tagged Pattern Annotation with shading, Tagged Pattern Annotation with bounding, Tagged Pattern Annotation with new compartments and Stereotype enhanced UML diagrams represent the role each modeling element plays in a design pattern, but the notations make the information really hard to read. Pattern Instance Notation represents the roles each modeling element plays in a design pattern and focus on the multiple design pattern instances, but this approach is still in progress. Furthermore, all these notations do not focus on the visualization of different types of overlapping in design patterns. We present an extended evaluation framework which compare features of all existing notations as given in Table 1.

There are no standard metrics to measure and compare features of different notations such as comprehension, complexity and flexibility. We deeply analyzed features of existing notations and defined our self-scales to measure these features for the purpose of visualization. For example, we defined three scales for measuring the comprehension. These scales are easy, moderate and hard. The easy scale means that comprehension of a notation is user friendly and it is not complex to understand. The moderate scale means that comprehension is between easy and hard scales. The hard scale means that comprehension of a notation is difficult. Similarly, other features are also measured based on our self-scales. The major challenge for visualization approaches is generalization of scalability feature for the visualization of design patterns information. The existing approaches ensure scalability for small and medium size of software packages, but the scalability for large software applications is challenging.

TABLE. I. COMPARISON OF DESIGN PATTERN REPRESENTATION APPROACHES BASED ON DIFFERENT VISUALIZATION ATTRIBUTES

Approaches/ Attributes	**Venn diagram-style pattern annotation [3]**	**UML Collaboration Notation [3]**	**Pattern: Role Notation [3]**	**Pattern Enhanced Class Diagram[14]**	**TPA [13]**	**TPA with shading [13]**	**TPA with bounding [13]**	**TPA with new compartments[13]**	**Stereotype Enhanced UML diagrams [9]**	**Pattern Instance Notation [11]**	**Pattern Matching Views [20]**
Representation Style	Strongly visual	Visual & Textual	Visual & Textual	Strongly visual	Strongly visual	Visual & Textual	Visual & Textual	Visual & Textual	Strongly textual	Visual & Textual	Visual
Visualization Scope	Static	Static	Static	Static	Static	Static	Static	Static	Static & Dynamic	Dynamic	Static & Dynamic
Level of Complexity	Low	Medium	Low	Low	Medium	Medium	Medium	Medium	High	Medium	Medium
Comprehension	Easy	Hard	Easy	Easy	Moderate	Moderate	Moderate	Moderate	Hard	Moderate	Moderate
Tool Support	No	No	No	No	No	No	No	No	Yes	No	Yes
Scalability	Small	Small	Medium	Small	Medium	Small	Small	Medium	Medium	Medium	Small
Flexibility	Less	Less	Medium	Less	Good	Good	Good	Good	Good	Good	Good
Participation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Composition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Role	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Class Role	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Attribute Role	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operation Role	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Multiple Instance	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
1-1 Overlapping	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No
1-M Overlapping	No	No	No	No	No	No	No	No	No	No	No
M-M Overlapping	No	No	No	No	No	No	No	No	No	No	No

TPA: Tagged Pattern Annotation

It is visible from features of the state of the art design pattern visualization notations in Table1that there is no notation that can visualize all types of overlapping. The comprehension of different notations varies when the size of an application increases. In order to overcome the limitations of above mentioned design pattern visualization techniques, this paper is intended to propose an approach that integrates the best features of Pattern: Role notation[3] and stereotype enhanced UML diagrams[9] while overcoming their limitations. The proposed approach also appends new functionality regarding visualization of different types of overlapping in UML class diagrams which is important for the comprehension of software applications.

IV. Proposed Hybrid Approach

It is apparent from discussion in Sections 2 and 3 that the current design pattern visualization approaches are unable to capture all the aspects of design pattern visualization which is important for the comprehension of any software application e.g., the role that a class, attribute and operation play in a design pattern. Similarly, there exist multiple instances of a design pattern and different types of overlapping among different classes. The key motivation for this approach is to represent and visualize the pattern related information in the composition of design patterns. Our hybrid notation is elaborated in the following three subsections.

A. Building on Pattern:Role Notation

Our proposed notation is given below:

Pattern [Pinstance]: Role [Rinstance]

Where Pattern represents the design pattern name in which a class participates. Pinstance represents the instance of a specific design pattern as there can be multiple instances of a design pattern in the software design. Role represents the role name a class plays in the associated design pattern. Rinstance represents the multiple instances of a class role. We will use this field to visualize different types of overlapping among different classes. A note box containing design pattern information is attached to each class. For the sake of simplicity, if there is only one instance of a design pattern then Pinstance can be omitted. Similarly if there are not multiple instances of a class role then Rinstance can be omitted for ease. For example, file class plays the role of leaf in composite design pattern as shown in Fig. 1. As there is only one instance of leaf therefore Rinstance can be omitted. Also if the design pattern and the class role names are same then the class role can be omitted. For example, directory class plays the role of composite in the Composite design pattern and there is only single instance of the composite design pattern. Thus for the sake of simplicity, the role and the Pinstance fields are omitted as shown in Fig. 1.

The following example further explains how our notation represents information when a single class plays more than one role in different design patterns:

Adapter [1]:Adaptee[1]
Strategy [2]: Context [1]
Bridge [1]:Implementor[1]

Suppose above notational information is attached to a Class A. The notations reflect that Class A plays the role of Adaptee in the first instance of an Adapter design pattern. The same Class A plays the role of Context in the second instance of Strategy design pattern and a role of Implementor in the first instance of Bridge design pattern. The ‘1’ on the right hand side of above notations state that Class A is overlapped in three design patterns with different roles.

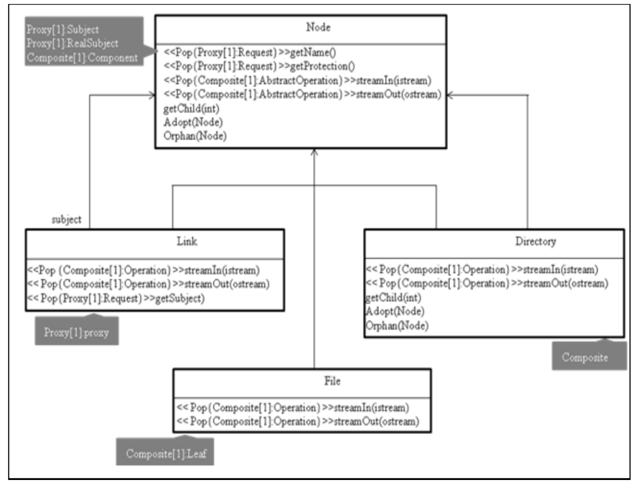


Fig. 1. File System Class Diagram based on our Integrated Approach

B. Incorporating UML Profile for Design Patterns Visualization

Stereotypes are used to extend UML profile by defining tagged values and constraints. These tagged values and constraints corresponding to a stereotype get attached to modeling element to which that stereotype is branded [17]. Two stereotypes <<Pat>> for Pattern attribute and <<Pop>> for Pattern operation are defined to explicitly visualize the role that an attribute and operation performs in a design pattern. Each element is associated with its respective stereotype e.g., stereotype <<Pat>> is associated to all such attributes of a class that plays a specific role in a design pattern. Similarly, <<Pop>> stereotype is associated with all operations of a class that are the participants of a design pattern. The tagged values corresponding to these stereotypes are defined in Table 2. The semantics and constraints on applied stereotypes are discussed below:

1) Semantics

The detailed semantics of the stereotypes and their corresponding tagged values are given in Table 2. <<Pat>> and <<Pop>> stereotypes are defined to be associated with the attributes and operations of a class that play specific roles in a design pattern respectively. Each stereotype is applied on the corresponding modeling element and the role of that element is identified by the tagged value. The format of the tagged value is Pattern [Pinstance]: Role, Pattern specifies the design pattern name in which this attribute or operation participates, Pinstance specifies the number of design patterns instance to which this attribute or operation belongs to, Role specifies the certain role name that this attribute or operation plays in the design pattern. For example, in Fig. 1, getName () operation of class Node plays the role of Request in Proxy design pattern. There is only one instance of Proxy in the given system. Therefore, the stereotype <<Pop {Proxy [1]: Request}>> is branded to the getName () operation of class Node. It may be possible that an attribute or operation play different roles in different design patterns.

TABLE. II. STEREOTYPES AND TAGGED VALUES ON ATTRIBUTE AND OPERATION

Stereotypes	Applies to	Tagged value	Description
<<Pat>>	Attribute	Pattern[Pinstance]: Role	Identifies that the associated attribute performs the role of Role in this specific instance Pinstance of a design pattern named Pattern
<<Pop>>	Operation	Pattern[Pinstance]: Role	Identifies that the associated operation performs the role of Role in this specific instance Pinstance of a design pattern named Pattern

2) Constraints

We discuss in detail the constraints that are imposed on the stereotypes used by our approach. As stereotypes are associated with modeling elements (attribute and/or operation), constraints also get associated with them. These constraints compel certain kinds of restrictions on the modeling elements. We used Object Constraint Language OCL [18] to write these constraints formally. To define constraints for <<Pat>> and <<Pop>>, we will use standard properties of OCL such as self.a, where a can be a reference or any base class. The constraints for the stereotypes <<Pat>> and <<Pop>> are defined as follows:

<<Pat>>:
self.baseClass = Attribute and self.taggedValue -> exists (tv:taggedValue | tv.name = “Pattern[Pinstance]:Role” and tv.dataValue = Boolean)
<<Pop>>:
self.baseClass = Operation and self.taggedValue -> exists (tv:taggedValue | tv.name =“Pattern[Pinstance]:Role” and tv.dataValue = Boolean)
The Pattern and the Role fields of the tagged values in <<Pat>> and <<Pop>> cannot be empty.
<<Pat>>:
self.taggedValue.name.Pattern -> notEmpty
<<Pop>>:
self.taggedValue.name.Pattern -> notEmpty
<<Pat>>:
self.taggedValue.name.Role -> notEmpty
<<Pop>>:
self.taggedValue.name.Role -> notEmpty
The Pinstance field of the tagged values in <<Pat>> and <<Pop>> can be omitted if there is only one instance of a design pattern. See for example below:
<<Pat>>:
self.taggedValue.name.Pinstance -> isEmpty or self.taggedValue -> exists
(tv:taggedValue | tv.name.instance -> notEmpty)
<<Pop>>:
self.taggedValue.name.Pinstance -> isEmpty or self.taggedValue -> exists
(tv:taggedValue | tv.name.instance -> notEmpty)

The Pinstance field of the tagged values in <<Pat>> and <<Pop>> cannot be omitted if there are multiple instances of a certain design pattern. For example;
<<Pat>>:
self.taggedValue.name -> exists (n1, n2: name | n1.name = n2.name) implies (n1.Pinstance -> notEmpty and n2.Pinstance -> notEmpty and n1.Pinstance != n2.Pinstance)
<<Pop>>:
self.taggedValue.name -> exists (n1, n2: name | n1.name = n2.name) implies (n1.Pinstance -> notEmpty and n2.Pinstance -> notEmpty and n1.Pinstance! = n2.Pinstance)

C. Visualization of Composition

Design patterns are mostly used in a composed form and multiple types of overlapping occur among different instances of design patterns. Visualization of the overlapping in recognized design patterns play an important role for the program comprehension during forward as well as reverse engineering. When the design patterns are composed with each other, there may occur three types of overlapping namely one to one, one to many and many to many overlapping. State of the art design patterns visualization approaches did not pay attention to detect and visualize overlapping. In this paper, our focus is on visualizing all three types of overlapping for forward as well as reverse engineering purposes. We want to clarify that our approach takes extracted result of design pattern recovery tools and then visualize information related with design patterns. One to one overlapping: If there is only one leaf class in the Composite pattern and the composite pattern is composed with the Adapter pattern in such a way that this leaf class is adapted by the adapter then that is a one-to-one overlap. In this case, the same class plays two different roles in two different design patterns. One to many overlapping: If there are multiple leaves of Composite pattern and the Composite and Adapter patterns are composed with each other in such a way that two or more leaves of the Composite pattern are adapted by the same Adapter pattern then this is called one-to-many overlapping. Finally, many to many overlapping: this type of overlapping occurs among patterns when more than one role in a pattern are reused more than one time in another pattern. Zhu et al. [19] presented the composition of Composite and Adapter design patterns with many to many overlapping. In this composition, there are multiple instances of component leaf of Composite design pattern. There are some instances of Leaf class that are adapted by multiple instances of target of Adapter design pattern. Hence, there are multiple targets for multiple leaves. This is an example of many (Targets) to many (Leaves) overlapping.

Figs. 2, 3 and 4 give a view of visualization of one to one, one to many and many to many types of overlapping using our hybrid approach.

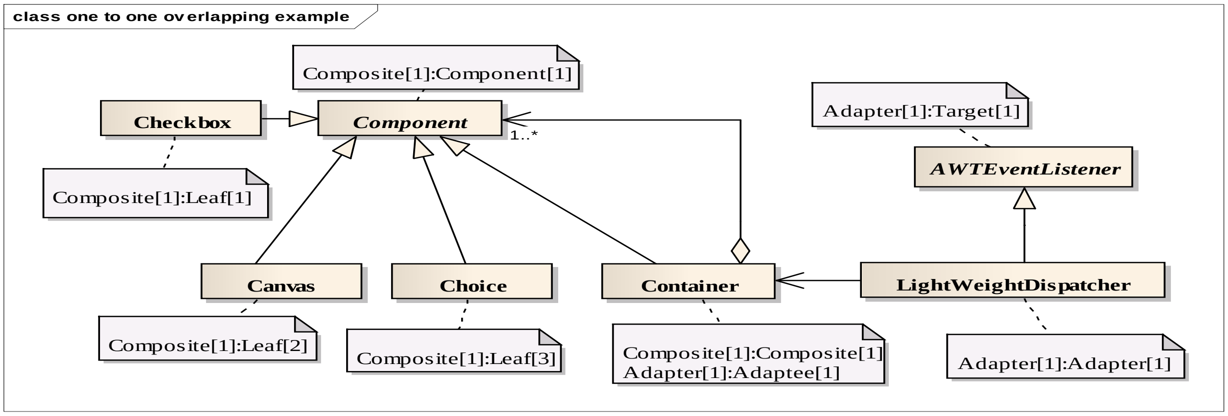


Fig. 2. Visualization of One to One Overlapping in Java.awt

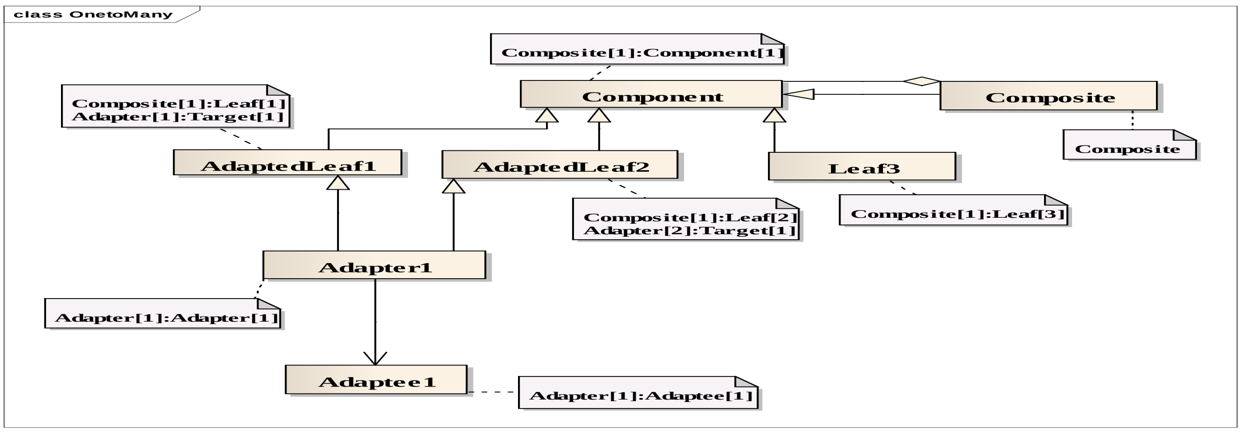


Fig. 3. Visualization of One to Many Overlapping

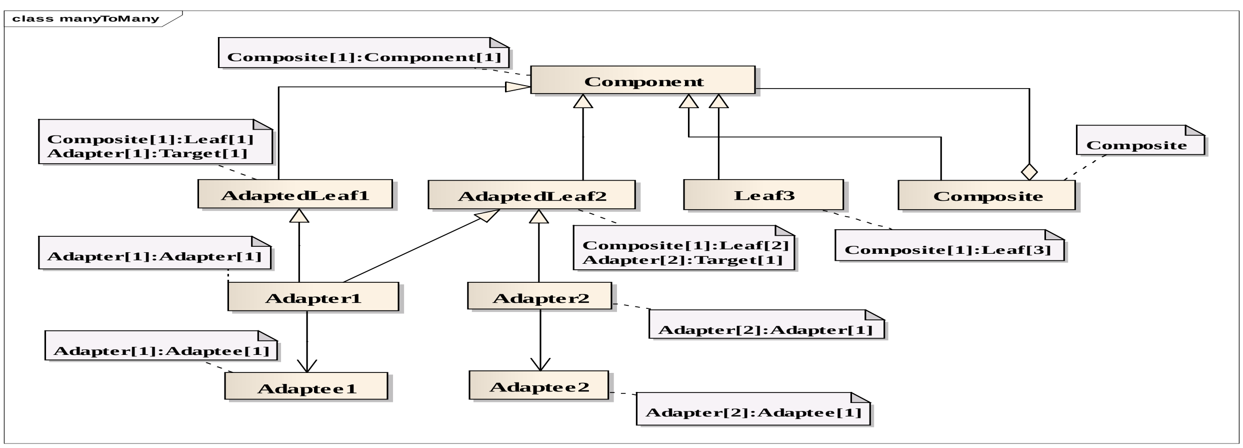


Fig. 4. Visualization of Many to Many Overlapping

V. PROTOTYPING TOOL

A prototype tool, VisCDP is developed for the realization of proposed approach. VisCDP is used to visualize design pattern information related to classes, operations and/or attributes in the composition of recognized design patterns. It provides static as well as on demand (dynamic) visualization in UML class diagrams. On demand option is used for filtration and highlighting information about roles participating in different design patterns. For example, by moving the cursor in a class, operation/attribute name, a box with highlighted design pattern information is displayed. These highlighted boxes improve the visibility and comprehension of information. VisCDP supports filtration option on both class and design pattern names and the user can view any specific class and/or design pattern information in a tabular form.

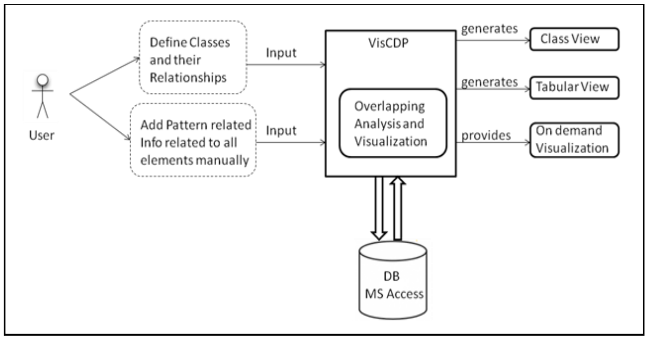
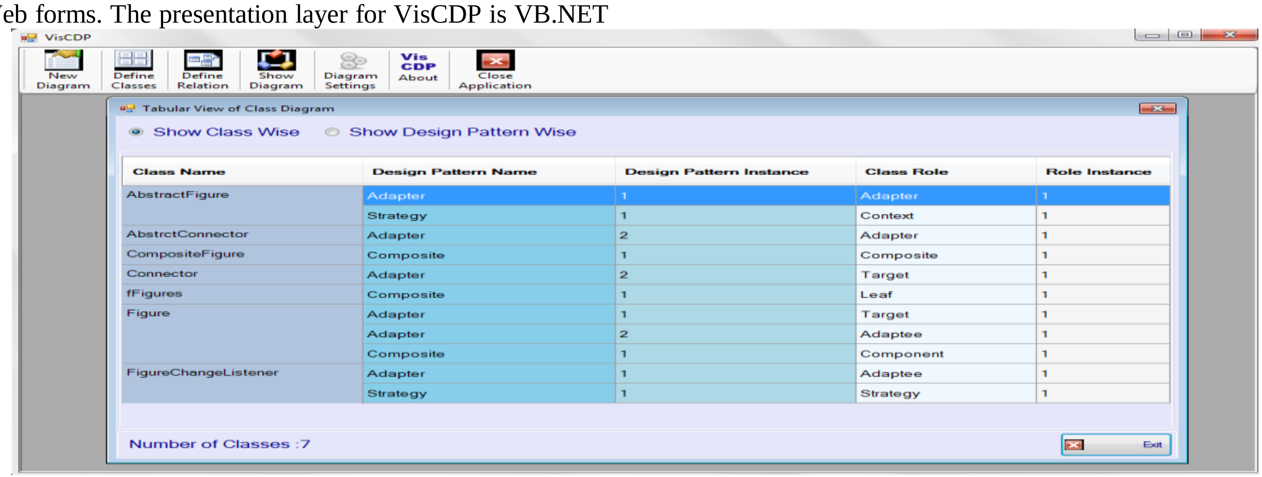


Fig. 5. Architecture of VisCDP

The user enters the class and associated design pattern information manually into the tool and then he/she can visualize the output in pictorial and tabular view according tohis/her requirements. Fig. 5 presents the architectural overview of VisCDP. The Visual Studio.NET is used to create the Web forms. The presentation layer for VisCDP is VB.NET forms with user controls. VisCDP takes the input from the user through these forms and then stores this information in a database (MS Access). The user can define the classes, their relationships and all the design pattern information related to classes, operations and attributes. VisCDP displays the original UML diagram and UML diagram with design pattern information related to class and/or operations. It also generates the tabular view of design pattern information related to classes and facilitates on demand visualization.

VisDP is also capable to display design pattern information in a tabular form which is important to know the impact of each class in different design patterns as shown in Fig. 6. The first column in Fig. 6 shows name of a class and the second column show name of design pattern in which a particular class exists. The third column shows the number of design pattern's instance in which a class exists. The last column in Fig. 6 shows that how many roles a particular class is playing in different design patterns.



Class Name	Design Pattern Name	Design Pattern Instance	Class Role	Role Instance
AbstractFigure	Adapter	1	Adapter	1
	Strategy	1	Context	1
AbstrctConnector	Adapter	2	Adapter	1
CompositeFigure	Composite	1	Composite	1
Connector	Adapter	2	Target	1
fFigures	Composite	1	Leaf	1
Figure	Adapter	1	Target	1
	Adapter	2	Adaptee	1
	Composite	1	Component	1
FigureChangeListener	Adapter	1	Adaptee	1
	Strategy	1	Strategy	1

Fig. 6. Design Patterns Information in Tabular Form (Class Wise)

VI. Evaluation of Approach

The presented approach is evaluated on a JHotDraw-5.1software package which is implemented using different design patterns. This version of JHotDraw-5.1[22] contains 136 classes and total lines of source code are 30860. We partially selected a set of nine classes from this software package to demonstrate our approach as proof of concept. We also implemented other two approaches [3, 9] using same software package. The partial software package design is composed of five design patterns: two instances of Adapter and a single instance of Strategy, Composite and Bridge design patterns. Figure class, playing three roles in three different design patterns, is a central abstraction of the drawing editor framework. It represents a graphical figure that users can work with. The objective of selecting this software package is to evaluate our hybrid approach and to compare the results with the other two approaches [3, 9]. Although, we compare eleven different pattern representation approaches in Table 1, but we selected these two approaches for evaluation and comparison with our approach as these are most representative approaches.

Pattern: Role notation (Gamma's Approach) does not represent the role that an attribute and operation play in a design pattern. Multiple instances of a design pattern may exist in a class diagram, but this approach cannot distinguish the multiple instances of a design pattern. Fig. 7 represents the resulting diagram after implementing the Gamma's approach on our case study.

Stereotype enhanced UML diagrams (Dong's Approach) represent the roles that a class, operation and attribute plays in a design pattern. This approach also distinguishes the multiple instances of a design pattern, but the text overload considerably increases the size of the classes and consequently it becomes really hard to read a design pattern related instances of a design pattern, but the text overload considerably increases the size of the classes and consequently it becomes really hard to read a design pattern related information. in different types of overlapping. Fig. 8 presents the resulting diagram after implementing the Dong's approach on our case study.

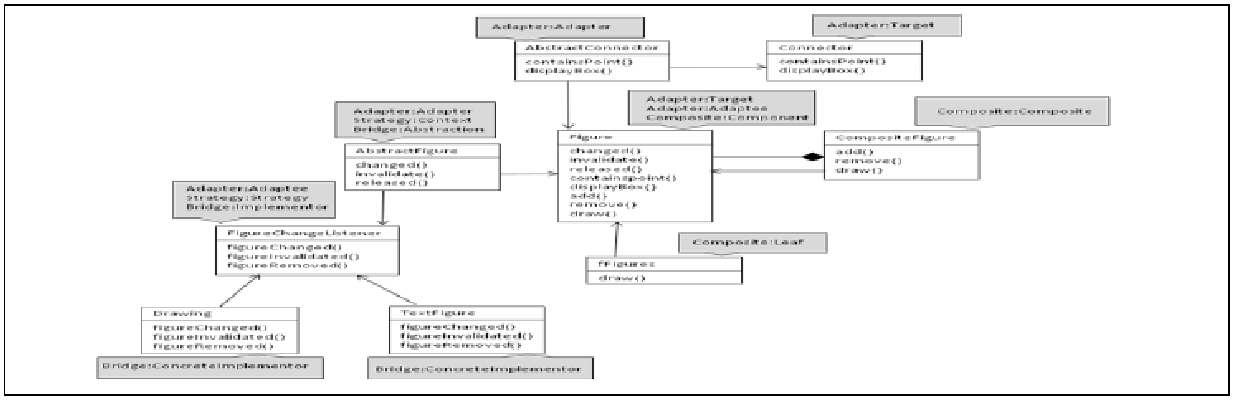


Fig. 7. Gamma’s Approach Implemented on JHotDraw-5.1

The proposed approach representing design pattern information on a subset of JHotDraw-5.1 classes is shown in Fig. 9. The notation “Bridge [1]: ConcreteImplementor[1]” attached to class Drawing represents that Drawing class plays the role of ConcreteImplementor in the Bridge. “Bridge [1]:ConcreteImplementor[2]” attached to class TextFigure represents that TextFigure class is the second instance of ConcreteImplementor in the same instance of design pattern Bridge.

Table 3 presents the comparison of Gamma, Dong and our hybrid approach based on the key features used by visualization approaches. One of the major characteristics of our hybrid notation is to represent the multiple instances of a class role that a class plays in different design patterns. This feature exactly determines different types of overlapping i.e. one to one, one to many and many to many which differentiate our approach from state of the art approaches.

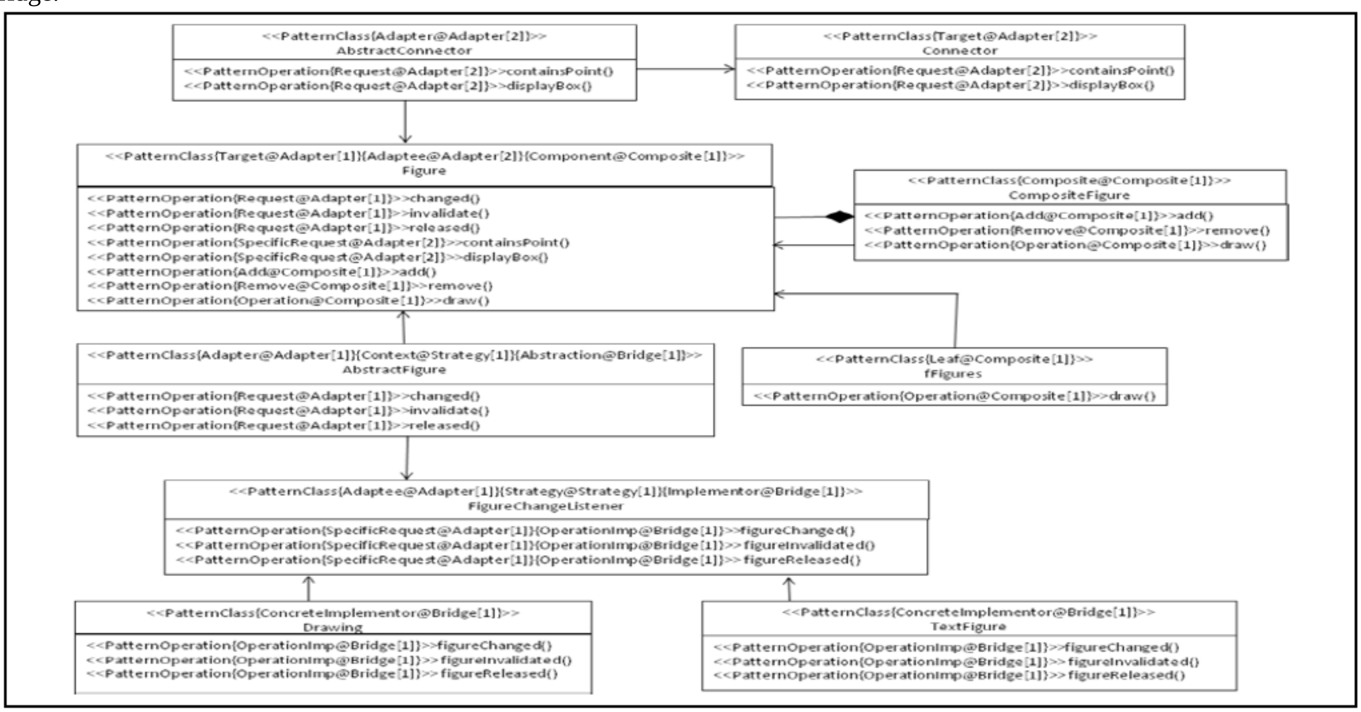


Fig. 8. Dong’s Approach Implemented on JHotDraw-5.1

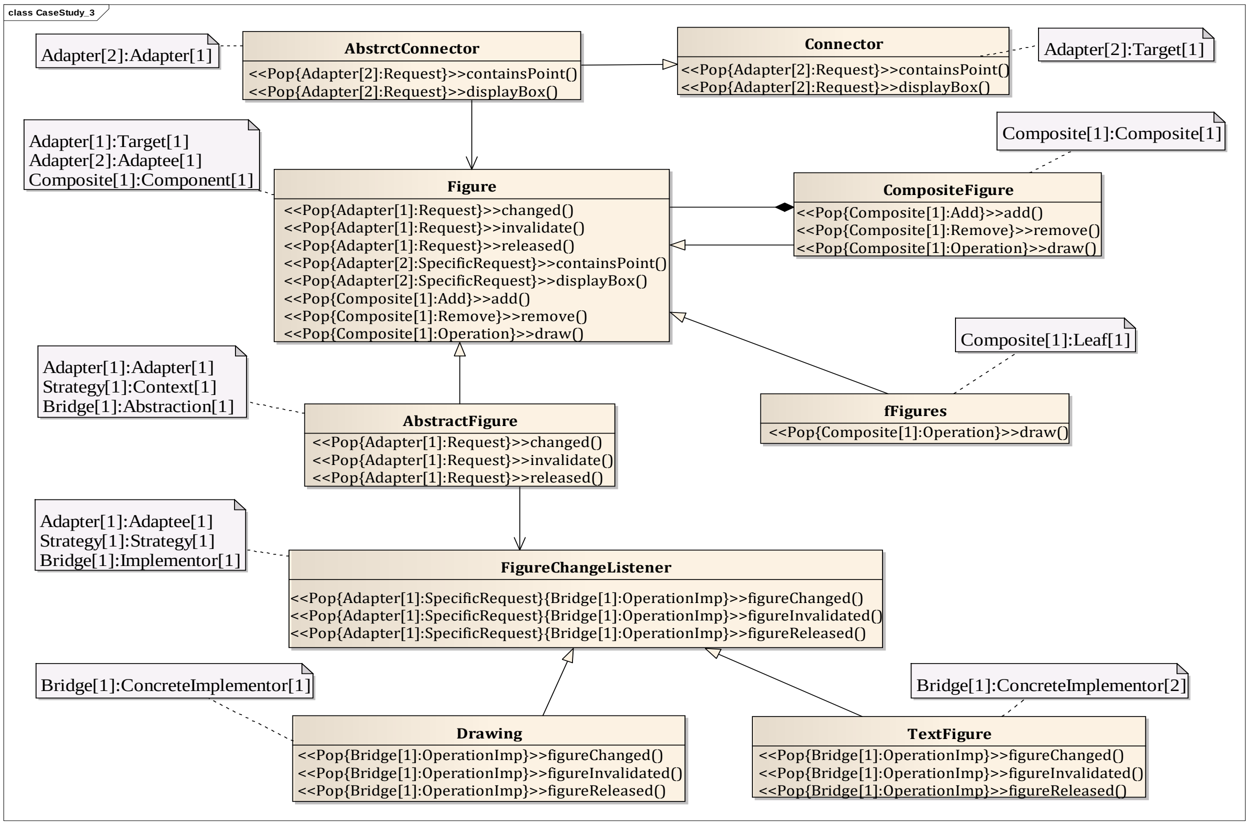


Fig. 9. 1 Hybrid Approach Implemented on JHotDraw-5

TABLE. III. COMPARISON OF GAMMA, DONG AND OUR HYBRID APPROACH BASED ON KEY FEATURES

DP Representation Features	Gamma's Approach [3]	Dong's Approach[9]	Our Hybrid Approach
Visualization Style	Visual	Strongly Textual	Both Textual and Visual
Overlapping type	No	1-1	All three types
Visualization support	Forward Engineering	Forward Engineering	Forward and Reverse Engineering
Participation	Yes	Yes	Yes
Composition	Yes	Yes	Yes
Class Role	Yes	Yes	Yes
Attribute Role	No	Yes	Yes
Operation Role	No	Yes	Yes
Multiple instances of a design pattern	No	Yes	Yes
Multiple instances of a Class Role	No	No	Yes
Level of Complexity	Low	High	Medium
Comprehension	Easy	Hard	Moderate
Tool Support	No	Yes	Yes

Our proposed approach has visualization support for forward as well as for reverse engineering cycles as compared with approaches of Gamma and Dong. We support all types of overlapping which are important for comprehension of visualization for different instances of design patterns in any software.

Similarly, our approach uses combination of visual and textual aspects of design patterns information for better visualization as compared to previous approaches. Finally, our approach achieved the comprehension at moderate level. We validated comprehension of our approach through a questionnaire. We sent a questionnaire to 20 master students that were studying a course on software visualization at COMSATS Institute of Information Technology. We sent three samples of visualization styles for our approach and other two approaches [3, 9] as a part of the questionnaire. 85% of the students rated comprehension feature of our approach moderate.

Validity is the major concern for researchers and practitioners to validate the results of information retrieval techniques. Regarding construct validity, one of the major threats to the results of our approach is related to design patterns identification from source code and analysis of dependencies as there is a lack of standard definitions for design patterns. The structural and implementation variations are key factors which impact the accuracy of design pattern detection tools. We reduced this threat as we used results of extracted patterns which are already verified. To ensure internal validity, we used JHotDraw-5.1 as a case study. JHotDraw-5.1 is a drawing editor and it is developed by using different design patterns. The source code is available freely for validation of results. However, threats to external validity are related to what extent we can generalize our results. Thus in case of large scale systems, our results for class view may be a threat to the external validity of our visualized results. Regarding reliability validity, we used JHotDraw-5.1 which is open source software and is publically available.

VII. Conclusion and Future Work

The comprehension of large and complex systems based on design patterns is a challenging problem. Different representations of design patterns have been proposed, but each representation has its strengths and limitations. Current design pattern visualization approaches are unable to capture all the aspects of design patterns visualization which is important for the comprehension of any software application e.g., the role that a class, attribute and operation plays in a design pattern. Similarly, there exist multiple instances of a design pattern and different types of overlapping among different classes.

With the critical analysis of state of the art design pattern visualization approaches, we propose an approach that integrates the best features of Pattern: Role notation [3], stereotype enhanced UML diagrams [9] and appends new features to visualize the design patterns in class diagrams. The proposed hybrid notation is used to represent design pattern information related to roles and to visualize different types of overlapping. Stereotypes, their associated tagged values, semantics and constraints are defined to represent the design patterns information related to attributes and/or operations of a class. We used a subset of open source software JHotDraw-5.1 to evaluate our approach and compared the results with the other approaches. The proposed approach improves the visualization of design patterns as compared with previous approaches [3 9]. A prototyping tool named VisCDP is implemented to support our research work and to validate the concept of our hybrid approach. VisCDP is used to visualize design pattern information related to classes, operations and/or attributes in the composition of recognized design patterns. It provides static as well as on demand (dynamic) visualization in class diagrams. It is worthwhile to mention that our current approach is limited only to the visualization of design pattern information in class diagrams and we do not focus on visualization of information in sequence, collaboration and other types of diagrams. We evaluated our approach on a subset of the small scale case study (i.e., JHotDraw-5.1) and scalability of approach for large scale systems is questionable which will be investigated in future. The approach is also limited to visualize the standard representations of GoF patterns and we do not consider variants of same design patterns. In future, we plan to evaluate the scalability of our hybrid approach on large and complex systems.

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Adaptive Case Management Framework to Develop Case-based Emergency Response System

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***Abstract*—Emergency response to crisis, disaster, or catastrophe incidents is a clear example of knowledge-intensive and collaboration-heavy process facing all public safety-related organizations. Software systems to support emergency response have existed for decades. However, the limitations of these systems and their development approaches are still significant in terms of flexibility and dynamicity. With the emergence of Adaptive Case Management (ACM) as a new software development approach to support knowledge work and the empower knowledge worker, the authors found that ACM is a promising approach that can be extended to support emergency response especially in large-scale situations. This research aims to study how ACM can be leveraged to design and implement case-based emergency response systems (ERSs). In particular, the authors propose a domain-specific and vendor-neutral Case Management Framework (CMF) that incorporates the essential capabilities to support the ERSs. As a proof-of-concept, the authors support the proposed CMF by a case-based ERS prototype. Finally, the authors conclude that ACM has a great potential to enhance the effectiveness and efficiency of ERSs. This work can be considered as an attempt to advocate the adaptation of ACM in such context.**

Keywords—Adaptive Case Management; Case Handling; Case Management; Emergency Response System

I. Introduction

Presently, there is a strong demand for more effective and efficient ways to respond to small or large-scale emergency incidents. This demand requires cohesive coordination among all emergency response stakeholders especially in the case of crises and disasters events [1]. With the advent of the Smart City vision that can be realized through various advanced technologies—e.g. internet-of-things—public safety personnel and residents expect smarter ways to manage emergency response with less effort and costs. Furthermore, the availability and affordability of sophisticated technologies—e.g. pervasive sensors, multimedia surveillance, mobile computing, data analytics, social media, and cloud computing—make it quite possible to improve the effectiveness and efficiency of emergency response process [2]. Nevertheless, there are still major limitations associated with the traditional software development methodologies for supporting emergency response systems (ERSs)—e.g. Business Process Management (BPM) and Workflow technologies [3][4]. These approaches are too rigid and require considerable design and deployment cycles to enable mission-critical capabilities to deal with new or changing requirements. This primarily returns to the unpredictability, unrepeatability, and complexity nature of the emergency response process, which is time-critical, knowledge-intensive, unstructured, very dynamic, and very complex to be completely predetermined [5-9]. Exceptions are norms in a crisis [10], and emergencies in most of the cases are not "routine" because each emergency can present unusual elements [11]. Therefore, ERSs must be scalable, flexible, and adaptable enough to enable a collaborative response approach, empower the coordination of engaged domain experts, and accommodate unexpected requirements—e.g. emergent course of actions—on the fly (run-time) [7, 12-15]. However, designing a software system to address an unstructured and adaptive process style is challenging [4, 16, 17]. In addition, there is still an imperative requirement for further domain-specific research and development in the BPM-related methods and tools to effectively support various use case applications such as ERSs [4, 18-20].

With the latest improvements in BPM research and practice in recent years, Adaptive Case Management (ACM) has been introduced as a promising paradigm shift to support knowledge-intensive processes (KIPs)—also known as knowledge work—in various application domains, such as healthcare, social services, legal services, insurance services, and many others. [16, 21-29]. ACM is a goal-and data-driven approach built on the traditional case management concepts that promote a collaborative and ad-hoc work to resolve cases and achieve certain goals. In fact, an emergency incident can be seen and treated as a case using the case management approach. Furthermore, emergency management (incident management) is one of the most appropriate application area for the ACM because it is a knowledge-intensive work process [16, 21, 30-33]. ACM offers the most flexibility and adaptability ever sought by emergency responders to deal with large-scale crises, disasters, or catastrophes. However, adopting ACM is not an easy or straightforward endeavor especially for complicated domain-specific applications, such as ERSs. ACM is still an emerging trend with many arguments on its capabilities, implementations, and challenges. Consequently, there is an open challenging research arena to deeply study what is exactly ACM and how it can support ERSs.

This research aims to investigate how ACM's concepts and technologies can be utilized to design and implement case-based ERSs. Specifically, the authors propose a domain-specific and vendor-neutral Case Management Framework (CMF) and describe its characteristics and capabilities to support ERSs. Furthermore, the authors demonstrate a case-based ERS prototype on a leading commercial CMF. This work can be a starting point to guide the design and development of case-based ERSs as well as an attempt to scope and formulate the ACM functionalities and capabilities in such context.

The rest of this paper is organized as follows: Section II is a summary of related works in BPM to support ERSs. Section III specifies the characteristics and capabilities of case management platform to support ERSs. Section IV describes the proposed CMF and its essential components to support the ERSs. Section V outlines the development methodology that should be considered to build effective case-based ERSs. Section VI presents a prototype demonstration of a case-based ERS. Finally, Section VII summarizes the key findings of this research and indicates possible future work.

II. Related Work

The BPM and Workflow technologies are very useful and promising in developing the ERSs and have been discussed for several years [4, 34, 35]. Hofmann et al. [4] conducted a structured and comprehensive literature review to identify and discuss the BPM-related approaches—covering 98 scientific contributions from 1999 to Oct 2013—in supporting disaster response management (DRM). They also consolidated a catalog of general requirements and research gaps for designing effective process-oriented DRM approaches. Wang et al. [36] presented a formal and intuitive approach for the modeling and analysis of workflows to support the flexibility of the incident command systems (ICSs).

The adaptation in BPM to support emergency response process is an emerging research direction to support incident management [18, 35]. De Leoni [37] described an adaptive process management system (PMS) called “SmartPM”, which supports automatic adaptation techniques to cope with highly dynamic scenarios, such as emergency management. Catarci et al [38, 39] described the main results of a European project called WORKPAD, a two-level architecture (front-end and back-end) and used a user-centered design methodology that supports rescue operators in disaster response based on process management and geo-collaboration. Wagenknecht and Rueppel [40] presented a process-centric approach to support flood response management by using formal process models and adapting process management methods. They also suggested further research to achieve more flexibility in process support by focusing on dynamic changes of running processes.

Hofmann et al. [41] presented a (semi-)automated method called “DRP-ADAPT” to analyze disaster response process (DRP) models by considering place-related conflicts and their resolutions. However, this method is still based on some assumptions and limitations that might be irrelevant in practical scenarios. In addition, Hofmann et al. [42] extended the DRP-ADAPT by using the Precedence Diagram Method (PDM) to generate a list of valid execution traces with time consideration ranking.

Kushnareva et al. [5, 43] examined an activity-oriented paradigm of a flood management process implemented as a part of a smart city solution called “COS Operation Center” (COSOC) and compared it with an alternative state-oriented and statecharts paradigm. Finally, they concluded that state-oriented modeling with statecharts has a great potential for modeling a crisis management process. Furthermore, Kushnareva et al [44] combined MAP (goal-oriented) and statecharts (state-oriented) formalisms to model and align the strategic and operational levels of crisis management as an intension-driven approach to a recommendation system of COSOC.

Most of the related works presented in this section (except the state-oriented research, which is more related to ACM) are based on the traditional BPM and Workflow technologies. These technologies are too restrictive and not flexible enough to support the knowledge work of emergency response, which is non-repeated, unpredictable, emergent, and requires a robustness in the face of varying conditions [29, 45-50]. BPM is a control-driven and an activity-centric approach to coordinate the control flow of the process activities based on a pre-specified process model. In contrast, ACM is a goal-driven and a data-centric approach to empower the knowledge worker to perform knowledge work (e.g. emergency response) with the help of a guiding template and adaptation capabilities. Despite the significant efforts in the last decade to make process-aware information systems (PAISs) more flexible in front of required process variability, looseness, adaptation, and evolution, case handling—i.e. ACM—is a paradigm shift to support knowledge-intensive work and enable user-and data-driven processes [51].

Cummins [52] described the ACM as the next generation BPM. ACM is using the principle of “design for people, build for change”, which is a more lean approach than the structured and predicable approaches often automated with BPM suites [33]. ACM enables both the planning at design-time (“doing-by-design”) and planning at run-time (“design-by-doing”) [25, 26]. ACM has both the ability of “flexibility-to-use” and “flexibility-to-change” to support knowledge work, whereas BPM and BPM 2.0 failed to provide support in this direction [53]. ACM typically uses functional languages (declarative) to enable dynamicity at the execution time instead of procedural languages (imperative) usually used in BPM [26, 54-57]. Some researchers discussed the strengths and weaknesses of BPM and ACM, and suggested a combination of both capabilities to overcome some inherited limitations when only considering one over the other [16, 58-60].

III. Capabilities of ACM Platform

This section briefly highlights the common capabilities that mainly distinguish the ACM platforms from other approaches, such as traditional BPM platforms (also known as BPMS). These capabilities are very important to be considered when evaluating or selecting the appropriate ACM platform to develop and maintain the case-based ERSs.

Swenson [21] classified the ACM systems (platforms) capabilities into three levels: required in all ACM systems (level 1), common extensions in ACM systems (level 2), and advanced extensions for ACM systems (level 3). Level 1 includes the essential capabilities that a typical ACM system must support, such as team, folder, goals, history, security, communication, adaptation, and reporting capabilities. Level 2 consists of some additional capabilities that can extend the ACM system, such as business entities, data interchange, business rules, resource state model, granular access control, sensors and triggers, and conformance guiding. Finally, Level 3 describes the advanced capabilities that can be considered to enhance the ACM system, such as process mining, social mining, federated case folders, ontology or taxonomy, and resource sharing.

Hill et al. [16] identified nine critical capabilities for evaluating commercial BPM-platform-based CMFs. These capabilities include adaptive case handling, content interaction, runtime collaboration, integration and interoperability, data capture and output management, out-of-the-box components, intelligent upgrades, role-based user experience, and role-appropriate analytics. The importance of each capability relies on the application use case. Gartner also provided a weighting for the nine critical capabilities based on four use cases: investigative cases, incident management, service request, and process-to-decision.

IV. Proposed ACM Framework

Developing ERSs is very complicated and requires special considerations for guiding design principles and concepts [10, 61-64]. These design principles and concepts consider the most important issues in emergency response requirements. In addition, frameworks and best practices provide an effective guidance in developing ERSs [64]. In this framework, the authors focus on the data and process technologies to enable effective and efficient case handling and decision-making.

In fact, there are many debates on what must be included in the ACM supporting platforms in terms of components and capabilities. The reason of these debates, in general, relies on the unavailability of a standardized framework and definition for a typical ACM. ACM industry vendors often look at the ACM from disparate perspectives based on their platforms' capabilities and technology offerings. The diversity of these perspectives has, unfortunately, increased the doubts of what is the ACM and what it must include.

The ACM market offers many generic case management frameworks (CMFs) that can serve a variety of domains' applications [26]. The problem with such offerings comes from the fact that a one-size-fits-all solution does not effectively work to support all various use cases in different domains. Therefore, there is a strong call from academic research for BPM and ACM domain-specific frameworks and systems [4, 18-20]. In addition, the ACM industry trend is to provide ready-made solution templates suitable for particular domain requirements to have a jump-start, reduce the time-to-market, and leverage pertained best practices.

Therefore, the authors propose a domain-specific and vendor-neutral CMF as illustrated in Fig. 1. This CMF can represent a high-level reference model for a ACM platform to effectively support ERS. The proposed CMF is composed of several components that are briefly described in the following subsections.

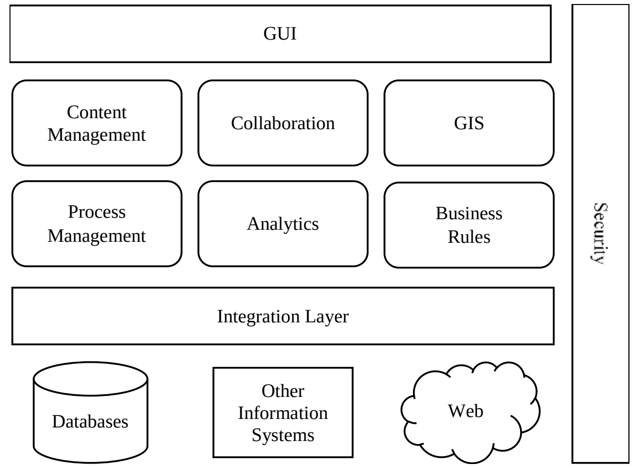

Fig. 1. Proposed adaptive case management framework for emergency response system

A. Graphical User Interface (GUI)

Graphical User Interface (GUI) is the medium for end users (e.g. emergency responders) to interact with the ERS. This includes all the input forms and output reports usually accessed by emergency-related personnel during or after the emergency incident. The *GUI* component has to be user-friendly and intuitive to support tired–dirty–hungry responders who operate under extreme stress. The *GUI* has also to combine and effectively display both graphical (e.g. map) and textual (e.g. incident detail) incident-related data in an appropriate manner that is suitable for different devices (e.g. desktop, laptop, notebook, and smartphones).

The *GUI* should be a web-based that is able to support multiple views based on various user requirements and authorization permissions. More importantly, the *GUI* has to be configurable with less hard-coding efforts to build or customize the system's look-and-feel, entry forms, or output reports.

B. Content Management

Data are the heart of ERS that *Content Management* is supporting an essential ACM component. Emergency situational awareness totally relies on the availability and accessibility of incident-related data, which include structured (e.g. rational databases) or unstructured (e.g. social media) contents. The structured data contain all of the incident's details (e.g. type, date and time, and location), responding units' details (e.g. type, name, numbers, and status), and responding activities (e.g. standard operating procedures, tasks assignments, and tasks status).

The unstructured data can include free-text, images, audios, videos that originated from social media or other sources (e.g. multimedia surveillance systems). The management of this complex information is very challenging, considering the information overload in the stressed and extreme events, as well as the privacy and security concerns pertaining to the incident, such as victims, responders, and places.

Consequently, the *Content Management* component has to be capable and flexible to store, process, retrieve, and archive all kinds of incident-related data in an organized and structured manner—i.e. case folder. Furthermore, given that the emergency response is data-driven (situational awareness), the *Content Management* component has to be capable to drive and automatically initiate the response operations (tasks) based on content arrival or modification.

C. Process Management

Emergency response involves intensive coordination efforts to support cross-organizational personnel coming from multiple agencies (e.g. government, private sector, and non-governmental organizations) and different levels (e.g. local, state, and federal), especially in the situation where the number of emergency responders exceeds the local capacity, and further state or federal assistance is requested. In fact, each emergency responding discipline (e.g. police, fire, and EMS) has to conform with its own emergency operations plan (EOPs), standard operating procedures (SOPs), and internal or external policies or regulations. Although there are many standard responding activities plans already in place before any incident occurrence, each incident case can present unique, emergent, and unpredictable challenges.

Therefore, traditional process styles (e.g. BPM and Workflow technologies) are inadequate to effectively support the management of emergency response operations because they are based on explicitly predefined process models that are too rigid to be modified at the run-time. In contrast, the *Process Management* component of ACM has to be adaptive and flexible to support handling of ad-hoc response actions at the run-time beside the capability to integrate with the traditional process styles, which might be required to run specific process fragments. In addition, the *Process Management* component has to interact seamlessly with the *Content Management* component to create task or trigger process segments based on data arrival or modification.

D. Collaboration

Knowledge exchange and information sharing among decision makers, emergency responders, and domain experts are fundamental requirements to effectively manage the emergency incident. People involved in emergency incident management used to communicate and coordinate their responding activities by using the traditional wireless telecommunications systems (e.g. mobile radio systems). However, from several past experiences and lessons learned, these approaches seem to be ineffective and insufficient due to the infrastructure and compatibility issues especially when different responding agencies are engaged with their own different telecommunications systems (e.g. different radio frequencies).

With ACM, the *Collaboration* component should provide flexible and effective means for sharing and discussing any details of the emergency incident among all responding participants at the real-time, such as using emails, instant messages (IMs), social media, and many others. ACM has to ensure a centralized and governed platform for knowledge sharing that can easily be accessed, monitored, archived, and audited at any time.

E. Analytics

The analysis and reporting of emergency incident-related data are crucial to support decision-making during the incident management. Getting insights from the rich structured and unstructured incident contents are very helpful at the real-time to enhance the response operations, and later to review the case historical data for auditing or compliance checking. The *Analytics* component plays a major role in the ACM to gather, analyze, process, and summarize the actionable knowledge pertaining to the emergency incidents. The *Analytics* component has to support all kinds of reporting and decision-making during or after the incident through the utilization of business intelligence and data mining techniques.

One example is the enabling of emergency responders and decision makers to define and monitor the required key performance indicators (KPIs) to ensure the maximum utilization of resources and activities during the incident management. Another important aspect of the *Analytics* component is the capability to guide the management of the current incident based on the course of actions and lessons learned from the prior similar incidents.

F. Geographic Information System

Geographic Information System (GIS) is an essential part of any ERS to support decision-making and enable effective collaboration and information sharing. *GIS* helps all incident management personnel in analyzing and visualizing the incident-related data on multi-layered maps. This improves the situational awareness and facilitates the identification of all incident-related places and affected areas. For example, the emergency responders can use the *GIS* to effectively understand the scope of the incident, plan the logistics, deploy the resources, support the search and rescue operations, define the evacuation paths, and others.

Moreover, the people affected by the incident can use the *GIS* to locate the evacuation roads, sheltering places, dangerous areas, and so on. The generic commercial ACM platforms do not usually encompass the *GIS* by default. However, the domain-specific ACM has to be capable of seamless integration and interaction with *GIS* to effectively support the emergency response use case.

G. Business Rules

ERSs are similar with other business applications that are governed by domain rules, government regulations, or policy compliance. The *Business Rules* component supports the decision-making and regulatory compliance as well as ensures the consistency and accuracy of the work outcomes. Traditionally, *Business Rules* were embedded into the software logic, such as control flow in the Workflow technologies. However, this approach is inefficient because to cope with any business rules updates or changes, the specialized developers might have to do frequent changes to different places in the software internal code.

Presently, the best practice is to separate the software logic from the rules logic to simplify the complexity of rules management through a centralized business rules engine (e.g. definition and update) that can be handled by business analysts instead of specialized developers. The *Business Rules* can then be utilized by multiple software applications and only need a single update to be reflected into all applications. In emergency response context, for example, the *Business Rules* can be used to automatically prioritize the emergency incident based on its details (e.g. type, size, and complexity), create or assign response tasks, or trigger process fragments (e.g. SOPs).

H. Integration Layer

ERS is not a stand-alone system and has to be integrated with multiple internal or external systems and databases, such as surveillance systems, citizens' records, medical records, hazardous material (HazMat) guides, and buildings blueprints. The *Integration* Layer component has to support the integration requirements of ERS to any system of records. This includes the ability to incorporate all types of data such as data on movement (e.g. surveillance or social media feeds) or data on rest (e.g. stored database records).

ACM has to provide a broad set of standardized application programming interfaces (APIs) or mediation technologies (e.g. enterprise service bus) to facilitate the interfacing requirements of ERS to any system or database—including any incident-related content available on the Web via the Internet.

I. Security

Security is an imperative component for ACM to effectively and efficiently support the ERS—especially when connected to the Internet. ERS is a mission-critical system that has to be secured from any potential cyber-attacks or security threats. ERS also includes sensitive data that has to be protected from any disruption or unauthorized access. The *Security* component has to ensure the confidentiality, integrity, and availability (CIA) of all the incident-related data with the appropriate required level of authentication and authorization. Emergency responders and other public safety personnel usually come from multiple agencies and have different information needs during or after the incident for either decision-making or reporting purposes.

ACM has to provide the flexible means to manage and maintain the ERS access rights and privileges based on different system levels (e.g. system access, system pages, and incident details) and users' roles (e.g. Incident Commander, Operations Section Chief, and Public Information Officer). ACM has also to support multiple system views to be created or customized according to each system user's requirements and conforming to any agency or government policies and regulations.

V. Development Methodology

The design and development of case-based ERS are not a straightforward endeavor. The complexity, dynamicity, and variation of ERS requirements complicate the system development because they cannot be stably and completely defined in advance. *Therefore*, the traditional waterfall development approaches are inappropriate to build an effective and efficient case-based ERS. Agile software development methodologies can play an important role in this domain to mitigate the risks of changing requirements.

Agile approaches enable the iterative and incremental features development with high engagement of the knowledge workers (e.g. emergency responders) to evaluate and validate the introduced set of required features (prototype). Therefore, the improvements can be gradually attained by going through multiple iterations—considering the changing requirements and *case* workers' feedback. Recently, the DevOps approach (development and operations) has been introduced in the software development domain to bridge the gap between development and operation teams. The DevOps approach considers the agile methodologies along with other practices (e.g. continuous delivery and continuous deployment) to enhance the software development lifecycle, decrease the number of deployment failures, and reduce the time-to-market. ACM platforms should support the adoption of DevOps' practices to facilitate the effective development of case-based ERSs.

VI. Prototype

To evaluate the capabilities of ACM to support the ERS, the authors develop a case-based emergency response prototype by using a leading ACM commercial platform [16, 65] called IBM Case Manager 5.2.1. The IBM Case Manager is deployed as a virtual machine (VM) image on our private IBM Cloud platform for academic research and teaching.

The IBM Case Manager includes many capabilities to enable flexibility for both design-time and run-time that can support the unpredictability and unrepeatability nature of the emergency response process. The core components of the IBM Case Manager to design and process case-based systems include *Case Manager Builder, Case Manager Client, Case Manager API, Case Manager administration client, Content Platform Engine*, and *FileNet Workplace XT* [47].

A. Design

In the ACM approach, the first step in system development is often to design a basic template that covers the predictive and essential requirements of the targeted system, such as case design, task design, case documents, and business rules. Creating an ERS using the IBM Case Manager includes three levels: defining the system with *Case Manager Builder*, refining the system by using more advanced configuration, and customizing the system by using custom code [47]. Fig. 2 shows a sample screenshot of the ERS essential definitions that include: *defining case properties*, *defining roles*, *defining in-baskets*, *defining document types*, *defining case types*, *defining views*, *defining business rules*, and *defining tasks*.

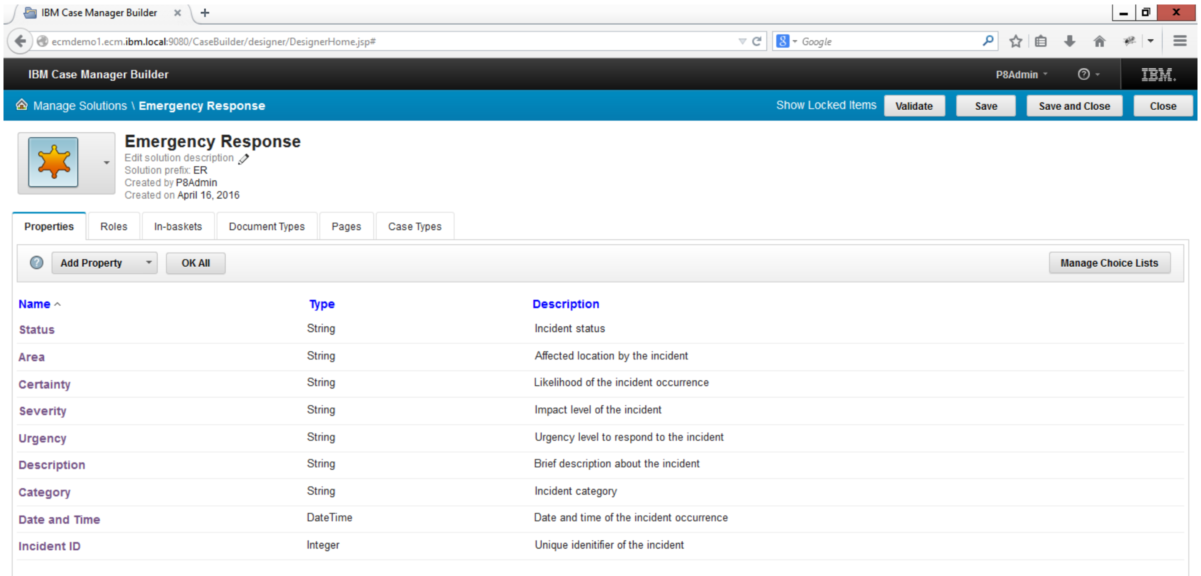

Fig. 2. Defining the ERS prototype with IBM Case Manager Builder

B. Deployment and Testing

The defined ERS prototype has been successfully deployed in the development environment. Fig. 3 shows the successful deployment status as a green rounded icon with a check mark in the IBM Case Manager Builder. The development environment enables the system analyst and end user to dynamically test and validate the developed functionalities, which can be achieved by creating a test case and checking the data and process flow as per required response actions defined in the design phase.

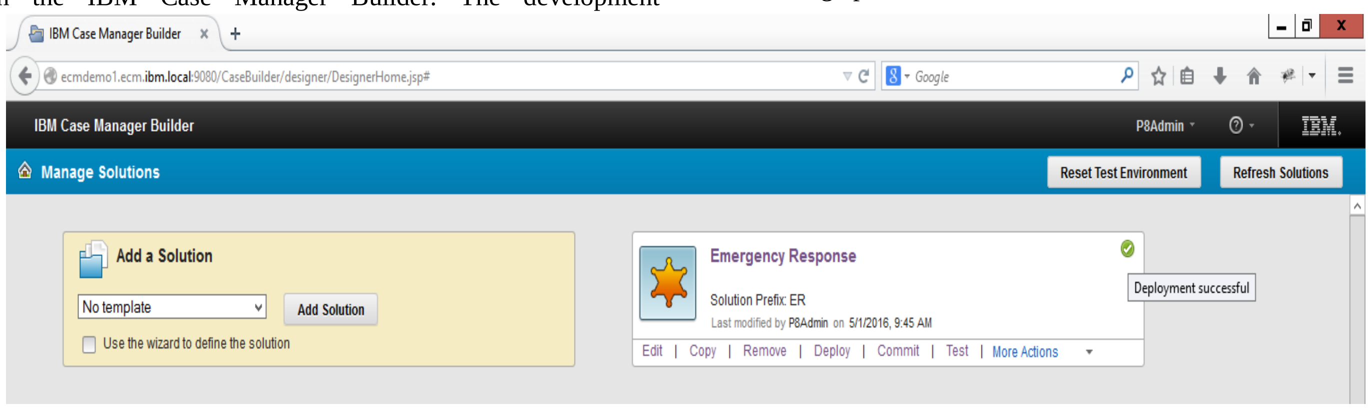

Fig. 3. ERS prototype deployment

Then, the deployed ERS prototype is tested by creating a sample incident case as shown in Fig. 4 (all entered values are fictitious for test purposes only). The creation of the incident case can be done manually or automatically. In manual creation, the end user (knowledge worker) enters the incident details manually based on the reported information of the incident via phone, papers, and others. On the other hand, in automatic creation, the incident details are entered automatically by fetching the data from other systems such as detection systems, computer-aided dispatch (CAD), and others. More details on the incident can also be accessed from other sources such as internal or external databases.

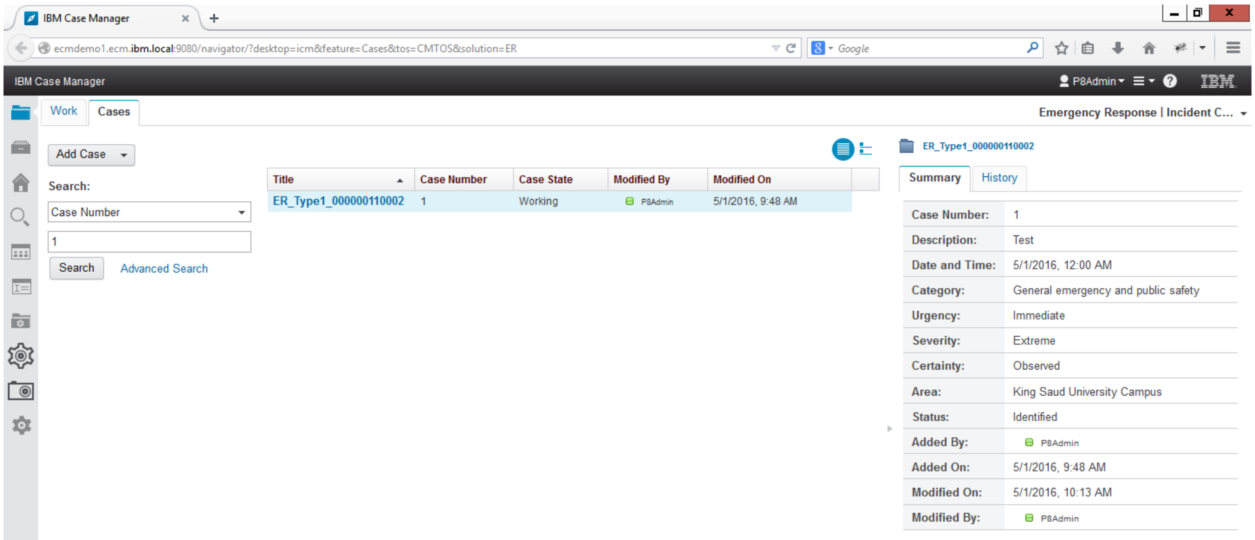

Fig. 4. An example of an incident case

As shown in Fig. 5, the ACM platform has automatically created a set of different tasks, and assigned them to different roles based on the defined template. These tasks appeared with three different statuses: *Waiting* (waiting for a precondition), *Ready* (manual task), and *Started* (automatically started). The active tasks are with the status *Started* and are automatically sent to the corresponding role in-basket that can only be accessed by the authorized user. The *Waiting* task is started when the precondition(s) is met. The *Ready* task can be started when manually initiated by the user (discretionary tasks).

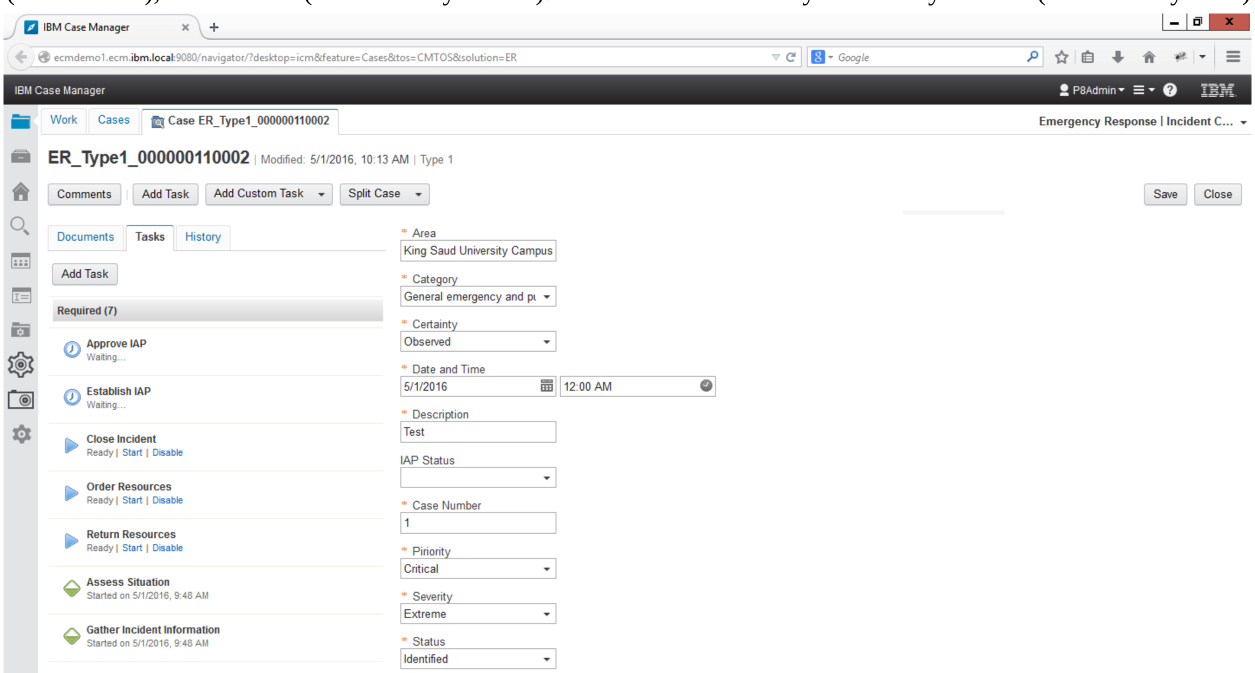

Fig. 5. Tasks automatically generated for the sample incident case

VII. CONCLUSION AND FUTURE WORK

The response to large-scale emergency incident, such as crisis, disaster, or catastrophe, is a complicated process and poses a challenge to public safety personnel. Large-scale emergency incidents are unpredictable and unrepeatable, which make incident management and decision-making very challenging. These incidents often exceed the local capacity and require additional support from state or federal agencies, which implies intensive coordination and management of hundreds (or even thousands) of responders from diverse government, private sector, and non-governmental organizations.

In the past decades, many attempts have been carried out to design and develop sophisticated information systems to support emergency response utilizing the latest technological advances. Nonetheless, those efforts are still inadequate to effectively and efficiently empower the emergency knowledge workers who require a flexible, adaptable, and scalable system to handle large-scale emergency incidents. Most of the existing emergency response systems are built based on traditional software development approaches—e.g. Business Process Management and Workflow. These approaches are too rigid, require considerable time and effort to be customized or modified, and restrict the emergency responders from adapting to the dynamic and emergent requirements during the response operations.

With the introduction of Adaptive Case Management as an emergent knowledge work support approach, the authors found that there is great potential to extend the ACM concepts and technologies beyond the traditional use cases, such as healthcare, legal services, and insurance. ACM is a goal-and data-driven approach that can effectively and efficiently support the concept of management-by-objectives recommended in handling the emergency response. ACM can deal with all types of data and processes (structured and unstructured) and can also provide the emergency responders with the most flexible and adaptable mechanisms to define the course of action at the design-time (defined template) or even during the run-time (ad-hoc activities).

In this research, the authors proposed a domain-specific and vendor-neutral Case Management Framework that incorporates all essential capabilities to develop an effective and efficient case-based ERS. The proposed CMF consists of nine major components: *Graphical User Interface, Content Management, Process Management*, *Collaboration, Analytics, Geographic Information System, Business Rules, Integration Layer*, and *Security*. The authors outlined the required capabilities and characteristics of each component to support the ERS in accordance with the ACM concepts and principles. In addition, the authors indicated that the proposed CMF should be accompanied with an agile development methodology to facilitate a rapid system development and mitigate any associated risks.

In addition to the proposed CMF, the authors demonstrated a prototype on a leading commercial ACM platform (IBM Case Manager) to evaluate the basic capabilities necessary to design, develop, and deploy a case-based ERS. The authors concluded that ACM—with its advanced capabilities—has great potential to enhance the emergency response by significantly including situational awareness, response coordination, and decision-making.

Although the authors attempted to study, investigate, and evaluate how the ACM can support the ERS, this work still encompasses some limitations. The major limitation is the lack of real-life implementation because the authors performed this research study on a lab-setting with limited access to actual resources that are usually required in real-life situations. The authors admit that real-life implementation is more complicated, and usually includes technological and non-technological challenges.

Finally, our future work will be focused on the real-life implementation considerations by involving subject matter experts (SMEs) to refine and discuss how the ACM can help in designing, developing, and implementing case-based ERS in the real-life context. Additionally, further research is required to investigate how ERS can benefit from data analytics capability in ACM to predict and enhance incident handling based on knowledge of similar previous incidents.

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Novel Intra-Prediction Framework for H.264 Video Compression using Decision and Prediction Mode

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***Abstract*—With the increasing usage of multimedia contents and advancement of the communication devices (along with services), there is a heavy demand of an effective multimedia compression protocol. In this regards, H.264 has been proven to be an effective video compression standard; however, its computational complexity associated with out and various other issues has been impediment towards mainstream of research towards compression. Therefore, we present a novel framework that enhances the capability of H.264 compression method by emphasizing on accomplishing the cost effectiveness of computational operation during intra-prediction mode. A simple and novel encoding mechanism has been formulated using H.264/AVC using decision mode of macro block as well as selection of prediction mode exclusively for intra-prediction in H.264/AVC. The study outcome is found to offer a superior signal quality as compared to conventional H.264 encoding mechanism.**

Keyword—Encoding Mechanism; H.264 / AVC; Intra-Prediction Mode; Video Compression; Visual Quality

I. Introduction

The joint development of ITU-T and MPEG has recommended H.264/AVC as an industry standard for video compression in the year 2003, which delivers 50% more compression efficiency as compared to previous standards as well as it supports very high video quality over channels of lower bit rates. This improved efficiency of H.264/AVC paves the foundation of many promising and potential applications and services on mobile devices over wireless networks with ease of coding, transmission and error resilience [1] [2] [3].The gain in high performance on such devices with H.264/AVC is obtained at the very high cost of computation as the overhead of processing for power constraint mobile devices is a major tradeoff as more processing requires more power consumption. Therefore, it is an open research problem to conceptualize, design and device a mechanism involves into H.264/AVC encoding processes to achieve higher performance with least computational overhead by low complex implementations [4][5]. Typically, an H.264/AVC encoding process involves removal of spatial, temporal and statistical redundancy of video signal. The transformation of macro blocks, (a basic coding unit of 16 x 16 block of displayed pixel) by quantization of transform domain (spatial frequency components/ co-efficient) from spatial domain provides the considerable amount of compression. The complexity of the process is reduced in the H.264/AVC as compared to other such processing or computation functions by means of efficient implementation of integer function and minimal transformation of the block size in this case. Modern applications which has been conceptualized in various domains of business applications such as collaborative communication, visual sensors based applications, advanced medical applications, entertainment, etc which runs on a synchronized heterogeneous devices and platform right from desktop, laptops, smart phones, custom devices till cloud commuting architecture extended to internet of things are image, multimedia and video. The successive growth of expectations of better Quality-of-Services (QoS) with general accepted visual quality in real time basis always poses a tradeoff between availability of bandwidth, storage, communication, computation and transmission [6][7][8]. This is a core reason for evolution of design of video compression as video codec. The futuristic aim is to cope up with the demand of rich visual dimension of video streaming application [9] [10]. Historically, the basic of the design of video codec were surrounded across a custom designed hardware to overcome the constraints of limited processing capacity by optimizing the computational capacity as an objective function. The inventions of the advanced processor have helped to overcome these issues and provided an improvement in performance in a reliable way as well as they were rate successful and had wider availability. As a result, the "software only approaches" of video codec become practicable [11] [12].

At present, there is much discussion about the trend of using H.264 compression standard owing its beneficial factors. There are also certain extents of research work being carried out towards overcoming the flaws in existing system. The proposed study presents one such work. Section A discusses about the existing literatures towards assessing the usage pattern of H.264 standard of multimedia compression. The existing research work in adoption of H.264 is discussed in Section II. Section III exhibits the problems being identified by the proposed study followed by brief highlight of the contribution of proposed system in Section IV. The algorithm being implemented in order to accomplish the research goal is discussed in Section V followed by discussion of result accomplished in Section VI. Finally Section VII gives some concluding remarks.

II. Review of Literature

This section discusses about the existing research techniques towards adoption of H.264. We have reviewed about the existing techniques to improve the performance of video compression in our prior work [13]. This section of document closely investigates and writes an inference about intra-frame prediction and a reconstructing mode decision of video input signals. Our prior work has already reviewed existing literatures towards H.264 [13]. This section we further update about the related works. Qual et al. [14] in the year 2010 in their paper has classified fast intro predication mode decision into three categories based on block features, mode feature, and edge or directional information. Song et al. [15] have presented an approach of hierarchical intra-prediction method for video application for mobile based on orientation gradient based discretization of total variation. In their method, they shrink the candidate mode set in the Rate-Distortion Optimization (RDO) process. Lim et.al [16] introduces two mechanism 1) fast block size decision (FBSD) and 2) fast mode decision (FMD) by considering a metric called similarity of the higher position pixels and left position pixels individually, which leads to a reduction of computational complexity. The simulation fallout shows maxima of 79% and 77% common instance investments with irrelevant cost in PSNR and bitrates. The coding performance of H.264/AVC can improve as per its operating conditions of types of modes as well the efficient optimization of the rate distortion in order to select the optimal mode. This approach introduces an additional overhead to the encoder as it requires compute Rate-Distortion (RD) price for the coding mechanisms. Lee et al. [17] have proposed a technique for quick mode assessment especially for the inter picture micro block (MB), which minimizes the cost for RDO. This method approaches to correlate spatial-temporal homogeneity for estimating the cost of the motion in both Intra and inter modes. A significant coding efficiency is maintained with relatively lower encoding time. Significance of edge feature is also laid by various research papers towards efficient coding scheme. In order to ensure optimal video compression technique, it is also essential to undergo the study of transcoding procedure to visualize the acceptability of the compatibility issues using H.264. Study in this direction was carried out by Liu et al. [18] where the authors have considered mobile transcoding of MPEG-2 video to H.264/AVC format. The outcome of the study shows that energy trend of DCT of macro-blocks of MPEG-2 is potentially correlated to the intra-prediction modes of H.264/AVC. Study towards fast intro-coding scheme was emphasized by Wu et al. [19], where the authors have discussed about the existing outcomes of the study and showed significant reduction in the encoding time, however, there exist low quality video while reconstruction. Similar work is presented by Shen et al. [20], where quad tree structured Coding Unit (QTS-CU) is used for provisioning the recursive splitting process into N- equal sized block, where N=4. The mechanism exhibits effective correlation among the three namely 1) prediction mode, 2) Motion Vector and 3) Rate distortion cost for varied depth levels and spatially-temporally coding units with overall minimization of 49% to 52 % computational complexities on multiple kinds of video sequences for different coding mechanisms. Studies toward adoption of orthogonal modes elimination strategy was seen in the work of Peiman et al. [21]. The authors have used RD theory and selected only one of the orthogonal modes. Studies towards accelerating the mode decision process is also witnessed in literatures for the target of minimizing the quantity of methods mandatory to be tested for each macro blocks. For better coding efficiency, it is required to furnish better coding interoperability. Study in such direction was carried out by Su et al. [22] to provide the interoperability between MPEG-2 and H.264/AVC. The investigational outcomes disclose that typical 85% of computation time (a speed-up factor of seven) can be reduced compared to the encoding schemes. It is essential the video compression technique should also be tested on futuristic video file formats like UHD format. Studies in this direction has been carried by Lin et al. [23], in which the authors illustrates an interlaced block reordering scheme with a preliminary mode decision method to resolve the data dependency between intra-mode decision and reconstruction process in their encoding mechanism with 77% minimization of computational complexity, further more studies on algorithm efficiency on video compression was conceded by Lin et al. [23], where the authors proposes an efficient cascaded mode decision MPEG to H.264 I-frame encoding. The outcome of the study shows efficient PSNR, bitrates and reduced computation complexity performance. Therefore, there are various techniques towards encoding system presented in existing system.

III. Problem Identification

The problem identified from the existing research techniques are highlighted as follows:

- Existing techniques directly implements H.264 without emphasizing over the possible computational complexity associated with it.
- Majority of the present approaches doesn't emphasize on the encoding process keeping in mind about the low powered devices with limited computational capability.
- The compression algorithm implemented till date using encoding techniques incorporates sophisticated mode decision approaches that may result in significant degradation of visual quality of the transmitted signal.
- The existing approaches using intra-prediction mode doesn't emphasize over the potential computational complexity associated with deblocking filters.
- The mechanism of minimizing the number of modes for assessing the performance of rate distortion theory was less attended in existing literatures by the researchers.

Therefore, it can be seen that along with contribution, the existing literatures have significant amount of problems that are open ended yet. The next section briefs about proposed solution.

IV. Proposed Solution

The prime aim of this paper is to evolve up with a framework that uses H.264 for taking decision of macro-block mode along with selection of mode of prediction. The sole purpose is to perform improvement over intra-prediction deploying H.264 standard. The architectural scheme is shown in Fig.1.

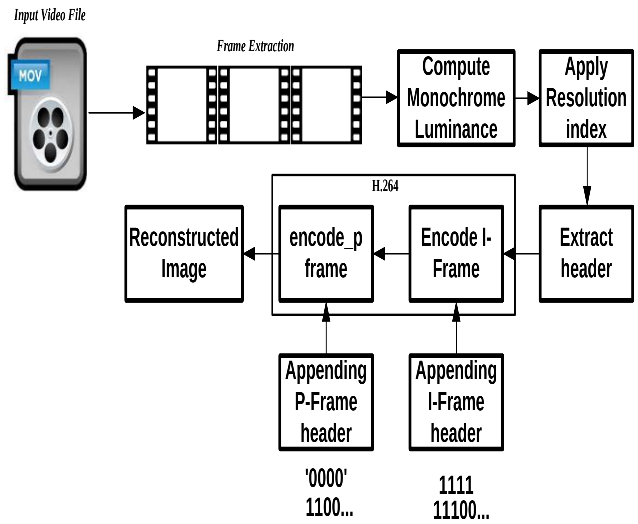

Fig. 1. Architectural Scheme of Proposed System

The proposed system takes the input of video resulting in conversion of frames which is further subjected to computation of monochrome luminance for 4x4, 8x8, as well as 16x16 blocks as intra-prediction modes over vertical direction horizontal direction, DC, as well as plane mode. Different from any existing prediction technique, the proposed system computes cost of rate distortion by applying resolution index. Header information is extracted height, weight, quantization parameter, size of block, and frame ranges followed by encoding of I and P frame sequentially to obtain reconstructed image. The next section outlines the algorithm implemented for this purpose.

V. Algorithm Implementation

This proposed system offers a mechanism of encoding and decoding of specific frame using H.264 encoder in order to improvise the prediction selection mode. The algorithm takes the input of the video file converts it into frame, which after being subjected to novel enhanced H.264 encoder yields an output of reconstructed signal. The steps involved in the proposed algorithm are as follows:

Video Compression technique using H.264 codec

Input: $I_{frames,}$ F_{rang}, QP, *i*, *j*, k, $F_{size,}$ IB_{size}

Output: $I_{recframes}$

Start

1. I = [I_{frames}]

2. R🡐arb($F_{rang,}$ F_{size})

3. Y🡐255*[convert RGB to Gray (I, R)]

4. K🡐[$F_{size,}$ $IB_{size,}$ QP]

5. Y🡐[Y, $H.264_{Encode}$, K]

6. for K=1:j

7. I_{rec}🡐$H.264_{Decode}$(Y, R, i)

8. End

9. $I_{recframes}$ 🡐rec [I_{rec}, I_{frame}]

End

The flow of the proposed algorithm is as follows: The algorithm initially reads the complete input video and extracts the frames based on configured start and end frame values. This step is further followed by implementation of H.264 codec with feature to opt for specific quantization parameter with specific selection of multiple frame size e.g. i) QCIF (144 x 176), ii) CIF (288 x 352), iii) WVGA (480 x 800), and iv) HD (720 x 1280). The algorithm also considers intra-block size of 4x4, 8x8, and 16x16. The selected frames of the video are indexed and are subjected to calculation of monochrome luminance. The algorithm also extracts the respective information about the height and width of the frame and extracts header information from the respective sample. A discrete function is made for the header file which considers the following input arguments e.g. height, width, quantization parameter, frame range, and size of block etc. This is basically the mechanism of performing the encoding of I frame that is further followed up by the encoding of the P-frame. For the purpose of encoding, we apply 4 times the size of the block when we perform encoding of P-frames. While performing encoding of I frame, we append 1111 to the I-frame header and consider it to be a bit stream. Similarly, the study considers appending 0000 as a part of appending P frame header in order to generate the bit stream. The encoding of the p frame is carried out considering an array mainly consists of frame information and quantization parameter that after processing yields the output of encoded P frame. The dependable parameters used for this encoding techniques is lagranrian multiplier used as i) an essential component to perform motion estimation and ii) in selection of partition mode.

This encoding mechanism is carried out using a novel prediction-based strategy that implements a motion prediction of non-translation origin. This technique basically adopts a mechanism where two dimensional functions is developed using elastic motion model in order to perform evaluation of motion of non-translational origin existing among the structured blocks. The proposed algorithm implements a mode decision system whereby the variance score existing among the macro-blocks are utilized for performing an effective modeling of intra frame prediction mode decision. The algorithm considers an assumption that complexity associated with the texture basically corresponds to variance of the macro blocks. The operation of the algorithm is basically classified into two stages wherein the first stage corresponds to the computation of variance factor among the macro blocks that are required to be encoded as well as the threshold factor too. However, if the variance of the macro blocks is found to be more than the threshold factor that the mechanism selects only 14-18 macro blocks or else it performs selection of more number of macro blocks greater than 18. This mechanism is found to offer faster response time as compared to the existing algorithms.

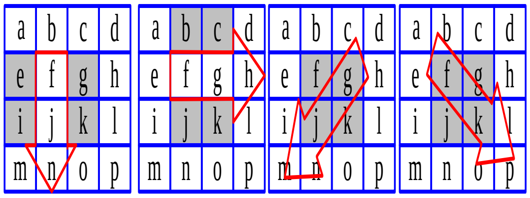

Fig. 2. Analysis of Multiple Orientations

Fig.2 shows the multiple forms of orientation in the order to vertical orientation, horizontal orientation, diagonal down-left orientation, and diagonal downright orientation. The algorithm performs respective computation of intensity gradient over all the direction followed by selection of significant three modes that has minimal score of gradient intensity of the pixel. In this case, the approach also assumes DC and most probable mode have higher probability of selection as modes for candidate prediction. The computation of the rate distortion is then carried out from the finally chosen modes of candidate prediction. At the same time, the encoding of macro blocks is carried out using H.264 over the mode that has been explored to posed minimal cost of rate distortion. The study considers a prediction mode to be equivalent to most probable mode that is assessed to have minimal mode of prediction quantity between the blocks of top neighbor and left neighbor. On the other hand, the system considers switching over to DC mode from most probable mode in case there is no availability of top neighbor block and left neighbor block. At the same time, it is highly feasible to have significant functions for gradient intensities with equivalent score of gradient intensities as it is believed to possess integer precision only. In an adverse scenario, the number of the gradient intensities possessing similar number of gradient could have only 8 as a value. Therefore, in such cases, the selection of the modes for candidate prediction is carried out on the basis of the modes that are found with minimized number of prediction among the gradient intensity. The prime reason behind this is the arrangement of the prediction number that is carried out using frequencies. On the other hand, if the algorithm chooses the vase of 18 macro blocks than the mode of selection prediction is carried out by dividing the 8x8 blocks into 2x2 sub-blocks of 16 numbers. This is carried out as shown in Fig.3. Finally, all the end sub-blocks are subjected to averaging all the sub-blocks obtained. a_8

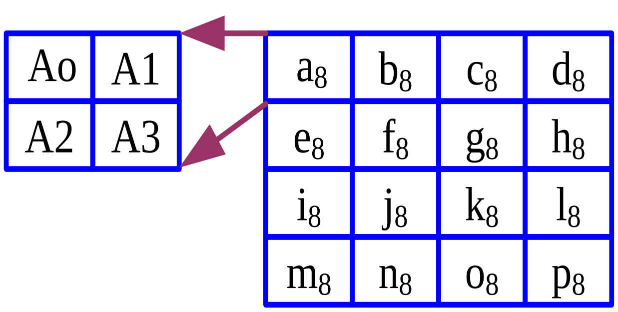

Fig. 3. 4x4 Blocks from 8x8 Blocks

Interesting fact to notice here is that selection of the 14 macro blocks prediction is found nearly same as the next process. However, if the system finds less number of gradient intensity value that is found to be equivalent to most probable mode than the system fairly implements the selection strategy for gradient intensity with two modes only in the form of candidate mode. This step potentially minimizes the computational complexity associated with encoding multimedia video of larger dimension or resolution. Finally, in case of 116 macro blocks, we divide the macro blocks in 4x4 blocks of 16 numbers. All the pixels associated with sub blocks are averaged followed by computation of gradient orientation. In this phase, the selection of the modes of candidate prediction is carried out by on the basis of the minimal value of modes with gradient intensity and DC. For the purpose of computing the cost of rate distortion, we perform selection of prediction modes only. Therefore, the proposed system maintains a good balance between the encoding operation as well as computational complexity by introducing a novel mode decision based on macro blocks as well as selection of prediction mode. The next section discusses about the outcome being accomplished in the proposed system.

VI. Result Analysis

The implementation of the proposed study was carried out in Matlab considering the video dataset from [24]. The prime observation being carried out over the encoding implementation work is mainly the size of the video, number of original bits, numbers of compressed bits, compression ratio, and Peak Signal-To-Noise Ratio (PSNR).

Fig. 4. Original Input frame

Fig. 5. Resized Luminocity

Fig. 6. Reconstructed Frames

The study outcome was testified using multiple forms of performance parameters exhibited in Table 1. The greater the PSNR, the improved the excellence of the compressed or reconstructed image. The MSE and PSNR is the two error matrix utilized to look at picture compression quality. MSE signifies the increasing squared error amongst the compressed and the unique image, while PSNR signifies an amount of peak errors present in an image. The lesser the value of MSE, lower the pear errors. To calculate the PSNR, the primary block is initially calculated utilizing the MSE with following equations:

$$PSNR(dB) = 10 * \log\left(\frac{255^2}{MSE}\right)$$

$$MSE = \sum_{i-1}^{x}\sum_{j-1}^{y}\frac{\left(\left|A_{ij} - B_{ij}\right|\right)^2}{x * y}$$

TABLE. I. COMPARATIVE PERFORMANCE ANALYSIS

	Video-1		**Video-2**		**Video-3**	
	Proposed H.264	**Existing H.264**	**Proposed H.264**	**Existing H.264**	**Proposed H.264**	**Existing H.264**
Video Size	QCIF (144 X 176)		CIF (288 X 352)		WVGA (512 X 832)	
Intra Block Size	4	4	8	8	16	16
QP	16	16	16	16	16	16
No. of Original Bits	2027520	2027520	8110080	8110080	34078720	34078720
No. of Compressed Bits	1166726	629941	2319575	1116281	32823374	23971812
Encoding Time (Sec)	21.400980	27.65221	65.189897	872.66512	101.196864	127.5429
Mean PSNR	47.8189	23.6518	52.1431	31.2887	51.9164	38.8721

The study outcome has been testified using the proposed mechanism of encoding using H.264 and conventional mechanism of H.264. We find that in every sense the performance of the proposed system has excelled better as compared to existing H.264. We find that proposed system offer better compression performance that is highly suitable for transmission of multimedia contents over wireless channel. The lower outcome of encoding time also elaborates the fact that proposed system offer better solution to computational complexity by offering faster response time. Finally, the proposed system offer better signal quality as seen from the PSNR of the reconstructed signal.

VII. CONCLUSION

The projected scheme has emphasized an exclusive video compression and reconstruction scheme for different video formats. In all the cases presented in this paper, the Mean PSNR of the decoded video sequence always exhibit a similar behaviour; i.e. .the quality steadily decreases with the increment of the quantization factor. The results obtained in these experiments opinions out the great association among the AQI and the human visual system for H.264 video coded sequences, in contrast with the Mean PSNR, as a reliable way to measure the perceptual quality of images. This fact opens the possibility of incorporating self-regulated compression parameters depending on the perceptual quality. It also gives good compression ratio as well as efficient encoding timer is used to encode the videos. PSNR is very commonly used in measuring the encoded video quality, but the drawback is PSNR is not totally correlated to the subjective quality of the video. This means a human being may feel a lower PSNR video has better quality than a higher PSNR video which is compressed from the same video sequence.

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An Efficient Approach for the Security Threats on Data Centers in IOT Environment

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***Abstract*—Internet of Things has progressed from the conjunction of wireless knowledge, MEMS which is termed as micro electromechanical systems, micro facilities and the Internet. The conjunction has helped scratch down the storage walls concerning operating technology (OT) and information technology (IT), and allowing amorphous machine created data to be examined for understandings that will drive enhancements. The Things known as IOT is an arrangement of interconnected computing procedures, mechanical and digital machineries, substances or matters that are delivered with inimitable identifiers, and the ability to handover data over a system without necessitating human to humanoid, or human to computer collaboration. However, the security is one of the main concerns in Internet of things, which should be minimized. There are unnecessary requests from the attacker to overload the data center, which results in the hanging of the servers, decreasing the throughput, and requesting a transmission to the Data centers. This paper deals with an efficient approach to decrease the unwanted request at the Data Centers, so that the sessions will be reduced, and the unnecessary load will be reduced on the data centers, in order to mitigate the effect of attack as much as possible.**

Keywords—Internet of Things; Data centers; sessions; Security Threats; Networks

I. Introduction

The complete Internet of Things framework will comprise of billions of entities, distinct devices, and amenities that can interrelate to exchange facts, and figures. Due to rapid progressions in mobile communication field, mobile Ad-hoc networks (MANET) and Radio Frequency Identification (RFID) modernization and apparatuses in IoT can hypothetically cooperate with one another anytime, anywhere and in any form[1][2]. The main target of Internet of Things is the development of smart surroundings and embarrassed independent devices for example smart conveyance, smart substances, smart metropolises, smart fitness, smart living. In business trends, Internet of things signifies tremendous outlook for dissimilar types of administrations which also includes IoT requests and service breadwinners, IoT policy providers, telecom machinists and software merchants.[4][5][6]. According to some approximations, over thirty billion associated things with extra 200 billion recurrent connections will produce around 714 billion in income proceedings by 2020. Many upright sections are predictable to knowledge a double digit evolution in upcoming centuries. The most forthcoming vertical solicitation provinces are consumer electronics, automotive productions, healthcare and intelligent constructions and conveniences [7][8][9].

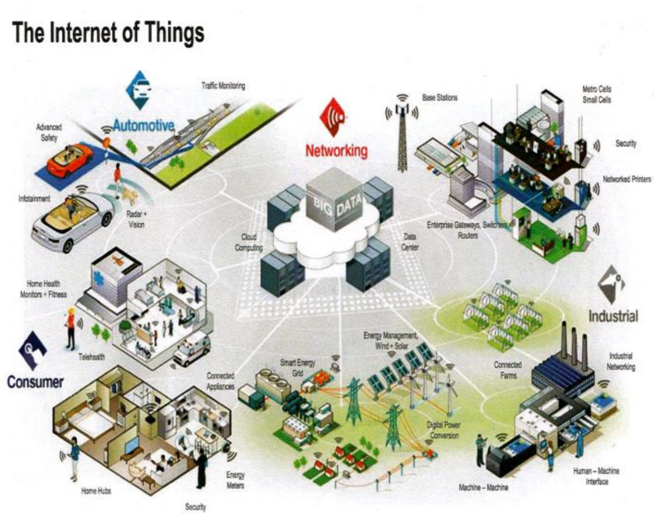

Fig. 1. Smart living criterion [http://www.mbuguanjihia.com/business/smart-living-understated-benefits-internet-things.html]

Some few examples related to the Internet of Things.

1) Heart Monitoring System
2) Smart mobile technology
3) Technology related to the wearable devices
4) Smart fabrication
5) Real time thermostat wireless systems.
6) Monitoring exercises
7) Smart Lightening System

The Internet of Things demonstrates a network deals with the physical objects that link to each other using internet. The objects and other valuable things can handover information wirelessly instead of any human efforts [10] [11] [12]

II. Application of Internet of Things

1) **Parking in Smart Manner**

It will help in the parking of vehicles in the appropriate manner so that it will manage efficiently in an organized manner through wireless systems.

2) **Operational Health Structure**

The IOT trends help in monitoring of vibrations and material conditions in building, bridges and different constructive areas.

3) **Detection of Smart Phones**

Detection of various devices based on Android and IOS operating systems in smart manner, which will also helpful in dealing with various theft cases.

4) **Filed levels based on Electromagnets**

The internet of things scenarios is very helpful in measuring the radiations which consists of electromagnetics signals from the Wi-Fi routers and cell base stations for high telecommunication applications.

5) **Smart transport infrastructure**

The IOT held devices is able to monitor the transport infrastructure and pedestrian intensities to enhance driving and mobile routes

6) **Managing Waste Materials**

Recognition of rubbish heights in vessels to optimize the garbage collection courses [13][14][15].

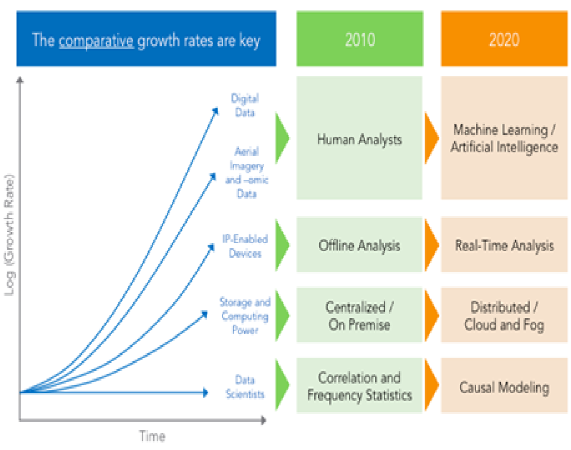

Fig. 2. The Increasing Trend of Internet of Things [http://www.viascience.com/meta-trends-iot/]

The figure2 mentions a glance about the growing rate of internet enabled devices. The development of Internet Protocol based enabled strategies means that extra scrutiny needs to transpire in real time scenario.

The IOT technology moving at the rate where statistics about individuals took period to transform and consequently analysis occurred over day by day. The quantity of loading space obtainable is also rising nonetheless at the similar rate as the quantity of data being produced by IP based devices. The number of associated strategies in the world is set to produce from 20 billion to 80 billion in the following five years. Storage planetary is now flowing to a more dispersed cloud contribution [16][17][18].

III. SECURITY THREATS IN INTERNET OF THINGS

As in Internet of Things moat of the attacks are determined and embattled where challengers use manifold trajectories of security threats to increase traction in the network from which is to be controlled as much as possible. In this atmosphere network executives cannot control the security approaches in which they merely get rid of the low hanging fruit of security vulnerabilities hoping that attackers would quickly move on to the next easy target [19] [20]

1) **Intruder Attack:** This type of attack is generally made on assumption. An intruder which is result the system and which can interrupt all communication ever communicated among IoT strategies and centers. The intruder is enormously accomplished and can even exceed the National Security Agency. But its aptitudes are slightly improbable. Attacks only get healthier, they not ever get inferior. Therefore, protection will be plentiful tougher if Internet of Things arrangement is considered to be intruder resistant. [21][22]

2) **Denial of service:** This type of dangerous attack is an effort to create a machine or resource inaccessible to its valuable users. The mainstream of strategies in Internet of Things is susceptible to supply occurrences because of low memory skills and limited reckoning possessions. The majority of security machineries involves high computational processes, and is afterward not appropriate for resource controlled IoT. Since in Internet of Things these attacks can occasionally deals with very costly behavior, investigators have to deal with extraordinary preparation to discriminate diverse types of alike attacks, also efficient policies to protect against them. The number of DoS attacks are in majority that may be hurled in contradiction of the IoT, example channels jamming process, high computational consumption possessions like recollection process, bandwidth, disk storage or processing time, and disruption of node information behavior.[23][24][25]

3) **Physical attacks:** These attacks interfere with hardware mechanisms. As the unattended and dispersed environment of IoT, most of the devices characteristically work in outdoor surroundings, which are extremely vulnerable to physical bouts.

4) **Attacks on privacy:** As the IoT makes huge capacities of info easily obtainable through distant access machineries; privacy fortification in IoT is becoming hard challenging criteria. The antagonist needs not to be actually present to transmit out investigation, but info gathering can be finished namelessly with very little risk [26][27][28].

TABLE. I. COMPONENTS OF SECURITY INFLUENCING SECURITY FUNCTIONALITY [29][30]

Component	Functionality of component	Goals of security
Authorization	Controlling and Accessibility	Data confidentiality and integration
Authentication	Authenticating user and devises	Authenticating accountability
Key management and exchanging	Cryptography process	Communication integration and confidentiality
Trust Management	Service levels and user density collection	Service trust and reputation

IV. LITERATURE REVIEW

Nima Bari, Ganapathy Mani, Simon Berkovich et al. [5] describes the new methodology for the internet of things in terms of science and quantum mechanics which shows that it will be the constructive approach for them to design any system which is based on internet. They have presented the synchronization process with less fault tolerance in cellular automation substructure. They have worked on holographic criteria which is very useful for the determination of all required characteristics of quantum mechanics.

Alfred Zimmermann, Rainer Schmidt, Kurt Sandkuhl, Matthias Wißotzki, Dierk Jugel, Michael Möhring et.al [6] related the real world with the internet of things which will relate today's numeral policies with troublemaking business functioning prototypes and fast varying marketplaces. As the trends are totally based on internet and due to the increasing diversity of this current technology, products administrations have to control and extend earlier Enterprise Architecture determinations to enable commercial value by assimilating Internet of Things planning. Both structural design manufacturing and information schemes management and commercial models are multifaceted and currently assimilating beside the IOT synergistic themes, like cloud computing services, semantic decision provision through physics methodology and knowledge derived systems, mobility and alliance systems.

Mohamed Abomhara,Geir M. Køien et.al [7] presents the real world security issues in internet of things. As Internet systems will be abundant and universal, there is lot of number of safety and confidentiality matters will rise. Reliable, inexpensive, well organized, and actual security and discretion, for Internet of things are obligatory to confirm exact and precise discretion, integrity, and substantiation among others. In this valuable paper, they have inserted the vision of IOT numerous security intimidations challenges in the area of IoT are presented. The existing state of investigation on IoT refuge supplies is deliberated, and future investigation guidelines with admiration to IoT refuge and discretion are presented in this paper.

Md. Mahmud Hossain, Maziar Fotouhi, and Ragib Hasan et.al [8] describes the analysis of security subjects and opens glitches in Internet of Things. As the deployments of the internet of things devices increases day by day, then there are a lot of chances of the malicious attacks to cooperation the sanctuary and confidentiality of the IoT strategies. Number of researchers has discovered various security trials; there is an unsuccessful lack of a methodical study of the refuge tests in the IoT. So in this paper they have gone thorough examination of IoT sanctuary experiments and difficulties. They present thorough analysis of attack exteriors, danger reproductions, sanctuary matters, necessities and contests. They also deliver exposed problems in IoT refuge and discretion to direct the courtesy of investigators into resolving the utmost dangerous difficulties.

Hui Zhu, Fen Liu, Hui Li et.al [9] presented an efficient approach as a framework for the security threats in Internet of Things for the location based scenarios. As the mobile technology is increasing day by day and the advancement of wireless communication skill, location constructed facilities have made human life more suitable, and they have provided polygons longitudinal interrogation, which is able to provide more flexible approach and consumes substantial interest freshly. The embellishment of polygons longitudinal query statically faces many experiments including the evidence privacy. In their approach, they have presented a well-organized and confidentiality conserving framework based location services called Polaris.

Problem statement deal with the security of the network, which is one of the main issue in Internet of Things. Therefore, there is no any bullet who can resolve the issue in IOT. The attacker can attack on IOT based products, and it will create a huge chance to drop the packets, which contains necessary information, and will decrease the lifetime of the network. As the amount of data being transferred is increasing due to number of increasing users, there is need of expanded bandwidth growth. The attack on Data center will increase the unwanted number of sessions, which will produce unnecessary loads on data center and halts the operation.

The proposed methodology deals with the mitigation of the attack scenario to decrease the vulnerability for the security of the network and will have high network lifetime.

V. Proposed Methodology

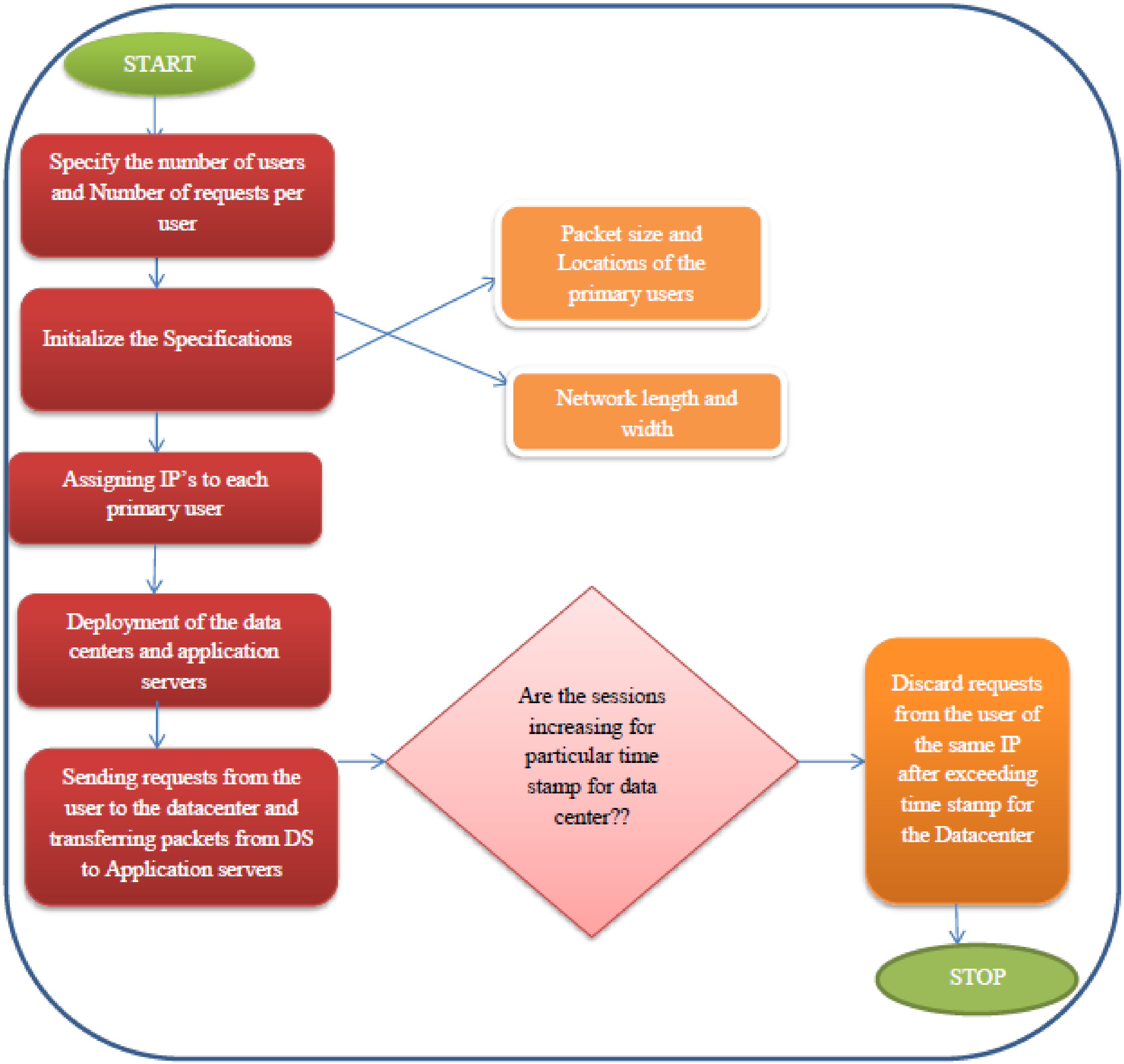

Fig. 3. Flow diagram of the proposed approach

```
1.  // Initialize the Specifications
2.  Initialize network length and network width
3.  Evaluate the Locations for the primary users
4.  For each primary user i do so
5.          Calculate x-locations and y-locations for the primary user
6.          Store the Id and their IP addresses for each user
7.  End
8.  Deployment of the data centers and Application servers for the execution of the requests
9.  // Initialize the Number of Sessions
10.  For each user i do
11.         If no_sessions > time_period for the execution of the Data center
12.                Load on the Data Center Increases
13.                Unnecessary Requests Increases and Suspect Occurs
14.         End
15.  End
16.  // Evaluation of the parameters in the presence of attacks
17.        Calculate the Ec, Td, Np
18.          Ec = Energy Consumption of the Data Center to execute the REQ
           Td = Time Delay to reach the Request of the user to the Data Center
           Np = Number of packets received
19.   Mitigate the Attack by excluding the requests coming from the same IP addresses after exceeding Tp for
the   Data Centers for the execution of REQ
20.  // Evaluation of parameters after Applying proposed approach
21.         Calculate the Ec, Td, Np and compare it with the parameters in the presence of attack
```

Fig. 4. Pseudo code for the proposed Scenario

VI. Result and Analysis

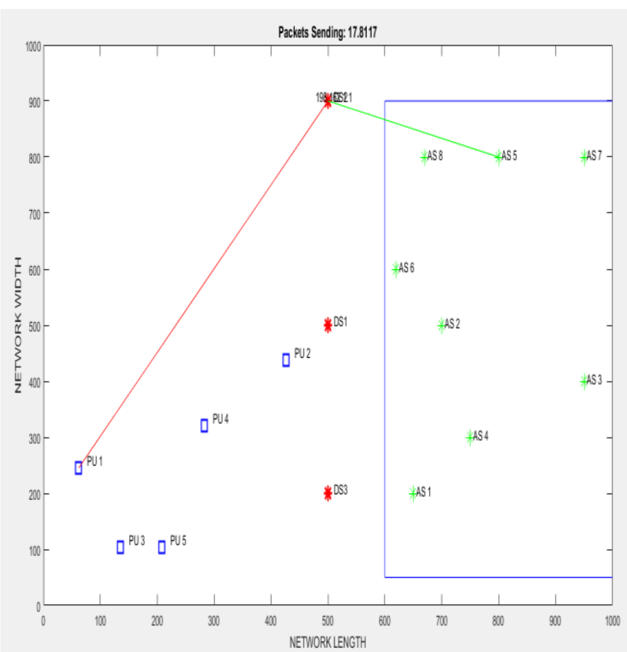

Fig. 5. Simulation scenarios for the proposed network

Figure 5 shows the simulated scenario of the proposed networks, which deals with the Primary users, Data Centers, Application servers, and shows the communication from the primary user to data centers. With the IP address in red color line and from green color to the Application servers in green color which deals with the execution of the requests from the primary users to the data centers.

$$\text{Energy Consumption} = (\sum xi*ds) * \sum V_i \qquad (1)$$

Where

1) Xi is the energy consumed for the data center to be transmitted requests to the application servers.

2) Ds is the delay for the primary user for the request to be executed at the Data Center.

3) Vi is the total number of application servers responsible for the excitation of the number of requests.

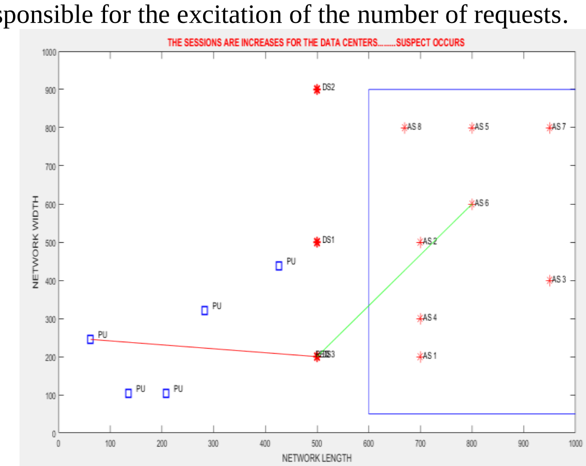

Fig. 6. Simulation for the attack scenario

Figure 6 shows the attack simulation with the increase of the number of sessions at the particular time for the data center, to receive the requests. As the number of sessions increase in the particular time, the receiving requests increase for the data center, then the suspect occurs and the indication of the attack will be found in the network.

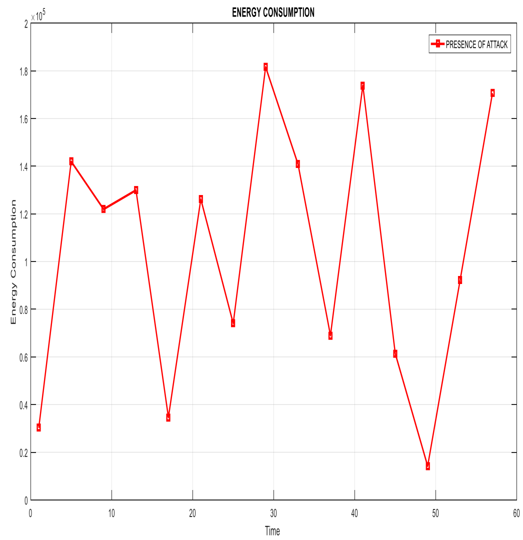

Fig. 7. Energy consumption (presence of attack)

From the figure 7, it is clear that the data center is consuming more energy in the presence of attack, which should be less for the appropriate working of execution of the requests from the primary users.

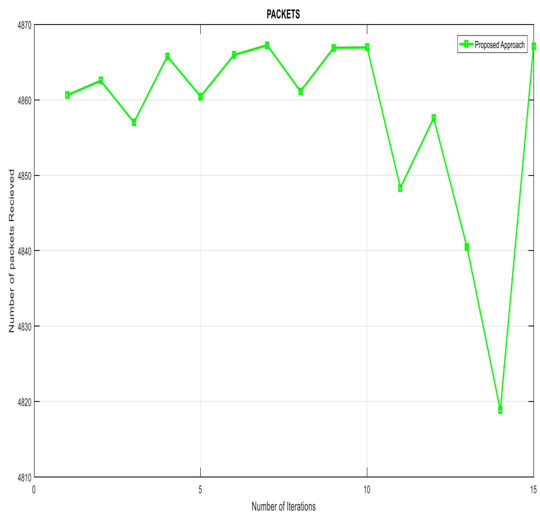

Fig. 8. Energy consumption (proposed approach)

Figure 8 shows the Energy consumption after mitigation of attack. Therefore, as a result of that, it appears that the proposed approach performs well, and helps to mitigate the effect of the attack.

$$\text{Number of Packets received} = \frac{(\sum xi * \sum ri)}{N} \quad (2)$$

Where

1) Xi is the energy consumed for the data center to be transmitted requests to the application servers.

2) Ri is the number of requests per user to be executed.

3) N is the total number of Primary users.

$$\text{Delay time} = \frac{(\sum Pi)* (\sum ri)}{N} \quad (3)$$

Where

1) Pi is the total number of packets received.

2) Ri is the number of requests per user to be executed.

3) N is the total number of Primary users.

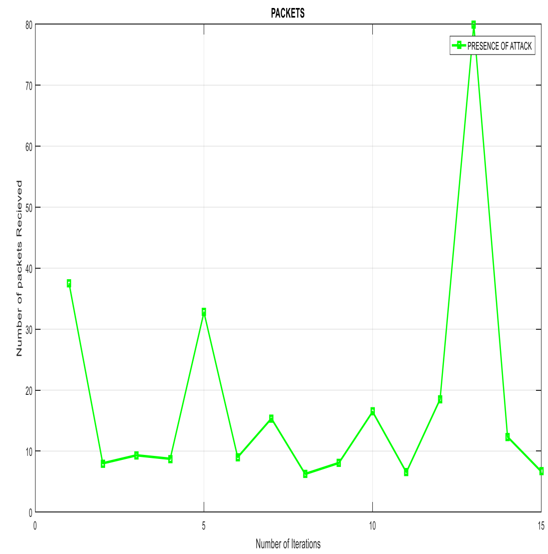

Fig. 9. Packets reception in presence of Attack

Figure 9 shows the packets reception rate in the presence of the attack. The number of packets should be received more to the data centers because more the number of packets will be received by the Data Centers, more will be the successful execution of the requests of the primary users.

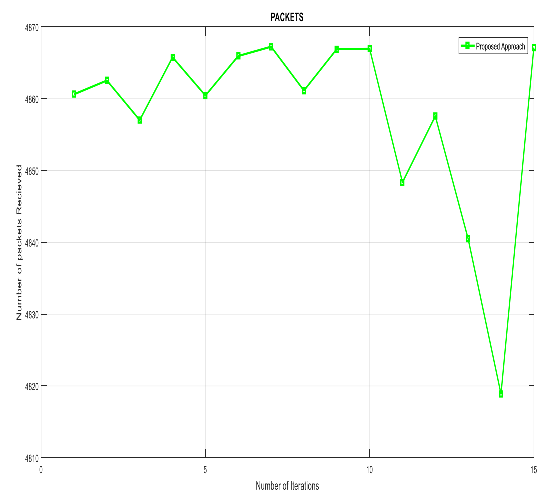

Fig. 10. Packets reception (proposed approach)

Figure 10 shows that the packets are successfully delivered, to complete the execution of the requests, as processed by the data center, and helps to low down the effect of the attack in IoT environment.

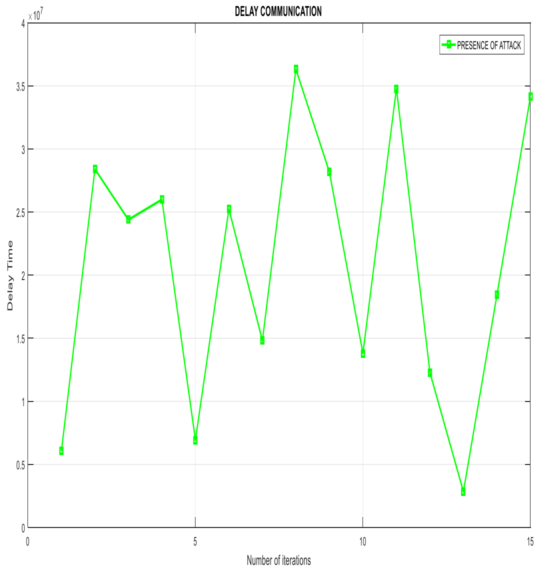

Fig. 11. Delay (presence of Attack)

Figure 11 shows the delay rate in the presence of the attack. Less number of packets is receiving with high delay, which decreases the execution of the network, and increases the response time of the network, which degrades the performance of the network.

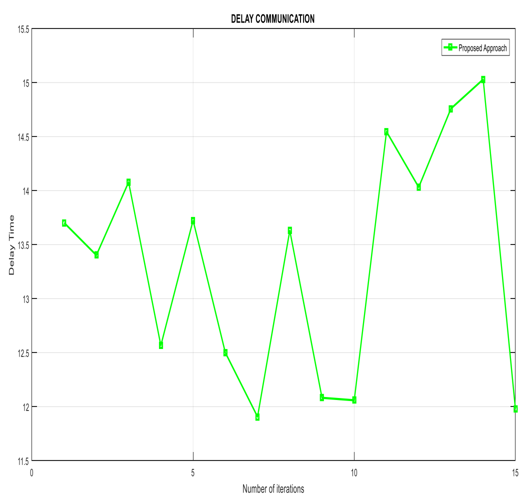

Fig. 12. Delays (Proposed Approach)

Figure 12 shows that Delay for the execution of the requests by the data center is less, which shows the less effect of the attack in the IoT environment, and deals in the high efficiency of the network by executing the probable requests, and rejecting the unnecessary requests at less delay time.

VII. Conclusion and Future Scope

As a rapid development of Internet things based applications in real world, the chances of the security threats are increasing in the IoT environments. Therefore, it should be diminished as much as possible up to great extent, and the proposed area of research deals with the same scenario to mitigate the effect of the attack environment, and shows the evaluation of attack on data centers, and their mitigations are diminishing for the same.

The future of this paper deals with such hybridization of the security algorithms, which deals with the efficient encryption of data, which will be sent to the data centers for the secure communications.

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Using Weighted Bipartite Graph for Android Malware Classification

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***Abstract*—The complexity and the number of mobile malware are increasing continually as the usage of smartphones continue to rise. The popularity of Android has increased the number of malware that target Android-based smartphones. Developing efficient and effective approaches for Android malware classification is emerging as a new challenge. This paper introduces an effective Android malware classifier based on the weighted bipartite graph. This classifier includes two phases: in the first phase, the permissions and API Calls used in the Android app are utilized to construct the weighted bipartite graph; the feature importance scores are integrated as weights in the bipartite graph to improve the discrimination between malware and goodware apps, by incorporating extra meaningful information into the graph structure. The second phase applied multiple classifiers to categorise the Android application as a malware or goodware. The results using an Android malware dataset consists of different malware families, showing the effectiveness of our approach toward Android malware classification.**

Keywords—Android malware; Bipartite graph; Classification algorithms; machine learning

I. Introduction

Smartphones have become increasingly essential part of our daily lives, leading to an exponential growth in the number of smartphone users. Android is a extensively used operating system for smartphones and represents more than 84 % of the smartphone market in the first quarter of 2016 [1]. The new advanced capabilities of the smartphones, coupled with the popularity of Android OS, have attracted many developers to offer useful applications— commonly called apps. The basic market for Android apps is Google Play, also several third-party stores are availabe. The number of hosted apps on Google Play was around two million apps in February 2016 [2].

The increasing number of both smartphone users and available apps has attracted malware developers to design malware apps for smartphones. The amount of new Android malware apps in 2015 was 884,774; this number has increased to more than three times compared to 2014 [3]. As more new sophisticated Android malware apps evolve, their detection using traditional signature based approaches become more challenging.

Android presented the system of permissions as a potential approach to restrict access to user resources. Android apps request user approval for permissions to access smartphone resources. Thus, the Android permissions have been introduced to protect users from malware apps.

There are many permission-based approaches for Android malware detection [4,5,6,7]. However, the existence of some permission is not sufficient evidence to classify the App as malware, as most of the permissions requested by goodware apps are also requested by malware apps. Moreover, the permissions stated in the Android-Manifest.xml are not necessarily employed by the App [8,9]. Several researches considered the API call used in the apps' code to differentiate between malware and goodware apps [10,11,12,13,14]. However, these methods need many API calls for malware classification.

This paper proposes an effective approach for Android app classification as malware or goodware using weighted bipartite graph mining. The contributions of this research are as follows:

- This paper, shown improved results compared to several other approaches for the problem of classifying Android malware apps. The carefully crafted weighted bipartite graph structure based on Android permissions and API calls, combined with the support vector machine classifier, achieves better performance and discriminates between the goodware and malware apps efficiently with low false positive rates. This paper aims to utilize both Android permissions and API calls in the building of the weighted bipartite graph for Android malware classification.
- This paper introduced the use of the important score of Android permissions and API calls as weights in the edges of the constructed bipartite graph. This approach improves discrimination between malware and goodware apps by signifying the association level between an Android app and its used features.

This paper is structured as follows: the related work is presented in section 2. The details of the approach for Android malware classification based on the weighted bipartite graph mining have been discussed in section 3. In Section 4, the used data set and results has been discussed. In Section 5, the conclusions of our study have been presented.

II. Related Work

Dynamic and static approaches are the two main approaches for Android malware analysis [15]. In the dynamic approach, the required features are monitored and collected during the running of Android app in a mobile device or emulator. Examples for the features extracted dynamically include SMS and call information [16], and logs of the system [17]. In the static approach, the features of Android app are extracted from the decompiled Android Dalvik bytecode. API calls and permissions features could be extracted statically .Felt et al. [4] proposed a tool that provides a list of expected permissions for the application, and then it compares them with the really requested permissions. In [18], authors proposed Kirin which is a security service to protect the smartphone. The dangerous permissions requested by the app are formulated as rules in Kirin. During the installation of the app, if the requested permissions do not satisfy the security rules of Kirin, the installation of the app is disallowed. Sanz et al. [19,20] introduced an approach for Android malware categorization based on the user features and the permissions available in the AndroidManifest.xml. In the proposed approach, they employed several machine learning algorithms using a dataset contains 357 goodware and 249 malware apps; the achieved classification accuracy was 86%. [21] used the matches of the requested permissions and the behavioural characteristics, such as the method of installation, to detect Android malware.

Analysing the system calls for Android malware detection is another research area. Schmidt et al. [22] obtained the system calls from the Android Apk file and matched them with the system calls used in malware apps to classify apps as either malware or goodware apps. Crowdroid [17] is a client server model for Android malware detection; the clients collect the system calls from the Android app and send them to the server for classification using clustering algorithms. In DroidAPIminer [23], different classifiers used to discriminate between goodware and malware apps based on feature sets consisting of API calls.

Andromaly [24] used anomaly detection techniques to classify the malware apps by monitoring different system Metrics. Bartel et al. [25] found that several Android apps declare permissions in their AndroidMainfest.xml file but those permissions are never used. Thus, exploring the permissions only in the manifest file may not provide accurate classification of malware apps. All the API calls used in an Android app are associated with corresponding permissions; therefore when an API call starts, the Android OS verifies the approval of its associated permission before executing it. Good Android malware classification results can be achieved by using features combination approach. [24] Showed that higher accuracy of malware detection can be attained when combing the permission and API Calls. Grace et al. [9] proposed a method using data and control-flow as static features that give 9% False Negative (FN).

Our work differs from the aforementioned works in that, this paper presents an effective classifier for Android malware using the weighted bipartite graph; the permissions and API Calls used in the Android app are utilized to construct the weighted bipartite graph, and to understand the benefits of incorporating additional meaningful information into the graph structure. Moreover, we employed a classification method based on efficient classifiers.

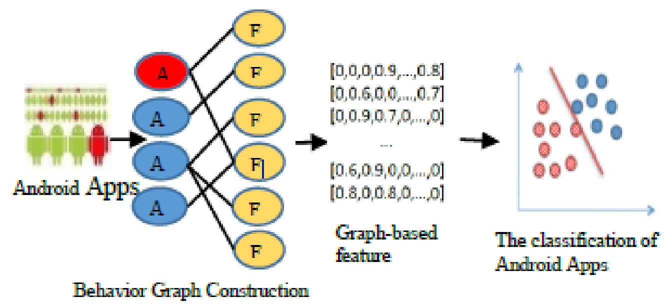

Fig. 1. The proposed approach for Android malware classification

III. Android Malware Classification based on Weighted Bipartite Graph

In this section, the proposed approach for Android malware classification is discussed. As shown in Figure 1, the proposed approach includes the following steps:

A. *Behavior Graph Construction*

First, the features extracted from the Android app to differentiate between goodware and malware apps were presented; then the method how these features are used to construct the weighted bipartite graph is described.

1) *Android app Features*

Using the most informative features, which represent the basic characteristics of Android apps, has significant impact on the classification accuracy. In this research, the Android API calls and permissions are obtained from the Android app files using apktool [26] and utilized as features for the categorization of Android apps as malware or goodware apps.

a) Android Permissions

Android introduced Permissions as a potential mechanism for security. Basically, no Application is permitted to perform any activity that affects the users. The applications can share data and resources by explicitly declaring the permissions in the application file. Therefore, the permissions based features are important features for analysing the Android apps [27]. Before the Android app is installed, Android shows the user the permissions needed by the app; Figure 2 shows examples for permissions stated in the Manifest.xml file of the bgserv malware application.

b) API Calls

It is a collection of defined functions and methods that enables the apps to communicate with each other and with the Android OS. For efferent classification of Android malware app, it is most important to focus on the APIs that frequently used by the malware, instead of considering all API calls in the app. Seo et al. [28] explored malware apps and specified the suspicious API calls that malware apps frequently use. They compared the frequency of using suspicious API calls in malware and goodware apps. The API calls extracted manually, which are similar to the suspicious API calls defined in [28], from the Android app. These API calls perform tasks such as gathering the information of the user or device, websites’ accessibility, receiving and sending SMS, and app installation.

2) Bipartite Graph Construction

The weighted bipartite graph G ={V,U, E} contains a set of vertices V ={v1, v2, ..., vn}, a set of vertices U={u1,u2,…,un} and a set of edges E={eij | edge between vi and uj, i, j <= n}, where n denotes the vertices number. The edge E is linked with a weight w: E→R, where R represents the set of real NUMBERS. The vertices are elements of interest and relationships between the elements are represented by the edges. In this research, the V set of vertices in the constructed bipartite graph represents the Android apps and the other set of vertices U represents the permissions and API Calls used in the Android app. Because the weights can reflect potential systems properties [29], we integrated the features importance scores as edge weights to improve the discrimination between the malware and goodware apps, by signifying the association level between the Android app and the used features.

Information Gain Ratio algorithm finds the similarity score between the Android permissions and API calls; this algorithm then provides the highest weight value to the significant permissions and API calls considering the class of goodware and malware Android applications [30].

```
<?xml version="1.0" encoding="utf-8"?>
<manifestandroid:versionCode="14" android:versionName="2.2"
 package="com.virsir.android.chinamobile10086"
 </activity>
 <intent-filter>
 <action android: name="com.mms.bg.FILTER_ACTION" />
 </intent-filter>
  <meta-dataandroid:name="com.package.name"
android:value="com.virsir.android.chinamobile10086" />
<uses-permission    android:name="android.permission.SEND_SMS"
/>
<usespermissionandroid:name="android.permission.RECEIVE_SMS
" />
<usespermissionandroid:name="android.permission.ACCESS_NET
WORK_STATE" />
 <uses-
permissionandroid:name="android.permission.WRITE_EXTERNAL
_STORAGE" />
<usespermissionandroid:name="android.permission.INTERNET" />
</manifest>
```

Fig. 2. Example for AndroidManifest.xml file

The information gain ratio is calculated using the following equations:

$$gain\_r(\text{eij, C}) = \frac{gain\_r(\text{eij,C})}{split\_info(C)} \quad (1)$$

$$split\_info(C) = \sum_i \left(\frac{|C_i|}{|C|}\right) log \frac{|C_i|}{|C|} \quad (2)$$

Where, gain r (eij,C) indicates the gain ratio of the feature eij regularity in the class C. Ci and |Ci| indicate the regularity of feature Z in class C, the subclass *i* of C and the total number of features in Ci. Let W(eij) be the weight matrix of the bipartite graph G, for each edge eij the weight W (eij) can be computed using the information Gain algorithm as follows:

$$w(e_{ij}) = \begin{cases} gain\_r(e_{ij}, C), if\ e_{ij}\ exists \\ 0, \qquad otherwise \end{cases} \quad (3)$$

B. The algorithm used for graph-based vector classification

A support vector machine is an efficient machine learning technique for classification [31]. It finds a decision boundary with the closest training patterns and classify new patterns based on the decision boundary. The SVM algorithm has a number of advantages, which are significantly important for the classification of Android apps. For example, it has the ability to handle large feature spaces and robust to overfitting spaces. In this paper, four SVM kernel functions: polynomial, linear, radial basis functions and sigmpoid, as well as the state-of-the-art algorithm for learning linear SVM Stegasos [32] were used for graph-based vector classification.

IV. Experimental Results

The experimental results and performance evaluation of the proposed Android malware classification based on weighted bipartite graph mining are presented in this section.

A. Data Set

To assess the proposed classifier's performance, we conducted experiments based on dataset contains 250 malware apps and 250 goodware apps. The goodware apps have been sourced from the well-known market for Android applications, Google play; the malware apps from the Android Malware Genome Project [33].

B. Performance metrics

We used the following metrics for evaluating the proposed approach for Android malware classification:

True Positive Ratio (TPR): the ratio of Android malware apps that were classified correctly as malware apps.

$$TPR = \frac{TP}{TP+FN} \quad (4)$$

Where TP represents the malware apps which classified correctly and FN represents the malware apps which incorrectly classified as goodware apps.

True Negative Ratio (TNR): is the ratio of goodware apps that were classified correctly as goodware apps.

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

where TN represents the goodware apps which correctly classified as goodware and FP represents the goodware apps which incorrectly classified as malware apps.

Accuracy: the ratio of malware apps which classified correctly as malware apps:

$$\text{Precision} = \frac{TP}{TP+FN} \quad (6)$$

TABLE. I. SAMPLE FROM THE WEIGHT MATRIX OF ANDROID APP BIPARTITE GRAPH

	Read_Phone_State	System_Alert_Window	Receive_Boot_Completed	Internet	Write_External_Storage
App1	0.2746	0.2529	0.2366	0.0776	0.0414
App2	0	0	0	0	0
App3	0.2746	0.2529	0.2366	0.0776	0.0414
App4	0.2746	0	0.2366	0.0776	0.0414
App5	0.2746	0	0.2366	0.0776	0
App6	0.2746	0	0.2366	0.0776	0.0414
App7	0.2746	0.2529	0.2366	0.0776	0.0414
App8	0.2746	0	0.2366	0.0776	0
App9	0.2746	0	0.2366	0.0776	0
App10	0.2746	0.2529	0.2366	0.0776	0
App11	0.2746	0.2529	0.2366	0.0776	0
App12	0.2746	0	0.2366	0.0776	0.0414
App13	0.2746	0	0.2366	0.0776	0.0414
App14	0.2746	0.2529	0.2366	0.0776	0.0414
App15	0.2746	0.2529	0.2366	0.0776	0.0414
App16	0.2746	0.2529	0.2366	0.0776	0.0414
App17	0.2746	0	0.2366	0.0776	0.0414
App18	0.2746	0.2529	0.2366	0.0776	0.0414
App19	0.2746	0.2529	0.2366	0.0776	0.0414
App20	0.2746	0.2529	0.2366	0.0776	0.0414

C. Results and Discussion

The dataset described in section 5.2 is utilized to investigate the performance of the introduced classifier for Android malware based on the 10-fold cross validation. The dataset of goodware and malware apps is randomly divided into 10 groups. Each time, we choose one group consisting of goodware and malware apps as dataset for testing, and the rest 9 groups are used as dataset for training.

The Android permissions and API calls were extracted from each Android app in the dataset and used to construct the bipartite graph. The important scores of the Android permissions and API calls for discrimination between malware and goodware apps were computed based on the Information gain method and used as weights in the constructed bipartite graph.

From the weighed bipartite graph of Android app depicted in Table 1, we can gain additional insights into the behaviour of Android malware. READ_PHONE_STATE permission is the most discriminative feature between the malware and goodware apps; this permission is essential to get the phone identification information such as device ID. This permission is also required by malware apps that attempt to achieve a financial gain by sending the phone number to a charged service. The second most discriminative feature is RECEIVE_BOOT_COMPLETED permission. This feature is used by a malware app to execute background services without the user's interference. SYSTEM_ALERT_WINDOW permission permits the app to display a window; malware developers could use the SYSTEM_ALERT_WINDOW permission to popup a window to evade the user and steal sensitive information.

The applications that are part of the Android operating system only need the SYSTEM_ALERT_WINDOW permission; an example for the alert window is the window shown when the smartphone is out of battery.

In the experiment, different SVM variants were adopted to categorize the Android apps as malware or goodware apps. The performance of our classifier is evaluated by computing the precision, true positive rate and false positive rate as explained in Table 2.

TABLE. II. PERFORMANCE EVALUATION OF DIFFERENT SVM CLASSIFIERS

Classifier	TP Rate	FP Rate	Precision	ROC Area
Pegasos-SVM	0.940	0.060	0.941	0.940
Linear-SVM	0.900	0.100	0.901	0.900
Radial basis function-SVM	0.888	0.112	0.892	0.888
Sigmoid-SVM	0.760	0.240	0.803	0.760
Polynomial-SVM	0.668	0.332	0.721	0.668

Table 2 shows the performance of variant types of SVM kernel functions. It is clear from Table 2 that the Pegasos-SVM classifier achieves the highest precision of 0.940 % with a minimum false positive rate of 0.062. Pegasos-SVM outperforms all other SVM kernel functions due to its significantly better convergence bounds. The polynomial SVM kernel function achieved the lowest precision of 0.803 with the highest false positive rate of 0.240.

The Receiver Operating Characteristics (ROC) is also utilized to compare between the different approaches. ROC compares the performance of different classifiers using the false positive rates and true positive rates. In the ROC graph, the true positive rate is displayed on the Y axis and the false positive rate is displayed on the X axis. To evaluate the classifiers performance, the area under the ROC curve (AUC) [39] is used. The AUC value is in the range [0.5, 1]. The accuracy of the classifier is 100% when AUC = 1.

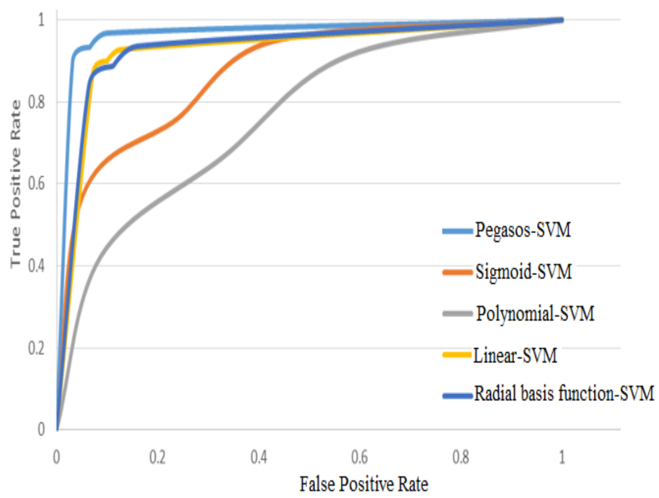

Fig. 3. The RUC curves for the Pegasos-SVM, Linear -SVM, Radial basis function -SVM, Sigmoid –SVM and Polynomial -SVM classifiers

Figure 3 shows the RUC curves for the Pegasos-SVM, Linear -SVM, Radial basis function -SVM, Sigmoid –SVM and Polynomial -SVM classifers. The AUC results confirm that the Pegasos-SVM classifier's area under the curve (AUC=0.940) is greater than all the other classifiers, namely, Linear -SVM (AUC=0.900), Radial basis function-SVM(AUC=0.888), Sigmoid–SVM(AUC=0.760) and Polynomial -SVM(AUC=0.668).

Figure 4 shows the performance comparison between the proposed approach based on Pegasos-VM and the Naïve bayes, Neural network and Decision table respectively. It is clear from Figure 4 that the proposed approach outperforms the classification algorithms: Naïve Bayes, Neural network and Decision table. The proposed approach based on Pegasos-VM achieved the highest precision of 0.941 with a minimum false positive rate of 0.06.

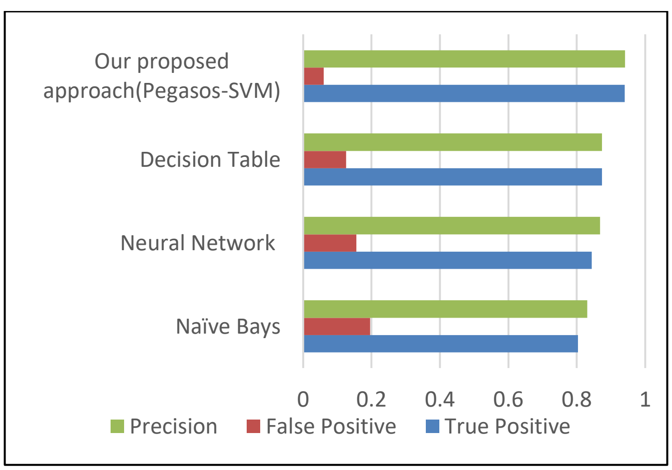

Fig. 4. Performance comparison between the proposed approach based on Pegasos-VM and Naïve bayes, Neural network and Decision table classification algorithms

The proposed classifier's performance is compared with other approaches as shown in Table 3. The results clearly show that the proposed approach achieved an improved accuracy level of Android malware classification with a minimum false positive rate of 6% compared with other approaches. The proposed approach has the capability to integrate the importance scores of Android permissions and API calls as weights in the bipartite graph to improve discrimination between the malware and goodware apps, so that it achieves the minimum false positive rate.

TABLE. III. PERFORMANCE EVALUATION OF THE PROPOSED CLASSIFIER AND OTHER APPROACHES

Classifier	Classification accuracy
K-ANFIS [34]	FP = 10%.
Apposcopy [14]	FN= 10 %
DroidMOSS [35]	FP = 7.1% to 13.3%.
DREBIN [36]	FP = 6%.
Crowdroid [17]	FP = 20%.
RiskRanker [37]	FN = 9%.
AndroSimilar [38]	FP = 7%
Andromaly [24]	FP = 10%
The proposed classifier	FP = 6 %

V. CONCLUSION

Developing efficient and effective approaches for Android malware classification is emerging as a new challenge. This paper, introduces a classifier for Android malware based on the analysis of a weighted bipartite graph constructed from the Android API calls and permissions. The importance scores of the Android API calls and permissions are integrated as weights in the bipartite graph to improve the discrimination between the malware and goodware apps. The graph-based feature vector is constructed from the weighted bipartite graph sent to a support vector machine to categorize the Android apps as malware or goodware apps. The results show a significant improvement over other malware classification approaches.

For future work, more advanced classification techniques will be considered to detect advanced Zero-day malware attacks.

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A Parallel Simulated Annealing Algorithm for Weapon-Target Assignment Problem

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***Abstract*—Weapon-target assignment (WTA) is a combinatorial optimization problem and is known to be NP-complete. The WTA aims to best assignment of weapons to targets to minimize the total expected value of the surviving targets. Exact methods can solve only small-size problems in a reasonable time. Although many heuristic methods have been studied for the WTA in the literature, a few parallel methods have been proposed. This paper presents parallel simulated algorithm (PSA) to solve the WTA. The PSA runs on GPU using CUDA platform. Multi-start technique is used in PSA to improve quality of solutions. 12 problem instances (up to 200 weapons and 200 targets) generated randomly are used to test the effectiveness of the PSA. Computational experiments show that the PSA outperforms SA on average and runs up to 250x faster than a single-core CPU.**

Keywords—Weapon-Target Assignment; Multi-start Simulated Annealing; Combinatorial optimization; Parallel algorithms; GPU

I. INTRODUCTION

The Weapon-Target Assignment (WTA) problem is an NP-complete combinatorial optimization problem at field of military operation research [1]. The WTA Problem aims to find best assignment of weapons to targets, to minimize the expected damage of the defended area in order to increase chances of survival. Several exact methods are studied in the literature [2-4] but these methods can solve only small-size problems. Thus, heuristic methods such as Simulated Annealing [5, 6], Genetic Algorithm [6, 7], Tabu Search [6], Variable Neighborhood Search [3, 6], Ant Colony [7-9] and Particle Swarm Optimization [10] are proposed for the WTA.

Simulated Annealing (SA) is an efficient algorithm for solving the WTA problem [5, 6]. The SA is a flexible algorithm to implement any problem like the WTA. On the other hand, each iteration of the SA depends on the previous iteration. Therefore, runtime of the SA method is not as good enough as other heuristic methods. Parallelization of the SA can be presented as a solution to overcome this problem.

Nowadays, GPUs are very efficient hardware platform to develop parallel algorithms. Several parallel implementations of the SA on GPU are presented in the literature [11-12]. These methods have achieved good quality results in the applied areas. In this paper, a parallel SA algorithm (PSA) is developed to solve the WTA problem. PSA has been developed on GPU and has used the multi-start technique to obtain better results.

This paper is organized as follows. In Section II, mathematical formulation and definition of the WTA problem is introduced. The SA algorithm is described in Section III. Section IV gives details about the PSA. Computational experiments and results are presented in Section V and finally Section VI states some conclusions.

II. THE WTA PROBLEM

In the WTA problem, assets of the defense want to destroy attacks of the targets directed by offense. The defense has a finite number of weapons to defend incoming threats from the offense. There are two models as static and dynamic of the WTA problem. In this paper, the static of the WTA problem has been studied. In the static model, all inputs of the problem are static and the assignments of weapons to targets are performed in a single step. The expected damage for assignments is evaluated after all weapon-target engagements have been completed. Parameters and variables of the problem are defined as follow:

- n , the number of the targets (1, 2, …, n),
- m , the number of the weapons (1, 2, …, m),
- v_i , the value of the target i,
- p_{ij} , the probability of destroying by assigning the jth weapon to the ith target,
- $x = [x_{ij}]$, the decision variable that is nxm matrix, where

$$x_{ij} = \begin{cases} 1 \text{ if weapon } j \text{ is assigned to target } i, \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

The survival probability of target i when attacks weapon j is $\left(1-p_{ij}\right)^{x_{ij}}$. The problem can be formulated as follows:

$$f(\pi) = \sum_{i=1}^{n} v_i \prod_{j=1}^{m} \left(1-p_{ij}\right)^{x_{ij}} \tag{2}$$

$$s.\,t.\ \sum_{i=1}^{n} x_{ij} = 1, \quad j = 1,2,\ldots,m. \tag{3}$$

All weapons must be assigned to targets. In this paper, it is assumed that number of target equals to number of weapons and only one weapon can be assigned to one target.

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III. Simulated Annealing Algorithm for the WTA

Simulated Annealing (SA) is a heuristic algorithm to obtain optimum or near-optimum of a given function in a large space. Kirkpatrick and Vecchi [13] have developed the SA in 1983 to solve a problem for economic activities. In the SA algorithm, each step generates a random solution using the current solution that is achieved in the previous step. Acceptance of the new solution depends on parameters of the method and the difference between neighbor solutions. Metropolis criterion [14] and Boltzmann distribution are used for the acceptance of the new solution. Also, these methods ensure that the SA does not stick to a local minimum or maximum. The acceptance probability function is shown as follows:

$$P(\Delta f) = \begin{cases} 1 & \text{if } \Delta f < 0, \\ exp(-\Delta f / T) & \text{otherwise,} \end{cases} \tag{4}$$

where T is temperature at each step and decreasing by cooling factor (α) for each step. P is acceptation probability of the current solution in annealing process. A new candidate solution is found by randomly selecting two weapons q and r, then swapping assignments to targets between selected weapons. Δf is the difference between two neighbors' solutions in a given function and defined as follows:

$$\Delta f = v_q(p_{qq} - p_{rq}) + v_r(p_{rr} - p_{qr}) \tag{5}$$

After swapping operation, the new candidate solution is calculated by formula as given below:

$$f(\pi') = f(\pi) + \Delta f \tag{6}$$

When T reaches to a temperature T_{final} that is determined as a parameter by user, the method is terminated. Except for that, time dependent and iteration number dependent termination methods are also used. The pseudocode of the SA is as follows:

Algorithm 1: Pseudocode of the SA Algorithm.

Begin
$T \leftarrow T_0$;
$s \leftarrow s_0$;
$f \leftarrow F(s)$;
$s_{best} \leftarrow s$;
$f_{best} \leftarrow f$;
while $T > T_{final}$ **and** stopping criterion is not met yet **do**
    $s_{new} \leftarrow rnd(s)$;
    $f_{new} \leftarrow F(s_{new})$;
    if $P(f, f_{new}, T) > rnd(0,1)$ **then**
        $s \leftarrow s_{new}$;
        $f \leftarrow f_{new}$;
    end if
    if $f < f_{best}$ **then**
        $s_{best} \leftarrow s_{new}$;
        $f_{best} \leftarrow f_{new}$;
    end if
$T \leftarrow T \times a$;
end while
End.

The function *rnd(s)* returns a random number sequence using simple local search algorithms like swapping, 2-opt etc. for permutation *s* and the function *rnd(0,1)* returns a random number between 0 and 1.

The main steps that compose the SA algorithm for the WTA problem are described below.

Stage 1: Initialization

1) Inputs: Probability of destroying matrix p, value of targets v, array of permutation s of the weapons that is assigned to each target
2) Set the SA parameters: T, T_{final} and a.
3) Solve the WTA using (2) as an initial solution f with the permutation array s that is generated randomly.

Stage 2: The SA Execution

1) Generate two different index numbers randomly for s and swap them.
2) Calculate Δf using (5).
3) Accept or not to accept the s_{new} using $P(\Delta f)$.
4) If the s_{new} is accepted then set $s = s_{new}$ and go to step 8, otherwise go to step 9.
5) Calculate the f_{new} using (6) and set $f = f_{new}$.
6) Set $f_{best} = f_{new}$ and $s_{best} = s_{new}$ if $f < f_{best}$.
7) Set T = T . a;
8) Repeat Step 4 – Step11 until T is reached to T_{final}.

In the above stages, Stage 2 performs the SA algorithm after initialization of required variables and parameters in Stage 1. Stage 2 searches a new solution by swapping between weapon assignments of two targets (see Fig.1).

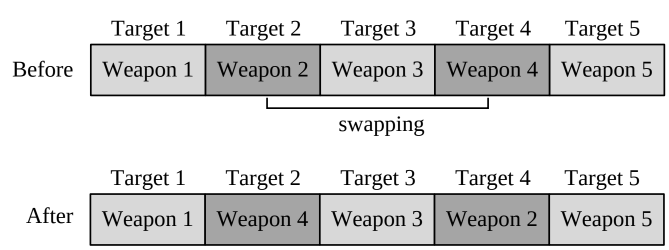

Fig. 1. Swapping between weapon assignments of the targets

IV. Paralellization on GPU

Implementation of the PSA has been performed using Compute Unified Device Architecture (CUDA) on Graphics Processing Units (GPUs). CUDA is a C/C++ language extension and a parallel computing platform created by NVIDIA Corporation [15]. CUDA platform is also a tool for General Purpose Computing on Graphics Processing Units (GPGPUs). GPGPU can be defined as a parallel processing methodology using GPUs for high-performance computing.

The technique of restarting a heuristic algorithm with different configurations is called multi-start and it is an effective method to improve quality of solutions for optimization problems. [16]. This technique is also used for the SA and proved its effectiveness [17, 18]. Only one heuristic method is run at a time and the method must be restarted to use the multi-start technique for a single-core CPUs. On the other hand, several heuristic methods run at the same time on a multi-core CPUs and many-core GPUs. In this paper, the PSA has been proposed with a multi-start technique.

In the PSA, every thread on GPU starts with a different *s*. cuRAND is a pseudorandom number generator library defined on CUDA platform and is used to provide multi-start technique. All threads have a different seed and different seeds are guaranteed to produce different sequences. Each thread runs the SA independently that is given the steps at Stage 2 in Section III. After each thread has run the SA, threads in a same block communicate with each other using shared memory. The best fitness value is found for each block in parallel using reduction method. The flowchart of the PSA handled by each thread is shown in Fig. 2.

After the best fitness values have been found for each block of the GPU, they are transferred to CPU. These operations are shown at the process before the Stop process in Fig. 2. Finding the best fitness value has been operated in parallel using reduction method. In the reduction method, half of the threads on a block are active. Transfer of the best fitness value of each block is performed by the first threads on blocks. In other words, only first thread on each block is active for transferring. After that, the best fitness value is found on CPU from the best values of all blocks.

In this paper, 1024 threads per block on GPU have been used. This means all threads on a block are used. When the number of blocks is increased, runtime of the PSA increases, too. The reason of this increment is accessing the global memory at a same time from many threads. Several configurations have been realized to optimize the runtime of the PSA. These are given below.

- *Short* gives better performance than *int* therefore *short* variables are used instead of *int* variables if suitable.
- --use_fast_math is a compiler parameter. It can be chosen for faster mathematical functions.
- Accessing the global memory is very slow in the CUDA platform. Shared memory is used for accessing *v* (values of the targets) to read/write much faster. Global memory must be used for the *p* (matrix array stores probability of destroying targets) because of the limitation of the shared memory.

Each thread performs the swapping operation on its own permutation list. In this context, each thread requires its own a copy of:

- The array of permutation,
- Two integer variables generated by randomly in each step for swapping operation,
- The fitness value of a given function,
- The delta value (difference between current and candidate solutions),
- The temperature value (parameter of the SA).

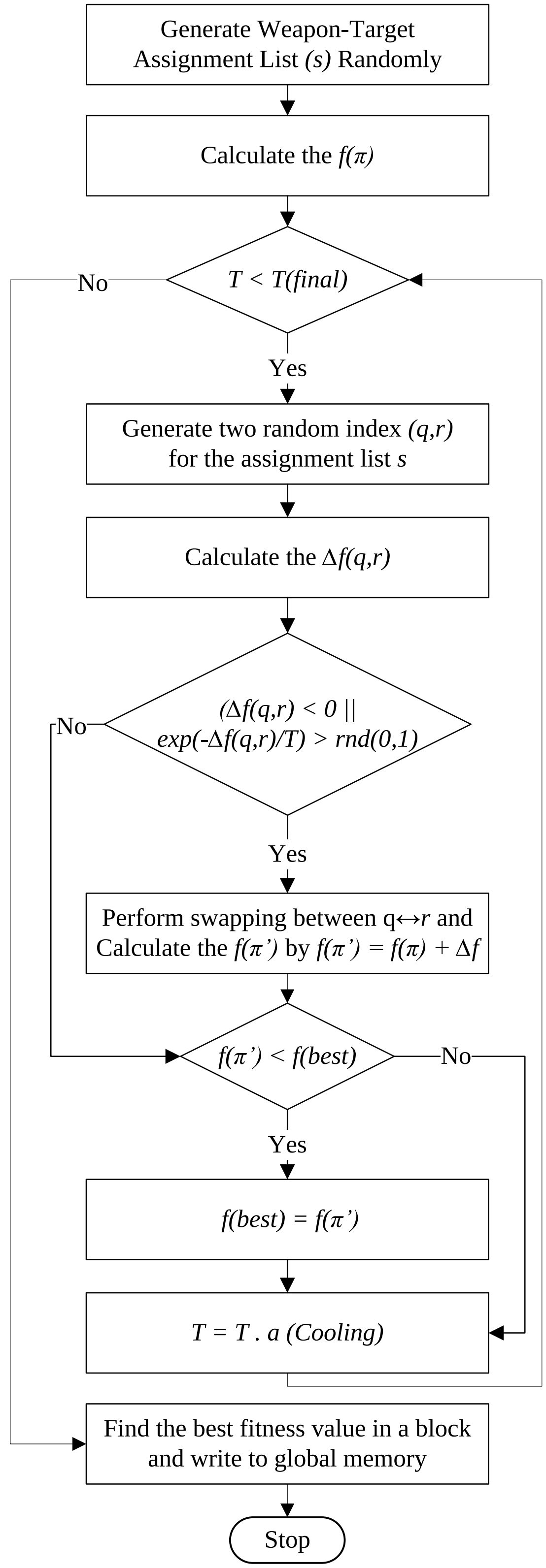

Fig. 2. Flowchart of the PSA

V. Computational Experiments

There are no benchmark problem datasets/instances in the literature for the WTA problem. That is why, various scenarios created to test the performance for proposed methods. In this paper, computational tests have been carried out on 12 problem instances in different dimensions (available at: *http://web.karabuk.edu.tr/emrullahsonuc/wta*). The values of targets are generated as random numbers from the uniform distribution in the range 25–100. The probabilities of destroying targets for weapon-target assignments are generated as random numbers from the uniform distribution in the range 0.60–0.90. Problem instances are generated with different dimensions which are in the range 5–200. Dimensions of the problem instances (WTA1-WTA12) are shown in Table I.

TABLE. I. Dimensions of the Problem Instances for the WTA

Problem	Weapon	Target
WTA1	5	5
WTA2	10	10
WTA3	20	20
WTA4	30	30
WTA5	40	40
WTA6	50	50
WTA7	60	60
WTA8	70	70
WTA9	80	80
WTA10	90	90
WTA11	100	100
WTA12	200	200

The performance of the SA depends on the parameters belonging to the method. Parameter configurations are determined as $T = 1000$, $T_{final} = 0.1$, $\alpha = 0.99999$. For each problem, results have been obtained by averaging of 10 independent runs on CPU. All tests are performed on CPU with Intel Xeon 2.4 GHz. The results of the SA on problem instances are presented in Table II. The best, the worst, the mean, the median and the standard deviation (SD) are listed in Table II for all problem instances.

TABLE. II. Results of the SA on Problem Instances

Problem	Best	Worst	Mean	Median	SD
WTA1	48.3640	48.3640	48.3640	48.3640	0.00
WTA2	96.3123	96.3123	96.3123	96.3123	0.00
WTA3	142.1070	142.1070	142.1070	142.1070	0.00
WTA4	248.0285	248.0285	248.0285	248.0285	0.00
WTA5	305.5016	305.5016	305.5016	305.5016	0.00
WTA6	353.0767	353.5702	353.3112	353.2610	0.14
WTA7	415.0528	415.7079	415.4068	415.4371	0.21
WTA8	498.1049	499.0167	498.5918	498.5860	0.30
WTA9	534.4408	536.2618	535.4559	535.5937	0.57
WTA10	594.0639	596.1228	595.3277	595.6466	0.72
WTA11	699.8357	702.1189	701.0054	701.2495	0.75
WTA12	1306.9126	1309.4616	1308.3382	1308.5187	0.86

NVIDIA GeForce GTX Titan X (3072 cores, 1.0 GHz) has been used for running the PSA. Results of the PSA for each problem instances are always same. The reason of this result is that the random number sequence generated by each thread is the same at every run. The PSA runs on GPU three times for each problem instance to obtain the average runtime. 24 blocks have been used on GPU to perform the performance comparison with CPU. Table III represents the experimental results of the PSA on problem instances. Table III also shows the best and the mean of the SA (SA Best & SA Mean) for comparing results. The best results are shown in bold.

TABLE. III. Results of the PSA And the SA on Problem Instances

Problem	PSA	SA Best	SA Mean
WTA1	**48.3640**	**48.3640**	**48.3640**
WTA2	**96.3123**	**96.3123**	**96.3123**
WTA3	**142.1070**	**142.1070**	**142.1070**
WTA4	**248.0285**	**248.0285**	**248.0285**
WTA5	**305.5016**	**305.5016**	**305.5016**
WTA6	353.4801	**353.0767**	353.3112
WTA7	**414.7340**	415.0528	415.4068
WTA8	**497.2972**	498.1049	498.5918
WTA9	535.5422	**534.4408**	535.4559
WTA10	595.3730	**594.0639**	595.3277
WTA11	**699.4143**	699.8357	701.0054
WTA12	1307.0154	**1306.9126**	1308.3382

Table III shows that the SA has better accuracy in 4 of 12 problems according to best results. If the mean results are considered, the SA has not any better accuracy than the PSA. The PSA has better accuracy in 3 of 12 problems. The SA and the PSA have same accuracy for 5 of 12 problems. The results maybe the optimum fitness value for these 5 problem instances. For each problem instance, runtime results in seconds and speedups are given in Table IV. Speedup is calculated according to a formula as below:

$$Speedup = \frac{runtime_{SA}}{runtime_{PSA}} \tag{7}$$

TABLE. IV. Runtimes in Seconds (S) and Speedups

Problem	SA (s)	PSA (s)	Speedup
WTA1	2985.92	19.28	155x
WTA2	2841.04	30.94	92x
WTA3	2752.49	17.56	157x
WTA4	2754.31	11.23	245x
WTA5	2760.78	12.15	227x
WTA6	2790.03	11.17	250x
WTA7	2787.45	14.09	198x
WTA8	2841.02	15.73	181x
WTA9	2868.79	18.12	158x
WTA10	2812.57	19.90	141x
WTA11	2805.83	20.60	136x
WTA12	2902.15	27.57	105x
Average	*2985.92*	*19.28*	*155x*

According to runtime results of the SA for problem instances, runtimes are close to each other on instances and average time is 2985.92 seconds. The average runtime of the PSA is 19.28 seconds. Speedups have been shown also in Fig.3. The average speedup of 12 problem instances is 155x. It can be said that this acceleration is capable of making the SA algorithm more efficient.

The reason why the speedup values do not increase linearly is due to the access on the global memory. Accessing global memory is efficient if there is a coalesced access to it. On the PSA, there is no coalesced accessing in the process of writing best results for each block to global memory. Thus, speedups can be uphill or downhill for various dimensions (see Fig. 3). The best speedup is 250x for the WTA6 problem instance and the worst speedup is 92x for the WTA2 problem instance.

If the PSA is considered, increasing the number of blocks will cause more access to global memory. For this reason, this will also increase the runtime as mentioned before. On the other hand, running of the PSA by more threads means new multi-start configurations. More multi-starts provide the possibility of increasing the quality of the results. The results obtained using 24, 48, 96, 128, 512 and 1024 blocks are shown in Table V. The best results are shown in bold. If the number of blocks is increased, then the quality of the results is improved. Results of first five problem instances (WTA1-WTA5) are same for all runs. When 1024 blocks are used for the PSA, all results have been improved except first five problem instances. Furthermore, when 1024 blocks are used for the PSA, runtime is less than half of the SA method corresponding to the PSA using 24 blocks.

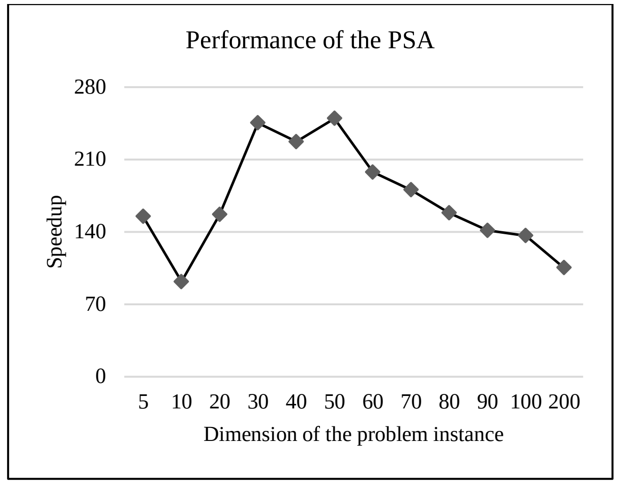

Fig. 3. Speedup against CPU for problem instances

TABLE. V. RESULTS OF THE PSA ON PROBLEM INSTANCES FOR DIFFERENT NUMBER OF BLOCKS

Problem	Number of Blocks (Results are shown on the first column and runtimes in seconds are shown on the second column)											
	24		*48*		*96*		*128*		*512*		*1024*	
WTA1	**48.3640**	19.28	**48.3640**	38.49	**48.3640**	75.96	**48.3640**	75.96	**48.3640**	383.39	**48.3640**	764.63
WTA2	**96.3123**	30.94	**96.3123**	59.76	**96.3123**	119.16	**96.3123**	119.16	**96.3123**	623.34	**96.3123**	1245.74
WTA3	**142.1070**	17.56	**142.1070**	33.25	**142.1070**	65.78	**142.1070**	65.78	**142.1070**	324.42	**142.1070**	642.34
WTA4	**248.0285**	11.23	**248.0285**	21.24	**248.0285**	41.66	**248.0285**	41.66	**248.0285**	217.12	**248.0285**	431.41
WTA5	**305.5016**	12.15	**305.5016**	23.18	**305.5016**	45.07	**305.5016**	45.07	**305.5016**	198.64	**305.5016**	391.05
WTA6	353.4801	11.17	353.3609	21.15	**353.0102**	41.03	**353.0102**	41.03	**353.0102**	233.08	**353.0102**	459.42
WTA7	414.7340	14.09	414.7340	26.85	414.7340	52.08	414.7340	52.08	**414.6011**	232.36	**414.6011**	428.31
WTA8	497.2972	15.73	497.2972	30.01	497.2972	58.23	497.2972	58.23	**496.7948**	278.67	**496.7948**	536.04
WTA9	535.5422	18.12	534.6199	34.76	534.3872	68.47	534.3872	68.47	**533.9201**	343.87	**533.9201**	670.37
WTA10	595.3730	19.90	594.4800	38.66	594.4658	76.44	594.4658	76.44	593.6951	382.01	**592.7965**	749.48
WTA11	699.4143	20.60	699.4143	40.25	699.4143	79.31	699.4143	79.31	**697.6242**	401.19	**697.6242**	787.51
WTA12	1307.0154	27.57	1306.8689	55.00	1304.4195	110.80	1304.4195	147.11	1304.4195	586.39	**1302.9348**	1181.51

VI. CONCLUSIONS

In this paper, the PSA is proposed to solve the WTA problem. Multi-start technique is used in the PSA to obtain better results on problem instances. The PSA runs on a GPU using CUDA platform. Results are compared both quality and acceleration. The PSA is up to 250x faster than a single-core CPU. In terms of quality solutions, the PSA is capable of delivering good quality results than the SA for problem instances in average. In future, the PSA can be optimized for coalesced accessing to improve runtime. Also, the PSA can be applied dynamic WTA problem which is other model of the WTA.

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A Review on Urdu Language Parsing

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***Abstract*—Natural Language Processing is the multidisciplinary area of Artificial Intelligence, Machine Learning and Computational Linguistic for processing human language automatically. It involves understanding and processing of human language. The way through which we share our contents or feelings have always great importance in understanding and processing of language. Parsing is the most suited approach in identifying and scanning what the available sentences expressed? Parsing is the process in which syntactic structure of sentence is identified using grammatical tags. The syntactically correct sentence structure is achieved by assigning grammatical labels to its constituents using lexicon and syntactic rules. Phrase and Dependency are two main structure formalisms for parsing natural language sentences. The growing use of web 2.0 has produced novel research challenges as people from different geographical areas are using this channel and sharing contents in their native languages. Urdu is one of such free word order native language which is widely shared over social media sites but identification and summarization of Urdu sentences is challenging task. In this review paper we present an overview to recent work in parsing of fixed order (i.e. English) and free word order languages (i.e Urdu) in order to reveal the most suited method for Urdu Language Parsing. This survey explored that dependency parsing is more appropriate for Urdu and other free word order languages and parsers of English language are not useful in parsing Urdu sentence due to its morphological, syntactical and grammatical differences.**

Keywords—Natural Language Processing; Machine Learning; Urdu Language Processing and Dependency Parsing

I. Introduction

In linguistic, human behavior can be assessed by considering three key aspects; speaking, writing and communication. The rise of machines like computer gave birth to the concept of communicating human with non-human devices. This particular concept proved as preliminary base for Natural Language Processing. Natural Language Processing is multidisciplinary area of Artificial Intelligence, Linguistic and computer science. The basic aim is to develop such system which can understand and generate natural human language. Normally, Machine Learning (ML) algorithms are used in recognizing and creating human language to achieve meaningful information. The growing use of web enabled technologies has changed the general trends in research and academia by endorsing huge availability of informative contents. Initially the extraction and interpretation of available contents was difficult but the progressive growth of Natural Language Processing presented easy and systematic solutions. In last few decades, NLP proved as an active research area by providing effective applications such as; Language Translation, Information Retrieval, Data Mining, Text Summarization, Sentiment Analysis, Speech Recognition. Cambria, E et al [1] reviewed the recent trends in natural language processing and stated that NLP evolved from the age of batch processing and punch cards to the era of social networking websites. In the era of batch processing single sentence might take 5 to 7 minutes while on the other hand novel technologies have changed the trends as millions of websites can be processed in seconds. Numbers of NLP tasks as Information Extraction, Text categorization, Named Entity Recognition, Parts of Speech Tagging, Word Sense Disambiguation and Parsing are addressed through Machine Learning algorithms [2]. In fact, NLP is backbone for Data Mining, Human Computer Interaction, Emotion Detection and Data Warehouse. Nowadays NLP is facing several challenges due to the advent of Web 2.0 and other social networking websites. Multi Linguistic text adaptation like Chinese, Japanese, Bengali, Arabic and Urdu is one of big challenge which gave birth to hundreds of other issues. Urdu is an Indo-Aryan language which now became the part of web contents. The availability of these valuable contents attracts the language engineers to utilize this data for the sake of analysis but not enough experiments have been performed for Urdu language processing due to lack of resources. The way through which we share our contents or feelings has always great importance in processing text for the sake of analysis. Parsing is the most appropriate method used in the interpretation of natural language sentences. Basically it is the process in which syntactic structure of sentence is identified using grammatical tags. The syntactically correct sentence structure is achieved by assigning grammatical labels to its constituents using lexicon and syntactic rules. Generally parsing generates a logical tree of sentence to eliminate the interpretation ambiguity as shown in Fig.1. Numerous techniques are available for English language parsing but there is lack of parsers for free word order languages i.e. Urdu & Hindi. In this article we have presented a review on parsing for English (Fixed word order) and Urdu (Free Word Order) Language. Much research has been done in NLP for English language. Limited work exists for free word order languages such as; Urdu and Hindi so the main focus of this review is to explore the most suited method for Parsing Urdu Language Sentences. The rest of the article is organized as; Section 2 provides brief literature on Past, Present and Future of Parsing, Section 3 presents URDU: A novel challenge for Natural Language Processing. Section 4 explores the basic idea of Dependency Parsing and Section 5 provides the conclusive remarks.

II. Past, Present and Future: Parsing

Parsing is mean of automatically identifying and building sentence syntactic structure. In general, grammar and lexicons are used in the construction of parse tree, where the grammar is set of rules that govern the overall structure of any given language and lexicon is list of words along with associated tags. While on the other hand Parser is a tool which is responsible for generating parse tree. In fact it is a procedural component which remains same throughout the generation of parse tree irrespective of the language but grammar does not remain same for all languages. Parser and grammar primarily depend on formalism being used. Mainly there exist two formalisms; ***Top Down Parsing (TDP)*:** In TDP a tree is generated from root/parent to leaf/terminal node. TDP formalism can also be viewed as expansion process as tree is expanded at each step. As it is preorder parsing so it has some merits and demerits. In the absence of start node such formalism never wastes time in generating parse tree which is advantageous while the limit of top down parsing is backtracking. ***Bottom Up Parsing (BUP)*:** In BUP a tree is generated from down (leaf/terminal) to up (root/parent) node. BUP formalism can also be viewed as reduction process as tree is reduced at each step. As it is post order parsing so it has its own merits and demerits. In the absence of leaves/tokens such formalism never generates parse tree which is helpful while the limit occurs in case of absence of root node. These formalisms are also considered as directionalities. Similarly Parsers have two search strategies either it searches one branch at a time which is depth first strategy or it follows breadth first strategy in which all possible branches are searched in parallel.

A. Parsing Techniques & Applications

It is obvious that tree can be generated in one of two ways; Top-Down or Bottom-Up. These two formalisms are considered as directional strategies. Parsing techniques generally based on the criteria of directionality and non-directionality. Non- directional methods generate the parse tree with different input order based on the criteria it fits but this specific strategy can't generate parse tree if the entire input is not available in the memory. In simple, parsing techniques are divided into two classes [3] directional and non-directional. In addition, parsing techniques in directional strategy are divided into Top-Down and Bottom-Up. Initially non-directional method was first proposed in 1968 by Stephen, H Unger [4], although this method has not gained noticeable attention but it opened the doors for parsing in Natural Language Processing. Cocke, J [5], Younger, D.H [6] and Kasami, T [7] (CYK) method was developed for generating syntactic structure of sentence. It is non-directional bottom up method in which parser goes from shorter to longer string by deriving substring through non-terminals. Later on Grune, D et al [3] proposed a more optimized form of CYK parser. The birth of corpora, lexicons and treebank has changed the way of generating syntactic structure of sentence. Treebanks and corpora proved as good sources for modern parsing algorithms. Pulman, S.G [8] presented a survey on modern techniques of parsing and stated that an efficient parsing algorithm be sound, complete and robust. It is fact that one cannot generate semantically correct structure without proper knowledge of language constructs. An ideal algorithm is one which generates efficient tree with minimum computational effort. Statistical and modern lexicalized statistical methods were introduced to meet these requirements. It is probabilistic parsing in which probability value is used to remove the structural ambiguity in language. Statistical model expresses the probability as P (T|S). Here T, S and P represents parse tree, sentence and probability respectively. Similarly statistical parser utilizes PCFGs (Probabilistic Context free grammars) and corpus of hand parsed text. Penn Tree Bank is the most well-known English corpus developed in 1993 for Natural Language processing [9]. Collins, M [10] proposed a state of art system for parsing the text of Wall Street journal and presented the improved understanding of various statistical parsers by testing their performance and concluded that head-driven statistical parser is dominant among others. Vadas, D et al [11] proposed a Noun Phrase (NP) bracketing model with numbers of lexical features. It is the first large scale NP parsing experiment. They explore the difficulties in parsing Noun Phrases with Bikel, D.M [12] implementation of Collins, M [10] model. They attained 93.8% and 89.14% F-score over simple and complex task respectively. Charniak, E [13] reviewed the task of sentence syntactic structure and stated that part of speech tagging is the preliminary step in parsing. This study explores that statistical information regarding to sequence of words helps parser in the generation of syntactic parse tree. Additionally comparative results disclose the fact that statistical parsers have good performance in comparison with tree bank style parsers. Tree bank parsers have few limitations as; Labor intensive, lack of head to head information, problem of conjoined words and speed of processing. The progressive development of parsers has shifted the trends of parsing from syntactic to semantic. Semantic structure provides more inner and fine grained information about the language because it follows both domain knowledge and linguistic in order to generate semantic structure instead of syntactic. Jia, R et al [14] proposed a novel framework which utilizes prior knowledge and recombines the data to achieve more semantic information. The results show that data recombination refined the Recurrent Neural Network (RNN) model by producing promising outcomes on standard GeoQuery dataset. In last few decades Artificial Intelligence is also playing active participation in Parsing & Natural Language Processing. Bowman, S.R et al [15] proposed artificial neural network based stack augmented parser-interpreter neural network. This system achieved the fine-grained semantic information through the combination of parsing with interpretation. The system outperformed the existing methods on Stanford NLI entailment task. Liang, P et al [16] presented a framework which demonstrates the learnability of statistical parser. The issues associated to generate automatic learnability of parser are also addressed. Their study aims to provide a paradigm for the automatic development of semantic parser from data. In modern linguistic, sentence of natural language has multiple writing styles which impose big challenge to semantic parsers. Han, B.C et al [17] proposed a rewriting based semantic parser to capture the semantic information in sentences without any care of language style because if a sentence to be parsed has different structure from that of target logical form then this system rewrite the sentence into its desired form. Semantic data of WEBQUESTIONS is parsed to assess the system performance and their system achieved satisfactory results with an average F1-Measure of 83.9%.

Parse Trees act as backbone in number of natural language processing tasks so parsing has numerous applications as *Sentence Recognition:* parsing provides different algorithms and software in the identification of sentence according to its grammatical sequence. *Information retrieval (IR)*: Parsing is the essential step in IR whereas information retrieval is the field of extracting desired information from stored data. *Sentiment Analysis:* is the problem of natural language processing in which public views, opinions and sentiments are mined in the analysis of desired entities and recognition of syntactic structure is the most necessary step in identification of desired opinions. *Summarizer:* Summary generation and compressed sentence creation needs proper implementation of syntactic structure so an effective summarization is highly dependent on the parsing strategy. *Plagiarism Detection:* Exact location of target document cannot be detected without appropriate sentence structure. *Word Sense Disambiguation*, *Machine Translation*, *Transformation & Topic Modelling* are also based on the syntactic nature of words/lexemes. This section covers the key contributions from past to present about sentence identification to automatic parser generation. In short, Wang, Y et al [18] stated that we can build an effective parser in just few hours even for new domain with zero learning examples. Although extensive research has been done for resource rich languages due to the availability of linguistic resources like corpora, wordnet, gazetteer lexicons, dictionaries and ML classifiers but at the same time unavailability of such resources is valid reason behind the lack of research for Urdu.

III. URDU: A NOVEL CHALLENGE FOR NATURAL LANGUAGE PROCESSING

The proliferation of social networks and microbloging websites permits billions of online users to publish text over these sites in their own languages. In past, many languages have been used and retrieved for multilingual and cross lingual information retrieval and data mining tasks but due to the lack of resources few languages have not examined properly. Urdu is one of widely used language over social networking websites. It is the prominent language of east with an average 300 million speakers all over the world. It is the official language of Pakistan. In recent past, Urdu Language Processing has become the hot topic of research as various NLP tasks are experimented for Urdu language as; Tokenization [19], Part of speech tagging [20], Morphology orientation [21], rule based stemmer [22, 23], Urdu grammar checker [24], word segmentation, Sentence Boundary Detection [25] Urdu text classification [26], Urdu WordNet [27], Named Entity Recognition [28], and Urdu corpus construction [29]. Instead of going to the details of other problems here our aim is to explore the recent experiments performed for Urdu language parsing. Recently few experiments are performed for parsing Urdu sentences but serious effort is required to extract more syntactic and semantic information for Urdu. Kabir, H et al [24] implemented a two pass parsing strategy for Urdu language text by applying phrase structure grammar and movement rules in order to reduce the redundancy of phrase structure grammar rules. Nivre-arc-eager algorithm and Maltparser system is used for parsing Urdu sentences with Urdu Dependency Treebank (UDT) [30]. Rizvi, S.J et al [21] proposed language oriented parsing algorithm for Urdu sentence identification. The algorithm generates syntactic structure of Urdu sentences through morphological closed word classes as verb morphemes tags, postpositions and conjunctions. This Parser is based on chunking which is achieved by applying grammar rules for performing shallow parsing to generate unambiguous syntactically correct Urdu Sentence. Mukhtar, N et al [31] offered a method for developing Urdu parse tree. Their proposed technique is based on multipath shift reduce strategy. The optimized parser is selected on the basis of probability value as numbers of stack were utilized for evaluating probability values of parse tree. Abbas, Q [32] proposed Earley algorithm based Urdu parser. This parser uses the morphological rich context free Urdu grammar. The parsing tasks are performed through syntactic and functional information accessed from Urdu Kon Treebank (UKTB). UKTB contains 1,400 tagged sentences. This study explores that parsers having high morphological information produce better results in comparison with other strategies for Urdu parsing. Previous studies validate that there is need of appropriate parsing techniques for Urdu language as it has many practical and potential applications; Urdu Language Understanding, Urdu Summarization, Urdu Plagiarism, Urdu Opinion Mining and Urdu text modelling etc.

IV. DEPENDENCY PARSING

In natural language processing, the syntactic structure of sentence can be described in two ways; Phrase Structure (PS) in which whole sentence is tokenized into constituents or phrases and a tree is generated as output shown below in fig.1 while the second way is Dependency Structure (DS) in which individual tokens are connected through links by ensuing dependency relations as shown in fig.2. Past experiments [33, 34, 35, 36] explored that phrase structure is effective for fixed order languages while dependency structure is better for free word order languages. As Urdu language is free word order so we discussed the dependency parsing, terminologies and its associated concepts to find appropriate direction for Urdu Language Parsing (ULP). In dependency parsing, each individual token has one of two labels; Head or Dependent. Head and dependent are connected through a link/relation. Dependent is also considered as modifier or child and similarly head is referred as parent or regent. Head is actually governor in dependency parsing. Mainly there exist two methods for dependency parsing, Grammar driven dependency parsing and data driven dependency parsing. In first method [37], grammar parsing algorithms are used for evaluating and analyzing the input string. Grammar driven parsing is sub classified into two types; context free grammar and constraints based grammar. Most of the grammar driven parsers are based on constraints based parsing. Nivre, J [38] presented the detailed study on data driven and grammar driven dependency parsing. Main focus of this study is to consider full parsing representation instead of Head driven and partial representation of parsing. In comparison with constituency parsing three key advantages of dependency parsing are underlined; Dependency parsing is more close to semantic relationship, more straightforward and word at a time operation instead of waiting for phrases.

Input Sentence: Economic news had little effect on financial markets.

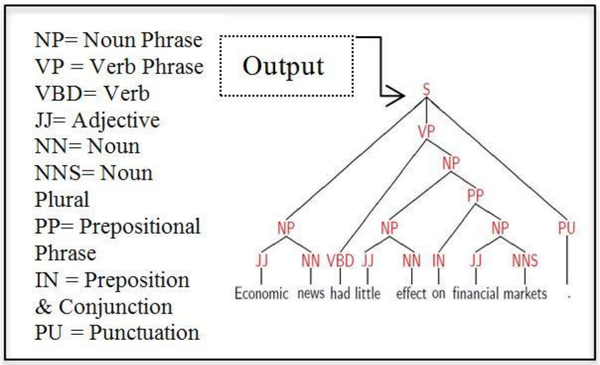

Fig. 1. Phrase Structure Parsing

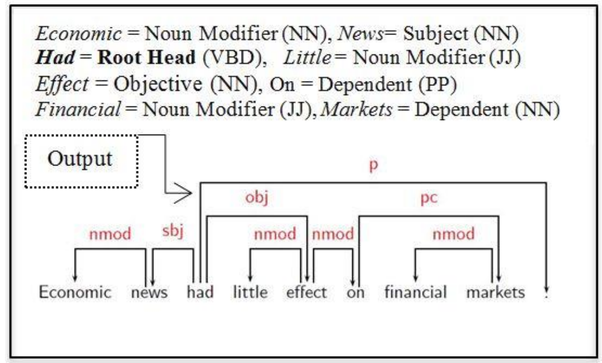

Fig. 2. Phrase Structure Parsing

Covington, M.A [39] proposed a novel algorithm for parsing English language sentences into the dependency trees. Instead of scanning and handling whole sentence collectively this algorithm deals with single word at a time on the basis of heads and dependents. This study followed six basic assumption in parsing as; *Unity:* The single structure is output, *Uniqueness*: Each word follows exactly one head, Projectivity*:* No crossing branches, *Word at a time operation*: One word is operated at time, *Left to right single pass*: No backtracking and *Eagerness*: connects the words as soon as possible. This study validates that a parser with these six assumptions produces more effective outcomes especially when direct object is missing in target sentence. For Example; *Sang Loudly*. Ali, W et al [30] proposed a data driven dependency parsing method for parsing Urdu text. Maltparser system was used to train Urdu parser using Urdu dependency treebank. UDT is annotated corpus of 2853 sentences at three different levels; POS, Chunks and Dependency Relation. Maltparser is used for performing all parsing tasks. Their results demonstrate that data driven dependency parser achieved promising results with an average labeled accuracy of 74.48%.

V. Conclusion

Linguistic Processing is one of prominent field of Computer Science which involves understanding and generation of human natural language to contribute in multiple real life applications; Information Retrieval, Sentence Recognition, Plagiarism Detection, Topic Modelling, Text Summarization, Sentiment Analysis and many more. Modern linguistic style and heterogeneous language adoptability produced number of challenges in NLP. Urdu is one of such language which got great attention in last few decades. We see that social sites are full of Urdu contents as millions of online users belonging from Asian countries especially Pakistan, Afghanistan and India are sharing informative contents about various interests. What they have shared is always a curious question for those who are interested in knowing these contents for the sake of analysis but there exists no such proper systems available which automatically identify and investigate the Urdu Language Text. Few essential tasks are always required in processing human languages such as Words Identification (Tokenization) Grammatical Labels (POS), Normalization (Punctuation, Stop words, Stemming & Coreference Resolution), Syntactic Structure (Sentence syntactic tree) and Semantic Information. In the light of these prerequisites, Urdu language is not handled accordingly due to resources scarcity so this language needs serious attention in comparison with others languages. Urdu language parsing is key problem which still have not been handled up to the satisfaction. Recognizing syntactic structure of sentence is one of key phase in every language processing task. Therefore, keeping in view the importance of Urdu language processing we have reviewed various experiments in parsing Urdu language text. To achieve suitable method for Urdu language parsing we reviewed parsing for both English and Urdu language and concluded that dependency parsing is more appropriate for Urdu and other free word order languages but parsers developed for languages like English are not workable for Urdu due to its morphological, syntactical and grammatical differences. We must encourage researcher community to develop algorithms using dependency parsing formalism for Urdu language sentences.

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A Novel Representation and Searching Algorithm for Opening Hours

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***Abstract*—Opening Hours can be considered a data type having a human representation; this means that it can be easily understood by human beings and hardly understood by computers because the lack of a standard structured representation. In essence, the opening hours gives us a simple information: opening state at a certain date and time, and this is our focus in this paper. So far, this kind of functionality does not exists in today's database management systems because there are no algorithms developed in this way. The purpose of this paper is to presents a novel and easy to implement algorithm for encoding opening hours in order to quickly search and get the opening state for records.**

Keywords—Opening Hours; Java; optimizations

I. INTRODUCTION

A few years ago an application normally only used to have thousands of users to tens of thousands of users in the most extreme cases, and currently there are applications that have millions of users and amount of data is increasing, so is very important to perform efficient search to get relevant information from data [7]. It is important to use search engines to access information, that has grown tremendously based on the needs of users [2]. The goal of information extraction methods is the extraction of specific information from data documents [1].

Opening Hours are becoming increasingly significant in online environment, because it is very important to know when a restaurant, store or other business is open, this information can help you avoid unnecessary roads, or in late hours you can search for open places where you can fix urgent problems: dentist, auto service and so on. Businesses is usually listed in directories where you can perform a search to get relevant results, but these results are not relevant to current time, nor the results will not be relevant for a future date.

If there would be a way to filter the results only get the ones that are open now or in a future date, then you will save a lot of time, otherwise you have to loop over the result list and check each opening hour. So far, there is no efficient algorithm to solve this problem.

This paper proposes an encoding of the opening hours, which can show in a very short time if it is opened or closed at a certain date and time. There are many representations for opening hours but this encoding is not assuming any, because there is not a standard representation. Instead it is a byte sequence, not easily readable by humans, which encapsulates opening hours info, so that if given a date and hour it can determine very fast if it is open or closed. This paper makes a first attempt to describe a new algorithm for searching through opening hours. To perform comparisons tests, we also achieved an implementation of algorithm written in Java language [4][5] for Apache Solr [6].

II. THE ALGORITHM REPRESENTATION

Opening Hours can be composed from many entities (day of week, date, time) and to easily represent them we must choose some notations. We consider the following primitives:

- Z - represents the day of the week using one digit, 1 (for Monday) through 7 (for Sunday)
- H - represents hour of the day using four digits, 0000 (for 00:00) to 2359 (for 23:59)
- D - represents the date of year (only month and day) using four digits, 0101 (for January 1) to 1231 (for December 31).

Having these three primitives, we can move forward and create some types representing time intervals.

A. ZHH type

With this format, we can encode one interval of opening hours in a single day. Therefore, encoding "Monday from 8:00 to 16:00" will produce 108001600. We can see this representation in Table 1 that indicates every primitive used:

TABLE. I. THE REPRESENTATION OF THE ZHH TYPE

Z	H	H
1	0800	1600
Monday	8:00	16:00

B. DHH type

Similar to ZHH but specifies an exact date instead of day of week. This is just great if you have some special hours in a date, because it can encode something like “Opened on December 25 from 9:00 to 12:00” to 122509001200, and the Christmas day is saved. We can see this representation in Table 2.

TABLE. II. THE REPRESENTATION OF THE DHH TYPE

D		H	H
1225		0900	1200
12	25	9:00	12:00
Dec	25		

C. ZDDHH type

This type extends ZHH and DHH types by adding a date interval. More precisely, it can encode something like “Opened every Sunday from 9:00 to 18:00 between February 12 and March 16” to 70212031609001800, so you can easily represent opening hours for seasons. The date interval must be greater than a week, otherwise you can use ZHH or DHH types. This representation is shown in Table 3.

TABLE. III. THE REPRESENTATION OF THE ZDDHH TYPE

Z	D		D		H	H
7	0212		0316		0900	1800
Sunday	02	12	03	16	9:00	18:00
	Feb	12	Mar	16		

D. -D

We can use this type to represent a closed date. Therefore, if we close on December 25 the encoding will be -1225. This representation is shown in Table 4.

TABLE. IV. THE REPRESENTATION OF THE -D TYPE

-	D	
-	1225	
Closed	12	25
	Dec	25

E. -DD

This type is just like -D type but specifies a date interval instead of a single date. Can encode a range of closed dates, “Closed between January 1 and January 3” to -01010103. We show this representation in Table 5.

TABLE. V. THE REPRESENTATION OF THE -DD TYPE

-	D		D	
-	0101		0103	
Closed	01	01	01	03
	Jan	1	Jan	3

Examples of encoded hours

Now that we have our types, we can go ahead and try to encode some opening hours. For example:

- Monday – Friday from 8:00 to 16:00

For each day of week, we must add a separate record of type ZHH: 108001600, 208001600, 308001600, 408001600, 508001600.

- Saturday from 9:00 to 13:00

Simply use a ZHH record: 609001300.

- Sunday - closed

We do not have to do anything, if there is no other data for opening hours we assume it is closed.

- Monday – Friday from 8:00 to 12:00 and from 14:00 to 18:00

Because each day contains two intervals of opening time we must add a ZHH record for each interval: (108001200, 114001800), (208001200, 214001800), …, (508001200, 514001800).

- Sunday from 9:00 to 12:00 – only during summer season

Considering the summer season as being between June 1 and August 31, we could just use a ZDDHH record: 70601083109001200.

There are some special hours:

December 24 from 9:00 to 13:00

December 25 - closed

January 1 & 2 - closed

For December 24 we must use a DHH record: 122409001300, for December 25 a -D record: -1225 and for January 1 & 2 a -DD record: -01010102.

We consider specifying a closed date record (-D or -DD) implies that you also use the other types to specify opening hours, otherwise it is pointless.

Special cases are:

- Opened 24/7

We must use seven ZHH records to specify the opening interval as 00:00 – 23:59 for each day of week: 100002359, 200002359, …, 700002359. Please note that specifying interval 00:00 – 00:00 is like saying that it is open only at 00:00 (exactly one minute, until 00:01).

- Monday – Friday from 18:00 to 02:00

In this case, the opening interval is past midnight, so it means we must split them in ZHH records to mark as open the first two hours of next day: (118002359, 200000200), (218002359, 300000200), …, (518002359, 600000200).

If Saturday or Sunday is closed, we must not specify a -D record for it.

F. Evaluation order algorithm

So far, we defined representation types and we know how to represent opening hours using our types. However, to know for a specified date and hour if it is opened or not, we consider that each opening hours contains a list of encoded representations in different types. We also set the evaluation order from the most specific to most general type and compare our date and hour to specified representation. For our representation types, the priorities are (from most important to less important): -D, -DD, DHH, ZDDHH, ZHH. We define further the related algorithm for determining opening state:

Let X = searched date (month and day)

Let Y = searched time (hour and

minute)

Step 0

Let Q = day of week for X

Step 1

Get next -D, if no -D goto Step 2. If X equals D return CLOSED else repeat Step 1.

Step 2

Get next -DD, if no -DD goto Step 3. If X between DD return CLOSED else repeat Step 2.

Step 3

Get next DHH, if no DHH goto Step 4. If X equals D and between HH return OPEN else repeat Step 3.

Step 4

Get next ZDDHH, if no ZDDHH goto Step 5. If Q equals Z and X between DD and Y between HH return OPEN else repeat Step 4.

Step 5

Get next ZHH, if no ZHH goto Step 6. If Q equals Z and Y between HH return OPEN else repeat Step 5.

Step 6

Return CLOSED.

III. Sorting and Searching Algorithm

In this section, we describe in pseudocode the logic for algorithm. We are not making any assumptions for the original format of opening hours because there is not a standard to represent them, so there could be many implementations. We just consider that there exists a list of records encoded using our representation types.

A. Sorting the list of records

Each type has different length (except closing ones, which will be put first) so we will use that to sort the records.

```
set Z to 1
set H to 4
set D to 4
set _D to D + 1
set _DD to _D to D
set DHH to D + H + H
set ZDDHH to Z + D + D + H + H
set ZHH to Z + H + H
set list[0] to  empty array
set list[1] to empty array
set list[2] to empty array
set list[3] to empty array

loop
 read record
 set len as record length
 if first char of record is '-' then
       if len is _D or _DD then
              index is 0
 else
       if len is DHH then index is 1
       if len is ZDDHH then index is 2
       if len is ZHH then index is 3

 push into list[len] the record

  concatenate list into one array:
 final list is list[0] concatenated with list[1]
concatenated with list[2] concatenated with list[3]
```

B. Searching through records

We consider that we have a sorted array of records. In the code below, we return if the records contains open day based on a specific date, hour and year.

```
set Z to 1
set H to 4
set D to 4
set _D to D + 1
set _DD to _D to D
set DHH to D + H + H
set ZDDHH to Z + D + D + H + H
set ZHH to Z + H + H
set delimiter to ';'
set close to false
```

```
set firstDigit to 0 // used for the day of the week
set length to 0 // used for type
set interval to 0
set cType to 0

read list that is a sorted records delimited by
semicolon
read date, hour, year
set currentD as week number for the corresponding
read data

loop through list as record
   if record is '-' then
        set close to true and continue
   if record is a number then
        if firstDigit is 0 then set to record
        set interval with interval * 10 + record
        else if record is delimiter then
          if close then
             if date is the interval or is between
interval then
             return false
             set close to false and continue
             if cType is more than 0 and  not the
same as previous type then
                return false
             if length is DHH then
                if date, hour and year is between the
interval then
                return true
                set cType to DHH
                if length is ZDDHH then
                 if firstDigit is currentD and date,
hour and year is between the interval then
                 return true
                set cType to ZDDHH
                if length is ZHH then
                  if firstDigit is currentD and date,
hour and year is between the interval then
                 return true
                set cType to ZHH
                set inverval,fistDigit and length to
0
return false
```

IV. Benchmarks

When comparing the performance of two search algorithms or two sorting algorithms, we consider two types of operations: data movements, or swaps and comparisons [3].

Because the test results depend on the computer on which these tests are carried out, it is important to note that all the results presented below in Table 6, were obtained from studies conducted on a computer with the following characteristics: processor Intel Core i7, 4 GB RAM memory and 320 GB SSD.

TABLE. VI. The Results of Tests

Implementation	Test	Time
Java	1.000.000 iterations	930ms
Java	12.000.000 iterations	10s
Java*	1.000.000 iterations	450ms
Java*	25.000.000 iterations	10s
Apache Solr no caching	100.000 documents	100ms full search

The results are based on the code written in the Java language by the authors [8].

In Java* implementation we can improve the speed of *isOpen()* function by removing the code that generates the *currentDay* integer (by creating a new Calendar instance), and pass it as an argument.

From results tests presented in Table 6 we can say that the resulted times are excellent: we can search through 1.000.000 database records/documents in less than one second and with optimization in less than half a second.

For *Apache Solr* the search through 100.000 documents took 100 milliseconds, which is great. In a real life case there will often be some enforced search criteria such as a limit or a category, city and so on; because it does not make sense to return 100.000 documents to end-user. In other words, the algorithm can handle very well millions of records if other search criteria are used.

Without taking into account the database management system where this algorithm is implemented, for the best results one must consider to:

- use a separate field for the encoded opening hours. Even if you can reverse the encoding, it is not a good idea because the format is intended for search only, so use your original format of opening hours if you want to show it to your users
- do the sorting once (when you insert or update), doing it on every search request will slow-down the process
- do not return the value of encoded field (to save bandwidth and speed-up the search)
- make sure that the check is done only when necessary. Remember that if you have A && B, B is not evaluated if A evaluates to false
- remove redundant records from opening hours (for example having a -D between a -DD is useless

V. Conclusions

To sum-up, the advantages of the algorithm are:

- O(n) complexity for search (in the worst case)
- covers all cases for opening hours, including special hours or season hours

- easy to extend (for example adding time zone support) and implement since it operates on a byte sequence

The only downside of algorithm is the size of needed byte sequence. However, when it comes to search, we will not have to worry about disk or ram space because speed comes first. However, there are some possible workarounds:

- add another types, such as ZZHH (which extends ZHH, using ZZ as interval) and a special one to represent always open

- use a fast method to pack and unpack the sequence (you can reduce the size to half by using something similar to BCD – binary coded decimal)

In the end we can say that our method is a good proof of concept for encoding opening hours in order to determine if is open or closed at certain date and time considering the low complexity and high speed of search.

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Improved Selfish Node Detection Algorithm for Mobile Ad Hoc Network

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***Abstract*—Mobile Ad hoc network (MANET) suffers from different security issues. Ideally, not all nodes in MANET cooperate in forwarding packets because of non-malicious intention. This node is called selfish node and it behaves so due to its internal state such as limited energy concerns. Selfish nodes drop packets and that harms the process of routes establishment and relaying packets. Therefore, it is very important to detect these nodes and avoid them, which guarantees improving the performance of the overall network. Here, an improved scheme has been developed for detecting selfish node in Ad Hoc On-demand Distance Vector routing protocol (AODV) based wireless routing network. Two algorithms were integrated for assuring least fault positive decision of selfish nodes detection; first one is to avoid false positive of detection of selfish nodes in forwarding Route Request (RREQ) and second one is to avoid false positive of detection of selfish node in forwarding data packets. This scheme guarantees improvement in performance of packet forwarding in terms of Packet Delivery Ratio (PDR) and End-to-End delay (E2E delay).**

Keywords—Selfish nodes detection; AODV routing; routing protocols; MANET

I. Introduction

Ad hoc networks are defined as networks that lack a fixed infrastructure and hence are flexible and adaptive in nature. Ad hoc networks consist of individual devices, also known as nodes that communicate with each other wirelessly without a central access point. The devices, hence, do not rely on a base station to coordinate the flow of messages.[1] Instead, the individual network nodes pass packets to each other within the network. Ad hoc networks can be used in multiple applications such as creation of communication networks at times of emergency when the existing communication is damaged due to natural disasters, creating conferencing networks for office use that do not rely on the internet, home networking and personal area networks, especially with Bluetooth devices associated with a single person. A mobile ad hoc network (MANET) is defined as an ad hoc network that uses mobile nodes that are arbitrarily located. The nodes in a MANET are highly dynamic and may join and leave the system frequently. Since the nodes are highly mobile, the topology of the network changes rapidly. MANET systems have found use in many applications such as military communication networks through mobile radio transmitters and receivers, rescue missions without adequate wireless coverage. Fig. 1. Shows an example of a MANET.

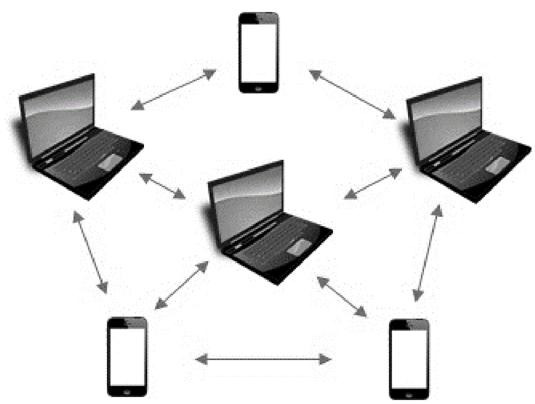


Fig. 1. Mobile Ad hoc Network

MANETs are highly efficient in establishing an impromptu mobile network. However, there are certain issues that these networks face. Since MANET networks are based on mobile nodes, these nodes usually operate within limited resources in terms of power and bandwidth availability, and quality of the node hardware. MANET networks may also face a problem of route optimization. Apart from these constraints, MANET may also face security concerns such as passive and active attacks for information extraction. Furthermore, MANET may contain malicious nodes that drop all or selective packets. This work focuses on malicious nodes that act selfishly in the network such that they drop packets to conserve resources while using the network to broadcast their own packets. Selfishness within nodes has imminent disastrous effect on MANET as it reduces the performance of overall network and can paralyze the network when the number of selfish nodes increases in the network. Therefore, there is high motivational aspect to address this problem from research perspective.

In the literature, numerous algorithms have been developed to detect selfish nodes in MANET. In the work of [2], a fuzzy reputation system has been proposed to discipline selfish behavior of nodes and motivate packet forwarding. [3] implemented secure and objective reputation-based algorithm in detecting nodes that are selfish in nature where every node is liable to keep track of other nodes or acquire the reputation from a centralized node. [4] suggested a credit-payment scheme. The objective of this scheme is to encourage nodes to forward packets by earning credits which they need in order to transmit their own packets. [5] proposed activity-based overhearing, iterative probing and unambiguous probing to detect multitude of selfish nodes in MANET. In another paper, [6] employed a fuzzy-based analyzer to differentiate trusted and selfish behavior in nodes. The method incorporated the concept of trust and certificate authority to combat selfishness. [7] proposed a collaborative watchdog to improve selfish node detection. [8] proposed two network-layer acknowledgement-based scheme to detect misbehaving nodes and then inform the routing protocol to avoid these nodes in the future. [9] used game theory to study behavior of nodes and apply reputation as a tool to encourage cooperation in nodes.

Above papers discuss about detecting selfish behavior of nodes in MANET and propose ways to encourage cooperative behavior. However, these papers overlook the aspect of false decision in detecting the selfish nodes. False detection of selfishness may degrade network performances, as normal nodes are susceptible to be falsely identified as selfish, resulting in elimination of participation in packet forwarding. Therefore, an improved scheme based on AODV routing protocol has been proposed in this paper. The work presented in this paper builds upon [10] and identifies key problems in it. Also, it provides a robust solution to minimize false detection of selfish nodes. The organization of this article is as follows. In Section II a problem statement is presented followed by methodology in Section III. Section IV presented the results obtained from tests and discussion on the results and this paper is ended with conclusion and future work in Section V.

II. Problem Statement

Selfishness within nodes has imminent disastrous effect on MANET as it reduces the performance of overall network. Therefore, detecting and eliminating these nodes is a vital step in ensuring a working system. [10] presented a method of detecting selfish nodes and tested the proposed method on an AODV routing protocol. Although the method looks promising and efficient, it suffers from several limitations. After implementing the protocol and running the method on MATLAB, it has been found that their proposed selfish nodes detection mechanism has two prominent drawbacks.

Firstly, the method failed to notice the problem pertaining to the first type of selfish node; dropping RREQ packets. Due to the dynamic structure of MANET, a node may receive RREQ more than once and from difference source nodes. This method suggests that when a node receives RREQ from a node with the same ID it has previously received, it will drop the packet, hence considered as potentially malicious node but it does not necessarily mean it is selfish.

Secondly, the method could not address an issue related to the second type of selfish node; dropping data packet. When a node receives a data packet, it forwards the packet to the neighboring node following the established route until the packet reaches the destination node. Problem arises when neighboring node may be out of coverage zone of the forwarding node. After sending a data packet, sending node does not know if the receiving node has successfully received the packet, and it might identify the receiving node falsely as malicious in case no forwarding action has been performed by the receiving node.

In both cases, the paper failed to see these problems and therefore could see the next node of a particular forwarding node as selfish in nature. This false decision will lead to lower performance as normal nodes could be terminated from the network while in fact, the nodes can participate in forwarding packets. This paper proposes a method to minimize false detection of selfish nodes.

III. Methodology

This work uses the (AODV) presented in [10] and builds upon the said protocol to reduce false detection of selfish nodes more efficiently.

This paper focuses on two behaviors that were used to identify the selfish nodes namely (*A*) Not forwarding RREQ messages and (*B*) Not forwarding data messages. The drawbacks of the above methods have been mentioned in the previous section. This section will present the potential methods to deal with the stated problems.

A. Not forwarding the RREQ message

As mentioned in the problem statement, the work presented earlier is not robust in its identification of the selfish node. It ends up classifying a normal node as selfish if the node has broadcasted an RREQ message previously but does not broadcast the same message again. This paper introduces a new type of packet known as the Route Request Confirmation Packet (RRC). The main purpose of this packet is to confirm to the other nodes that the current node has previously rebroadcasted the message and is not a selfish node. Hence, upon receiving the RREQ message, a normal node rebroadcasts the message in case it has not received it earlier. Otherwise, it sends an RRC packet to the sending node. The aim is to let the sending node know that it has forwarded the same message once and there is no need to do so again. Algorithm.1.presents the algorithm used in the modified protocol.

Algorithm.1. False detection of selfish node for not-forwarding RREQ

1: **Start.**
2: Source node sends RREQ to all of its one hop neighbors
3: Each normal neighbor node either rebroadcasts the RREQ to its neighbor nodes or sends an RRC packet to the sender node if it has already rebroadcasted the same RREQ before.
4: After waiting for a prefixed period of time, the source node checks its routing table and examines the behavior of its neighbors
5: **IF** the source node receives back the RREQ packet OR receives an RRC packet from its neighbor,
THEN this neighbor node is characterized as normal node.
ELSE the neighbor node is marked as potential selfish node.
6: Flooding of the RREQ continues. Each intermediate node receiving an RREQ must rebroadcast the message or send an RRC if it has rebroadcasted the same message before.
7: For each intermediate node, repeat Step2 to Step 4 and sender intermediate node is considered as the source node.
8: Process continues until destination node is reached.
9: **End**

B. Not forwarding the data packet

As mentioned in the earlier section, since the nodes of the network are mobile, a node may not be able to forward a data packet not because it is a selfish node, but because it never received the data packet in the first place, due to a break in the route. The existing work fails to recognize this possibility and hence may mark a normal node as selfish. In order to avoid false decisions about this type of selfish node, each node must update its routing table before it sends any data packet. To guarantee getting the most updated information about neighbors, the process of updating routing table has been transformed to be event-based instead of being periodic. Hence, each node before sending a data packet broadcasts a hello message and updates the routing table to confirm its connection to the next node. If the next node is not available, the node drops the packet and tells the previous node with a Path Break (PB) message that the next node is not available and it cannot send the data packet. Algorithm.2. Presents the algorithm used where (SN) stands for sender node and (RN) stands for receiver node.

Algorithm.2. False detection of selfish node for non-forwarding data packets.

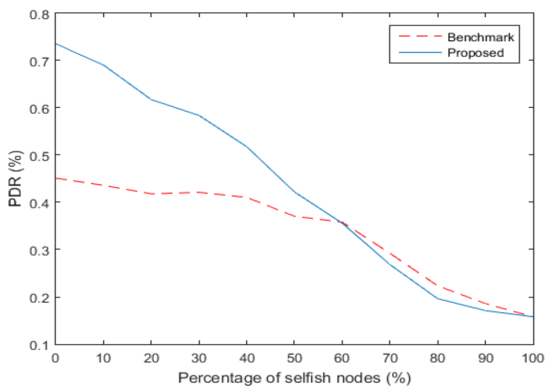
1: **Start.**
2: Initially SN is source node and RN is the 2nd node of the transmission path.
3: SN sends a Hello message to RN to confirm that RN is still present in the transmission route and updates its routing table.
4: **IF** SN does not receive back the hello message from RN,
THEN RN is considered to be out of the transmission route and another route is established.
ELSE RN is in the transmission route.
5: Data packet is sent from SN to RN.
SN and RN are modified whenever data packet reaches a new intermediate node of the transmission path. Whereby the previous RN becomes new SN.
6: Step 3 is repeated with new SN and RN nodes.
7: **IF** new RN is out of transmission path,
THEN SN sends a PB message to the previous node indicating a break in transmission path.
ELSE SN broadcasts data packet to RN.
8: **IF** new SN does not broadcast any data packet,
THEN SN is considered potential selfish node.
ELSE SN is a normal node.
Process continues.
9: **IF** SN = RN,
THEN the data packet has reached the destination successfully.
ELSE data packet has not reached the destination.
11: **End**
12: **End**

In order to validate the proposed method, MATLAB environment has been used for simulation. A MANET of 49 nodes has been established where each node has coverage zone equal to 250. The average size of packet is 80 bit. The mean velocity of nodes is 10 unit/sec. The timeout time after sending a route request packet is 1.5 sec and the route request buffer size is 1000 packet.

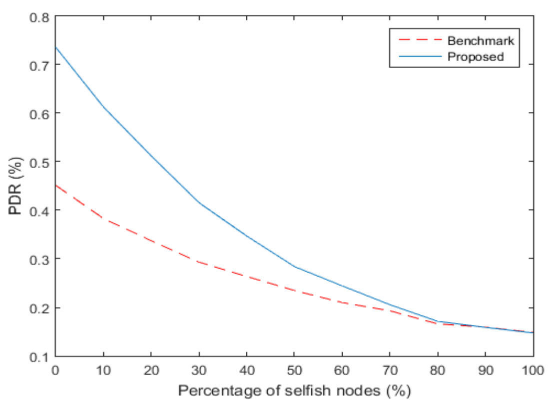
The size of route reply packet and route request packet is 100 packets. Data packet lifetime is 10 sec. To generate data packets, two Poisson random variables have been used where one is for generating random times with mean equal to 6 second and the other is for generating a random number of packets with mean equal to 2 packets. For the proposed method route request selfishness threshold and data packet selfishness threshold has been chosen to be 150 and 10 respectively whereas, in the benchmark case, the route request selfishness threshold has been chosen to be 1500 in order to decrease the number of false decisions during the execution. The results from the simulation have been discussed in detail in the next section.

IV. Results and Discussion

This section discusses the results from the conducted experiments in detail. The proposed modified algorithm was tested with respect to a benchmark in, Packet Delivery Ratio (PDR), End-to-End delay (E2E), overhead and energy consumption measures. The results are hereby published.



The First Type

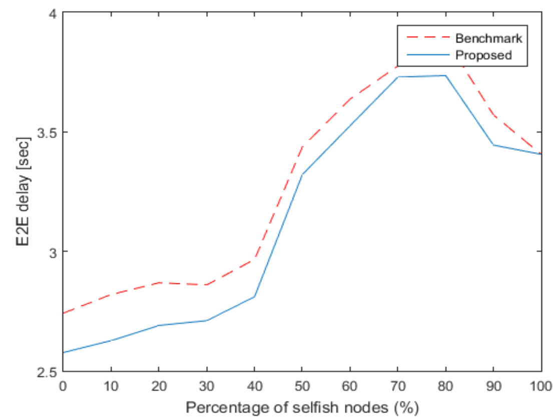


The Second Type

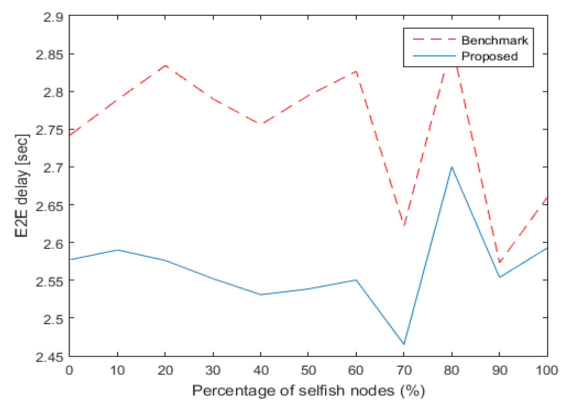
Fig. 2. PDR percentage vs selfish node percentage for first and second types of misbehavior

Fig.2. PDR percentage vs selfish node percentage for first and second types of misbehavior. Shows the comparison of the proposed algorithms with respect to the benchmark in PDR performance. The x-axis represents the percentage of selfish nodes in the network and the y-axis represents the PDR percentage. A false decision in marking a normal node as a selfish node decreases the PDR. It can be seen from Fig.2. that the proposed method achieves greater PDR performance in each of the two types of algorithms as compared to the benchmark. The results thus clearly indicate a decrease in the false decisions regarding the selfish nodes. In the first type however, the PDR performance drops slightly lower than the benchmark when the number of selfish nodes is more than 60%. This is because most of the nodes in the network are real selfish nodes. In the second type of algorithm, the PDR remains higher than the benchmark until the number of selfish nodes reaches 78% and is equal to the benchmark from then on. From Fig.2.By taking the reading at 0% of selfish node for first type and second type of misbehavior, the data points show similar values. Therefore, the improvements on PDR for both cases are calculated as follows.

$$Improvement\ PDR = \frac{0.74-0.45}{0.74}x100 = 39.2 \tag{1}$$



The First Type



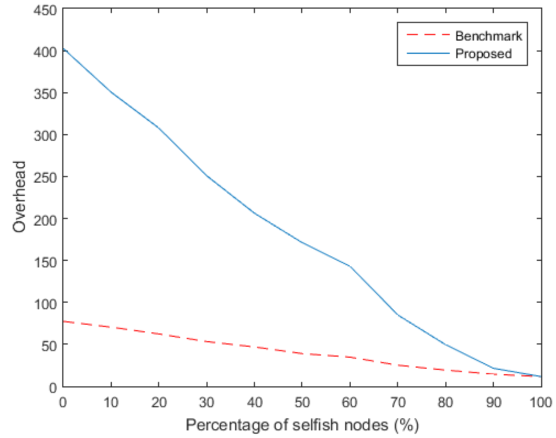
The Second Type

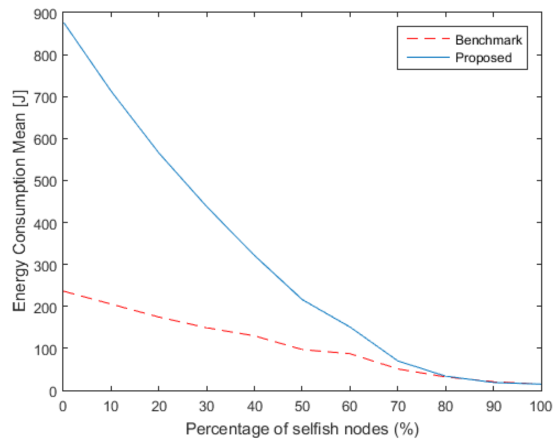
Fig. 3. E2E delay vs selfish node percentage for first and second types of misbehavior

Fig.3.Presents the comparison of the E2E delay of the proposed algorithms and the benchmark. The x-axis represents the percentage of selfish nodes whereas the y-axis represents the E2E delay. It can be seen from Fig.3.That the proposed algorithms reduce the E2E delay in both the algorithm. This is due to the reason that the proposed algorithm only identifies the real selfish nodes in the network hence reducing the time needed to establish the routes also more nodes relay packets from other nodes, hence reducing the E2E delay. By taking values at 0% of selfish node, the improvements on E2E delay for first type and second type of misbehavior are calculated as follows.

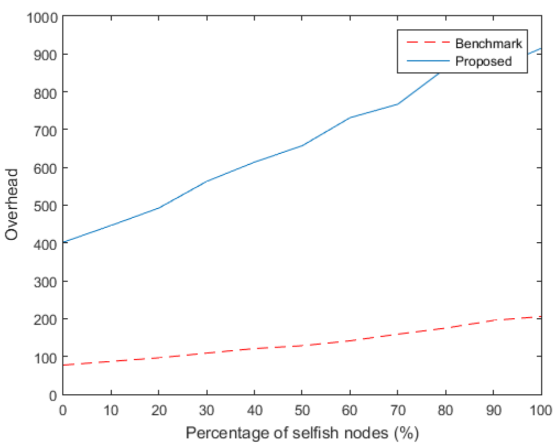
$$ImprovementE2Edelaytype1 = \frac{2.73-2.58}{2.73}x100 = 5.5 \quad (2)$$

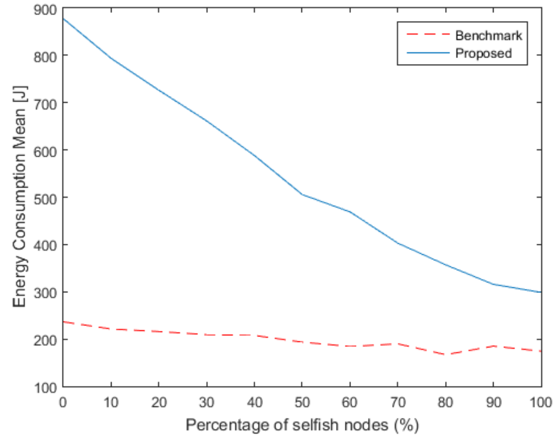
$$ImprovementE2Edelaytype2 = \frac{2.74-2.58}{2.74}x100 = 5.8 \quad (3)$$





The First Type





The Second Type

Fig. 4. Overhead vs selfish node percentage for first and second types of misbehavior on upper half of figure and mean energy consumption vs selfish node percentage in lower half

Fig.4. shows the performance of the proposed algorithm in comparison to the benchmark with respect to the overhead and the energy consumption measures. The upper half of the figure represents the overhead comparison with the y-axis representing the overhead value. The lower part of the figure shows the comparison of energy consumption. The energy consumption value is represented on the y-axis. The x-axis in both cases shows the percentage of selfish nodes. From the Fig.4. It can be seen that the overhead and energy consumption of the proposed algorithm is higher than the benchmark in both types of algorithms. This is due to the fact that a new packet i.e. Route Request Confirmation Packet (RRC) was introduced thereby increasing both, the overhead as well as the energy consumption. Furthermore, it should be noted that some of the selfish nodes in the benchmark algorithm are not identified properly, hence further reducing the overhead and energy consumption.

V. Conclusion and Future Work

Presence of selfish nodes in any network especially MANET may impact the performance of the whole communication system. As much as it is important to detect selfish nodes to improve network performance, false detection may also affect the network because of the result of avoidance of collaboration with selfish node. Based on[10], two main drawbacks are found. They are failure of a node to rebroadcast same packet more than once and hence it drops the packet, which results in being falsely identified as a selfish node. The second drawback is the possibility of RN being out of SN's coverage area. In this paper, an improved scheme has been proposed. This proposed scheme detects selfish nodes effectively in a MANET and at the same time works to minimize false detection of selfish nodes to ensure data packets are transmitted from the source node to destination node more efficiently. First type of selfish node issue has been handled by introducing a new packet type namely Route Request Confirmation Packet (RRC) which lets other nodes know that a node has forwarded a packet previously and it is not selfish. The second type of selfish node problem has been solved by updating routing table and making it event-based instead of periodic-based. Experiments and tests are conducted in MATLAB environment and the results show improvement with 40% of PDR and 5.5 – 5.8% of E2E delay. Future work is to validate the proposed approach is real world scenario. Another future aspect of work is to develop approaches of re-introducing the node to the network in case of changing the selfish behavior to normal.

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A Study on Ranking Key Factors of Virtual Teams Effectiveness in Saudi Arabian Petrochemical Companies

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***Abstract*—This research ranks effectiveness-related factors of virtual teams. The literature suggests various factors which could motivate or discourage management in using virtual teams versus co-located teams. Forty-eight interviews were done in petrochemical companies in Saudi Arabia. The Echo Method has been employed and eleven factors were identified. Results showed that the participants ranked efficiency and communication as first and second as a motivating factor in adopting the virtual team approach. While, the other three motivating factors which were ranked lower are flexibility, diversity and cooperation. On the other hand, the six discouraging factors (barrier) are miscommunication, scheduling preferences, unreliability of technology, incompetency of staff, varying standards and isolationist tendency. Suggestions were made to counteract the effects of the barrier-inducing factors and enhance the effects of the motivating factors.**

***Keywords*—Virtual teams; Social network; Echo method; Quantitative analysis**

I. Introduction

The drive towards speed, cost rationalization, quality of output and broad reach for dispersed market encourages organizations to consider virtual teams as an approach to organizing tasks and delivering result [32].

This paper examines the literature on this issue and performed a validation using social network survey research in identifying key factors which make virtual team deliver its promises.

The unique contribution of this work is the attempt to rank various factors as to why management would use virtual teams. Ranking the factors affecting the adoption of virtual teams is important so that the management could utilize more fully the driving factors and avoid (or use counteracting solutions) the discouraging factors.

These factors are deeply imbedded into the subconscious of the staff that one of the best ways of eliciting these factors is the use of Echo Method. Through the Echo Method, those staff was able to communicate their inner thoughts to the interviewer [25].

The driving factors (motivator), in terms of ranking, are: efficiency, communication, flexibility of work place and time, diverse skill sets and cooperative attitudes. The discouraging factors (barrier), in terms of ranking are: miscommunication, scheduling preferences, unreliability of technology, staff incompetence, varying standards and isolationist attitudes.

This paper suggests that in any undertaking utilizing the virtual team approach, the management should ensure that each member have a superior written communication skills and a tight work contract. Further, the management should have the latest update of information and communication technology infrastructures. Moreover, work procedures and decision rights should be properly documented and disseminated to all members and stakeholders.

The above-stated result of this paper is significant. By working on the inner thoughts elicited through the Echo Method, ranking them, and coupled with what are already discussed in the literature, this paper suggests a water-tight process of working with virtual teams.

This paper is organized by presenting the literature review and followed by a description of the research methodology. The results of the study are then presented and discussed, together with highlighting the conclusions and managerial recommendations.

II. Literature Review

The literature is filled with various aspects about virtual teams. In this review, we present the current thinking about what it is, why people resorts to the use of virtual teams, what are its benefits and drawbacks.

Based on various papers, virtual teams come about when a common goal is attained by different individuals working from different time zone, place and organization and coordinated by information and communication technologies [1,4,6-9,12,19-20,22-23,26,30]. Having cited these authors, it leaves us to explore the idea that virtual teams are communicating purely or partially through remote-based communication technologies? Martins, Gilson and Maynard stated that it is not necessarily either virtual or face-to-face. It could be a proportion of face-to-face communication or remote, technology-based communication. In fact, the use of remote related technologies depends on several factors: (i) the nature of the task, (ii) the technological resources at the team's disposal, and (iii) the team members' diverse background [21].

The idea that the team members are coming from different places, time zones and geographical areas suggests the issue of diversity (cultural, skills and language). It has been noted that as a natural consequence of team members' diversity, communication – the main means of human coordination, is heavily affected. Shachaf et. al. [29] has noted that communication among global virtual team members is more complex due to the fact that it is mediated by computers and involves cross-cultural communication. Hence, effective communication has become a critical factor for success in the virtual setting.

Amidst this characterization of virtual teams, more and more organizations have used virtual team approach as a means of managing any form of undertaking, short-term as in a project, or operational, as in call-centers. Efficiency has become one of the main drivers for using virtual teams. For example, the use of virtual teams significantly reduce the time and costs incurred in travel [5,9]. This finding has been reinforced by Ale Ebrahim who noted that within Malaysian manufacturing Small and Medium Enterprises (SMEs), virtual teams reduced research and development (R&D) costs and time [1].

The literature further indicates that the use of virtual team reduces the cost of accommodating employees. Virtual team approach translates into less traveling as the employees are working from home. This translates into less office and parking space and in the end the company reduces its real estate expenses [3,24].

Aside from the economic impact, the diversity factor of virtual teams brings in a lot of benefit to the company. The dimension of virtual team gives the company wider skill set, broader cultural understanding and bigger recruitment base for talents [21,1,5,13].

Flexibility has likewise resulted from virtual teams. The ability to work beyond time, organizational constraints and locations, enhances the competitive agility of organizations [21,26]. Further cross-territorial communication is attained by virtual teams. Since the individuals are coming from different areas, information from those areas are readily available for the virtual team [15,31].

While working towards a goal, the use of information and communication technologies (ICTs) form the backbone of the virtual team concept. The ICT is what makes it virtual. Email, collaborative software, video conferencing, phone and mobile devices form the basic technology support [15]. Martins [21] have asserted that the technology set used by the virtual team has a direct impact on the team's efficiency, commitment, and amount of communication and relationships among the team members. Jarvenpaa and Maznevski asserted that a mix of face-to-face interactions and ICT-based interactions is possible [14,22].

The permanency issue of the virtual team has been explored by various researchers [10,18,30]. A team who has a long-term possibility of staying together tend to perform better than a team who is there for a short time.

One key point that leads to an individual to work for the team is trust. Luo Lu [17] found that a member's trust is built if he perceives a similarity of values, attitudes and beliefs with the rest of the team. Another factor is benevolence: that is the team member believes that the other team members would like to do good to him [17].

While trust leads to an effort to work for the team, there are other factors that lead to positive knowledge sharing attitude. Killingsworth et. al noted that trust, reciprocal benefits, enjoyment and computer experience contributes to a positive knowledge sharing attitude [16].

Derven [11] identified four factors that lead to virtual team effectiveness. These are diversity and inclusion, purpose, people and processes. Derven asserted that a right mix of people should be attained in terms of gender, age, race, ethnicity, cultural background, education, sexual identity, orientation, values, thinking styles and others. Further, purpose should be clearly specified. People should be recruited based on requirements, relationships should we specified, and rewards and recognition should be made at an appropriate time. Finally, a formal process of governance and working together should be documented [11].

Summarizing, the literature presents virtual teams as a group of individuals who work together towards a common purpose. Interacting through the use of information and computer technology, they work across different time zones, different places, and organizational boundaries. The virtual team might exist permanently or for a short duration. As a result of having different people of diverse backgrounds in a group, the virtual team attains significant gains in terms of efficiency, broad collection of skills, flexibility, and other capabilities. The choice of technology set affects how the team coordinates with one another. On the other hand, the virtual teams could experience multiple challenges such as miscommunications and doubts regarding ones real agenda. Issues of doubts about one another should be addressed. Trust could be enhanced by team members having similar values, attitudes and beliefs. Aside from trust, reciprocal benefits, enjoyment, and computer experience positively affects work attitudes. Further, a well specified purpose, relationships and remunerations, and work processes enhance global virtual teams.

III. Research Method

This study tries to identify factors that helps in the adoption of virtual team approach and which factor hinders such adoption. The management has an option of putting all staff on day one in one huge office or allow the staff to work from dispersed places. Results of this study will be useful for managers who are accountable for the attainment of result within budget.

In order to identify those factors, this study looked at the inner psychology of members of previous team members. The Echo Method reveals the interviewees' perspectives, views, and thoughts, which in turn "echo" the interviewees' unique values and beliefs with minimal research interference [25].

The first part of Echo Method involves collecting general background information about the interviewee's current job, daily tasks/activities and role, and years of experience in the current position. The second part involves a network diagram as shown in Figure 1. The central node represents the interviewee, and the other connected nodes represent those with whom the interviewee interacts as part of the virtual team, which can include individuals (e.g., team leader), groups (e.g., team members), and technologies (e.g., virtual team technology).

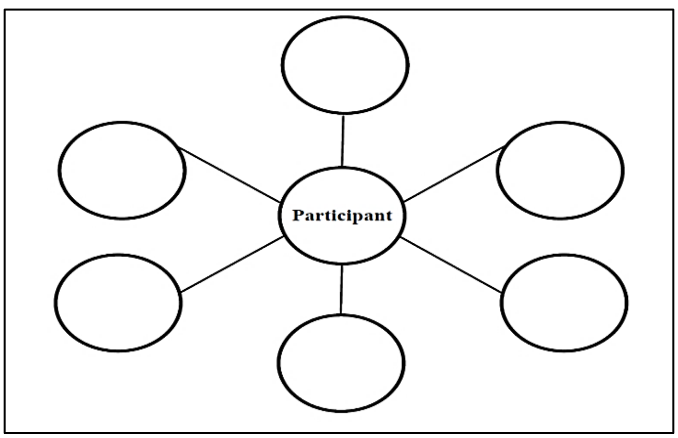

Fig. 1. Blank Social Network Diagram

In this second part, the interviewee is asked to identify behavioral examples with those nodes, for example, emailing. For such behavior, the interviewee is asked to code it as "helpful" (motivator) or "not-so-helpful" (barrier) in terms of attaining virtual team tasks. Forty eight interviews with staff working in maintaining high-technology materials and equipment were done in petrochemical companies in Saudi Arabia.

IV. Results and Analysis

After the 48 interviews were conducted based on the Echo Method, all interviews were transcribed. The text was systematically coded into two groups: examples of helpful behaviors (motivator) and examples of not-so-helpful behaviors (barrier). The first step of the analysis was performed using frequency by counting the number of behaviors in each of the two categories, as shown in Figure 2. Examples of helpful behaviors would be different skills/knowledge brought to the tasks while not-so-helpful behaviors would have loss of social contact (for example, handshakes) as its example.

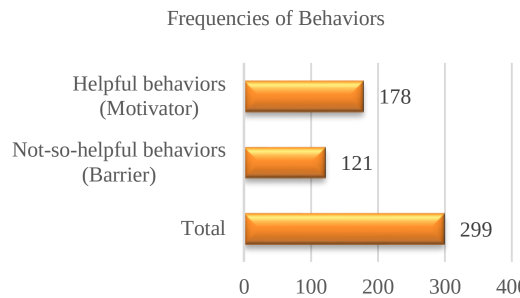

Fig. 2. Frequencies of Behaviors

A. Perceived Interaction Effectiveness Ratio (IE)

An indicator of the relative effectiveness of employing virtual teams is called the perceived interaction effectiveness ratio (IE). The IE is calculated as the ratio between the numbers of helpful statements (motivator) to the number of not-so-helpful statements (barrier) [27]. This study yielded the IE ratio to be 1.48, meaning there is 1.48 helpful statements (motivator) for every 1 not-so-helpful statement (barrier).

B. Categorical Analysis

In this second step, three independent researchers analyzed the responses for over a period of two months. The analysis was iterative, and after a consensus is attained by the three researchers, the factors were identified.

In this study, the researchers classified the helpful examples (motivator) into five different factors, namely: efficiency, communication, flexibility, diversity and cooperation. On the other hand, the not-so-helpful factors (barrier) were categorized into six factors, namely: miscommunication, scheduling preferences, unreliability of technology, incompetence of staff, varying work standards, and isolationist tendencies.

TABLE. I. DISTRIBUTION OF HELPFUL EXAMPLES (MOTIVATOR)

Factors	# of Examples	Working Definition	Typical Example
Helpful Behaviors (Motivator)			
Efficiency	(30.9%) (55)	The extent to which time, effort, or cost is well used for the intended task or purpose	Expedited decision making due to easy and quick ways to gather all stakeholders for a short meeting
Communication	(23.6%) (42)	The transfer of information from one unit to another	Easy way to share information/updates, “all members on the same page”
Flexibility	(21.9%) (39)	The freedom to choose the time and place for work	Centralized time zone allows for working with both east and west during working hours
Diversity	(14.6%) (26)	The variety of experiences and perspectives that arise from differences among members, governments, countries, etc.	Different skills and knowledge are brought into the tasks
Cooperation	(9%) (16)	The degree of willingness to help	Following up and coordinating with customers when one person is busy, “good backup”
Total	(100%) (178)		

Efficiency is the highest ranking factor on the helpful side, accounting for 30.9% of the total number of helpful examples. It is followed by communication, which represents 23.6% of the helpful examples. Thus, together, efficiency and communication examples dominate the area of helpful factors. Flexibility, with a proportion of 21.9%, is seen as another favorable outcome of the virtual teams. Diversity, with 14.6%, is also perceived as a favorable outcome, albeit to a lesser degree. Cooperation received the lowest number of responses, comprising only 9% of the helpful examples. These results are represented across the different factors in Table 1.

In terms of the not-so-helpful (barrier) factors, statements were classified into six factors. Table 2 shows the emerging factors, along with their frequencies, working definitions, and concrete examples.

TABLE. II. DISTRIBUTION OF NOT-SO-HELPFUL EXAMPLES (BARRIER)

Factors	# of Examples	Working Definition	Typical Example
No-so-helpful Behaviors (Barrier)			
Miscommunication	(36.4%) (44)	Cases in which information was not transformed as desired	Accent issues and weaknesses in the English language itself
Scheduling Preferences	(21.5%) (26)	Difficulties arising out of the technology (e.g., in choosing time and place) and the social norms established around its use (e.g., behavioral norms in a particular culture to which individuals are expected to conform).	Communication gaps created by the difference in time and the nature of virtual teams as to the actual timing of work days and weekends
Unreliability of technology	12.4% (15)	The instability of the technology in facilitating virtual teamwork	Frequent outages in IT services
Incompetency of staff	11.6% (14)	The lack of a normally expected degree of ability	Technical "know-how" difficulties; “not doing a good job or not doing what they are supposed to do”
Varying standards	(9.1%) (11)	The variety of experiences and perspectives that arise from differences among members	Age gaps between virtual team members; having different measureable standards than other countries
Isolationist Tendency	9.1% (11)	A degree of unwillingness to help	Resolving problems among team members is very hard; difficulty in supervision
Total	(100%) (121)		

As illustrated in Table 2, miscommunication is found to be the highest ranking factor, accounting for 36.4% of the not-so-helpful examples. In other words, communication issues tend to be a major issue in virtual teams. The second most prominent factor is scheduling preferences, which represents 21.5%. This factor reflects the complications and nuisances faced by the members owing to the inherent rigidity of the virtual team setting and the awkward social norms that develop around this setting. Unreliability of technology is the third largest factor, constituting 12.4% of the not-so-helpful examples. It refers to the typical unpredictability and unreliability associated with technology. In contrast, isolationist tendency is the least noticeable category, representing 9.1% of the total not-so-helpful responses.

V. Discussion

This section discusses the perceived interaction effectiveness ratio, as well as motivators and barriers to the implementation of virtual teams.

A. Perceived Interaction Effectiveness Ratio (IE)

The interaction effectiveness (IE) ratio was used to identify the perception of virtual team effectiveness based on concrete examples of helpful (motivator) and not-so-helpful (barrier) behaviors from a task-related social networking perspective. The IE ratio was found to be above 1 (1.47), which indicates that the virtual team environment is producing more helpful than not-so-helpful behaviors. This indicates that the virtual team approach is useful but not a panacea.

B. Virtual Team Motivators

Based on the data gathered, efficiency (31%) is the strongest driver of why management chooses to use the virtual team approach. This is probably due to the ease of communicating (24%) and flexibility of identifying work place and work schedule (22%). Since most undertakings have a specific target and goal, diversity came fourth (15%). It would be a different case if the goal is vague, and, therefore, a large set of knowledge is needed to be ready for deployment. Finally, cooperation came last (9%). Since members of the team needed to generate their work based on a particular work assignment, cooperation is rarely an issue.

The second driving force in the adoption of virtual team is communication (23.6%). There is a general appreciation for the use of virtual teams as ease of communication generally leads to overall efficiency. This finding is consistent with previous studies on communication within virtual teams [24,29].

The third ranking factor is the flexibility of work place and schedule. This accounts for 21.9% of the total helpful examples. This finding is consistent with former studies [10,13,21].

The fourth ranking factor is the diversity of skill sets. This was mentioned 15% of the responses. As the organizational goals are normally well-written out, there is no need to have on broad set of knowledge possessed by different people.

Finally, the last ranking factor is cooperation. This was mentioned 9% only. This might be due to the fact that many of the work contracts are well specified and therefore, there is no need for each team members to cooperate and give in during decision making.

C. Virtual Team Barriers

On the other hand, various discouraging factors (barrier) exist. At the top of the list is miscommunication, particularly verbal communication. This was mentioned 36.4% of the example statements. Many of the responses were identifying the lack of body language and hard-to-understand accents.

The second ranked discouraging factor (barrier) is scheduling preferences, which stood at 21.5%. Due to the different time zones, many of the team members would want to meet-on-line at their convenience.

The third ranked discouraging factor (barrier) is unreliable technology which was mentioned at 12.4%. This is brought about by financial constraints in most situations, but also caused by lack of knowledge of what type of technology is possible.

The fourth discouraging factor (barrier) is staff incompetence, which was mentioned 17% of the time. This is attributed to the loose recruitment requirements specification. Upon recruitment, specific work output has to be specified, and specific brand of technology also has to be known.

The fifth discouraging factor (barrier) is varying standards, which was mentioned at 9.1%. People with diverse cultural and educational background have different notion of what is normal. This too could be due to loose requirements specification.

The last, isolationist tendency is calculated at 9.1%. This is the least discouraging factor (barrier) as there are only few moments where a team member is asked to get out of his area of work to help out on a specific issue.

VI. Conclusion and Recommendations

This study has shown the rankings of various factors as to why the decision makers in an organization would opt for virtual team as a management approach. This is even reinforced by the greater than one interaction effectiveness (IE) ratio, indicating that virtual team carries so much promise.

Given a macro view of the results, and the corresponding review of literature, it shows that efficiency, doing more with less, is the primary driving force in adopting virtual teams. However, communicating with one another seems to be both a driving force as it is a discouraging factor (barrier). In order for this recommendation to be universal, it is recommended that written communication skills among team members be favored over verbal communication skills. In fact, if it is possible, form-based work-flows be used to coordinate various team members.

Moreover, due to the wide source of talents and skills, it is necessary to have a specific and tighter work contract be written out for each team member, including sample of work. In this case, each team member is fully aware of what is expected from him in terms of level of quality, quantity and turn-around time. Further, work procedures and decision rights should be properly spelt out and disseminated among team members and stakeholders. In this case, work responsibility is fully addressed.

Finally, the information and communication technology infrastructure should be properly updated. As much as possible, its fullest potential should be disseminated to the team members, and all team members should be using the full features of the technology deployed.

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Prediction of Naturally Fractured Reservoir Performance using Novel Integrated Workflow

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***Abstract*—Generation of naturally fractured reservoir subsurface fracture maps and prediction its production potential are considered complex process due to insufficient data available such as bore hole images, core data and proper reservoir simulator model.**

To overcome such shortcomings, the industry has relied on geo-statistical analyses of hard and soft data, which are often referred to as static data. This paper presents an integrated workflow that models and predicting fractured reservoirs performance, through the use of gradient-based inversion techniques and discrete fracture network modelling (DFN), which—through the inversion of well test data (i.e., dynamic data)—aims to optimise fracture properties and then predicting of the reservoir production potential. The first step in the workflow is to identify flow contributing fracture sets by analysing available core descriptions, borehole images, conventional log data and production data. Once the fracture sets are identified, the fracture intensity is statistically populated in the inter-well space. In the second step, 3D block-based permeability tensors are calculated based on flow through discrete fractures, and the fracture intensity is then propagated away from the wellbore, i.e., by relating to permeability tensors with fracture intensity. In the final step (fracture optimisation), the fracture properties are computed by DFN modelling, which includes distribution, orientation and geometry in different realisations. Fluid flow is simulated in these discrete fractures to estimate pressure change and pressure derivatives. The production rate associated with drill stem test that performed within this reservoir area has been successfully simulated using the optimised subsurface fracture map that has been generated from the first step.

Keywords—fractured reservoirs; production potential; fracture network map and finite element

I. Introduction

The characterization and predicting the performance of naturally fractured reservoirs are enormous challenges for oil and gas industry. Reservoir models that used to in the prediction of reservoir performance during the depletion optimization and field development planning processes must incorporate the effects of natural fractures in near the wellbore regions. Moreover, to predict their distribution in inter-well areas as well.

Distributing fracture properties methods that based on static data are presented extensively in the literature [1], [2], and [3]. Nevertheless, most of these geological models have failed to reproduce well production histories and capture the complex heterogeneity and anisotropy of the fracture system [4] and [5].

Since the 1970s, a significant progress has been made to generate a consistent methodology to characterise naturally fractured hydrocarbon and geothermal reservoirs by utilising well test and production data. This has been using static data and inversion techniques as stochastic algorithms, and gradient-based and streamline-based techniques [6], [7], [8], [9], [10], and [11].

Currently, three major approaches are used to simulate fluid flow through naturally fractured reservoirs, which include continuum, dual porosity/dual permeability, and flow through discrete fracture approaches. A review of these models can be found in the works of [12], [13] and [14] for continuum approach. [15], [16], [17], [18] and [19] for flow through discrete fracture approach.

In this paper, pressure transient data from a fractured basement reservoir offshore Vietnam has been used to evaluate the fracture map which is generated by statistical analysis of field data. In addition, a multiphase fluid flow simulator using finite element technique has been generated and used to evaluate the recovery potential of the naturally fractured reservoir under different driving mechanisms and to assess the optimised (generated) subsurface fracture map by comparing the predicted and history production data.

II. Generation of Subsurface Network Fracture Map

Object based simulation technique is used in generation of network fracture maps [20]. Fractures are treated as different objects and placed in the domain randomly. The number of fractures generated organized by fracture intensity and fractal dimension parameters.

A. Fracture Intensity

The fracture intensity is an important parameter to give an indication about the probability of fractures occurrence in a discrete fracture model [21]. The fracture intensity is defined as the number of fractures per unit bulk volume. The fracture intensity is calculated by dividing the studied into different grid blocks and fractures that cut each block are well-defined. Then, the number of these fractures divided by the bulk volume of the corresponding grid block. Fracture intensity map extracted from geological interpretations of reservoirs. Fracture intensity expressed as:

$$FractureIntensity = \frac{\sum_{i=1}^{N} Area}{Volume} \quad (1)$$

Where, N is the total number of fractures that intersect the corresponding grid block.

B. Fractal Dimension

Fractal dimension is used to describe the self-similarity of discontinuous objects. This property is used in describing fracture characterization, which include fracture length, fracture growth, and branching in a fractured reservoir [22]. The fractal geometry concept relates the number of fractures (N_{Rad}) to size (Rad) by fractal dimension (D) and proportionality constant (C) through the following relationship:

$$N_{Rad} = \frac{C}{Rad^D} \quad (2)$$

There are different methods used to calculate the fracture fractal dimension, which include box counting, index spectrum method [23] and area perimeter method. In this study, a box counting method used to determine the fractal dimension to generate discrete fracture network based on a comprehensive statistical study of core and logs data. The fracture system is contained in a square area of length (L_o) and this area is divided into L_o^2 / l^2 boxes of side length (l) depending on the number of boxes $N(l)$ intersect with fractures or contain fractures (see Fig.1). $N(l)$ can be expressed as:

$$N(l) = \frac{C}{l^D} \quad (3)$$

By plotting logarithmic curve between number of boxes and $1/l$, then fractal dimension (D) value can be calculated from the slope as shown in (Fig.2).

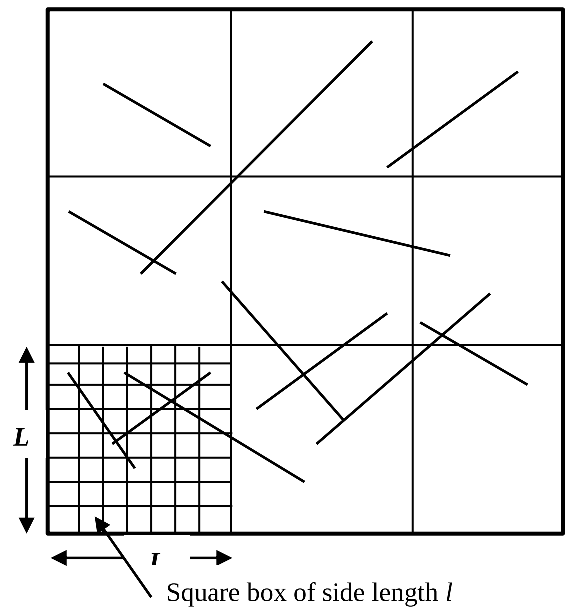


Fig. 1. Box counting method for solving fracture fractal dimension

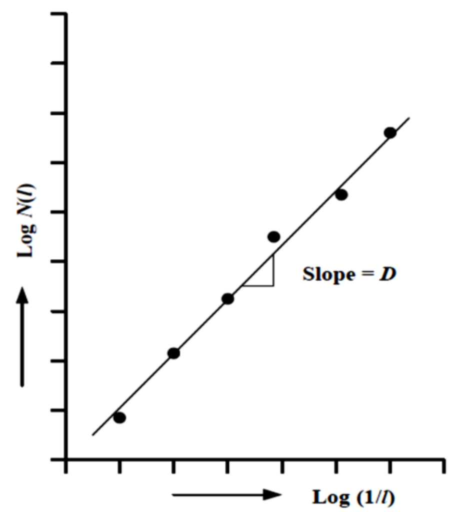


Fig. 2. Logarithmic plot for calculation fractal dimension using boxing counting method

III. DATA STATISTICAL ANALYSIS

3D fractures that have been generated stochastically using Gaussian stochastic simulation in which each fracture feature is generated based on the random realisation and it continues until the total fracture intensity and fractal dimension of the studied area are met.

Data related to fracture properties and pressure transient obtained from [22] and presented in Table I and Fig. 3. Formation Image Logs are available and used in the generation of subsurface fracture map. The main permeable intervals are divided into three zones: (a) zone (1) from 668 to 690 m; (b) zone (2) at 725 m and (c) zone (3) at approximately 760 m. Zone (1) has the major flow contributor and the remaining production is contributed by zone (2) and zone (3) (see Fig.4). PL results have proved that the fracture aperture and permeability existing in zone (1) are very high compared to other zones

The fracture sets are defined based on fractures dip, length, and azimuth. The initial data of fracture length and dip angles range from 9m to 60m and 70^o to 90^o respectively, and the fracture aperture ranges from 0.004 mm to 0.04 mm. Once the fracture set has been identified, it is used in the form of a fracture intensity plot.

Fig.5 shows the rose diagram for azimuth angles of the generated fractures, while (Fig.6**)** shows the histogram plot for dip angles of the generated fractures. The subsurface fracture map of the area (which include top, middle and bottom zone) around the tested well is generated by using the available field data of fracture intensity of 0.1m-1 [23] and the calculated fractal dimension of value (D =1.25) and presented in (Fig.7).

Fig.8 shows the optimised block-based 3D permeability tensors of the reservoir while Fig.9 shows the optimized generated subsurface fracture map that will used in the assessment of fractured reservoir potential. Fig.10 shows a good match between simulated and actual pressure data.

TABLE I. RESERVOIR INPUTS DATA

Property	**Value**
Dimensions of the reservoir	500m×500m×250m
Matrix permeability	9.865×10^{-16} m^2
Matrix porosity	2%
Fracture aperture	7.06×10^{-3}mm
Fractal dimension	1.25
fracture intensity	0.15m^{-1}
Initial reservoir pressure	34.9 MPa (5,063psia)
Injection pressure	54.9 MPa (7963.65psia)
Fluid viscosity	1.38cp
Fluid compressibility	10-8MPa^{-1}
Production time before shut in (tp)	72hrs
flow rate (shut in)	5571bbl/d

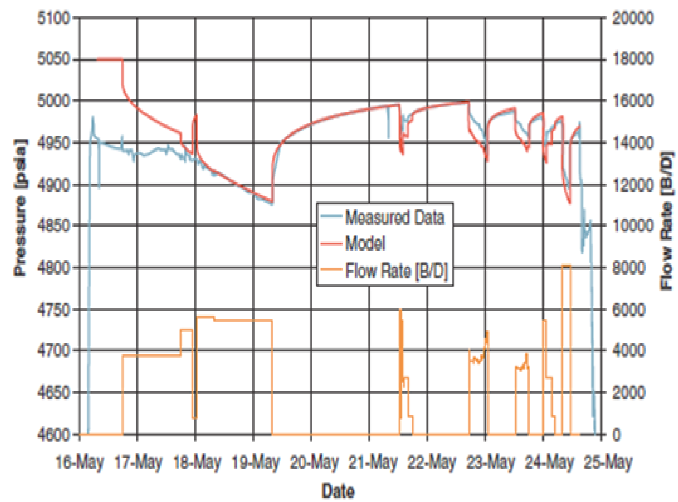


Fig. 3. Entire test history (DST test): measured and model data [22]; re-printed by permission of the Society of Petroleum Engineers)

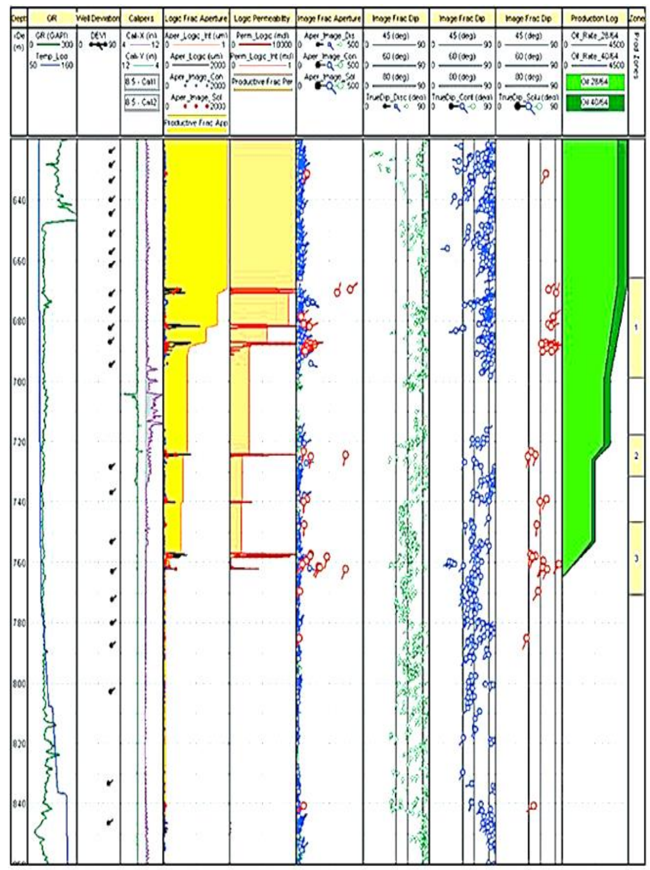


Fig. 4. Formation image and production logs for a typical basement well used for generating the discrete fracture network in the studied area ([22]; re-printed by permission of the Society of Petroleum Engineers)

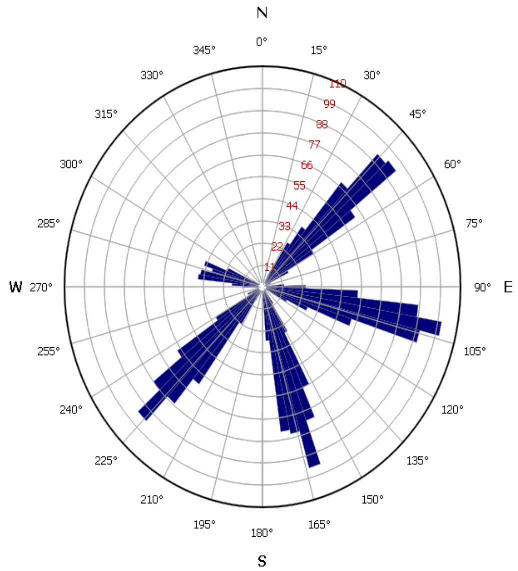


Fig. 5. Rose diagram of fractures azimuth angle

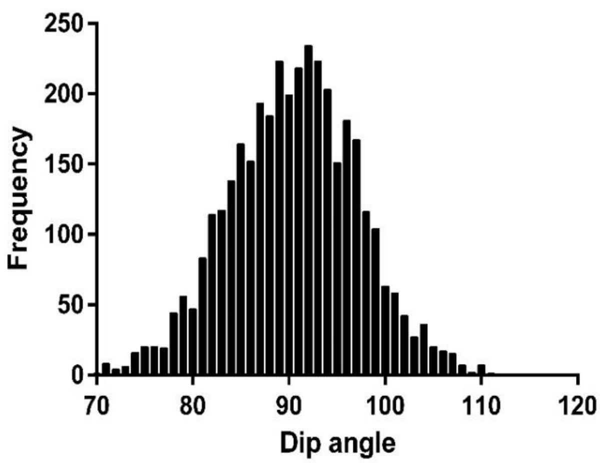


Fig. 6. Histogram plot of fractures dip angles (angles are ranging from 70^{o} to 110^{o} degrees). The plot is following the normal distribution function

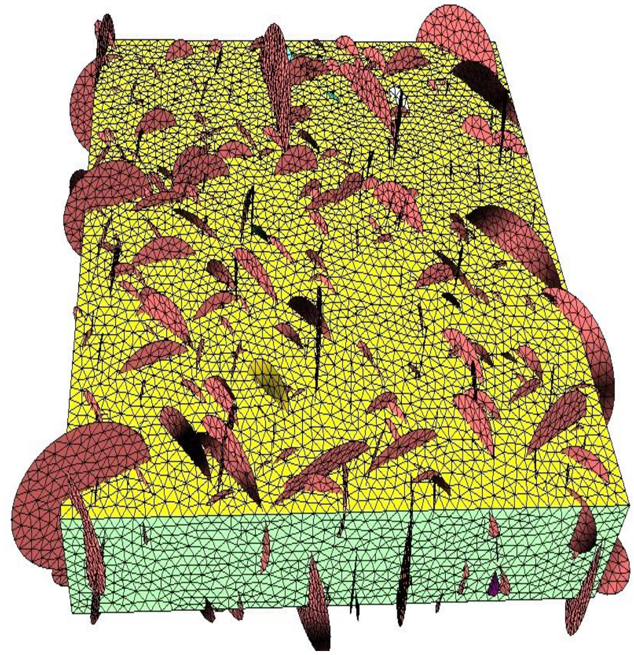
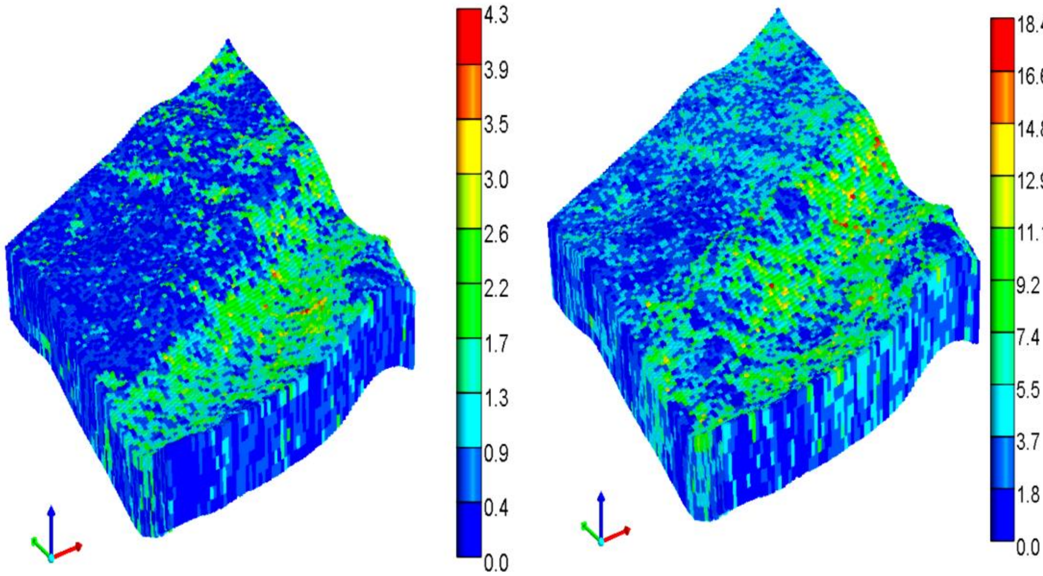


Fig. 7. 3D fracture map generated using object based model



(a) (b)

Fig. 8. (a) Initial block based RMS (Root Mean Square) permeability tensor and (b) Optimized block based RMS (Root Mean Square) permeability tensor

Fig. 9. (a) 3D optimized fracture map and (b) initial 3D fracture map generated in first realization

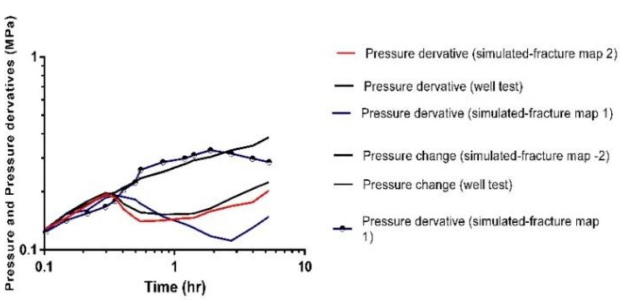


Fig. 10. Pressure change and pressure derivatives, this plot is produced based on hybrid approach

IV. Depletion Scenario

First, the drawdown test that was conducted in this reservoir is simulated for a period of 3 days of oil production. A production constraint of constant flow rate of 5571bbls/d is used to predict the drawdown pressure. From the results, it has been shown that the simulated well flowing bottom hole pressure before shut in (after 72hrs of oil production) is 4900psi which is very close to measured pressure (4880psi) obtained from DST (Fig.3). Then the evaluation of the production potential of this reservoir is performed under depletion drive mechanism using data in Table II. The producing well is slanted and intersected with a high fracture intensity blocks.

Fig.11 shows the pressure distribution after 3 days of oil production. Fig.12 shows the oil production rate for the producing well at constant bottom hole flowing pressure (31.8MPa). As shown in the figure that a sudden changes in oil production rate occurred and later the rate becomes steady. This is mainly due to the fact that at the beginning of the production process the fluids flow mainly through the fractures, which caused a sudden drop in wellbore pressure. Then, the matrix starts to feed the fractures network by fluid. During this flow period the oil production rate at the wellbore becomes very low and pressure starts to drop slowly. The calculated oil in place for the studied reservoir is 4.2MM bbl and the oil recovery for case of production under depletion drive mechanism is 1.25%.

TABLE II. RESERVOIR INPUT PARAMETERS USED FOR ESTIMATION OF OIL RECOVERY UNDER DIFFERENT DRIVING MECHANISMS

Parameter	Value
Reservoir dimensions	500m×500m ×250m
Fracture aperture (mm)	7.06×10^{-3}
Matrix porosity	2%
Matrix permeability (mD)	0.0095
Initial reservoir pressure (MPa)	34.9 (5060psi)
Bubble point pressure (MPa)	31.7 (4597psi)
Well Bottom hole pressure (MPa) (production)	31.8 (4612psi)
Injection pressure (MPa)	44.2
Initial water saturation	0.3607
Oil viscosity (cp)	1.37
Oil Density (kg/m^3)	899
Formation volume factor	1.3312
Reservoir fluid compressibility (MPa^{-1})	10^{-5}
Horizontal stresses (min &max) (MPa)	33.1 (4800psi)
Vertical stress (MPa)	41.3 (5990psi)
Young's modulus (GPa)	42
Poison ratio	0.28
Rock density (kg/m^3)	2800
Wellbore radius (m)	0.1

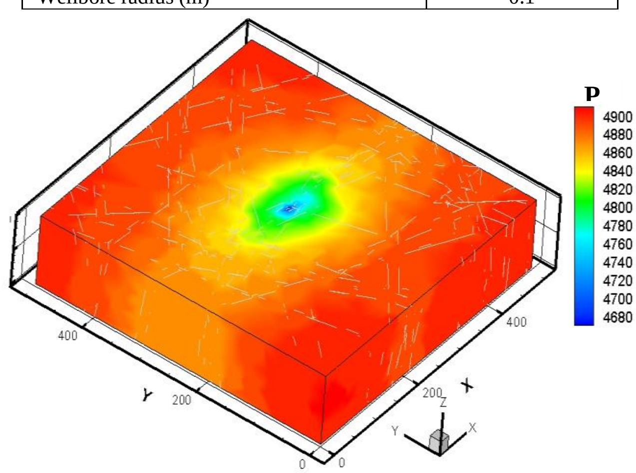


Fig. 11. Reservoir pore pressure distribution after 3 days of oil production with Pinit=34.9MPa, Pprod=31.8MPa σH =33.1MPa, σh =33.1MPa, σv =41.3MPa (depletion scenario)

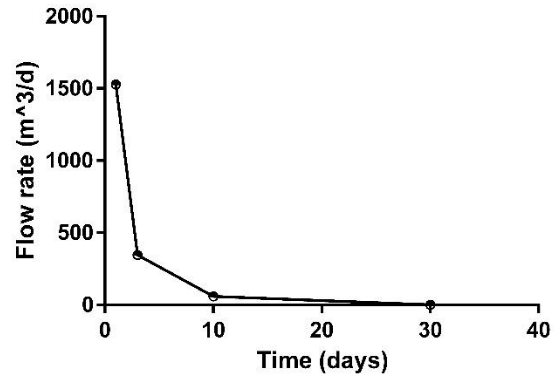


Fig. 12. Oil production rate under depletion drive mechanism with Pinit=34.9MPa, Pprod=31.8MPa σH =33.1MPa, σh =33.1MPa, σv =41.3MPa (depletion scenario)

V. WATER INJECTION SCENARIO

Injection of water into the reservoir started when the reservoir pressure is depleted. In this scenario, an inverted five spot pattern is used in which four producers are placed at the reservoir corners and one injector at the centre. Injectors and producers used in this case are vertical wells. Water is injected into the bottom of basement reservoir and oil produced from the reservoir top zone.

Fig.13 shows the oil production rate with time. As can be seen from (Fig.12) that the oil rate is decreasing sharply at the first 10 days of oil production and then the decreasing rate becomes slower. This attributed to the contribution of the injected water in supporting the reservoir pressure. However, the amount of injected water is not enough to compensate the production at the beginning of production process. Fig.14 shows that water cut production rate is very low until 10 days (time for water breakthrough) and then the increasing rate increasing rapidly. This is mainly due to the forming of water buffer near injection wells as a result of water injection at high injection rate. Thus, the water at the beginning of the injection process tends to stay near the injection wellbore region and form artificial water buffers. With continuous of water injection, large water buffers are generated and forming initially water/oil contact. Then, water starts to move upward by following the vertical direction, which resulted in increasing of water cut rate at later stages. Moreover, Fig.15 shows how history data of well (1) has been simulated successfully.

There are two groups of wells describe the dynamics of water cut production within the studied basement reservoir. The first group with rapidly increasing of water cut (well 2#, #3 and #4). In these wells (well #2, #3 and #4) , water cut curves have almost vertical trends which explain that these wells are intersected with high fracture intensity blocks (see Fig.15). The second group is a single well (well 1#) with low water cut due to low fracture intensity blocks surround the well.

In order to decrease the water production in this area, the bottom perforation of producing zones has to be shut or isolated. Therefore, in 2nd scenario, the bottom section of the four producers is shut (about 20 m) and the oil is produced from the upper perforated intervals (this is applied after 25 days of oil production). Fig.16 and Fig.17 show the water cut and oil production after shutting of the bottom perforations respectively. As can be seen from these figures that the water cut rate (for the four producers) increases till 25 days and then starts to decrease (see Fig.16). In addition, oil production rate (for the four producers) decreases sharply till end of 25 days, and then rates turn out to be steady (see Fig.17). The oil recovery in this scenario by end of 3 months of water injection is 40%.

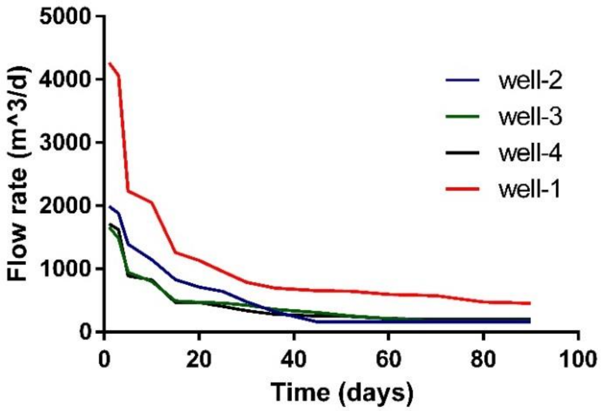


Fig. 13. Oil production rate under water flooding mechanism with P_{init}=34.9MPa, P_{inj}=44.2MPa, P_{prod}=31.8MPa σ_H =33.1MPa, σ_h =33.1MPa, σ_v =41.3MPa (1st scenario)

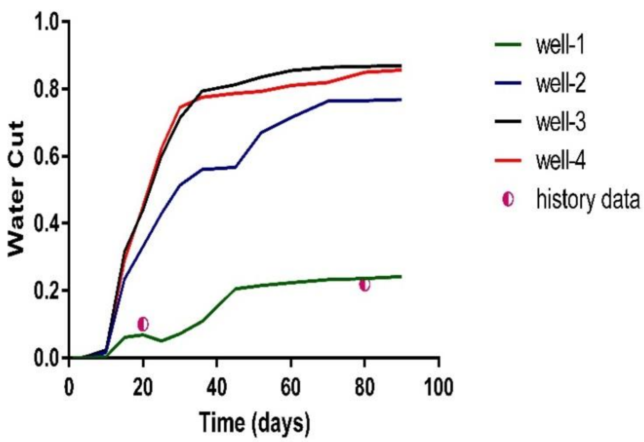


Fig. 14. Water cut at the production wells with P_{init}=34.9MPa, P_{inj}=44.2MPa, P_{prod}=31.8MPa σ_H =33.1MPa, σ_h =33.1MPa, σ_v =41.3MPa. (1st scenario)

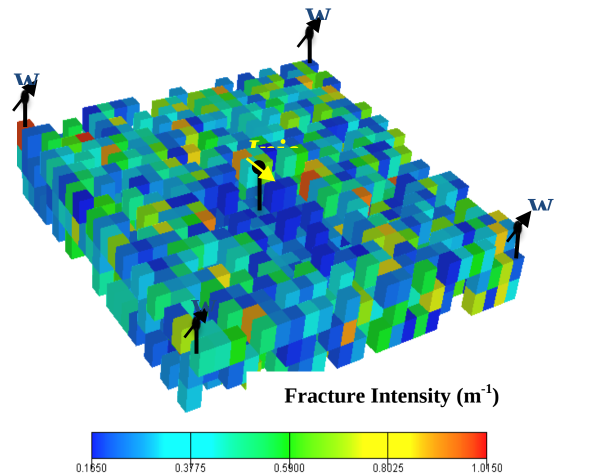


Fig. 15. Wells location and block based fracture intensity map for the entire reservoir region obtained by using the optimized block based permeability tensors the map is cut off by 0.165m^{-1})

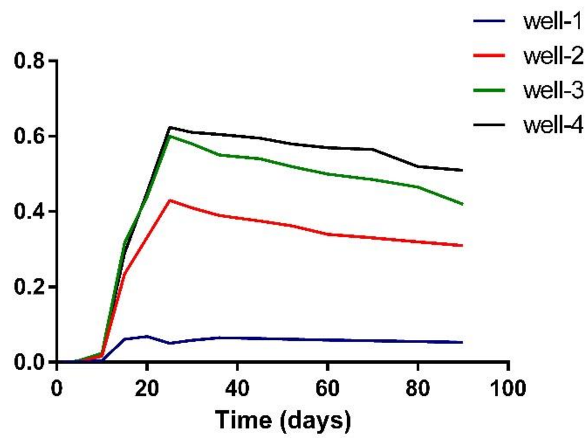


Fig. 16. Water cut at the production wells with Pinit=34.9MPa, Pinj=44.2MPa, Pprod=31.8MPa σ_H =33.1MPa, σ_h =33.1MPa, σ_v =41.3MPa. (2nd scenario)

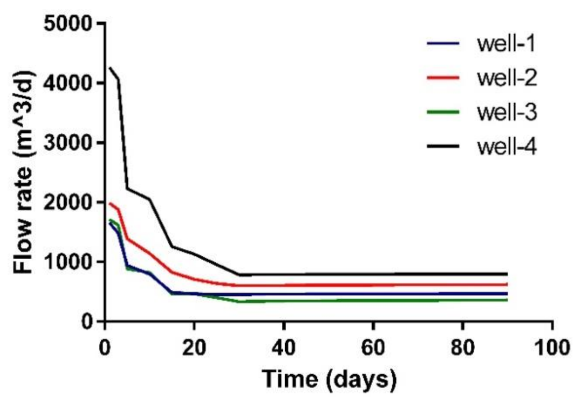


Fig. 17. Oil production rate under water flooding mechanism with P_{init}=34.9MPa, P_{inj}=44.2MPa, P_{prod}=31.8MPa σ_H =33.1MPa, σ_h =33.1MPa, σ_v =41.3MPa (2nd scenario)

VI. Conclusion

In this paper, the governing equations of single-phase fluid flow are derived from mass and momentum balance equations. These equations are used to simulate flows in discrete fractures and porous matrix media. The single-phase fluid flow is used as a forward fluid flow model in the history matching of well test data, and a gradient-based algorithm is used to optimise a sub-surface fracture map. The results show that the simulated well test data from the first realisation of fractures vary significantly (>2%) from the well test data.

A successful waterflooding can be achieved in naturally fractured reservoirs by understanding the geological characterization and fracture network system. Injection of water at the bottom section of these reservoir types will generate a large scale of water buffer helps in maintaining the reservoir pressure and significantly increase the oil recovery factor. Injector location sits in the reservoir centre (forming the five spot patterns) that concluded from the experience of developing the water flooding process in such reservoir types (Dang et al., 2011) and shutting the bottom perforations near water/oil contact tend to increase the reservoir sweep efficiency and the oil recovery factor.

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Secure Data Accumulation among Reliable Hops with Rest/Alert Scheduling in Wireless Sensor Networks

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***Abstract*—Wireless Sensor Networks (WSNs) are more inclined to attackers by outer sources. The total information must be secured to guarantee the uprightness and privacy. In sensor networks, the data collection and data accumulation are mainly based on the energy levels of the sensor hops. Due to the drain of the energy, at one particular point of time the sensor hops become obsolete and the data transmission will not take place. This research proposes a reliable and secure strategy with dependable hops utilizing own-key logic test with convention for sensor organization. This research work proposes to practice a few hops as dependable hops (Reliable-hops) to understand the insight nature of the nodes. With every hop, a secret authorization is shared among the sink and its neighboring hops. At this point, a network is developed for sending information to the sink hops in a progressive design. The hops encode the information by utilizing the secrecy authorization and advances to the next level in network. By improving the transmission structure of reliable-hops, the accumulated value was confirmed towards guaranteeing trustworthiness. The proposed system is demonstrated with various examples and carried throughout the paper.**

Keywords—Sensor Networks; Data Collection; Data Accumulation; Reliability; Security Key; Rest/Alert hops

I. Introduction

A wireless operated dedicated sensor / actuator system is a future innovation, has sought out a wide significant thought by the research and expert group. A few little, minimal effort gadgets constitute the sensor arrangement, which is really a self-sorting framework. Its primary capacity to show the actual nature of data to at least one sink hops [1].

In remote sensor organization, the fundamental operations performed are identified with checking the physical environment, detected data handling transmission to the specific aggregator hops. Consequently, outlining a productive convention for expanding the system lifetime is the significance in this vitality obliged framework [2].

Due to the positive elements of Sensor Networks, this framework is generally used in variety of areas. For example, robotization, medicinal applications, ecological checking, fire control system and movement direction etc...

In WSN, to save the energy and the lifetime of hops there are multiple strategies are available. One most quality oriented service is implemented by sleep/awake scheduling in the sensor hops. In many different WSN real time applications, the sensor hops should be able to communicate at much faster speed to send the adequate and necessary data to the sink hops. In this context delaying the data transfer due to any means will not be tolerated at any case. This paper broadly discussed about how to minimize the delay in propagation of data from one hop to another hop. [19].

A. Methods in WSN

In sensor network there are two primary jobs one to just collect the data from the hops and the other the accumulating the data from the hops. The data collection just collects the information from the hops and transmits directly to the centrally located sink hops. While transferring, the data collection will also sends the duplicate data collected by temporal or spatial collection methods.

The data accumulation works is on two folds: data collection and data accumulation. While collecting all the data from the hops, it removes the duplicate data before sending the data to its sink hops. Hence the data focuses on distributed data processing and energy conventions on the sensor networks and reduces the conflict of medium access layer in networks significantly [3]. Ease of use, Privacy and Flexibility are the significant qualities presented by data accumulation.

At critical situation, the vital use of the data collected by the accumulation process may be adjusted due to lack of creation as well as preservation of well-defined network construction. Nevertheless, such tactics are irrelevant because of the unstructured activities such kind of organic hazard, chemical venture and smoke fire, are some evident factor over choicest data collected by accumulation.

B. Different kinds of Attacks in Sensor networks data accumulation

Service Rejection: It is popular attack in WSN; it obstructs the wireless frequencies that send the wireless flags in communicating system. From the setting of accumulation, denial of service can appear as aggregator that decays the total detected information. Because of this, the final goal is not reached by the hop.

Different style of occurrence attack: In this attack, the aggressor spreads numerous personalities of the traded off hop. By creating different personalities, the attacker makes an approach to give extra information in favor of malignant collector hops in accumulation choice procedure and chooses the malicious hop as a collector. The attack actuates the most noticeably bad state of system.

Progressive Attack: Here the assailant took the control over the messages sent and received in sensor network by compromising the hop.

Repeat Attack: An intruder monitors the entire network routing and its traffic and keeps an eye over it, and then the intruder uses the same in different parts of the network by varying time to time. This assault misguides the collector that leads to network conflict. [4]

C. Security Requirements in Sensor Networks

Information Veracity: Information veracity is the procedure of empowering the communicated message is unchanged, unmodified, cracked or hacked by the assailants.

Information Secrecy: Information Secrecy is termed as the ability of the system to shields up the communicating data from the opponent over the transmitting medium. This feature supports to send the message in secret.

Information Readiness: Checks the capability of hops to use different resources and it finds suitable way to send the data in the available sensor network. To preserve a sensor network the readiness of the network is the critical part.

Information Precision: This shows the precision of value collected in the aggregator hops. Information precision is a benchmark for collecting information in data accumulation system.

D. Problem Identification

Generally in WSNs the data collection using accumulation is more liable to security threats. Due to security threats, the intruder tries to steal, divert and misalign the data as well as disturbs the flow of the network traffic. To overcome this, a novel idea is implemented by sending the data in a secured manner across the wireless sensor network.

In this paper, the idea of rest/alert hops are dependable and the effective output will be utilized in the present directing multiple data convention for the similar cases of wireless sensor transmission, for example, State Election Protocol. This rest/alert procedure is joined with the secured accumulation and the paper emphasizes a few hops as dependable hops (Reliable nodes) to screen the procedure of data collection through accumulation. As an expansion effort, this result gives a solution to the previously mentioned issues, and recommend to utilizing a safe and solid information accumulation system that use dependable nodes with rest/alert nodes for Wireless Sensor Networks.

II. Related Works

Prakash G L et al. [5] have proposed a total plan protection for data collection through data accumulation functions. The Cluster-based Private Data Accumulation (CPDA) influences logarithmic properties of polynomials and grouping convention. The aim is to overcome any issues among the data gathering by WSN and information protection. Furthermore, this method has crucially proved that they use minimum amount of transmission work.

M. Bahi et al. [6] have developed a protected information system works with a minimum vital key using elliptical cryptography on an end-to-end basis. Also, the plan permits the usage of maximum number of different tasks on encoded messages. It keeps the exact refinement among indistinguishable data within encoded messages. In addition, this method allows to use the minimum encoded keys, the key is so vital in the WSN.

Inria et al. [7] presented an encryption system that permits an effective data collection of encoded information. The security of their plan depends mostly on the attribute of a pseudo random function (PRF), a customary cryptographic method. On the way to ensure the uprightness of the collected information, the authors have developed a conclusion for total verification that is safe in contradiction of attackers. The projected method is reasonable for processing measurable qualities, for example, mean, difference, and standard deviation of detected information, while accomplishing huge data transfer capacity is achieved.

Huang [8] had projected a protected encoded data collection for remote sensor systems. Their proposed approach for data collection removes the duplicate sensor readings without utilizing encryption and keeps up information with high level of secret and privacy.

Ozdemir et al. [9] designed Data Accumulation and Confirmation convention, called DAC. The DAC is planned to incorporate wrong data location with data collection and classification. In order to cope the data collection with erroneous data identification, while observing hops of each information aggregator conducts data collection also generates tiny message authentic codes for data validation and verification. It also enables the high level confidential data transfer between two data collection hops on an encoded fashion rather than normal plain text.

Lin [10] proposes an n-dimensional strategy for protecting data privacy accumulation scheme in WSNs. The sensor has the capability of storing multiple values in the hops. By doing so, the energy used by the sensor hops will be retained for longer periods.

Zhijun Li et al. [11] put forth a method using the cryptic hash function to concise reasonable protected method of data collection by joining the with Bloom channel. This method is a powerful data collection method that is reasonable for a particular yet famous class in remote sensor systems. The preferred usage from secure Bloom channel, with no improbable presumptions, it satisfies the crucial security target of avoiding outside intruders internal hops from hurting the general system output.

Di Pietro et al [12] illustrated a method based on the idea of delayed data collection with peer checking of local hops. This method highlights the confidentiality and integrity of data collected through different data collection sensor networks. If the hops are under attack, then the hops will provide only the minimal numerical data, after detecting that the hops are under attack this provides a high security to adjacent sensor hop to protect the data loss from the attacked hops.

Haifeng Yu [13] has proposed a tree-testing method of calculation that specifically utilizes to answer the data collection inquiries and gives subjectively enhanced usefulness in connection to the existing secure data collection techniques. The primary favorable position fathoms an important key test examining by reducing the direct problems into mathematical based problems that uses logarithms as the process models. This method influences with certain properties of sampling viz., (such as nice and clean security techniques) to achieve the final stages of the goal proposed. By using a guaranteed sampling technique which eliminates the problems associated with sampling and thus making this approach an effective one when the number of inputs to the predicate functions is more.

Kavita Sharma et al [16] propose a method that will take into account, the energy levels of the hops prior creating the group hops. In this paper, concept of rest/alert method which uses the rest hops of high energy efficient and also high reliable source hops in the wireless sensor network transmission.

III. Suggested Solution

A. *The Insight Details of the suggested system*

Illustrated in a greater vision, this paper proposes to execute a safe data system with dependable hops utilizing key predicate test technique with rest/alert method for sensor systems. Consider all the sensor hops are static. A static sink is situated amidst the system hops. The hops equipped with full charge, hold the abilities to shift their charged levels to the adjacent hops. Every node detects the residual energy that it holds has the information to send to the sink station. The strategy practices a few hops as dependable hops which confirm the procedure of data accumulation. At first, by using stream cipher techniques, every hops produces a couple of keys, which is shared among sink station and adjacent hops. The data collector network is developed to send information to the sink in a multilevel structure. Accumulated data is encoded by utilizing secret code and advances to the next level. Prior sending data to the next data collector hop, the accumulated data value is checked with the data collected by reliable hops. If both data are equal, then the node is not under attack. If both data are not equal then the data by default becomes illegitimate, shows that the hops are under attack. The secrecy key is made available among neighboring hops, the possibility of hops to be traded off by intruder. Subsequently, hops with vital information key are kept at high vigil utilizing own-key predicate test. Hops that fulfills logic key test are set to red color and other different hops as yellow color. The hops which are marked by yellow color will not be considered for data collection and transmission of the sensor network.

B. *System Design of the Network (FRAMEWORK)*

Let us have the sensor network with n-number of sensing hops distributed in WSN sensing area. Every hop captures distinctive events. The captured data by the sensor hops by means of data accumulation are sent to the sink hop (Base Station) progressively. This method is utilized for the data collection and a network structure is built according to the sensor network. The network design is appeared in figure-1. All the hops are assumed to send the data to the sink hop within a random time period; subsequently, all the sensor hops are inherently works with synchronized clocks.

Data transfer Technique in WSN

The data transfer technique in WSN is majorly classified into three types, a Simple transmission design, Mmultilevel routing technique, Position based Routing techniques.

Simple transmission design

The basic class of routing protocol is the mutihop single transmission protocol. In single transmission protocol, every sensor hops coordinate to perform the sensing task in the sensor network. Due to multiple number of sensor hops, it is not possible to assign a common unique identifier to every hop. Due to the above problem which leads to a data centric routing in which the sink hops transmit signal to various areas and as well as in this particular areas, the sink hop anticipates for the data from the hops[17].

Multilevel Routing technique

The multilevel routing technique works with the concept of clusters in which every hop lies within WSN area are gathered together along with its adjacent hops creating a group called cluster. The data gathered by the sensor hops which originally belongs to the cluster are not sent to sink hops directly instead the data collected within that group creates a cluster head. The data collected are finally assigned to a group head that will send the data to sink hop. By doing so, the energy levels can be saved significantly. The multilevel routing techniques are divided into two major categories such as centralized and non-centralized routing techniques [20].

Position based Routing techniques

Sensor hops are location specific. Based on the signal strength, the adjacent hops distances are calculated. By reading the data of the adjacent hops, the data can be exchanged among adjacent hops either spatial or temporal [18].

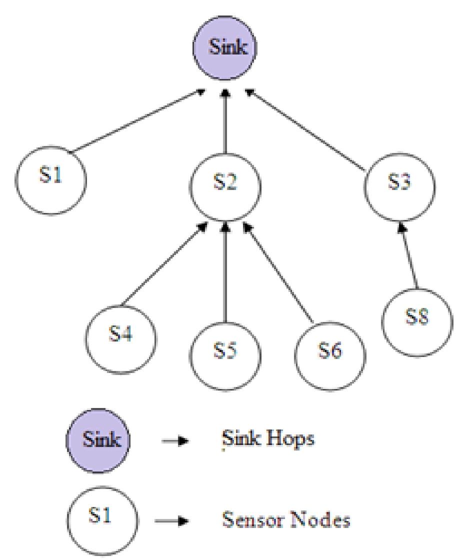

Fig. 1. Aggregation Tree Structure

C. Protected Key generation and sharing

At this point, it is expected that every hop creates a key stream utilizing SNOW [14] termed as stream cipher system. The secrecy key SKi is processed and imparted to sink hops and furthermore with adjacent hops. The pairwise key sharing technique is used to share Ski to its adjacent hops [15].

The network hops are helpless against security as information sent across the span of sensor network. The data collected from hops are sent over the sensor network are secured using probabilistic encryption function. Let's take KW () as probabilistic encryption function. Assume ZKi be the protected key and F be the data to be transmitted. At that point, KW () with m can be derived as,

$$\mathrm{KW}\,(F1, ZK1, m) = F1 + ZK1\,(mod\ m) \qquad (1)$$

Where m = modulo function

This additive homomorphic encryption scheme, used with probabilistic encryption function KW () is given as

$$KW\,(F1, ZK1, m) + KW\,(F2, ZK2, m) = (F1 + ZK1\,(mod\ m)) + (F2 + ZK2\,(mod\ m)) = F1 + F2 + ZK1 + ZK2\ (mod\ m) = KW\ (F1 + F2,\ ZK1 + ZK2,\ m) \qquad (2)$$

D. Data Collection with Reliable-hops

In these multilevel routing techniques, every hop can be either a data collector (Ai) or a Reliable hop. The hop Ai gathers information from numerous sensor hops (Si) in one level (a) of total network and advances to next higher level (a + 1). The detected information is sent from low level hop to the sink hop. The sink hop is the root.

After defining an aggregator (Ai) and Reliable node(R-node), an additional hop called as supplier hops (Pi) also defined, the Pi is used to collect data from the sensor hops and encrypts using the secret key ZKi and sends the data to the data collector (Ai).

With regular interval t, the supplier hops Pi (i=1, 2 ...n) is sending the data to the data collector node (Ai) in the specific three fold formats (PE_{Pi}, PR_{Pi}, PN_{Pi}).

Where,

$PE_{Pi} \longrightarrow$ Encrypted value of supplier hops P_i
$PR_{Pi} \longrightarrow$ received data collection value of P_i
$PN_{Pi} \longrightarrow$ Number of supplier hops

Taking the data from each supplier hop, the new accumulated value PNAi is generated. The PNAi is created will be defined as follows,

$$\mathrm{PNA_i} = \frac{\sum_{p=1}^{n}(\mathrm{PR_{pi}} * PN_{pi}^{-1}) + \sum_{p=1}^{n} PE_{Pi}}{n} \qquad (3)$$

Where n represent as $n = n_{p1} + n_{p2} + \ldots + n_{pn}$

During the calculation of PNAi at regular interval t, the any one of following two conditions can occur,

a) All supplier hops (Pi) at stage a will send data to collector hop Ai

b) A few supplier hops at stage a will not send its data to collector hop Ai

The data transfer from the supplier hops to collector hops will not take place when there might be no data transmission during that specific time interval. In that condition, the collector hop (Ai) includes secrecy keys (ZKi) of those sensor hops with new data accumulation function. At that point, KNAi is encoded by applying nonce value (N) and number of supplier hops (n).

Designing of Reliable-hop Set

The procedure of Reliable-hops helps to authenticate the exactness of accumulation function carried out by the data collectors. The Reliable-hops diagram is depicted below in Figure-2.

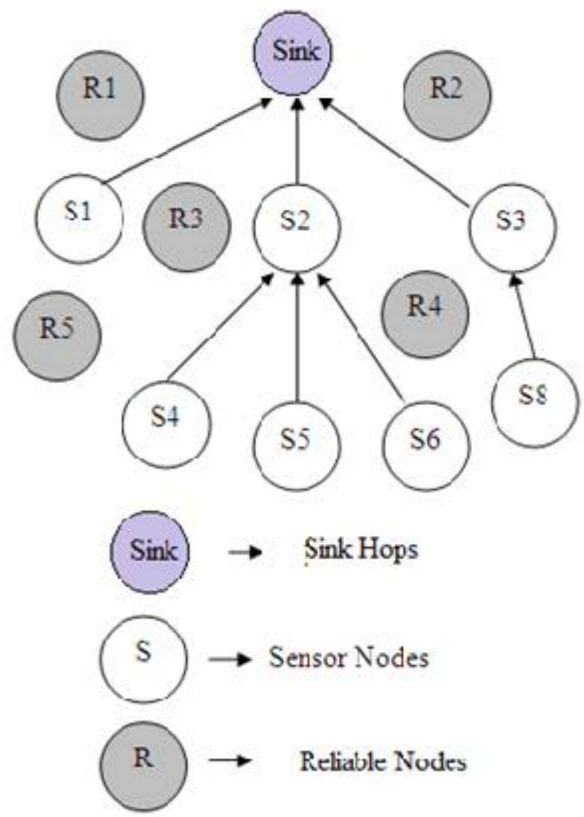

Fig. 2. Network with R-hops

The Reliable-hop set of data collector is indicated by Я (Ai). It incorporates the adjacent hops of Ai, which are not belongs to collection tree. The set (Ai) is made known to collector hops (Ai) and all Reliable-hops. This method ensures that all the supplier hops of (Ai) are equally known to all Reliable-hops.

Each elements of network hop is working under radio broadcast communication environment, every Reliable-node could catch the action of its adjacent hop. Similar technique is also used in data collector hops, every Reliable-hop can gather similar information collected by its adjacent data collectors.

Hence, this data collecting hop can assist Reliable-hops with verifying the collection procedure.

At the point when Ai is aggregating the data, the related R-node also collection the data, after time interval t, the gathered data of Ai and Ri are checked for equality. On the checking the data of Ai and Ri, the output of the hops are genuine only if both Ai and Ri are equal. If they are not equal, then the output of the hops are not genuine and the hops are under attack.

Design of working model -1

Let PNAi be the accumulated value of Ai

And Ri be the dependable node of Ai and PNRi be the data collected of Ri

In the event (PNAi = PNRi)

Here verification is true, Hops are authentic

Otherwise

Authentication is false, Hops are not authentic

In the situation when supplier hops of Ai are inside the scope of Ri, then the data collection verification process will take place by the approach given above. At this point, within the scope of transmission, when Reliable hops does not have straight communication with supplier hops of Ai, and then Ri plays out the data collection within maximum two hops.

E. Own-Key Logic Test

Illustrated in section 3.3, every hop has a secrecy key and that is shared between the sink hops and the adjacent hops. There are chances that hops can compromised by the intruders by false key, making the entire network under attack. Meanwhile a time interval t, the sink hops cross examine the secrecy key of the sensor hops for the exactness. In order to achieve this process, the sink hops uses a test called own-key logic test.

An own-key logic is defined as, $KP(S_p) = KP(S_q)$ (4)

p and q are data inputs and S is the number of device-sensors. The design makes use of two colour to explain (red and yellow) as two input data. By the outcome of own-key logic test, hops are set apart with different color. Hops that fulfill the own-key logic test are colored with red and hops which do not fulfill the own-key logic test are colored in the yellow.

At first, all hops remain uncolored. Hops having the key ZKi need to fulfill the test called own-key logic test. Consider every hop has different name as per their key value. Rather than utilizing the key deliberately, the sink uses distinct key parameter name given to sensor hops. As the initial stage of own-key logic test process, the sink communicates own-key logic communication to all hops in the system. The communication message incorporates the hops key name ZKi, the nonce value (N), the own-key logic and Message Confirmation Code (MCC) of N

$$\text{Sink hops} \xrightarrow{message} \text{All hops}$$

The sensor hops containing the secrecy key satisfies own-key logic test, sense the data back to the sink hop as a mark of reply. It is already discussed that hops are marked with red and yellow color to define the authentic and non-authentic hops respectively. After transmitting a message from own-key logic test the sink hop waits for a period of time, t, comes to the conclusion, whether the data sent by the hops are authentic or not, by differentiating the input color of the hops. The following is presented well in figure 3.

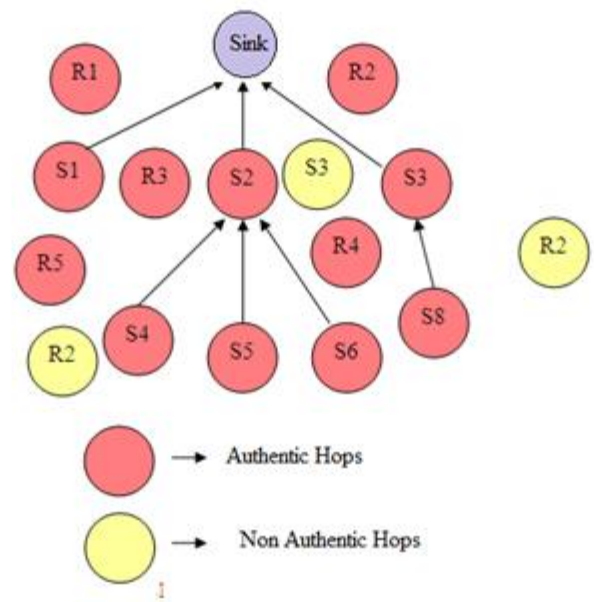

Fig. 3. Own-Key Logic Test

In the above figure 3, clearly illustrates the own-key logic test procedures. Hops with red shades are accumulated into the data collection system and hops with yellow shade will be discarded.

Design of working model -2

The proposed work plan to be incorporated (ALGORITHM -2)

A static sink is situated at the network's center

Hops were enriched by suitable electrical abilities can differ with the broadcast energy.

Each node detects network by the speed and dependable information send to the sink.

1) The data broadcast channel should be balanced. Hence, the power needed to send a data from input to a goal hop is the same as the power needed to send a similar data starting from the goal hop to input hop for a given Signal to Noise Ratio (SNR). The data transmit by the hop does not need retransmission because the broadcast environment is high contention and error free.

2) Let assume the sensor hops are scattered over the network in a random manner. Let u hops are in the network, out of that a small number of hops, termed as t hops are set with more energy in the multiples of α than the rest of the hops. The high energy hops termed as hi-energy hops and the rest hops are called as normal-hops, given by the formula (1-t) x u.

3) To begin with, the initial energy of the normal-hops is set to Ko. The energy for hi-energy hops can be calculated by using the term Ko x (1 + α). The entire aggregate strength of the new varied setting is equivalent to: u * ko * (1 + α * t)

So by using the term (1+ α * t), the overall energy of the system is increased so that there will be a high reliability of data transfers within hops.

a) Every hop which termed as normal hops will be converted into a group head hop after each pt * (1+ α * t) times; here pt means prob. to the group head hops.

b) Every high-energy hops will be converted into a group head precisely (1 + α) times at each one pt· (1+ α * t) iterations

c) The average number of group top hops / cycle / time period = u × pt

4) The selection of group head for the normal-hops is based on the following formula

$$T1(S_{nrm}) = \frac{P_{nrm}}{1 - P_{nrm}.\left(r\ .\mathrm{mod}\frac{1}{\mathrm{Pnrm}}\right)}$$

$if\, snrm \in \mathrm{H}G'$; normal – set of normal hops

0 $otherwise$ eqn (1)

Where r is the present cycle,

HG’ - set of normal hops that are not able to be the group heads till the last $\mathbf{1}/\mathbf{P}_{\mathrm{normal}}$rounds,

T1 ($S_{\mathbf{n}\mathrm{ormal}}$) is the value of threshold applied to the accumulated population by the factor u x (1 − t) (normal) hops.

This above formula ensures that every normal-node will turn into a group head precisely under every (1.0/ pt) x (1+ α * t) iterations/cycle, and the average number of group head hops which are normal-hops per round is equivalent to n x (1.0 − t) × pnormal.

5) The Selection of Group head hops for high-energy are calculated by the formula cited below:

$$GT2(GS_{progressivenode}) = \frac{GP_{progressivenode}}{1 - GP_{progressivenode}.\left(r\ .\mathrm{moduulus}\frac{1}{\mathrm{GPprogressivenode}}\right)}$$

Sprogressive nodes ∈ HG'' ;

GSprogressive node – set of advance or next hops in the network

0 $otherwise$ eqn (2)

Where HG'' is the set of hi-energy hops that are not able to be the group heads within the last GPprogressive node iteration

GT2 (GSprogressive node) is the value of the threshold applied to the populace of u x t (high-energy) hops.

This above formula ensures that each high-energy hop will turn into a group head precisely at every (1/pt) x (1+α * t) / (1+α) iterations.

6) In the view of conditions cited above, hops transmit the data value /information to their group heads and the energy utilized by the hops are ascertained as

J**node** = **k**. (J**Tx**. (**l**, **d**) + J**amp**) eqn (3)

7) The accumulated data will be collected and transmits to the sink hop by the group heads and energy utilization by the hop shall be figured out for every hop and every group head.

J**cluster** = **k**. (J**Tx**.(**l**, **d**) + J**Rx**.(**l**) + J**DA** + J**amp** eqn (4)

8) By utilizing the probability conditions, in next cycle, the normal-hops will be converted to be group head hops.

9) By determining of the group head hops, Hops transmit the information to their group head hops, chosen by the criteria of having the relatively smaller distance of a specific hop of the group head and the energy utilization can be computed.

*10)*Group head hops shall sum up the aggregated information and transmits it to the sink hop and the required amount of energy can be calculated.

*11)*Certain numbers of the hops say “q hops” will put under the rest mode to improve the sensor network’s life span and also to preserve their energy levels which are less than 1 Joule. In event that the more numbers hops are required for data transmission , then the nodes are brought in to dynamic action from the rests state to dynamic active state that directs the information to adjacent group head hops.

*12)*This procedure will go through the entire system until the said performances are reached in the data transmission.

IV. ADVANTAGES OF THE PROJECTED STRUCTURE

With the implementation of reliable node, it can able to track the intruder and locate the attacked hops.

By comparing the data values of both accumulated data and the data in the reliable hop with the key values, it could reach the maximum accuracy of the data being transmitted, makes the data under secured transmission,

By implementing the own-key logic test, the keys are accurately validated leaving no room for nodes comprising under keys.

Using rest/ awake strategy in secured data transfer in the Wireless Sensor Networks, hops lifetime, the residual energy will be maximum and the lifetime Performance will be more for the information to be transmitted.

A. Setup required for model design

Description	Values
Total No. of Hops	50
Size of the area	700 X 700
MAC address	802.11
Imitation Time	30 sec
Transportation Source type	CBR
Capacity of Each Packet	512
Transmit Power in watts	0.661 w
battery Power received in watts	0.396 w
battery Power in idle state in watts	0.036 w
Energy at initial stage measured in joules	10.1 J
Range of Transmission	75m
Total base stations	2
Total number of sources	4
Total number of data collector hops	6
Node values	Multiples of 2 and more..

B. Measuring the Quality Factors

Normal data Distribution Ratio: Proportion to the incoming data packets over the aggregate amount of data packets sent.

Power Consumption: It is the normal setup, that every hop will consume battery power for transfer of data to its neighboring hops, receiving data from other hops or any kind of service that took place in the network.

Data Loss/Failure: It's clear, that the normal amount of data packets / parcels failed to reach data collector hops because of attacks carried out by assailants.

C. Outcomes and Outputs

A detailed comparison is made through a graph for the different levels of attackers with various operational overheads such as assailant with packet drop and delivery, amount of power and energy used etc. The assailants are taken in multiples of 2… and so on.

The performance, quality factors are compared with the existing algorithm which works secured data transfer with reliable hops are compared with secured data transfer with sleep/ awake hops methods are illustrated as follows.

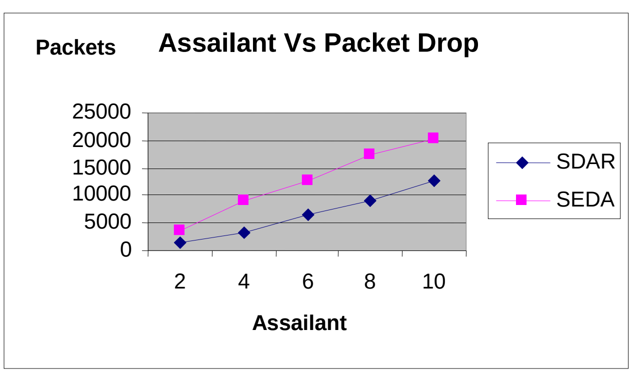

Fig. 4. Assailant Vs Drop

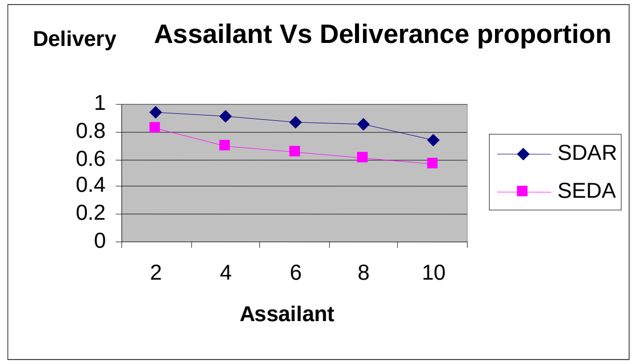

Fig. 5. Assailant Vs Deliverance proportion

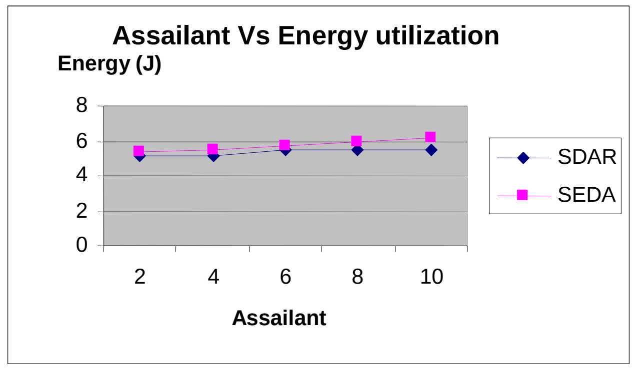

Fig. 6. Assailant Vs Energy

V. Conclusion

This research framework proposes the concept of rest/alert methodology to secure the data accumulation using own-key logic test with reliable hops. Here the hops are put to sleep and whenever it is needed they are dynamically activated, thereby save the energy of the hop tremendously. Using the above said framework, it is possible to compare the reliability and saving the energy on hops with some of the existing routing protocols. In this proposed work, certain hops as reliable hops that look after the job of the data aggregator. Between the hops and the sink hop, a secret key to be shared and all the hops know the value of the keys. After sharing, a tree is generated to transmit the data in a multileveled manner to the sink hop. The data collector hops encodes information utilizing secrecy vital key and advances to a next stage in collection network. The data collected by the reliable hops are checked for consistency and integrity by increasing the transmission attribute of reliable hops. The validity of the key is checked using the own-key logic test. By simulation, this strategy is finally demonstrated. The result proves there is a subtle increase in the data delivery ratio, thereby minimizing the data packet loss considerably. As a future work, this research can be extended with the implementation of dynamic robust key management system for securing sensor hops which have a greater impact in saving the hops from the intruder attacks.

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Human Gesture Recognition using Keyframes on Local Joint Motion Trajectories

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***Abstract*—Human Action Recognition (HAR) systems are systems that recognize and classify the actions that users perform against the sensor or camera. In most HAR systems, an input test data is compared with the reference data in the database using various methods. Classification process is performed according to the result obtained. The size of the test or reference data directly affects the operation speed of the system. Reduced data size allows a significant performance increase in system operation speed. In this study, action recognition method is proposed by using skeletal joint information obtained by Microsoft Kinect sensor. Splitting keyframes are obtained from the skeletal joint information. The keyframes are observed as a distinguishing feature. Therefore, these keyframes are used for the classification process. Keeping the keyframes instead of keeping the position or angle information of action in the reference database can benefit from memory and working time. The weight value of each keyframes is calculated in the method. The problem of temporal differences that occur when comparing test and reference action is solved by Dynamic Time Warping (DTW). The k-nearest neighbor's algorithm is used for classification according to the obtained results from DTW. The sample has been tested in a data set so that the success of the method can be tested. As a result, 100% correct classification was achieved. It is also suitable for working at real time systems. Breakpoints can also be used to provide feedback to the user as a result of the classification process. The magnitude and direction of the keyframes, the change in the trajectory of joint, the position and the time of its existence also give information about the time errors.**

Keywords—Human gesture recognition; dynamic time warping; local joint motion trajectory; Human action recognition; microsoft kinect

I. Introduction

Human Computer Interaction (HCI) is one of the areas that have been working hard in recent years [9]. HCI is directly interacting with human actions. Functions of monitoring, controlling and analyzing using human movements can be realized. Elderly and child individuals can be prevented from falling into dangerous situations by being kept under constant surveillance [11]. Controls of machines or robots can be provided by human actions. Analysis can be made by following the development process of the athlete or orthopedic patients. This and many other applications can be cited as examples of HCI issues [24]. Due to the increased sensitivity of the hardware that can be used in the HCI field, the accuracy and accuracy of the developed applications is also increasing. The quality of human life can be increased directly through the applications made on this area. As the main motivation of researchers in HCI field, positive contributions to human life can be shown.

Human Activity Recognition can be shown as a subdivision of the HCI field. Computer side developments provide positive contributions directly to the work done in this area. HAR is a method of recognizing Human Actions using various algorithms in the computer environment via cameras and sensors. As the accuracy and performance of the devices and equipment used in the process of recognizing the action increase, the availability and diversity of the work done increases. The development of RGB-D cameras in recent years and the increased sensitivity of these cameras have led to the use of many important field recognition actions [2]. New researchers have been working on this field, especially with interesting studies in health, safety, smart home systems, surveillance and control areas [3]. The most important advantages of HAR systems are that they can restore the motor skills of the person, make the physical therapy and rehabilitation exercises more feasible, and provide a fun environment [4].

During the Human Action recognition process, people perform their performance in front of the camera or sensor. This performance information is transferred to the computer environment through the hardware. Thanks to the sensors on the hardware, a 3D depth image can be obtained with RGB image. This data, called RGB-D, has become popular in the field of pattern recognition. In this way, the position information of the objects or persons on the real world can be reached. The important thing is that these 3D data can be obtained with low cost hardware.

With the widespread use of low-cost depth sensors, the number of human action recognition efforts using depth maps has also begun to increase [5]. Detection and classification of dance figures using the Kinect sensor can be performed in real time [6]. In drumkit simulator application, recognition and classification of drumkit actions can be realized in real time using kinect sensor [7].

Skeletal-joint based human gesture or action recognition applications use depth maps. Thanks to these depth maps obtained from depth cameras, skeletal-joint representation is used. Coordinates of joint points are used directly or indirectly in this field work. As the simplest and basic feature, the distances between the previous frame and the next frame can be used with reference to a coordinate system of the joints [8].

Changes in joints made in 3D space can also be used as a distinguishing feature [9]. Action recognition can be performed by using joint-joint angles joint-plane angles[10]. Various features are used as input parameters in human action recognition systems. The purpose of using different features is to get higher performance with higher accuracy. Using these features, many methods have been developed in the field of human action recognition. (HMM), Dynamic Time Warping (DTW), Support Vector Machine (SVM), Neural Networks (NN) [14], Logistic Regression (LR) [6], Adaptive Bayesian Models (ABM) [15], k-nearest neighbor (knn) [23] are the most commonly used methods in this area. These methods use human-joint representation as input parameters in human action recognition applications.

As the dimension of human-joint representation used as input parameter in human action recognition systems increases, the performance decreases. Joint-joint-based matching algorithms are not suitable for real-time applications due to this reason. Dimension reduction methods such as Principal Component Analysis (PCA) [16] and Linear Discriminant Analysis (LDA) [17] can be used to remove this problem altogether. Another solution is to use features with less size instead of using all the joint information from the position information in the human body skeleton representation. Instead of the trajectory of all body joints, action recognition can be performed using the trajectory of hand joint and the shoulder position [7]. The use of only significant joint trajectory rather than using all the joint information, can provide a significant increase in performance. Action recognition can also be performed by normalizing the angles of local joints and applying them as input to modified spherical harmonics (MSHs). The obtained information creates the angular skeleton system of action in the light. Then the joints in this system can be represented by the spherical coordinate system unit sphere function [18]. An action recognition system can also be realized by using the features of the most important and most informative joints in the series of joints that constitute an action [19].

In this study, local keyframes in the trajectory of the skeletal-joint positions were determined and used as input parameters in the comparison process. The local keyframes that make up the reference action and the local keyframes that make up the test action are compared using the DTW method. The obtained comparison results are applied as an input to K-NN classification algorithm and classified. The keyframes that make up an action have a distinguishing feature for comparison. By means of these keyframes, the errors between the reference action and the tested action can be determined in terms of time and amplitude and feedback can be provided to the user. It is suitable for real time operation due to its low memory requirement and high operating speed.

II. PROPOSED STUDY

In the action recognition process, the user performs his / her performance against depth cameras such as Kinect v2 sensor. Kinect sensor determines 20 joint position according to the user's skeletal joint representation. Each joint transfers its position over 3D space (x, y, z). According to the user's movements, these 20 joint position are kept in computer memory. The transfer is repeated 30 times per second [20]. The input parameters for action recognition applications are the series of joint position obtained as a performance result. Properties are extracted by performing various operations on the body joints sequences. The comparison is carried out by holding these properties in the test and reference motion sets. The test movement is then placed in the appropriate class. The block diagram of the system used to perform the human action recognition in this study is shown in Fig 1.

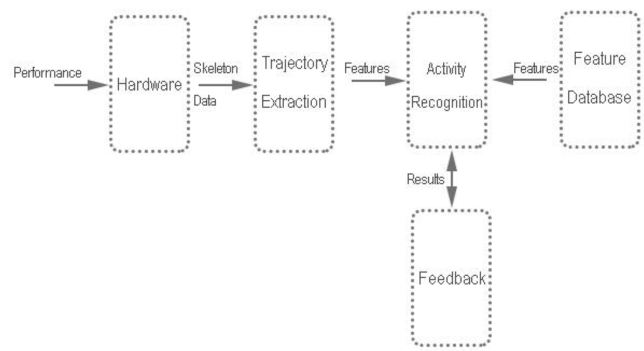

Fig. 1. General structure of the system

In a system with a total of 5 blocks, the flow is performed in sequential order. The performance information performed by the user as an input to the system is applied. This performance information is presented as feedback in the form of action information on the user through the devices and software.

A. Hardware

The part where the camera or sensor (e.g. Kinect) is used. In this section, user actions are performed in front of the sensor. The sensor creates a 3D depth map using the 2D images it receives. With these 3D depth maps, the position information of the joints of the person performing the action is obtained. The position information obtained is formed from the joint points shown in figure 2.

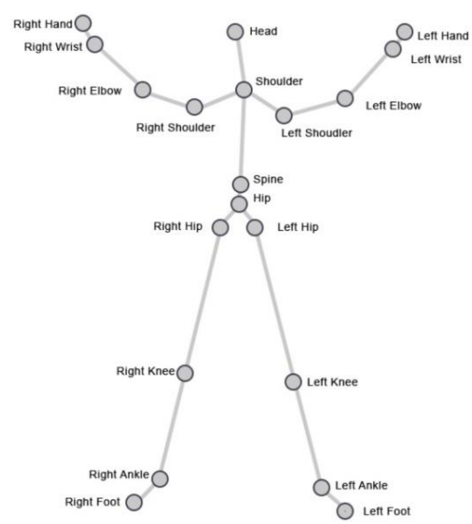

Fig. 2. Kinect Skeletal Joint Representation

This location information is transferred to the next block diagram in the form of skeleton data.

The positional information of a sample joint coordinate value (Right Hand Z coordinate) is shown in Fig 3. The action consists of a total of 48 frames.

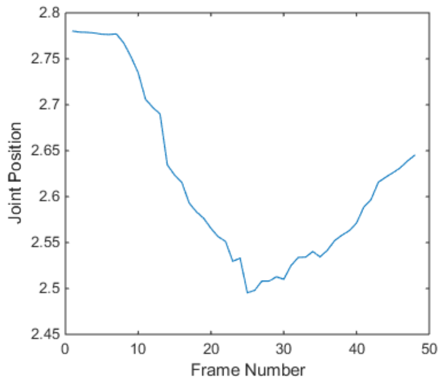

Fig. 3. Joint Coordinate Curve

The position $P_{i,t}$ of any i at any time t is kept in the series $P_{i,t}^{x}$ represents the position of the joint in the x coordinate system.

B. Local Breakpoint Extract

In order for the action recognition process in the system to work, it is necessary to detect the breakpoint first. The input time series used in this detection process is F^{p}. For the 20 joint points in the F^{p} time series, there are 60 pieces of coordinate information on the 3D coordinate plane.

$$F^{p}(t_0 : t_n) = < P_{i,t}^{x}, P_{i,t}^{y}, P_{i,t}^{z} > \qquad (1)$$

For each coordinate (*x*, *y*, *z*), coordinate information of each joint is applied as input to the system via hardware and API. The time series F^{d} holds the change value in each frame of the input series F^{p}.

$$F^{d} = F^{p}(t_{i+1}) - F^{p}(t_i) \qquad (2)$$

F^{bp} time series holds the local minimum and maximum values for F^{d} time series. a is the starting minimum for the local minimum point, b is the ending point. In that case;

$$F_{i,t}^{bp} = \sum_{j=a}^{b} F_{i,j}^{d} \qquad (3)$$

$$F_{i,t}^{bpp} = \begin{cases} t, & F_{i,t}^{bp} > F^{T} \\ 0, & otherwise \end{cases} \qquad (4)$$

The obtained $F_{i,t}^{bp}$ and $F_{i,t}^{bpp}$ features F_{i}^{b} are the keyframes. $F_{i,t}^{bp} i.$ the size of the fracture point of the joint is kept. If $F_{i,t}^{bpp}$, the frame number of the fracture point of the *i-th* joint is retained. Thanks to these features, we have information about each action. $F_{i,t}^{bpp}$ gives information about the time of the change in the relevant joint, while $F_{i,t}^{bp}$ gives information about the magnitude of these changes. If the magnitude of this change is smaller than the threshold value F^{T}, no breakpoint is added. The threshold value can be selected according to the feature of the system to be applied manually, or it can take different values according to the given data set such as average, average of positives, average of negatives. In this work the threshold value is set manually.

Many features can be obtained from skeletal information. Speed of movement, direction of movement, acceleration of joint, etc. We can obtain information from this skeletal knowledge. At the same time, when we examine all of this skeleton information, certain moments (frame intervals) can make more sense in terms of motion. In this study, these points are called break points. Figure 4 shows the fracture points of the joint points given in Figure 3. The break points feature allows you to determine which class the motion belongs to, without examining the entire time series that makes up the movement.

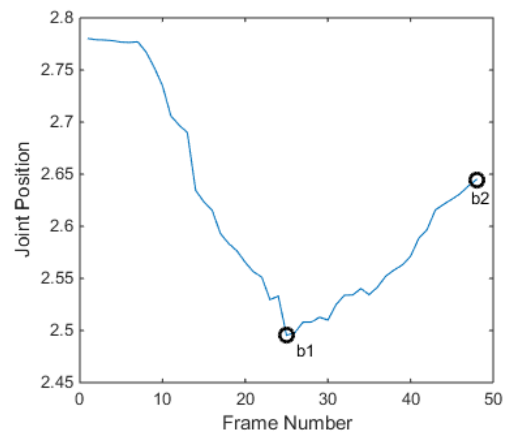

Fig. 4. Detection of break points

C. Feature Database

A reference training set is needed for the recognition or classification of movements. The performance characteristics are determined by comparing the characteristics of each reference movement in the training set. Generally, in order to be able to represent a movement in the database, recording may include position information of all the joints, as well as the only necessary features. In this way, the size of the database can be reduced. The feature database in this study contains only the required breakpoint properties instead of all the joint points.

D. Gesture Recognition

The breakpoint property information obtained from the performance performed by the user is compared with the breakpoint property information of the previously recorded actions in the database. Error rates and similarity ratios are calculated after comparison. As a result of this information, theaction class to which the performance belongs to is determined.

The properties obtained from the time series that are obtained as a result of the performance performed by the user are compared with the property values calculated by the only one-time algorithm in the database. Similarity and error rates of actions arise as a result of this comparison process. In Figure 5, when the same action is performed by different users, the change graph and fracture points at the same joint points are given.

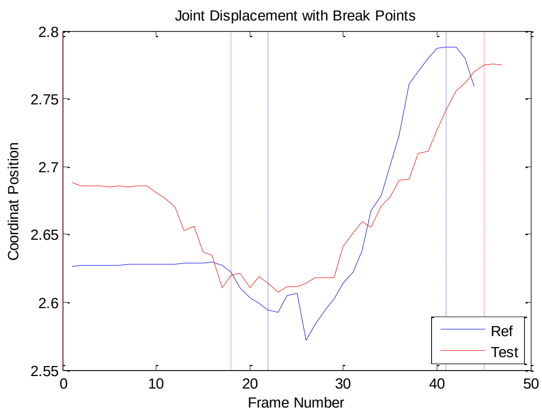

Fig. 5. Break Point Detection

It can be said that the action is similar but only the temporal shifts are observed.F_i^{td}The time shifts for the *i-th* breakpoint represent the errors in terms of amplitude for the *i-th* breakpoint. These values can be calculated for each time interval to find total slip and total error.

$$F_i^{ad} = F_{i,t}^{bp_x} - F_{i,t}^{bp_y} \tag{5}$$

$$F_i^{td} = F_{i,t}^{bpp_x} - F_{i,t}^{bpp_y} \tag{6}$$

x represents the person performing the reference movement, y the person performing the test movement. Direct comparison of acquired error information may not always yield accurate results. All breakpoints must match one another in order to give correct results. An erroneous hand movement, either at the beginning of the movement or at the time of its actualization, may cause the entire movement to be marked incorrectly. In such cases, we can provide the correct operation of the system with the DTW method. For this, it is tried to find the minimum distance between the series of reference breakpoints and the series of test breakpoints. By calculating the total cost computation according to Bellman's principle in total cost computation [21], the cost between two movements is found.

$$D_{i,j} = \min \begin{Bmatrix} F_{i,t+1}^{bp_x} - F_{i,t}^{bp_y} \\ F_{i,t+1}^{bp_x} - F_{i,t+1}^{bp_y} \\ F_{i,t}^{bp_x} - F_{i,t+1}^{bp_y} \end{Bmatrix} + \mathrm{d}(\mathrm{i}_k, \mathrm{j}_k) \tag{7}$$

Figure 6 shows two joint trajectory and local keyframes. For the reference action, at the keyframes in the joint trajectory t_1, at the fracture point t_3, instantaneously for the test action. The time shift t_{diff} can be calculated by taking the difference.

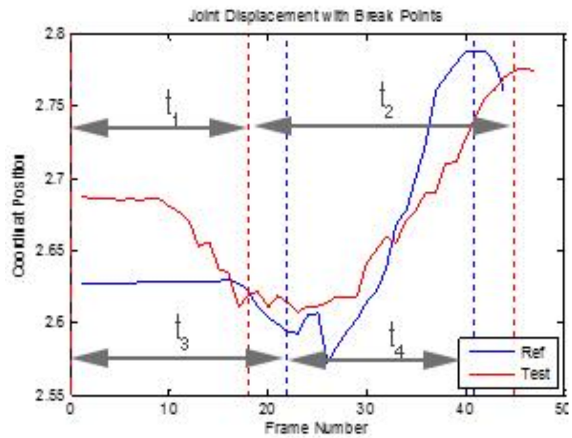

Fig. 6. Temporal shifts and amplitude difference

Not all joints move equally during an action. So while classifying it will not have an effect at the same time. To do this, each insertion must be assigned a weight value. In this study, as a function of weight, the ratio of the total change value of each joint to the total change value of all movements is found. Thus, each joint has its effect on the change value.

$$F_i^w = \frac{\sum_{t=1}^{n} \left| F_{i,t}^d \right|}{\sum_{i=1}^{i=n} \sum_{t=1}^{tn} \left| F_{i,t}^d \right|} \tag{8}$$

$$F^{err} = \sum_{i=1}^{n} D_{i,j} * F_i^w \tag{9}$$

The error value we will use for classification is F err. When classifying the test movement, the error values of all reference movements are calculated. Then classification is done using the k-nn algorithm.

E. Feedback

At the same time, the time shifts and joint faults for the detected class are presented to the user as feedback. Time shifts are temporal differences that occur as a result of fast or slow realization of action. Joint defects are the points that the joints have to reach or can not reach exactly.

III. Experimental Study

The developed method has been tested on a sample dataset. Test results are given in this section.The dataset prepared by Celebi et al. Was used as the data set for testing the work. This data set is a time series data set containing 224 motion information. In total there are 8 different gesture and 28 time series of each gesture. As in the original study, of these 28 time series, 8 were used for training and 20 were used for testing [12]. The gesture names are given in Table 1.

TABLE. I. MOVEMENTS IN THE DATASET

Number of Gesture	Name of Gesture
1	Left Hand Pull Down
2	Left Hand Pull Up
3	Left Hand Swipe Right
4	Left Hand Wave
5	Right Hand Pull Down
6	Right Hand Pull Up
7	Right Hand Swipe Right
8	Right Hand Wave

A. Results

In the developed application, action recognition is performed using joint motion keyframes. There are 8 different gesture in the dataset used as input in the study and 28 time series for each move [16]. The confusion matrix of the developed application over the dataset is given in Table 2.

TABLE. II. CONFUSION MATRIX

Number Of Gesture	1	2	3	4	5	6	7	8
1	100	0	0	0	0	0	0	0
2	0	100	0	0	0	0	0	0
3	0	0	100	0	0	0	0	0
4	0	0	0	100	0	0	0	0
5	0	0	0	0	100	0	0	0
6	0	0	0	0	0	100	0	0
7	0	0	0	0	0	0	100	0
8	0	0	0	0	0	0	0	100

In this study, a highly successful motion recognition application was performed using the detection of keyframes in the trajectory of all body joints. The success percentages of the studies performed with the literature studies that using same dataset are given in Table 3.

TABLE. III. SUCCESS PERCENTAGES

Method	Success
DTW	%84.41 [22]
State Of Art	%86.56
Weighted DTW	%97.13 [22]
WDTW With Keyframes	%100

IV. CONCLUSION

In this study, human action recognition system was developed using keyframes which constitute an action. The developed system has been tested on a sample dataset and found to work with high accuracy. keyframes are defined as the distinguishing feature for classifying actions. Also every joint is weighted and its effect is rearranged on the result. It has a high working speed thanks to the keyframes features it uses. The size of the features stored in the database has decreased in this respect. High operating speed has been achieved with few features. Therefore it is suitable for real time working. The system is robust against the noise generated by the user during the movement. Compared to other studies, high success was achieved. Because of highly discriminative feature vectors. All movements in the given data set are 100% successfully classified.

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A Proposed Fuzzy Stability Model to Improve Multi-Hop Routing Protocol

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***Abstract*—Today's wide spread use of mobile devices such as: mobile phones, tablets, laptops and many others had driven the wireless Mobile Network growth especially the Mobile Ad hoc Networks commonly referred to as MANETs. Since the routing process is regarded as the core of communication and is associated with the network performance metrics, then its improvement will be revealed in the whole network performance improvement. Due to users' mobility, limited battery power, and limited transmission ranges, the current routing protocols should consider the stability of routes. Hence, the lack of resources of MANETs may result in imprecise routing decisions. In this paper, the proposed fuzzy model is used to handle imprecision of routing decisions by Fuzzy stability model for Dynamic Source Routing (FSDSR). Regarding the number of hops per route, cache size, end-to-end delay and route discovery time, the results showed that FSDSR has outperformed the state of art protocol Dynamic Source Routing protocol (DSR).**

***Keywords*—MANET; Fuzzy Model; Routes Stability; OPNET; DSR; FSDSR; MATLAB**

I. Introduction

The Mobile Ad-Hoc Network (MANET) is a type of networks that requires no previous infrastructure or centralized control. The application set for MANETs is varying from large/small-scale. Search-and-rescue operations, multi-platform battle deployment, mobile sensors or satellite networks for quick sharing and acquisition of data in inhospitable terrain are examples of these applications as in [10].

One of the challenging issues in MANETs is delivering data packets among mobile nodes in reliably because of MANET's dynamic nature. Multipath routing protocols introduced a solution for that problem by setting a primary route and backup routes. Several Ad-Hoc routing protocols for MANETs were proposed in past years. Most of these routing protocols, such as Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing Protocol (OLSR), Ad-hoc On-demand Distance Vector Routing (AODV), and Dynamic Source Routing (DSR), were categorized to shortest-path routing protocols which may result in lower throughput and increased packet loss rate. To improve stability of new routes several adaptive protocols were proposed; such as Associativity Based Routing (ABR) and Signal Stability-based Adaptive routing (SSA) as in [4].

The common objective for all routing protocols is to find a stable path between any two communicating nodes with respect to reduction in time complexity and control packet overhead. However, these protocols do not concern stable connections maintenance between the nodes within the network as in [21- 24].

This paper is organized as follows: Section II provides an overview of related work. Section III shows Dynamic Source Routing DSR protocol overview. Section IV introduces fuzzy based DSR models. Section V presents the proposed fuzzy stability model. Section VI describes the simulation environment. Section VII discusses the derived results. Section VIII presents the conclusion and future work.

II. Related Work

Broadcasting a route request allows a node to discover multiple paths. Reducing the number of requests will reduce the routing overhead that occurs in the route discovery process in AODV, AOMDV, and DSR.An algorithm was proposed in [12] to describe that technique.

Adopting network coding as a mean of improving reliable data delivery decreases control overhead in a large scale networks. The lifetime maximization routing with network coding increases throughput, reduces energy consumption and improves lifetime significantly according to [14], by combining more packets and reducing the number of number of retransmission attempts.

Applying Quality-of-Service (QoS) using Resource Reserve protocol (RSVP) was proposed in [1]. The obtained results showed that DSR and AODV routing protocols had decreased the number of packets dropped.

A priority routing model based on fuzzy closeness approach was introduced in [15]. The derived results had proved that Fuzzy Closeness Based Priority Routing (FCBPR) performs better than DSR in terms of the QOS metrics; packet delivery ratio, throughput, end- to-end delay, jitter routing overhead and normalized routing load.

The proposed protocol in [5] considered two metrics, link and node stability together. Link Expiration Time (LET) and Residual Energy (RE) respectively based on fuzzy logic. The stability level of the entire path can be generated from composite metric of these two metrics. The protocol provided minimum control overheads, minimum delay and improved packet delivery ratio by using fuzzy based system.

A fuzzy logic system for caching decisions was introduced in [2], in order to improve routing efficiency. The proposed fuzzy optimal routing algorithm was used to balance the load along multiple paths. It was concluded that paths categorization using fuzzy optimization tended to minimize the disadvantages of both unipath and multipath routing.

III. Dynamic Source Routing Protocol

Dynamic Source Routing – DSR- protocol was classified as a reactive source routing protocol. i.e. it invokes a route discovery mechanism on-demand. Source routing collects the addresses of each node through a link from source to destination. Gathering addresses allow the intermediate nodes to update their route caches as in figure1.

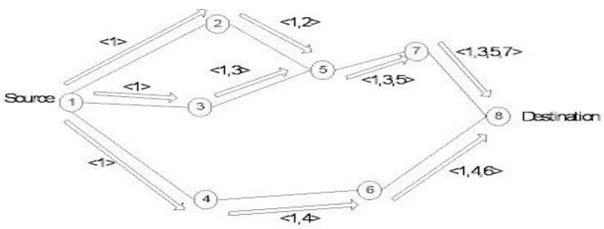

Fig. 1. Sourcing Routing[8]

Also it increases the routing overhead with increasing mobility [12, 23]. DSR protocol can be composed of two main mechanisms of Route Discovery and Route Maintenance.

A. Route Discovery

A route request (RREQ) is sent out by source node to discover a route. RREQ builds source route on every path through the network. Each node receives RREQ and has a route to destination it forwards the RREQ to destination node. Also; it drops all RREQs except the first one to the same destination. A node with large number of routes to target node has higher stability than a node that has single route. Destination node receives RREQ and unicast a route reply (RREP) back to sender node via each path.

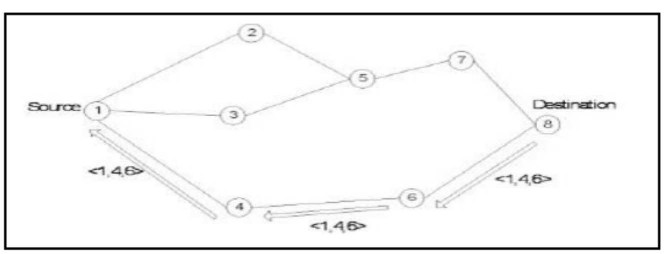

Fig. 2. Single&Multiple Routes [8]

Figure 2 illustrates that destination node replied to the first RREQ arrived through the link <1, 4, 6>. Node 6 has only single path to node 4 which has single route to the initiator while node 5 has two routes to the initiator. Node 6 may have mobility speed less than node 5.

B. Route Maintenance

A route maintenance process starts when a node send a route error (RERR) packet. Originating or forwarding packets are under the responsibility of each node will originate or forward packets to the next-hop. Therefore, a node which discovers a broken link, it will send a RERR to all neighboring nodes. After RERR had been received, each node had sent a packet over that link, it removes this route from its route cache. In figure 3, node ‘C’ discover no route to node ‘D’. A node ‘C’ sends a packet to node ‘D’, if node ‘D’ does not send back an acknowledgement packet. It sends out requests until reached the maximum number of times, and then advertises a broken link.

```
+-----+     +-----+     +-----+     +-----+     +-----+
|  A  |---->|  B  |---->|  C  |-->? |  D  |     |  E  |
+-----+     +-----+     +-----+     +-----+     +-----+
```

Fig. 3. DSR route broken

IV. Fuzzy based DSR models

In [3, 7], Fuzzy logic was introduced by Zaddeh, which is a mathematical technique that deals with imprecise data based on expert knowledge. It is an approach based on “degrees of truth” rather than the conventional computing with a discrete outcome of “true or false” or “1 or 0”. A typical fuzzy inference system (FIS) has four basic components as shown in figure 4. Fuzzy logic processes the input parameters to get a decision.

A fuzzy set is characterized by a membership function which has several types such as Gaussian, triangular and trapezoidal. It represents the degree of truth where a set belongs to a linguistic variable. Triangular membership function for m variable is as equation 1 [5, 20].

$$\mu(m) = \begin{cases} 0 & if m \leq TH1 \\ \frac{(m-TH1)}{(Th2-TH1)} & if TH1 < m < TH2 \\ 1 & if m \geq TH2 \end{cases} \quad (1)$$

Where TH1 is threshold to active system, and TH2 is threshold to identify level of activeness.

In FIS, a crisp value input converted into a fuzzy singleton with membership function. IF-THEN-rules form a fuzzy rule base. Each input value operates according to corresponding rule. Defuzzifier has the function to map the system output from the fuzzy domain to the crisp domain. Two popular fuzzy models are Mamdani and Sugeno model. The main different of these two models is their own method to generate crisp output. Mamdani FIS generate fuzzy output but Sugeno FIS uses weighted average for the same purpose.

In [16], it was suggested a stable route routing protocol by embedding fuzzy logic system. Based on DSR protocol, when a node wants to transmit data packet to destination node it broadcasts a RREQ packet into a network and when an intermediate node receives the RREQ packet, it calculates input parameters hop count (h_i) and stability factor (Sf_i)

currently in path. Then fuzzy logic system evaluates the output parameter fuzzy cost (fc) and determines route is available or not if the route is available, then RREQ is re-broadcasted and the node extracts route record. This process is to be done for each intermediate node until it reaches to the destination. Route reply message generated from destination is sent to source node via the path stored in route record. The rule base of that model is as in table I. Also, a triangular membership function is used in both inputs and output.

The performance analysis showed that fuzzy logic base proposed scheme has better packet delivery ratio and delay than DSR.

TABLE. I. FUZZY WEIGHTED METRICS RULE BASE [16]

Rule1: If hop count is L and Stability factor is L then fuzzy cost must be VH.
Rule2: If hop count is L and Stability factor is M then fuzzy cost must be H.
Rule3: If hop count is L and Stability factor is H then fuzzy cost must be M.
Rule4: If hop count is M and Stability factor is L then fuzzy cost must be H.
Rule5: If hop count is M and Stability factor is M then fuzzy cost must be M.
Rule6: If hop count is M and Stability factor is H then fuzzy cost must be L.
Rule7: If hop count is H and Stability factor is L then fuzzy cost must be M.
Rule8: If hop count is H and Stability factor is M then fuzzy cost must be L.
Rule9: If hop count is H and Stability factor is H then fuzzy cost must be VL.

Fuzzy logic was applied to manage routing policies and enhance routing performance dynamically as in [6]. The parameters signal power, bandwidth, mobility and packet forwarding ratio (PFR) were used as inputs. Gaussian membership function was used for getting the optimal and suitable route based on MANET's inputs parameters, which need to be smooth. The membership function is given by equation 2.

$$\text{Gaussian } (x; c, Ϭ) = e^{\left(\frac{-1}{2}\right)\left(\frac{x-c}{6}\right)^{2}} \qquad (2)$$

Where c represents MFs center, and σ determines the MFs width.

Also, the output was route optimality. The table II describes the input/output for that model. The obtained performance metrics showed that the overhead had reduced and the routing speed is up.

TABLE. II. INPUT/OUTPUT DETAILS [6]

Parameters	**Input/Output Membership Function**	**Parameter value**		
		0-0.4	**0.2-0.8**	**0.6-1.0**
Signal power	Input	Low	Medium	High
Bandwidth	Input	Poor	Average	Excellent
Mobility	Input	Low	Medium	High
Packet Forwarding Ratio	Input	Low	Medium	High
Route	Output	Below Optimal	Sub optimal	Optimal

According to [13], there is still no such model or approach that can provide help in MANET area to compute the behavior of protocols. Therefore, the fuzzy inference system was proposed and modeled for DSR routing protocol by considering some important metrics. The objective of FIS is to reduce the overhead to decide that in which types of network conditions the protocol performs poorly, satisfactory or acceptable. Therefore, tuning the behavior of DSR was implemented by using Mamdani method. A FIS as in figure 4, maps the input variables: Node Density, Pause Time, Node Mobility, Number of Packets transferred, and the Number of Connections, to output variables: Packet delivery Fraction, Normalized Routing Load, and Normalized MAC Load.

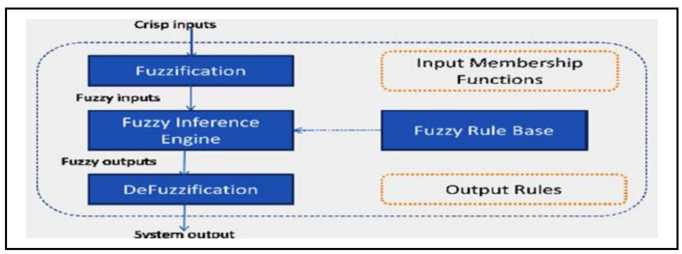

Fig. 4. Low chart of a fis [3]

Also, it was concluded that increasing the number of nodes or changing the speed of mobility, will degrade the DSR performance. While number of connection, number of packets, node density, node mobility speed and pause time is increased with proper ratio then DSR performance can be enhanced.

V. THE PROPOSED FUZZY BASED DSR OPTIMAL PATH STABILITY MODEL

The proposed model uses fuzzy based decision making technique to determine path stability. As an outcome of fuzzy decision rules, the process of path stability depends on two inputs that represent a node status: total routes in route cache and node speed.

The input variables are total number of routes in route cache (TR) and speed (S). The total routes (TR) is described through 9 linguistic variables (A = v.low, B = low, C = above.low, D = medium, E = above.medium, F = below.high, G = high, H = bleow.heavy, I = heavy), and speed (S) with 7 linguistic variables (A = resident, B = move, C = slow, D = above.slow, E = medium, F = fast, G = v.fast). The fuzzification membership function for both TR and S is triangular for all linguistic variables as in equation 1. The universe of discourse for TR and S are {0, 79}, and {0, 15} respectively. Figures 5 and 6 show the membership function with linguistic variables.

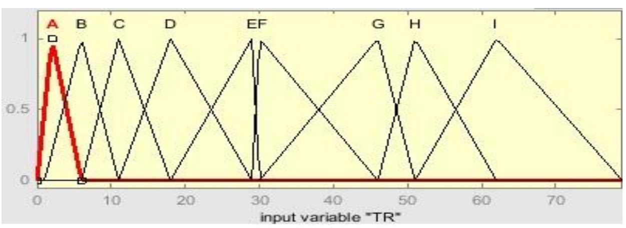

Fig. 5. Input Variable (TR)

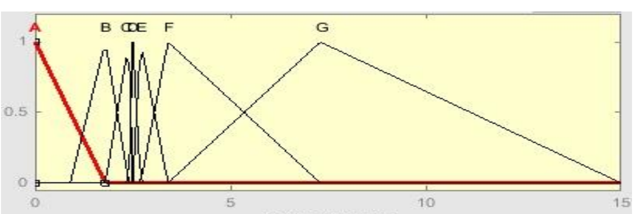

Fig. 6. Input Variable (S)

The FIS type is Mamdani, "And" method is min, "OR" method is max, and the defuzzification is centroid. The "IF-THEN-Rules" are 24 rules as in table IV, which had been obtained from fuzzy clustering algorithm. Fuzzy C-means algorithm (FCM) had been used to cluster collected data set. It had been run with [6, 7, 8, 9, 10, 11… 37, 38, 39, and 40] cluster number. Analysis for each run was obtained to get better cluster number and avoid un-discriminated feature(s).

The data set consists of 1497 records that were formed from 16 runs of OPNET Modeler 14.5 using different settings of MANET and default DSR protocol. Data set consists of total number of routes inside each node cache (TR), total number of routes for specified destination inside node cache (NS), the speed of node (S), and the inter-nodes distance between the node and the destination node (D). Also, a default random waypoint had been set for all runs. In this data set, 24 clusters are extracted and inter-nodes distance is not discriminated feature as authors in [17 – 19, 25] guided.

The output variable is the node stability (NS) which represents the number of routes in route cache for specified destination. The node stability (NS) is described through 6 linguistic variables (A = not.stable, B = near.stable, C = below.stable, D = stable, E = consistent, F = v.stable). The defuzzification membership function is triangular for all linguistic variables. Also, the universe of discourse for NS is {0, 18}. Figure 7 shows the membership function with linguistic variables.

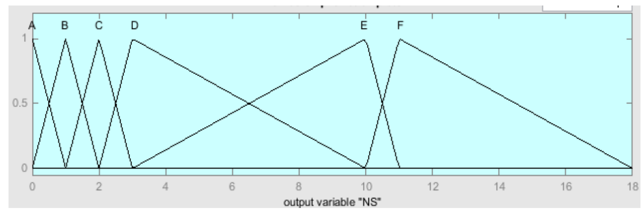

Fig. 7. Output Variable

The proposed fuzzy model I/O is as in figure 8. Also,the model's surface is as figure 9. The objective of fuzzy model is to find the most stable paths. when a source node wants to transmit data packet to destination node it broadcast a RREQ packet into a network and when an intermediate node receives the RREQ packet, it calculates input parameters TR and S currently. Then fuzzy model evaluates the output parameter node stability (NS) and determines node is available or not to participate with that request. If the node is available, then RREQ is re-broadcasted in case a node has no route to destination. This process is to be done for each intermediate node until it reaches to the destination. Route reply packet generated from destination is sent back to source node via the path stored in route record. Each node in each route receives a RREP packet, a fuzzy model calculates the node stability again because it may a node changed its speed or removed routes. If node is available, it forwards the packet to potential destination. Therefore, FSDSR model guarantees that each node along a path has more backup routes which reduce route error RERR. The fuzzy model flowchart is as in figure 15 that describes the process of the fuzzy model.

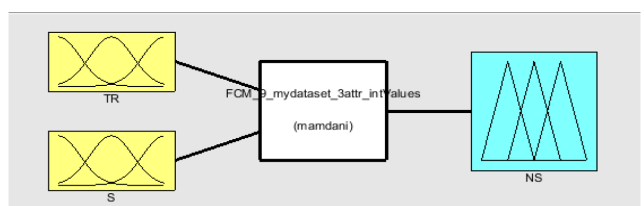

Fig. 8. Fuzzy Model I/O

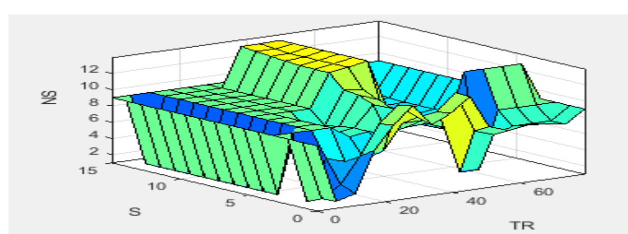

Fig. 9. Fuzzy Model Surface

VI. Simulation Environment

OPNET Modeler 14.5 and MATLAB R2014b fuzzy toolbox [8] were used to test the proposed fuzzy model. Two scenarios were used to compare standard DSR and Fuzzy Stability Model-DSR (FSMDSR) with table III settings. In addition, the accept condition is at node stability (NS) is 'E = consistent'.

TABLE. III. Simulation Attributes

Simulation Parameter	Value
Protocol	DSR / FSMDSR
Mobility	Random Waypoint (Record Trajectory)
Node Type	"manet_station_adv"
No. of Nodes	15 nodes
Area	1000*1000 m2
Simulation Time	30 min.

As demonstrated by the simulation results from series of experiments for number of hops per route as in figure 10, the number of hops per route represents the number of hops in each route to every destination in the route cache of all nodes. Therefore; a lower number of hops per route lead to the shortest path between two communicating nodes.

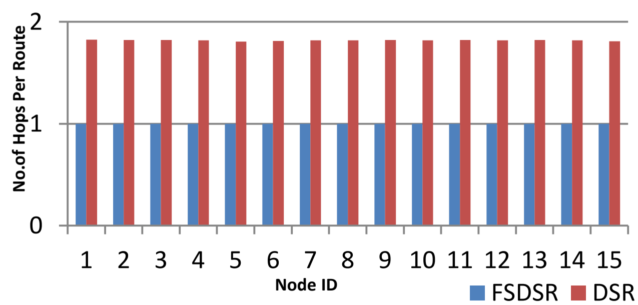

Fig. 10. No. of Hops per Route

Moreover, the route cache size represents the number of routes to different destinations. The node's route cache memorizes all routes which are collected by control packets through source routing. The results as in figure 11 showed the route cache size in the experiment.

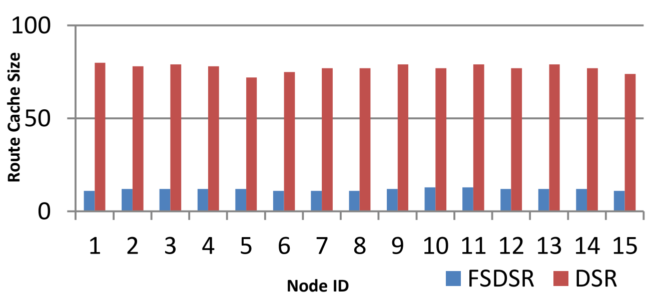

Fig. 11. Route Cache Size

A route discovery time is the time when a route request was sent out until route reply is received. In figure 12, the route discovery time results.

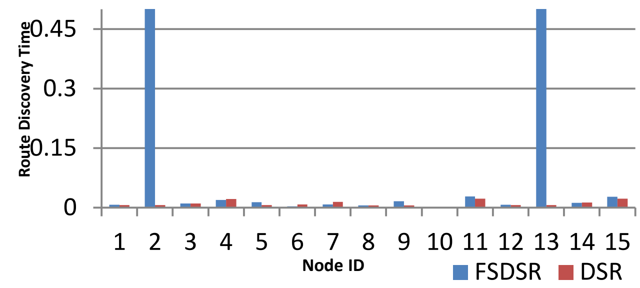

Fig. 12. Route discovery Time

Collected result as is in figure 13 represents the total replies sent from destination which is the total number of route reply packets sent out by all destinations and potentials. The total replies increases with the increase of RREQ.

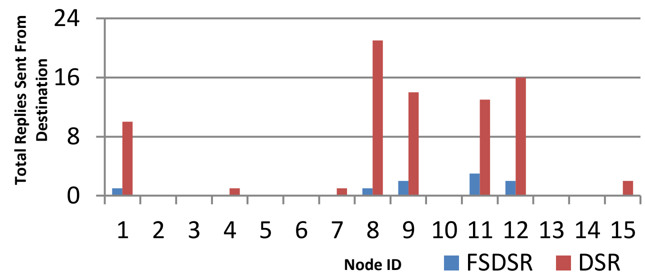

Fig. 13. Total Replies Sent from Destination

Figure 14 represents the wireless LAN delay results through experimental test. Wireless LAN delay is the end to end delay of all the packets received by nodes. Delay increases with increasing the number of control messages exchanging. Wireless LAN delay is expressed as in equation 3 [11].

$$D_{\text{end to end}} = N\,(D_{trans}+D_{prop}+D_{proc}+D_{queuing}) \qquad (3)$$

Where "$D_{\text{end to end}}$ is total end to end delay", "D_{trans} is transmission delay", "D_{prop} is propagation delay", "D_{proc} is processing delay", "$D_{queuing}$ is queuing delay", and "N is the total number of packets"

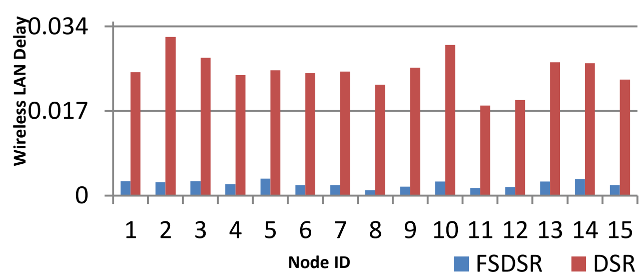

Fig. 14. Wireless LAN Delay

VII. Result and Discussion

Figure 10 showed that a node which uses FSMDSR will have a lower number of hops per route than when it uses DSR. FSMDSR (E = consistent - condition) limits response to a control packets. Therefore, a node that doesn't satisfy the fuzzy model condition, does not reply control packets within that path. Thus, the number of nodes along a path gets decreased.

On the other hand, DSR has no restrictions on processing all control packets.

In figure 11, by decreasing number of control packets, the node will decrease the routes in cache as well. Therefore, the node's route cache grows slowly on using FSMDSR. In contrast, overheard un-constrained control packets using DSR results in larger route cache size.

As shown in figure 12, route discovery time is a trade-off when using fuzzy-based MANET routing protocols. Due to each overheared control packet forms a route to be added in node cache. Therefore, node 2 and 13 cannot add all routes which formed from control packets in case of using FSDSR because of FSDSR limitations. Generally, the behavior of FSMDSR on other nodes matches DSR's performance.

In figure 13, the total number of route replies sent from destination in FSMDSR decreased as a result of the lower number of route requests packets and lower cache size. The node that uses DSR could memorize more routes for all its neighboring nodes; therefore, it has a variety of routes for all destinations. However, these routes may be stable or unstable.

Figure 14, by decreasing the number of hops per route in FSDSR, wireless LAN delay is going lower. Since, lower hop number leads to low send/receive control packets between nodes within a certain route. Moreover, it gives evidence that stored routes in route cache (cache size) in FSMDSR always links a source to destination with the lower overhead route.

It can be summarized that FSMDSR outperformed standard DSR for maximum number of hops per route with 45%, for maximum route cache size with 85%, for maximum total replies RREPs sent from destination with 86%, and for maximum wireless LAN delay with 89%. On the other hand DSR outperformed the FSMDSR with 95% in maximum route discovery time in some cases (node 2 and node 13) .

VIII. Conclusion

In this paper, a Fuzzy model was proposed to handle the imprecise values of number of routes in route cache and speed of node, to enhance DSR protocol. The derived results proved that the fuzzy model can help to obtain an optimal decision in MANETs.

The proposed fuzzy model (FSMDSR) outperformed the standard DSR in hops per route, total replies sent from destination and wireless LAN delay. Although not all QoS metrics are included in the comparison, it can be concluded that considering the node's route cache and the speed of nodes can improve the performance of Mobile Ad-Hoc network in terms of hops per route total replies sent from destination and wireless LAN delay.

At some node, FSMDSR has a trade-off like in route discovery time (node 2, 13). But generally, FSMDSR behaved better in DSR as shown previously.

The future work for this research will consider total cached replies sent route cache size and number of retransmission attempts in order to have a complete view of proposed model and standard DSR. Furthermore, a comparison between FSMDSR and other fuzzy model will be offered.

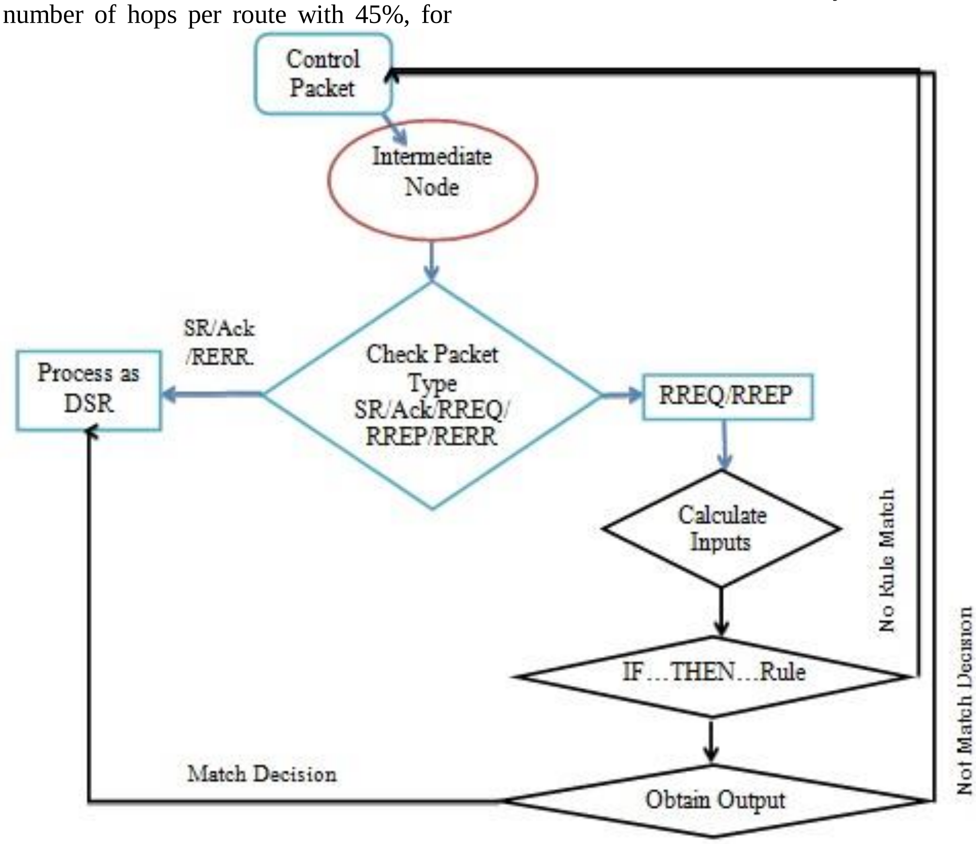

Fig. 15. Fuzzy Model Flow Chart

TABLE. IV. THE OBTAINED FUZZY IF THEN RULES

IF TR is	v.low	**And S** is	resident	**Then NS** is	not.stable
IF TR is	v.low	**And S** is	move	**Then NS** is	near.stable
IF TR is	low	**And S** is	resident	**Then NS** is	below.stable
IF TR is	low	**And S** is	slow	**Then NS** is	near.stable
IF TR is	low	**And S** is	v.fast	**Then NS** is	near.stable
IF TR is	above.low	**And S** is	resident	**Then NS** is	near.stable
IF TR is	above.low	**And S** is	above.slow	**Then NS** is	consistent
IF TR is	medium	**And S** is	resident	**Then NS** is	consistent
IF TR is	medium	**And S** is	move	**Then NS** is	stable
IF TR is	medium	**And S** is	slow	**Then NS** is	stable
IF TR is	above.medium	**And S** is	resident	**Then NS** is	v.stable
IF TR is	above.medium	**And S** is	above.slow	**Then NS** is	stable

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An Improved Machine Learning Approach to Enhance the Predictive Accuracy for Screening Potential Active USP1/UAF1 Inhibitors

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***Abstract*—DNA repair mechanism is an important mechanism employed by the cancerous cell to survive the DNA damages induced during uncontrolled proliferation of cell and anti-cancer drug treatments. In this context, the Ubiquitin-Specific Proteases (USP1) in complex with Ubiquitin Associated Factor 1(UAF1) plays a key role in the survival of cancerous cell by DNA repair mechanism. Thus, this put forth USP1/UAF1 complex as a striking anti-cancer target for screening of anti-cancer molecule. The current research is aimed to improve the classification accuracy of the existing bioactivity predictive chemoinformatics model for screening potential active USP1/UAF1 inhibitors from high-throughput screening data. The current study employed feature selection method to extract key molecular descriptors from the publicly available high-throughput screening dataset of small molecules that were used to screen active USP1/UAF1 complex inhibitors. This study proposes an improved predictive machine learning approach using the feature selection technique and two class Linear Discriminant Technique (LDA) algorithm to accurately predict the active novel USP1/UAF1 inhibitor compounds.**

Keywords*—Ubiquitinases; DNA repair mechanism; anti USP1/UAF1 molecule; High-throughput Dataset; Feature Selection and Discriminant Technique; Chemoinformatic Model; Classification accuracy; T-test

I. Introduction

Deubiquitinases (DUBs) are a specific group of enzymatic proteins that aid the process of deubiquitination on targeted proteins [1-2]. Recent findings have highlighted the role of deubiquitinases as oncogenes, due to their involvement in DNA damage repair mechanism leading to the survival of actively replicating cancerous cells [3 to 5]. The DUBs are broadly categorized into five families and the Ubiquitin-specific proteases (USPs) family constitutes of the largest number of different USPs. Among the many members of USPs, the USP1 is the most studied deubiquitinases due to its involvement in various type of carcinomas. Cancerous cell undergoes DNA damage during targeted anti-cancer drug therapy and uncontrolled rapid cell proliferation [6-7]. This leads to dependencies of the cancerous cell upon DNA damage repair mechanism for their continuous proliferation and persistence [8]. The upregulated USP1 in cancerous cell promotes the DNA damage repair pathway enabling the survival and proliferation of the DNA damaged cancerous cell [3-4]. Therefore, inhibition of DNA repair pathway is currently a very eminent anti-cancer strategy [9-10]. Past Studies from various researchers have shown that DNA repair mechanism of USP1 is carried out in the association of a cofactor UAF1 (USP1 associated factor 1), that controls the enzyme activity of deubiquitinases [11-12]. The association of a cofactor UAF1 induces a conformational change in the active site of USP1 thereby increasing the deubiquitinases activity naturally by stabilizing it [13]. It is be noted that upon treatment of DNA targeted drug make the cancerous cell dependent on DNA repair mechanism of USP1 for survival, therefore a combined therapy of UAF1 inhibitor with DNA-damaging therapeutic molecule will enhance the therapeutic efficacy of the therapy against cancer. Thus, this makes the USP1/UAF1 complex a potential anti-cancer target for the exploration of molecules having anti deubiquitinases activity [14]. In this context, the University of Delaware and the NIH Chemical Genomics Center developed a miniaturized quantitative high-throughput screen assay to identify small molecule having anti USP1 activity from the NIH Molecular Libraries Small Molecule Repository (MLSMR) from PubChem [15]. Considering the significance of identifying more inhibitors to USP1/UAF1 complex a chemoinformatic classification model was built using the predictive capacities of machine learning approaches [16]. The machine learning based predictive computational model proposed by Wahi et al. 2015 has a potential to screen potentially active inhibitors of USP1. However, the accuracy of base classifier (random forest) selected for building the predictive model had a sensitivity of 79.44 %, specificity of 81.36 % and an accuracy of 81.35 %, which is presumably low for an efficient and rigorous chemoinformatic predictive model. The objective of the present study was to develop a more rigorous chemoinformatic model for predicting potentially active USP1 inhibitors with high accuracy, sensitivity, and specificity. The proposed method is a hybrid technique based on feature selection technique and discriminant algorithm for active USP1 inhibitor molecule prediction. The proposed classification method seek to increase the accuracy of classifying active USP1 inhibitors from high throughput screens so that genuine hits are optimized using a low-cost large-scale computational virtual screening tool.

The later part of the research article is organized as Sections II present the description of the AID 743255 dataset and an elaborate description of the methodology. In Section III the results of the hybrid technique are discussed. Section IV report the conclusions of the present research work.

II. Material and Methods

A. Bioassay dataset

In the present study, the high throughput screening data set conforming to bioassay identifier AID 743255 was targeted to screen inhibitors of the USP1/UAF1 complex [14]. The dataset comprised of 389,560 compounds and based on their PubChem activity score the compounds were characterized into the active and inactive molecule. The chemical compounds with an activity score of zero were considered inactive (n=369,898) and compounds with a score ranging from 40 to 100 were considered active (n=904). Moreover, the remaining compounds with a score ranging from 0 to 39 were considered unspecific and irrelevant and were not considered for further analysis.

B. Predictive model building

In order to build a Machine learning based predictive tool, a workflow has been built to predict the active USP1 inhibitors from AID 743255 dataset by employing Data Mining Techniques (DMT) for the analysis of high-throughput screen data, and then the result of DMT are extracted to be used as a Knowledge Base for our model to carry out the prediction process. Fig. 1 shows the proposed workflow consisting of (1) Pre-processing of dataset and generation of molecular descriptors; (2) Determination of Best fit descriptors and data segmentation (3) Implementation of classification algorithm, (4) evaluation phase to evaluate the performance and accuracy of the built model using a data mining evaluation technique.

1) Pre-processing of dataset and generation of molecular descriptors

The structural Data format (SDF) files of both the active and inactive compound from bioassay AID 743255 dataset were downloaded from PubChem. Since it was not possible to process the whole SDF file of both active and inactive molecule as a single file, therefore, the SDF files of both the group of molecules were divided into files of smaller sizes by applying the SplitSDFiles present in Mayachem tools [17]. Furthermore, PowerMV a publicly accessible software for descriptor creation and viewing [18] was applied to create two-dimensional molecular descriptors for both the inactive and active compounds of AID 743255 dataset. A total of 179 descriptors were created from the input structural files of compounds using PowerMV of which 8 descriptors were assigned for property descriptor, 24 descriptors were classified under weighted burden numbers and 147 descriptors accounts for pharmacophore fingerprint. The property class of molecular descriptors includes a properties namely Blood-brain barrier (BBB), H-bond acceptors and donors, molecular weight, bad group indicator, the number of rotatable bonds, partition coefficient, and polar surface area.

A group of continuous molecular descriptor based on the burden connectivity matrix namely weighted burden numbers were generated by PowerMV. The burden connectivity matrix considers three important properties namely partial charge, atomic lipophilicity, and electronegativity. Lastly, Pharmacophore fingerprints are descriptors which are expressed as 0 and 1 (binary form) and the grouping of atoms and group are based on biosteric principles such that the atoms and groups having similar activity are grouped together in a specific group (class). Pharmacophore fingerprint descriptors in PowerMV are classified into six major groups that include, ring systems containing aromatic and hydrophobic centers, hydrogen bond donors and acceptors, and positively and negatively charged atoms or groups.

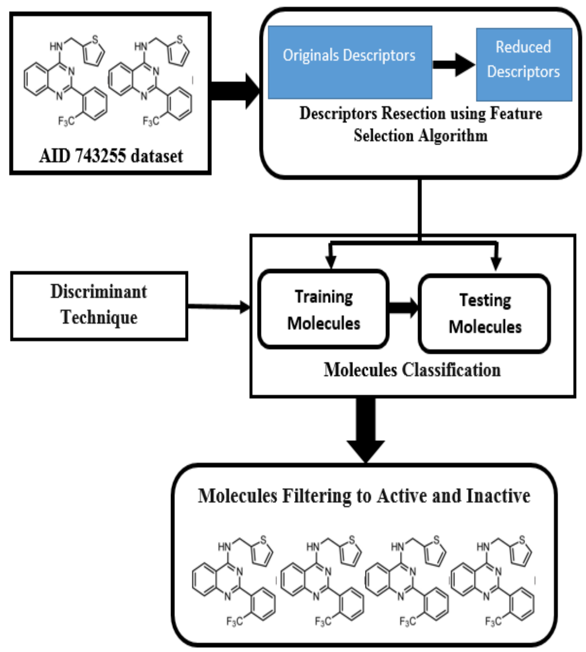

Fig. 1. Proposed workflow for the generation of predictive machine learning based chemoinformatic model

2) Determination of Best fit descriptors and data segmentation

Feature selection (FS) is a technique to pre-process the dataset so that repeated descriptors can be removed and include descriptors which are of relevance in model building. Employing feature selection strategy will not only reduce the dimensionality of the dataset but also will enhance the computational process of the model by reducing the computation time to analyze large data and eliminate the noise from the dataset [19]. The feature selection algorithm explores all set of combinations of molecular descriptors from the dataset and brings forth features which contribute most towards the construction of an efficient classification model [20]. Feature selection algorithm employs search method in combination with a feature evalautor method [21]. This experiment conducted to differentiate the active and inactive molecular from the AID 743255 dataset. Feature selection method was applied first as a feature reduction to reduce the number of the molecules descriptors. Only the number of the extracted descriptors using feature selection algorithm is considered as significant features. Then, the AID 743255 dataset was divided into 10 parts as 10-folds cross validation. Each part had certain molecules (active and inactive). The experiments were run 10 times with nine parts of these groups as training dataset and one part as a testing dataset.

3) Implementation of classification algorithms

In chemoinformatics, machine learning approaches have been used in the past to build predictive chemoinformatics model from sets of known compounds and predict biological activities of the unknown molecule [22-25]. In this study, to categorize and classify the active USP1 inhibitor molecules from the inactive molecules from the AID 743255 dataset, the two class Linear Discriminant Algorithm (LDA) was applied on the training and testing data. Two class LDA have previously been successfully applied to classify cancer based on gene expression data and has been reviewed as one of the important tools for chemoinformatics classification studies [26-27]. The basic concept of two class LDA is to calculate a linear transformation that helps in binary classification of the data set and the classification is executed in the transformed area formed based on some distance metrics namely euclidean distance as proposed by Fisher, 1936 [28] and shown using the following equations:

Assume that we have a set of "n" number of molecules with f dimensional features (attribute) $x_1, x_2, \cdot\ \cdot\ \cdot, x_n$ (where $x_i = (x_{i1}, \cdot\ \cdot\ \cdot, x_{if})$) classified into two classes, C_1 and C_2. Here C_1= Active molecule and C_2= Inactive molecule. Scatter matrices for given two classes (active and inactive molecule) is shown below:

$$S_i = \sum_{X \in c_i} (X - \bar{X}_i)(X - \bar{X}_i)' \qquad (1)$$

Here $\bar{X}_i = \frac{1}{n_i} \sum_{X \in c_i} X$ and n_i is the total number of molecules present in C_i. Therefore, the total scatter matrix for Intra-class is represented as:

$$\sum\nolimits_w = S_1 + S_2 = \sum_i \sum_{X \in c_i} (X - \bar{X}_i)(X - \bar{X}_i)' \quad (2)$$

The scatter matrix for inter-class is calculated as

$$\sum\nolimits_b = \sum_{i=1}^{n} (X - \bar{X}_i)(X - \bar{X}_i)' \qquad (3)$$

Where $\bar{\boldsymbol{X}}_{\boldsymbol{i}}$ is the mean for each class and $\bar{\boldsymbol{X}}$ is total mean vector given by $\bar{\boldsymbol{X}} = \sum_{i=1}^{n} \bar{\boldsymbol{X}}_{\boldsymbol{i}}$ [29]. Rayleigh coefficient, for the proposed sample, is defined as the ratio of the determinant for the inter and intraclass scatter matrix. For the maximum utilization of Rayleigh coefficient fisher recommended the use linear transformation (Φ):

$$\mathcal{J}(\phi) = \frac{|\phi^t \hat{\sum}_b \phi|}{|\phi^t \hat{\sum}_w \phi|} \qquad (4)$$

Equation (3) can be answered as an eigenvalue problem provided $\hat{\sum}_w$ is non-singular, and subsequently ϕ is calculated using the matrix $\hat{\sum}_{\boldsymbol{w}}^{-1} \hat{\sum}_{\boldsymbol{b}}$. of eigenvectors.

After transformation Φ is calculated, the classification of the dataset into specific classes is performed within the transformed space based on Euclidean distance and cosine measure, respectively. The equations 5 and 6 represents the calculation of distance using Euclidean distance and cosine measure, respectively:

$$d(x, y) = \sqrt{\sum_i (x_i - y_i)^2} \qquad (5)$$

$$d(x, y) = 1 - \frac{\sum_i (x_i - y_i)^2}{\sqrt{\sum_i x_i^2}\sqrt{\sum_i y_i^2}}. \qquad (6)$$

Once instance z is initiated, the instance z is classified to

$$= arg_k min\ d(z\phi, \bar{x}_k) \qquad (7)$$

Here $\bar{\boldsymbol{x}}_{\boldsymbol{k}}$ is the centroid of the k^th class.

The pseudo code for the execution of LDA algorithm for processing AID 743255 dataset is illustrated in Figure 2.

```
Algorithm Linear Discriminant Analysis (LDA)
  Input:
  //A Set X of Active and Inactive molecules{with descriptors}
  //The LDA is "trained"
      LDA test = new LDA(data, group, true);
  //Now we will try to classify new data
     double[] testData = { testi };

System.out.println("Predicted group: " + test.predict(testData));
  //Let's have a look at the values of the discriminat functions

double[] values = test.getDiscriminantFunctionValues(testData);
     For(int i = 0; i < values.length; i++){
        System.out.println("Discriminant function " + (i+1)
             + ": " + values[i]);
     End for
```

Fig. 2. Pseudo code for the execution of LDA algorithm in AID 743255 dataset

In all the cross-validation experiment applied on the dataset, accuracy result, and area under the curve (AUC) were computed. The classifying accuracy calculated using the standard classification equation:

$$\text{Accuracy} = \frac{(TN + TP)}{(TN + FP) + (TP + FN)} \qquad (8)$$

Where,

True Positive (TP): The active molecules correctly categorized as active; False Positive (FP): The inactive molecules that were incorrectly classified as active.; True Negative (TN): The inactive molecules correctly classified as inactive; False Negative (FN): The active molecules incorrectly classified as inactive molecules.

SPSS Clementine tool was used to perform the experimentation and the analysis of results. SPSS Clementine tool is an SPSS enterprise-strength data mining workbench. The Clementine tool is used by business organizations to enhance the client and people relations by performing a thorough consideration and analysis of data [30].

III. Experimental Results and Discussion

A. Model construction and evaluation

A total of inactive (n=369,838) and active (n= 904) molecules from AID 743255 bioassay data was downloaded and using PowerMV 179 2D descriptors were created. Upon, post data processing using the feature selection method the total descriptors contributing to the generation of the predictive model came down to 45. The dataset was divided into two sets: (1) 90 % of the data as a training set, and (2) 10 % of the data as an independent test set. After the implementation of the LDA algorithm to the preprocessed data set a predictive model was built and the statistical performance parameters of LDA algorithm are tabulated in Table I. An average accuracy of 96.76 % and 96.40 % was obtained for training and test data, respectively to screen active anti USP1 inhibitor was obtained upon 10 fold cross validation of AID 743255 dataset. Since accuracy alone is not sufficient to evaluate the efficiency of the model, therefore, another statistical parameter namely the AUC value was calculated from the ROC plot for both training and test set of data as shown in Fig. 2 and 3.

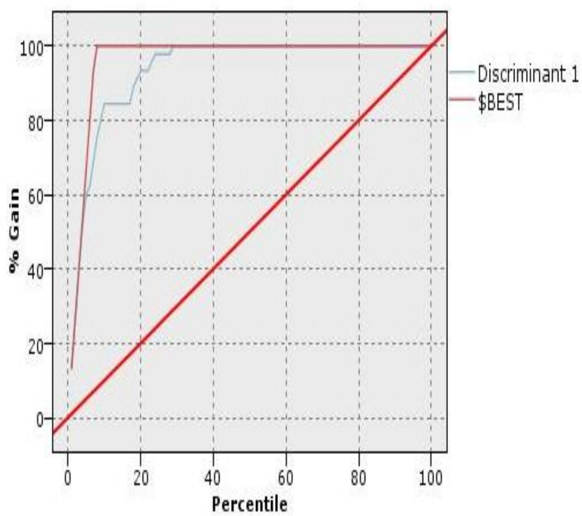

Fig. 3. Average prediction accuracy of LDA algorithm for 90 % training data set

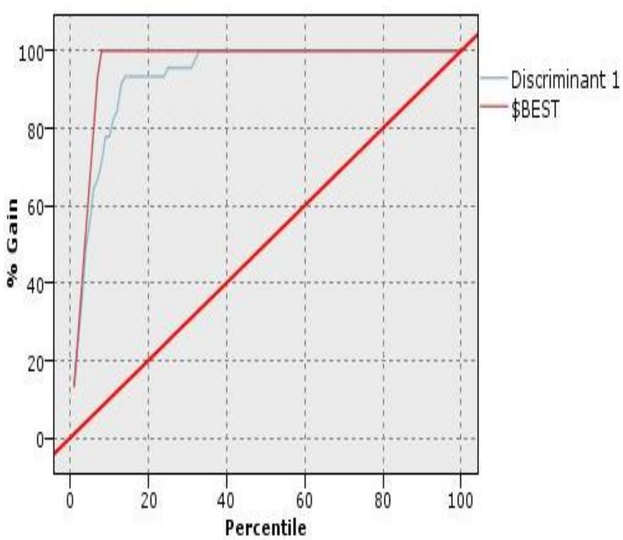

Fig. 4. Average prediction accuracy of LDA algorithm for 10 % testing data

The average value of AUC upon implementation of LDA algorithm to the training and independent test set of data was found to be 0.97 as shown in Table I.

TABLE. I. RESULTS ON THE AID 743255 DATASET USING LINEAR DISCRIMINANT ALGORITHM (LDA) ALGORITHM

Dataset Part	Accuracy		Error		Area under the curve	
	Training	Test	Training	Test	Training	Test
1	100	93.4	0	6.6	1	0.96
2	100	100.0	0	0	1	1.0
3	94.1	96.22	5.9	3.78	0.97	0.97
4	93.7	94.08	6.3	5.92	0.94	0.97
5	99.2	98.68	0.8	1.32	0.99	0.99
6	98.9	100.0	1.1	0	0.99	1.0
7	97.9	95.09	2.1	4.91	0.99	0.96
8	94.7	92.40	5.3	7.6	0.97	0.94
9	95.9	95.17	4.1	4.83	0.90	0.92
10	93.2	99.04	6.8	0.96	0.97	0.99
Average	**96.76**	**96.40**	**3.24**	**3.6**	**0.972**	**0.97**

As the AUC value of the predictive model is close to 1, therefore, we can propose that the chemoinformatics model generated using LDA classification algorithm will classify active anti USP1 inhibitor from any given dataset with high accuracy and specificity. All these statistics values were obtained by execution of the classification algorithm on the independent test set. The current predictive based on LDA classifier is more robust, efficient and accurate in predicting USP1 inhibitor molecule from AID 743255 dataset than the predictive model proposed by Wahi et.al [16].

The accuracy and AUC value of all the base classifier used by Wahi et al 2015, are lower than the present model which has a higher accuracy and AUC value as shown in Table II Therefore we say the present model is more robust and accurate in predicting active anti-cancer molecule having anti USP1 activity from a given dataset.

TABLE. II. COMPARATIVE PERFORMANCE EVALUATION OF CHEMOINFORMATICS MODELS

Algorithm	**Model performance evaluation parameters**		
	Accuracy	**Error**	**Area under the curve**
Random Forest	81.35	18.65	0.872
Naive Bayes	80.01	19.99	72.8
J48	80.1	19.9	78.3
SMO	80.21	19.79	78.7
Linear Discriminant Analysis (LDA)	96.76	3.24	0.97

IV. CONCLUSION

Targeting cancer by inhibiting USP1 is evolving as a promiscuous cancer therapy due to its specificity and efficacy when compared to the present-day anti-tumor remedies. The present drug discovery program involving experimental identification of a potent inhibitor of a target protein from huge chemical repositories is both a time taking and costly process.

The use of machine learning tools to analyze the huge data generated from high throughput screening (HTS) has paved the way to build a predictive chemoinformatics model for the screening of more anti-cancer molecule. In this regard, we have generated a computational predictive tool based on the properties and structure of known USP1 inhibitors from the high throughput screening experimental data. The present in silico predictive model can predict unknown inhibitors of the USP1/UAF1 complex with higher accuracy and reliability. The present chemoinformatics model generated using LDA algorithm has better accuracy to predict the anti USP1 activity of unknown compound when compared to random forest model proposed by Wahi et al in 2015. Our descriptor-based virtual screening computational predictive model will be of immense importance in prioritizing lead molecule against USP1/UAF1 complex and therefore fast-tracking the anti-USP1 drug discovery process. Moreover, the present chemical descriptor based predictive method can reduce the requisite for cost-intensive biological screening and encourage low-cost virtual screening on a larger scale to enhance the anti-cancer drug discovery process.

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Instant Diacritics Restoration System for Sindhi Accent Prediction using N-Gram and Memory-Based Learning Approaches

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***Abstract*---The script of Sindhi Language is highly complex due to many complexities including abundance of homographic words. The interpretation of the text turns so tough due to the possibility of multitudinal meanings associated with a homographic word unless given specific pronunciation with the help of diacritics. Diacritics help the readers to comprehend the text easily. Due to the rapidly developing nature of this era, people don't bother writing diacritics in routine applications of life. Besides creating difficulties for human reading, the absence of diacritics does also make the text abstruse for machine reading. Relatively alike human, machines may also lead to semantic and syntactic complexities during computational processing of the language. Instant diacritics restoration is an approach emerged from the text prediction systems. This type of diacritics restoration is an unprecedented work in the realm of natural language processing, particularly in Indo-Aryan languages. A proposition for a framework using N-Grams and Memory-Based Learning approach is made in this work. The grab-point of this mechanism is its 99.03% accuracy on the corpus of Sindhi language during the experiments. The comparative edge of instant diacritics restoration is its being source of expedition in the performance of other natural language and speech processing applications. The future development of this approach seems vivid and clear for Sindhi orthography is highly similar to those of Arabic, Urdu, Persian and other languages based on this type of script.**

Keywords--Sindhi Language; Instant Diacritics Restoration; Text Prediction; N-Grams; Memory-Based Learning

I. Introduction

Sindhi orthography abounds in such words which possess different meaning but identical morphological structure. These words are called homographs in linguistics. The solution to this problem is the assignment of diacritic marks to the homographs. Sindhi orthography has two types of diacritic signs used for the correct pronunciation of the words [1]. The superscript signs assigned over the letters and subscript ones beneath the letters. The routine scripts of Sindhi language are written without diacritics such as newspapers, magazines and books. Such absence brings about critical challenges facing computational processing of the language [2]. In more elaborate way, homographic words can be interchangeably meant or interpreted if diacritics are absent. They may be meant and pronounced erroneously as well. Without disambiguation, it is rather difficult to figure out the intended meaning and pronunciation of words during the process of different linguistic and speech processing applications.

The automatic assignment of diacritics in Sindhi script is essential for its processing into natural language and speech applications [3] [4]. Therefore, the literature of this type of research is replete with the details of the research works on diacritic restoration particularly by using statistical approaches [5] [2]. Firstly, the results of previous research works are not satisfactory or at acceptable level and secondly, the instant diacritics restoration is taken into consideration for the first time for Sindhi. The objective of the study is the development of automatic system that will convert the un-diacritized words into the diacritized ones by assigning the diacritic signs instantly during typing.

This research study aims at the development of automatic system that assigns diacritics to the words which at first are un-diacritized during typing instantly. For this, an investigative study with the combination of N-Grams and Letter-Level Approaches is carried out to meet the objective.

The rest of the paper is organized as follows: some research contributions of diacritics restoration of Arabic script-based languages are presented in Section II. The overview of corpus preparation is given in Section III. The proposed model for the task of instant diacritics restoration is described and depicted in Section IV. In Section V, execution process of developed software application is explained, while in Section VI, implementation process of proposed model and detail evaluation of calculated results are given and finally, the paper is concluded in Section VII with core results and conclusion.

II. Related Work

The study of literature on this topic reveals that diacritics restoration is performed at letter and word level. Diacritics restoration has been centered by using various techniques at word and letter level as well, like N-Grams [6] [7], Neural Networks [8], Maximum Entropy [9], Memory-Based Learning [10] [11], and Weighted Finite State [12]. Majority of researchers has received encouraging results at word level using N-Gram language model [6] [7] [2] whereas Memory-Based Learning Approach [13] also yields good results at letter level for the same task on Arabic script-based languages including Sindhi [14].

The task of automatic Sindhi diacritics restoration is mainly considered and taken by the researchers using statistical approaches such as maximum entropy [1], N-grams [5] and memory-based learning approach [14]. The acceptable results are achieved with memory-based learning and N-gram based language modeling approaches. Hence, the proposed instant diacritics restoration mechanism is also based on the N-Grams and Memory-Based Learning approaches. Making use of this mechanism high accuracy in less time is attained.

III. Corpus Preparation

As a matter of fact, two types of data sets are always required for experimentation of diacritics restoration systems [1]. Therefore, two types of corpora are designed and developed. The first subsumes complete diacritized text and the second undiacritized text. In addition to them, a lexicon is also built. The experiments of the proposed method were performed by making use of both types of data sets; corpora and lexicon.

A data set of corpus having 2, 65,257 words are built in Sindhi language for the purpose of training and testing the system. The organized information of the developed corpus in is given in Table I. The corpus is classified into three segments: the antique books that are completely written with diacritics like Shah Jo Rosalo [15], the poetry books that possess partially diacritized text and the recently published text of different genres which are entirely void of diacritics like newspapers, magazines and text books.

TABLE. I. Words Information of Developed Sindhi Corpus

Type of Corpus	**No. of Sentences**	**No. of Words**
Fully Diacritized	8326	49,462
Partially Diacritized	10190	93,188
Not-Diacritized	14869	1,22, 607
Total	**33385**	**2, 65,257**

A. Developed Lexicon

In addition to the development of Sindhi corpus, a lexicon of Sindhi text has been created for it is an essential component for the proposed method of instant diacritization. The mechanism of the instant diacritics restoration has the basis of memory based learning approach with the aid of letter level learning approach. Relatively, a table having the letters in different forms of diacritized as well as un-diacritized is developed. The specimen of this table is given in “Fig. 1”. It should be noted here that each letter is assigned a unique number for the identification. This identification is required for the execution of the letters into the system.

IV. Proposed Model

The nine components work altogether as the constituents of the proposed mechanism: Calculation of word probabilities, specimens of letters, pattern matching and comparative function of homographic structures, K-NN Classifier and Class Labels, calculation of distance between instances using overlap metric, calculate the features weight, nested hash and tokenization. The proposed model in “Fig. 2” is used to show the execution process of the complete system.

The corpus functions as a patron on which the probabilities are dependent; hence, training corpus design is a delicate matter to deal with. The more specified training corpus leads to the more accurate probabilities which help the task to be achieved conveniently. The N-grams are probabilistic models that help the provision of direction for the assignment of probabilities to the words. The unigram, bigram, trigram and so on models are used for the calculation of probabilities. A unigram is an N-gram of 1, bigram of 2, and consequently trigram of 3, and so on with the progressive numbers [16]. The text is a sequential series of structured words and can be given representation as below:

$$P(W_1, W_2, \ldots W_{n-1}, W_n) \tag{1}$$

For a bigram grammar

$$P(w_1^n) \approx \prod_{i=1}^{n} P(w_i \mid w_{i-1}) \tag{2}$$

The trigram is same as bigram except the condition on two previous words as under.

$$P(w_1^n) \approx \prod_{i=1}^{n} P(w_i \mid w_{i-2} w_{i-1}) \tag{3}$$

The ultimate product on the part of the system is the provision of the option to the user to choose the suitable or correct words as per the requirement. Therefore, the language modeling is used for the computation of N-Grams up to quad one. The probabilities of all the words given in the corpus are individually calculated and stored into a specified table in the designed lexicon. The purpose of this whole process is to support the further process of the mechanism.

tblLetterLevel: ...Base\DBINSDR.sdf)

ID	Letter	Word	LetterV	WordV
100001	ا	اِنْسَانَ کَ	ا	انسان ک
100002	نْ	نْسَانَ کَيَ	ن	نسان کي
100003		سَانَ کَيَ		سان کي
100004	کَ	انَ کَيَ سَ	ک	ان کي س
100005	يَ	نَ کَيَ سَبِ	ي	ن کي سب
100006		کَيَ سَبِ		کي سب
100007	سَ	کَيَ سَبِ کَ	س	کي سب ک
100008	بِ	يَ سَبِ کَا	ب	ي سب کا
100009		سَبِ کَان		سب کان
100010	کَ	سَبِ کَان	ک	سب کان
100011	ا	بِ کَان بِ	ا	ب کان ب
100012	ن	کَان بِهِ	ن	کان به
100013		کَان بِهِر		کان بهر
100014	بِ	ان بِهِرِي	ب	ان بهري
100015	هِ	ن بِهِرِيَن	ه	ن بهرين
100016	رِ	بِهِرِيَن	ر	بهرين
100017	يَ	بِهِرِيَن بِ	ي	بهرين ب
100018	ن	هِرِيَن بِنَ	ن	هرين بن
100019		رِيَن بِنَهَ		رين بنه
100020	بِ	يَن بِنَهَن	ب	ين بنهن
100021	نَ	ن بِنَهَنَج	ن	ن بنهنج
100022	هَ	بِنَهَنَجَن	ه	بنهنجن
100023	نَ	بِنَهَنَجَنَ	ن	بنهنجن

Fig. 1. Sample Database Table for Instant Diacritics Restoration

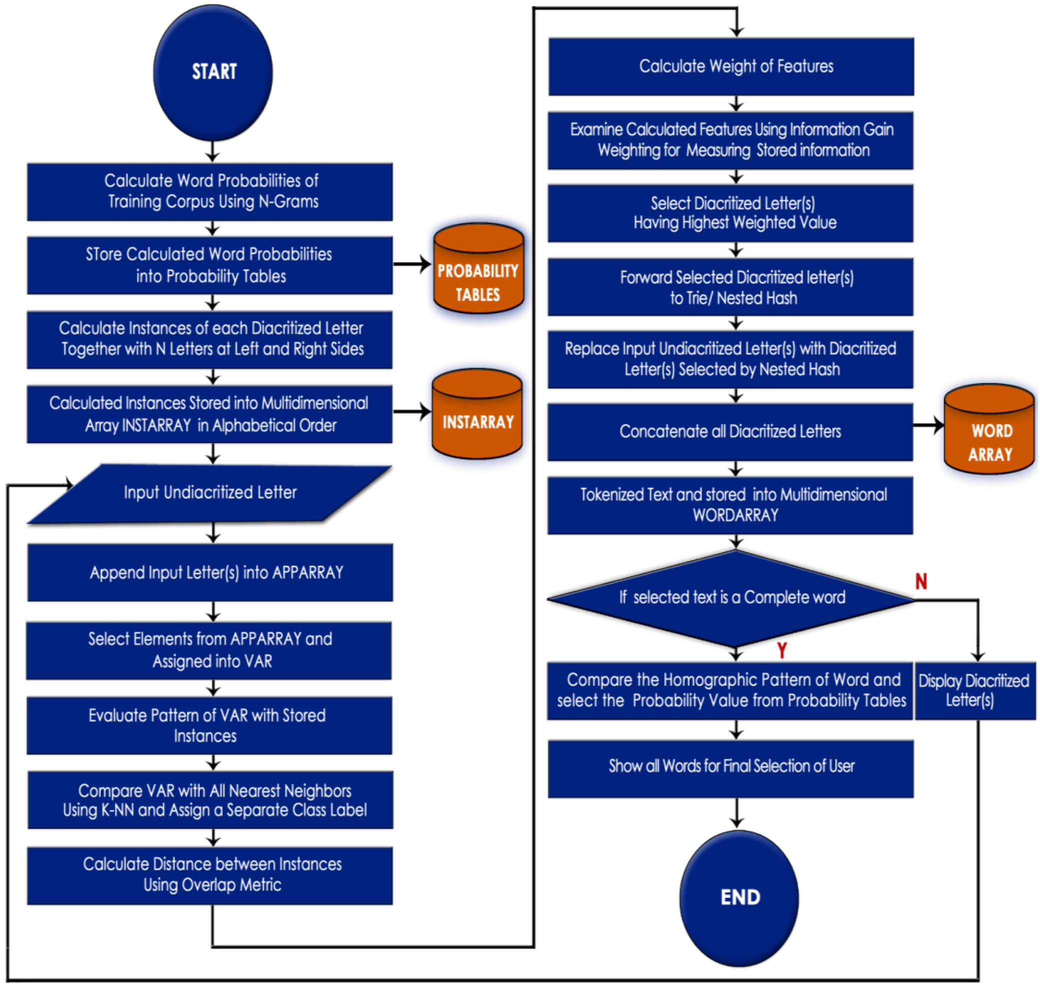

Fig. 2. Proposed Model for Sindhi Instant Diacritics Restoration

After the words probabilities are calculated, the system starts computation of the available instances of each diacritized letter. For this, almost all the possible instances of all the letters in corpora calculated with every diacritic mark; i.e., بَ, بِ , بُ are calculated altogether with the surrounding letter (N letter) on both left and right sides. At the same time, the calculated instances are saved in a multidimensional array ascending. At least 1224688 instances are taken from the available corpus taking care of the particular notations given to the white spaces (SP), commas (CO) and dots (DO) alike [11] [13]. A vector based multidimensional array is used for the storage of these examples. The corpus same from [1] is given below and the related sample of feature vectors extracted from the same source is presented in Table II.

ڪِنهن بہ نِظامَ کي سَنوارڻ ۽ بِگاڙڻ ۾ اَسان سَڀني جو
ڪِٿي نہ ڪِٿي هَٿُ ضَرُورِ هُوندو آهي اَسان مَان هَرِ هِڪَ
مَاڻھُون پَاڻ مَان بَدِديَانتِي ڪَڍِي ڇَڏِي دِيَانتدَارِي پَنھَنجو
پَاڻ پَيدَا ٿِي پَوَندِي اَسَان سَڀُ ڪُوڙ کَان پَاسو ڪَيُون سَچُ
پَاڻھِي سَامُھُون اَچِي وِيندَو

TABLE. II. SAMPLE LETTERS AND FEATURE VECTORS

Letters	Feature Vectors
ڪَ	: ڍ, ي, SP, چ, ڏ, SP, ي, ت, ن, ا : ي, و, ن, CO, SP, SP, و, س, ا, پ
ڪِ	: ن, هه, ن, SP, ب, SP, SP, SP, SP, SP : ٿ, ي, SP, ڪ, ٿ, SP, و, ج, SP, ي : ٿ, ي, SP, هه, ٿ, SP, هه, ن, ي, ٿ
ڪُ	: SP, م, ا, ڻ, و, هه, SP, ر, هه, SP : و, ڙ, SP, ک, ا, SP, پ, س, SP, ن
هَ	: ٿ, SP, ض, ر, و, SP, ي, ٿ, ڪ, SP : ي, DO, ا, س, ا, ا, SP, و, د, ن : ر, SP, هه, ڪ, SP, SP, ن, ا, م, SP : ن, ج, و, SP, پ, ن, پ, SP, ي, ر
هِ	: ن, SP, ن, هه, ن, ن, ڪ, SP, SP, SP : ڪ, SP, م, ڻ, هه, SP, ر, هه, SP, ن : ي, SP, س, ا, م, ڻ, ا, پ, SP, چ
هُ	: و, ن, د, و, SP, SP, ر, و, ر, ض : و, SP, پ, ا, ڻ, ڻ, ا, م, SP, ڪ : و, ن, SP, ا, چ, م, ا, س, SP, ي

The absence of diacritical marks lead to many complexities in the text regarding various possible vowels sounds used in a word [11]. The word سکن may be taken for example. The system performs comparison of the pattern of the un-diacritized word with the diacritized ones available in the corpus. System receives two types of words سُگنِ and سِگنِ. Pattern matching process is carried out using regular expression approach. The system, then, acknowledges the pattern of un-diacritized input word with the diacritized one. The suitable word on the basis of the highest probability is fixed at the same location. Sample regular expression example is given graphical representation below:

سُگنِ:-

Step-1 “ (ـ) ن, (-) ک, (و) س”

Step-2 {(ـ) ن, (-) ک, (و) س =}

Step-3 {(ـ) اکر ن, (-) اکر ک, (و) اکر س=}

(گنِ) , (سُنِ) , (سُکَ) = (نِ) (کَ) (سُ)

سِگنِ:-

Step-1 “ (ـ) ن, (-) ک, (ـ) س”

Step-2 {(ـ) ن, (-) ک, (ـ) س =}

Step-3 {(ـ) اکر ن, (-) اکر ک, (ـ) اکر س=}

(گنِ) , (سِنِ) , (سِکَ) = (نِ) (کَ) (سِ)

The complete group of examples is extracted from the corpus for each complex letter structure. Each letter from the set is taken one by one including the surrounding neighbors from both sides. Then, the system compares with the available instances in the corpus. The KNN classifier is used for this comparison process. The value of each feature vector is calculated and stored in the built-in metric. All of the values of each feature are weighted and tagged with labels whether matched or mismatched structures. These instances are divided in accordance with the assigned labels. The instance based learning algorithm is taken into use for the comparison of new problem examples with instances stored already in the memory. K-nearest neighbor algorithm is the proven simplest method of an instance-based learning one; on the other hand, K-NN method categorizes the objects based on the nearest training example in the feature space. The core model is given below [17]:

$$f(x_q) = \frac{\sum_{i=1}^{k} f(x_i)}{k} \tag{4}$$

All of the input instances are compared individually with the all the closest neighbors by using KNN classifier. Finally, the system accepts the most frequent ones. A multidimensional array in the system saves the training examples containing feature vectors. The label specifies each example according to its class. The highest numbers of votes including with neighbors categorize the labeled entity.

While the process of classification undergoes, a unique test instance is fed to the system, using the distance Δ(X, Y). This computes the sameness of the new examples and all of the other examples in memory. Overlap metric is used for this task particularly considering the distance between instances manifested by N-features. It is only to show the distance per feature [13] [14].

$$\Delta(X, Y) = \sum_{i=1}^{n} \delta(x_i, y_i) \tag{5}$$

The metric performs counting of the entire number of feature-values in both patterns regardless of matching or mismatching for the addition of the domain knowledge bias to the weight.

For the weight of the features, statistical information is calculated through an examination to reach the better predictors of the class tags. Information Gain (IG) examines each feature individually and prepares measurement for the information to be produced and stored knowledge for valid class label.

Immediately after the above process, hash table begins the process of storing data in an associated network manner. This table stores the data in the array format and each data value receives a unique index within. This way the data is quickly accessed after knowing the index of the required data. Hashing technique is widely known technique that is used for the conversion of a range of key values to a range of the array indexes.

Tokenization of the script of Sindhi is also one of the challenging tasks due to the complexities in the text, particularly the complexities of homographic structures. A compound word needs to be entitled as a single token but the embedded space required in between creates ambiguity for the tokenization process. The embedded space is required in between due to the cursive nature of Sindhi script and its connecting and non-connecting letters. Therefore, more attention is to be paid because of these complications facing the tokenization. Mahar's [1] tokenization model is taken in this research project.

In fact, Sindhi script abounds in homographic words. As a result, the ambiguity is often observed when the text is undiacritized. A simple word and root word of Sindhi قسم has such constituent letters which may be interchangeably taken in almost two way as قَسَمُ (an oath) (noun), قِسِمُ (kind) (noun). The taken words without diacritics are exactly identical. Thus, they create ambiguity for NLP applications. Viterbia Algorithm is one of the efficient approaches to find the most likely path transitions in such cases. This algorithm produces the most likely possible word on the basis of the highest probability value calculated by using N-grams [16].

V. Execution Process of Application

Text prediction is the basic idea that ignition to the Instant Diacritics Restoration. The former was proposed to save time and energy simultaneously by offering assumptions of possible upcoming set of letters after typing the beginning letters of words. By typing each succeeding letter, the user receives possible suggestions in different forms of popup to adopt with a single click only rather than typing all the upcoming letters of the word. For example, user wants to type the word انسان.

After typing the first letter, he will be shown some popup carrying some most possible and frequently used words begging with ا. Then, he will type the next letter ن, he will again be shown some set of most possible and frequently used set of letters after the two begging ones. If he finds the same letter in the popup, he would just hit a single click to get the word typed rather than hitting five strokes for all the five letters in the word.

This function of text prediction gave birth to the idea of instant diacritics restoration. The predictive approach of instant diacritization facilitates the user to type the words with their exact pronunciations which further helps in reading it correctly. The editor actively and simultaneously works with the user and assigns the diacritics automatically. The user has to type the words only. The diacritics will automatically be assigned immediately. For example, the user wants to type the word اِنّسَانُ, he first types the first letter ا, the editor will assign it the superscript diacritic sign ـَـ initially, for the system is assigned this task for every first letter. After ا, the user types another letter ن, the system will immediately calculate the probability of the possible diacritics to this couple of letters and assign ـّ to ن, simultaneously the ـَـ to ا will change into ـِـ .

The user is to type س now, as he types س the system again goes for the calculation of the probability of the possible diacritics to this combination of letters and assigns the diacritics to all of the three according the highest found match in the corpus. Now, the user moves ahead to type ا and then ن, the system will simultaneously work with the letters and the diacritics while calculating the probabilities of the letters and diacritic signs from the given corpus. After the user is done with typing اِنّسَانُ, the system finalizes its diacritics with the same procedures detailed above. The same process takes place by typing each letter in the editor.

VI. Implementation And Results

The training and testing set design stand as the foundations to the final results. Therefore, both are mainly concerned till the results are derived. Different techniques like Word Error Rat, Diacritic Error Rate, Precision, Recall and F-measures were in the use previously. We have also taken Precision which is one of them due to the fact that its performance is observed to be better at letter level approach [1]. Moreover, the complex letters assign the target features for being trained; hence, the task is performed at the lowest basic level of letters. Three mainly used diacritics, i.e., Zabar, Zair and Pesho in Sindhi are considered in experiments.

The Letter Level Learning method processes every letter taken from the corpus and creates a ten letters vector. Each vector is put into an array. Consequently, each letter is pre-processed with its calculated probability. After receiving the testing data set, system throbs the comparison of all the undiacritized letters of the testing data set with the pre-processed data available in the arrays and after the said process replace the letter with the diacritized one.

From the total sets of instances taken from the developed corpus, 159330 instances are experimentally tested from each set. The testing examples are approximately 15% of the whole set of examples. Table III, Table IV and V depict the results attained with N=1, 3 and 5. The tables show the ambiguous letters extracted from the developed corpus, the precision as the result by applying instance-based learning at letter level.

TABLE. III. Ambiguous Set of Letters, Examples and Achieved Precision with N=1

Ambiguous Set	**Total Examples**	**Tested Examples**	**Precision Achieved**
اَ اُ اِ	99,262	14889	91.22%
بَ بُ بِ	15,881	2383	93.51%
ٻَ ٻُ ٻِ	6,447	967	92.71%
ڀُ ڀِ ڀَ	14,752	2212	90.84%
تَ تُ تِ	34,169	5126	91.36%
ٿُ ٿِ ٿَ	11,223	1684	90.33%
ٽُ ٽِ ٽَ	10,227	1534	92.42%
ٺُ ٺِ ٺَ	4,673	701	90.01%
ثَ ثُ ثِ	850	127	89.19%
پَ پُ پِ	12,273	1841	92.62%
جَ جُ جِ	41,688	6253	88.24%
جَهه جِهه جُهه	5,486	823	83.61%
ڄُ ڄِ ڄَ	782	117	94.56%
ڃُ ڃِ ڃَ	238	36	94.62%
چُ چِ چَ	18,852	2828	90.41%
ڇُ ڇِ ڇَ	10,293	1544	92.55%
حُ حِ حَ	20,790	3118	93.77%
خُ خِ خَ	8,039	1206	95.71%

دُ دِ دَ	30,477	4572	97.09%
ڌُ ڌِ ڌَ	993	149	94.22%
ڊُ ڊِ ڊَ	274	41	95.11%
ڏُ ڏِ ڏَ	25,622	3843	94.63%
ڍُ ڍِ ڍَ	691	104	96.12%
ذُ ذِ ذَ	532	80	90.81%
رُ رِ رَ	48,033	7205	90.01%
ڙُ ڙِ ڙَ	1,943	291	93.32%
زُ زِ زَ	849	127	90.54%
سُ سِ سَ	24,237	3635	94.90%
شُ شِ شَ	994	149	94.32%
صُ صِ صَ	592	89	94.88%
ضُ ضِ ضَ	231	35	95.62%
طُ طِ طَ	838	126	89.21%
ظُ ظِ ظَ	201	30	90.01%
عُ عِ عَ	11,421	1713	93.79%
غُ غِ غَ	841	126	93.88%
فُ فِ فَ	12,840	1926	94.56%
ڦُ ڦِ ڦَ	556	83	93.76%
قُ قِ قَ	605	91	94.55%
ڪُ ڪِ ڪَ	54,837	8226	95.64%
کُ کِ کَ	28,444	4267	95.99%
گُ گِ گَ	14,766	2215	94.06%
گھِ گھَ گھ	2,495	374	81.58%
ڳُ ڳِ ڳَ	348	52	94.93%
ڱُ ڱِ ڱَ	173	26	92.27%
لُ لِ لَ	55,121	8268	92.77%
مُ مِ مَ	60,270	9041	95.74%
نُ نِ نَ	101,126	15169	90.31%
ڻُ ڻِ ڻَ	126	19	90.91%
وُ وِ وَ	55,664	8350	95.05%
هِ هَ هه	84,033	12605	88.64%
ءَ ءُ ءِ	76	11	93.03%
يُ يِ يَ	126,023	18904	90.88%

TABLE. IV. Ambiguous Set of Letters, Examples and Achieved Precision with N=3

Ambiguous Set	Total Examples	Tested Examples	Precision Achieved
اَ اُ اِ	99,262	14889	94.55%
بَ بُ بِ	15,881	2383	96.86%
ٻَ ٻُ ٻِ	6,447	967	94.66%
ڀُ ڀِ ڀَ	14,752	2212	95.14%
تَ تُ تِ	34,169	5126	96.31%
ٿُ ٿِ ٿَ	11,223	1684	92.23%
ٽُ ٽِ ٽَ	10,227	1534	93.76%
ٺُ ٺِ ٺَ	4,673	701	95.85%
ثَ ثُ ثِ	850	127	94.63%
پَ پُ پِ	12,273	1841	92.62%
جَ جُ جِ	41,688	6253	92.54%
جَهه جِهه جُهه	5,486	823	87.41%
ڄُ ڄِ ڄَ	782	117	95.33%
ڃُ ڃِ ڃَ	238	36	97.02%
چُ چِ چَ	18,852	2828	94.48%
ڇُ ڇِ ڇَ	10,293	1544	95.88%
حُ حِ حَ	20,790	3118	96.77%
خُ خِ خَ	8,039	1206	96.07%
دُ دِ دَ	30,477	4572	98.21%
ڌُ ڌِ ڌَ	993	149	95.99%
ڊُ ڊِ ڊَ	274	41	96.79%
ڏُ ڏِ ڏَ	25,622	3843	97.13%
ڍُ ڍِ ڍَ	691	104	96.88%
ذُ ذِ ذَ	532	80	93.22%
رُ رِ رَ	48,033	7205	93.66%
ڙُ ڙِ ڙَ	1,943	291	96.22%
زُ زِ زَ	849	127	94.34%
سُ سِ سَ	24,237	3635	95.42%
شُ شِ شَ	994	149	97.32%
صُ صِ صَ	592	89	95.07%
ضُ ضِ ضَ	231	35	97.65%
طُ طِ طَ	838	126	93.44%
ظُ ظِ ظَ	201	30	93.71%
عُ عِ عَ	11,421	1713	95.17%
غُ غِ غَ	841	126	95.48%
فُ فِ فَ	12,840	1926	95.06%
ڦُ ڦِ ڦَ	556	83	96.72%
قُ قِ قَ	605	91	95.15%
ڪُ ڪِ ڪَ	54,837	8226	96.99%
کُ کِ کَ	28,444	4267	97.01%
گُ گِ گَ	14,766	2215	95.06%
گھِ گھَ گھ	2,495	374	87.25%
ڳُ ڳِ ڳَ	348	52	95.91%
ڱُ ڱِ ڱَ	173	26	94.87%
لُ لِ لَ	55,121	8268	96.44%
مُ مِ مَ	60,270	9041	97.14%
نُ نِ نَ	101,126	15169	96.53%
ڻُ ڻِ ڻَ	126	19	95.11%
وُ وِ وَ	55,664	8350	96.57%
هِ هَ هه	84,033	12605	91.84%
ءَ ءُ ءِ	76	11	93.78%
يُ يِ يَ	126,023	18904	96.77%

TABLE. V. Ambiguous Set of Letters, Examples and Achieved Precision with N=5

Ambiguous Set	Total Examples	Tested Examples	Precision Achieved
اَ اُ اِ	99,262	14889	98.26%
بَ بُ بِ	15,881	2383	99.17%
ٻَ ٻُ ٻِ	6,447	967	99.09%
ڀُ ڀِ ڀَ	14,752	2212	99.74%
تَ تُ تِ	34,169	5126	99.22%
ٿُ ٿِ ٿَ	11,223	1684	99.04%
ٽُ ٽِ ٽَ	10,227	1534	98.51%
ٺُ ٺِ ٺَ	4,673	701	99.64%
ثَ ثُ ثِ	850	127	99.61%
پَ پُ پِ	12,273	1841	99.55%
جَ جُ جِ	41,688	6253	98.14%
جَهه جِهه جُهه	5,486	823	94.38%
ڄُ ڄِ ڄَ	782	117	99.23%
ڃُ ڃِ ڃَ	238	36	99.88%
چُ چِ چَ	18,852	2828	99.66%
ڇُ ڇِ ڇَ	10,293	1544	99.17%
حُ حِ حَ	20,790	3118	99.47%
خُ خِ خَ	8,039	1206	99.47%
دُ دِ دَ	30,477	4572	99.91%
ڌُ ڌِ ڌَ	993	149	99.87%
ڊُ ڊِ ڊَ	274	41	99.73%
ڏُ ڏِ ڏَ	25,622	3843	99.44%
ڍُ ڍِ ڍَ	691	104	99.81%
ذُ ذِ ذَ	532	80	99.88%
رُ رِ رَ	48,033	7205	99.22%
ڙُ ڙِ ڙَ	1,943	291	99.11%

زُ زِ زَ	849	127	99.14%
سُ سِ سَ	24,237	3635	98.66%
شُ شِ شَ	994	149	98.93%
صُ صِ صَ	592	89	99.28%
ضُ ضِ ضَ	231	35	99.33%
طُ طِ طَ	838	126	99.17%
ظُ ظِ ظَ	201	30	99.32%
عُ عِ عَ	11,421	1713	99.37%
غُ غِ غَ	841	126	99.57%
فُ فِ فَ	12,840	1926	99.22%
ڦُ ڦِ ڦَ	556	83	99.13%
قُ قِ قَ	605	91	97.55%
ڪُ ڪِ ڪَ	54,837	8226	99.18%
کُ کِ کَ	28,444	4267	99.63%
گُ گِ گَ	14,766	2215	99.26%
گھِ گھَ گھ	2,495	374	94.52%
ڳُ ڳِ ڳَ	348	52	99.01%
ڱُ ڱِ ڱَ	173	26	99.61%
لُ لِ لَ	55,121	8268	99.14%
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وُ وِ وَ	55,664	8350	99.51%
هِ هَ ه	84,033	12605	97.35%
ءَ ءُ ءِ	76	11	98.17%
يُ يِ يَ	126,023	18904	99.26%

Three different window sizes were tested to reach the best one. Among the window sizes of two, six, and ten letters (i.e., N= 1, 3, 5), the calculated accuracy with N=1 is 92.52%, accuracy of 95.12% is received when N=3 and 99.03% is calculated with N=5. Window size for the greatest and most efficient accuracy was observed up to ten nearest accompanying letters (i.e., N=5) where N stands for the number of letters from each side of the letter under process. The calculated cumulative precisions with different experimented window sizes are shown in “Fig.3”.

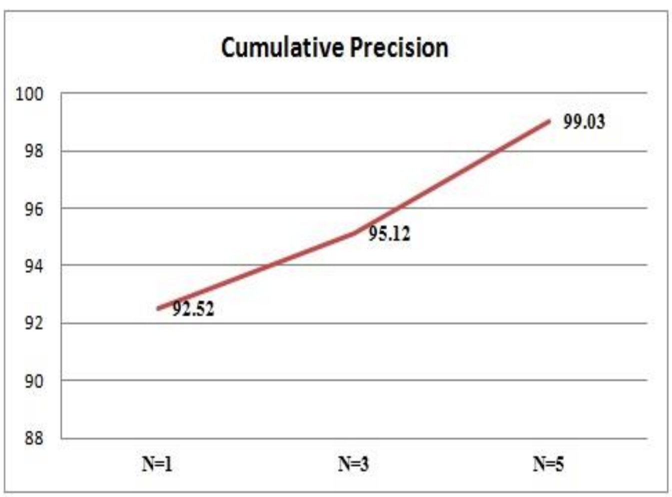

Fig. 3. Calculated Cumulative Precision with Different Window Sizes

The figures, given in the tables, show that a considerable difference can be found among them; in addition to this, the calculated results reveal that the window size is also decisive in increase and decrease of results. Therefore, N=5 proves to be the most suitable and reliable window comparatively.

VII. Conclusion

Automatic instant diacritic restoration is essential component for many NLP applications. The restoration is attempted with the most possible intelligent use of two approaches; N-grams based and Letter Level Learning-based. Each of both methods has their own specifications along with the limitations. The proposed mechanism in this study is experimented on our developed corpus of Sindhi language. The window (N=5) is found the best one after testing different sizes. The Precision with this window is achieved at 99.03%. The proposed method is also capable for the instant diacritics restoration of Arabic, Urdu and Persian languages after slight modifications.

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An Enhanced Breast Cancer Diagnosis Scheme based on Two-Step-SVM Technique

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***Abstract*—This paper proposes an automatic diagnostic method for breast tumour disease using hybrid Support Vector Machine (SVM) and the Two-Step Clustering Technique. The hybrid technique is aimed at improving the diagnostic accuracy and reducing diagnostic miss-classification, thereby solving the classification problems related to Breast Tumour. To distinguish the hidden patterns of the malignant and benign tumours, the Two-Step algorithm and SVM have been combined and employed to differentiate the incoming tumours. The developed hybrid method enhances the accuracy by 99.1% when examined on the UCI-WBC data set. Moreover, in terms of evaluation measures, it has been shown experimentally results that the hybrid method outperforms the modern classification techniques for breast cancer diagnosis.**

Keywords—Two-Step Clustering; Breast Cancer; SVM classification; Diagnosis; Tumors

I. Introduction

Now-a-days, Breast cancer is one of the serious dilemma facing the radiology scientists. Indisputable information is not available, but rather it was assessed that the newly malignancy examples in 2012 is more than 1,600,000 whereas the number of tumour passing away would spread more than 570,000 [1]. Breast cancer represented 29% of assessed new womanly tumour patients (790,740 patients), making it the most regularly diagnosed malignancy among ladies[1]. Diagnosis of cancerous cells in the breast is one of the biggest real-world medical problems. The diagnosis has always been a major problem in the medical field, based on various tests conducted on various patients. Tests are meant to aid the physician in making a proper and accurate diagnosis. However, miss-diagnosis sometimes occurs, especially in tumour and cancerous cells since it can be difficult to make an accurate diagnosis, even for a medicinal cancer expert. One of the drifting issues in the medicinal field is a diagnosis of the tumours. Mass descriptive tumour information and feature data on cancer studies can now be obtained with the aid of information technology. Mammography by radiologists and physicians has long been the means of predicting breast cancer. In 1994, ten radiologists analyzed and interpreted 150 mammograms to classify the tumour categories in the breasts [2]. The variation of the radiologists' clarifications brought on a low accuracy of diagnosis even though the value of using mammograms was proven. Above 89.5% of radiology scientists identified less than 3% of tumors from the study.

The remaining of the manuscript is sorted out as pursues. Section2 discusses the related literature review. In Section 3 and Section 4, the concept of the SVM and Two-Step Clustering algorithm. Section 5 provides a description of the involved idea of a hybrid technique. Section6 discusses Dataset. Experimental design of the hybrid approach was described in Section7. Section8 deals with results discussion of the introduced approach. Finally, section9 discusses the Conclusions and future work.

II. Related Works

Several technologies are now employed for the collection and analysis of the datasets. Given the large volume of cancer cases available, it is difficult for a medical doctor to absorb every particular feature of cancer. Accordingly, physicians increasingly depend on data analysis methodologies for making decisions related to cancer diagnosis. Some researchers are also relying on machine learning methods and data mining techniques (DM) for predicting and classifying breast tumour to accuracy improvement and deal with the increasing tumour information and feature data. A broad mixture tool and software for knowledge discovery (KD) behind large-scale data, DM is highly appropriate in the real world. Machine learning approaches and data mining were employed into a software-assisted system for breast tumour diagnosis by Wolberg [3], and Pena-Reyes [4]. Knowledge discovery techniques were used in tumour classification with positive results as demonstrated by the results of Pena-Reyes and Sipper's research, and the current breast tumour diagnosis became an obstacle of classification in the knowledge discovery domain. The current tumour feature datasets were classified separately into benign and malignant groups. Evaluating the classifier made it possible for a new incoming tumour to be classified, using the tumour's historical data, by finding out a classifier to divide the tumours types. Based on the related work a data mining methods were used to diagnose tumour based on cancer features data. The computational time increases as the number of descriptive tumour features increases. Different approaches in recognizing tumour shapes and getting the needed information and data for breast tumour diagnosis are investigated in this study to work with a huge amount of tumour attributes. This research conducted to find an accurate and efficient approach to analyzing and detect the incoming tumour pattern with the assist of knowledge discovery methods. Because the tumour features can be described in great detail, the unnecessary details lead to a higher computational time for complex estimation without much influence to the concluding predictor. It is significant to note that a part of the basic requirement for cancer diagnosis also includes time complexity. In addition to time efficiency, a way of mining and extracting the essential data from the tremendous information, filtering the features and predicting the classification of the new tumour instances accurately is now of concern. Sequential backward and forward search to choose the most important mixture of features using the multilayer perceptron neural network to classify tumours had been proposed by Nezafat et.al [5]. F-score for finding the DNA virus discrimination was proposed for the selection of the best subset of DNA diseases for breast tumour analysis based on SVM [6] and [7]. Combining an SVM-based approach with feature reduction technique for diagnosis of breast tumour was proposed by Akay [8]. Through the use of the F-score for the measuring of the feature discrimination, the study conducted a consuming time for the optimal parameters adjusting mixed on the precision diagnosis to nominate the best subclass of the basic tumour attributes for learning stage by support vector machine[7]. Prasad, Biswas, and Jain [9] proposed a another combination method of SVM and heuristics to find out the significant attributes subclass for SVM learning stage rather than the extensive search. In addition to an improvement in diagnosis cancer accuracy, their results also combined with PSO technique to cut down the time complexity for the significant training due to the inference on dimension feature space and searching for the best feature. Accurate diagnostic measurements are taken on the FNA [10] in this dataset. These statistics claim that compared to other forms of cancer, breast tumour places the 3rd position among diagnosed new patients, the first and second places being occupied by genital organs and digestive systems tumour, respectively. The surgical biopsy is the best approach for confirming malignancy with high-level sensitivity in the prognosis of the disease and breast tumour diagnosis. But it is an expensive operation with a negative impact on the patient's psychology. Dubey, A. K., U. Gupta, et al. [20] investigated the influences of k-means clustering method based on distance, centroid, epoch, split method, and iteration to identify and consider the integration of computational measures for possible extract highly accuracy of breast cancer Wisconsin dataset. Their method obtained 92% accuracy in term of precision. Zheng, B., S. W. Yoon, et al.[21] proposed a breast cancer diagnosis method using a combination between K-means and SVM technique. The method used feature selection technique to extract the important feature for the potential to improve the diagnosis accuracy. The hybrid approach achieved 97.38% accuracy results in term of evaluation measures. S. Aruna et al. [22] examined different classification methods such as SVM-RBF kernel, RBF neural networks, simple CART and J48 methods to extract the optimum classifier in WBC dataset. The experimental output proves that SVM-RBF kernel is better than other classification techniques with 96.84% accuracy scores in WBC dataset.

Considering the afrementioned research work, there is a shift towards less invasive data mining methods which can give the same rates of accuracy without the problems associated with surgical biopsy. The current study proposed a hybrid SVM-Two-Step method as one of the diagnostic solutions when the aim is to classify and predict the patient's medical information to detect the level of breast cancer accurately. Identifying a difference between malignant and benign cancer is the function of diagnosis. Once the cancer is diagnosed, it is necessary to follow with a classification of the expected the disease course. More importantly, the Two-Step Clustering methodologies and an efficient probabilistic support vector machine are also studied in this research.

The different between the TwoStep-SVM method and other classification techniques is that the hybrid approach used a clustering output as an input feature which it can help for improving the diagnosis accuracy. Where the other classifiers used an original dataset feature as an input. Another difference is that the twoStep clustering algorithm can group the breast cancer dataset automatically to select the similar samples and features. Thus it can increase the correlation between the input features to assist a classifier in extracting accurate results.

III. SUPPORT VECTOR MACHINE (SVM)

The SVM is a modern technique rapidly gaining popularity as a result of the helpful results that have been accomplished in a widespread diversity of data mining issues, due to their strong hypothetical, theoretical underpinnings in statistical learning theory [11], [12] and [13]. SVM is a binary classification method according to the theory of statistical learning that has been used with much success in different defy on large datasets and nonlinear classification problems [14] and [15]. It has been found valuable in solving linear separated (LS) as well as non-linear separated problems (NLS) [16]. SVM predictors use the hyper-plane in separate classes. Each hyper-plane is defined by its direction (w), the exact location in space or a threshold is (b), (xi) is the input vector of element N or text content and indicates the class. A group of the training cases is presented by equations 1 and 2.

$$(\mathrm{x1},\mathrm{y1}),(\mathrm{x2},\mathrm{y2}),\ldots,(\mathrm{xk},\mathrm{yk});\ \mathrm{Xi}\in R^{d} \qquad (1)$$

k is the training dataset number and d represents the number of dimensions of input dataset: $\mathrm{yi}\in\{-1,+1\}$; i = 1, 2, . . . , k. The decision function of the form Eq. 2.

$$f(\mathrm{x},\mathrm{w},\mathrm{b}) = \mathrm{sgn}\big((\mathrm{w}\cdot\mathrm{xi}) + \mathrm{b}\big), \mathrm{w}\in R^{d}, \quad \mathrm{b}\in\mathrm{R} \qquad (2)$$

The margins are the region among the hyper-plane, which separates two classes; the margins demonstrate the classification of breast cancer by SVM. Let the distance from the adjacent data point to the hyper-plane be $\frac{1}{||w||}$. There is one optimum separating hyper-plane among separate hyper-plane, and the distance of two SV points from diverse sides of this hyper-plane is maximal. Then the vertical distance from the origin to this hyper-plane is $\frac{1}{||w||}$, and the margin distance separating hyper-plane is $\frac{2}{||w||}$. The minimum distance of the margin is equivalent to $\frac{1}{2}||w||^2$ (named primal problem) and getting the maximum potential margin is the primary knowledge of SVM method. Figure 1 demonstrates the prediction of breast cancer utilizing Support Vector Machine.

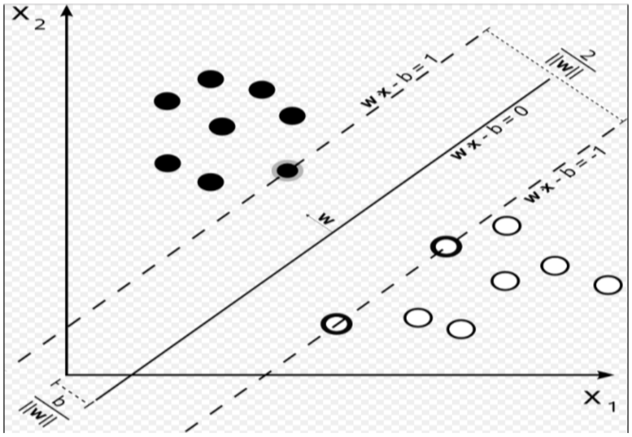

Fig. 1. Classification of breast cancer using SVM

IV. Two-Step Clustering Algorithm

Several approaches used Two-step clustering algorithm in different felids such as [23,24, and 25]. Najjar, A et al. [23] proposed an exploring analytics method extending from Smyth study [24] for analyzing healthcare data. The proposed method used the two-Step clustering algorithm for heterogeneous finite mixture model using two-step; firstly, including a joint mix of multinomial distribution and Gaussian to handle categorical and numerical inputs. Then, featuring a mix the hidden Markov model to handle orders of categorical input. The method is measured on a real-world system and the obtained good results for identifying health services with big families. V. Deneshkumar et al. [25] proposed a method for detecting the outlier and defining the effect influence in the diabetic people using two-step clustering algorithm and different data mining methods. The method tried to find the patterns and relationships within large medical data to extract new clinical knowledge.

The TwoStep Clustering algorithm is associated wildcat method proposed to disclose natural clusters (or groups) inside a knowledge set that might or not be obvious [17]. The method utilized by this process has many different options that distinguish it from ancient clustering methods:

- The capability of make groups of elements that can support each continuous and categorical variables.
- Determine the number of clusters automatically.
- Analysis a big corpus efficiently.

A. Principles of Clustering

To handle continuous and categorical variables, the TwoStep Clustering algorithm applies a likelihood distance measure that supposes that variables within the group model are freelance. Additionally, every categorical variable is intended to own a multinomial distribution, and every continuous variable is expected to own a standard (Gaussian) allocation. Experimental internal testing specifies that the process is properly strong to violations of each the belief of individuality and therefore the spatial arrangement assumptions. The two-steps of the algorithm's rule are concluded as:

- **phase 1.** The process starts with the development of a Cluster Features (CF) Tree. The tree starts by putting the first case at the tree root in a leaf node that conveys variable information for that case. Every consecutive case is then supplemental to associate existing node or forms a new node according to the distance similarity between the existing nodes.
- **phase 2.** By using agglomerative clustering (AC) mechanism, the leaf nodes of the Cluster Features tree are then clustered. The AC can be employed to range the produced solutions. The best number of clusters can be determined by comparing these clusters using the Akaike Information Criterion (AIC) or Schwarz's Bayesian Criterion (BIC).

To define the similarity score between the object, the Euclidean distance measure is used in a proposed hybrid method as show in Eq. 3.

$$\mathrm{Dist}(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \qquad (3)$$

A Euclidean vector is the position of a point in a likelihood n-space. Therefore, X is ($Xn, Xn, \ldots, Xn$) and Y is ($Y1, Y2, \ldots, Yn$) are likelihood vectors, beginning from the origin of the space, and two points are indicated by their tips [18].

V. Hybrid Approach

The introduced technique is a hybrid method for breast cancer dataset prediction using Two-Step clustering and SVM methods and consists of two sub-methods: Two-Step data clustering based on features similarity using likelihood distance measure, and classification breast cancer dataset based on the SVM algorithm. The purpose of this research is to introduce a cancer diagnostic classification approach with the aid of a hybrid Two-Step data clustering algorithm and the SVM prediction method for the enhancement of the classification accuracy (effectiveness) and to reduce the rate of misclassification. This work pioneers a new approach which combines the supervised and the unsupervised learning methods Two-Step clustering algorithm and SVM techniques. A qualified research has been conducted on the SVM classification and Two-Step data clustering structure on breast cancer features. Then the results of clusters used as inputs to the prediction method using the SVM technique as classifiers for cancer cases. The Hybrid TwoStep-SVM technique is considered to investigate the result of the trained method. As a result of a large number of cases correlated with the cancer data, The dataset was split into ten parts as 10-folds cross-validations for training and testing the TwoStep-SVM method. **Figure 2** shows the stages of the introduced technique (TwoStep-SVM stages).

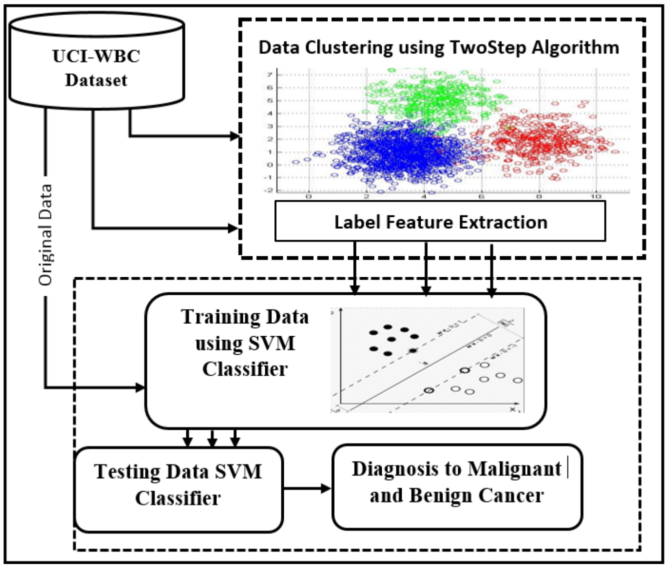

Fig. 2. Hybrid TwoStep-SVM Approach

VI. Dataset

This research was conducted based on the Wisconsin Breast Cancer (WBC) corpus. The corpus was widely used as [7,8,9,20,21 and, 22] and always used to discriminate cancerous (malignant) from the non-cancerous (benign) sample. Table 1 gives a description of the WBC dataset. The WBC dataset is made up of a group of features with some instances and classification patterns. The number of cases and samples of this dataset is 699, with 11 features classified into two classes.

TABLE. I. Features of Breast Cancer

No	Feature and Range
1	Sample code number: id
2	Clump Thickness:1 - 10
3	Uniformity of Cell Size: 1 - 10
4	Uniformity of Cell Shape: 1 - 10
5	Marginal Adhesion: 1 - 10
6	Single Epithelial Cell Size: 1 - 10
7	Bare Nuclei: 1 - 10
8	Bland Chromatin: 1 - 10
9	Normal Nucleoli: 1 - 10
10	Mitoses: 1 - 10
11	Class: (2 for benign, 4 for malignant)

In the group thickness, cancerous cells are usually gathered in multilayer, while benign cells tend to be assembled in monolayers. Whereas in the homogeny of cell shape and size, the cancerous cells tend to differ. That is why these parameters are important in defining if the cells are malignant or not. Healthy cells a tendency to stick together in Marginal adhesion cases, where cancerous cells most often lose this capability. Thus, the damage of adhesion is a sign of cancer. In the case of the single epithelial cells size, the size is associated to the uniformity stated above. Significantly, enlarged epithelial cells may be malignant cells. Nuclei that is not surrounded by cytoplasm (the rest of the cells) is called the bare nuclei. Typically, they are seen in benign cancer. The Bland Chromatin refers to a uniform "texture" of the nucleus seen in benign cells. The chromatin is often more coarse in tumour cells. The normal nucleoli are minor structures realized in the nucleus. In healthy cell, the nucleolus is typically small extremely, if observable at all. The nucleoli be more distinguished in cancer cells; occasionally there are further of them. Lastly, Mitosis is nuclear division plus cytokines which extract two duplicate daughter cells through prophase. The cell divides and replicates by this process. Counting the number of mitoses can enable pathologists to determine the grade of cancer.

VII. Experimental Design

This research conducted an experimental design using UCI WBC breast tumour dataset for the assessment of the performance of introduced algorithm. To compare the accuracy of cancer predictors, experiments ran the *Two-Step-*SVM training method using 10-folds cross validation. The dataset was broken down into ten sets. Each set represented 10% from the original dataset to allow every slice of the dataset to take a turn as a testing data. For each round, the experiment used nine sets for training process and the reminder one for the testing process. The *Two-Step* technique is employed for grouping tumours based on similar class benign and malignant tumour features. From the explanation of the Two-Step clustering algorithm, the result of Two-Step algorithm extract 5 clusters with a different number of instances and features distributed from feature 1 to feature 11. The algorithm automatically determines the optimal number of groups with the assistance of the criterion defined in criterion cluster of the grouping. Table 1 describes the outcomes clusters while Table 2 illustrates the distribution of these clusters.

TABLE. II. Result of Instances Distribution Clusters based on All Breast Cancer Features

Feature Name	Number of Instances for Each Cluster				
	1	2	3	4	5
ID	387	0	9	2	4
Normal Nucleoli	1	85	0	46	0
Clump Thickness	21	0	4	2	3
Uniformity of Cell Size	13	0	6	0	9
Uniformity of Cell Shape	5	0	10	0	4
Marginal Adhesion	8	0	10	2	10
Single Epithelial Cell Size	0	0	3	0	1
Bare Nuclei	0	0	2	0	6
Bland Chromatin	0	0	14	0	7
Mitoses	0	0	3	3	3
Class	12	0	3	0	1

In Table 2, TwoStep clustering algorithm results extracted 5 clusters or groups; these are all important clusters. The distributed numbers of instances members are 447, 55, 85, 64, and 48-form cluster 1 to cluster 5 sequentially. It is shown that the highest number of instances due to the similarity of the member features is scored by cluster 1. The majority of the members of cluster 1 are similar in Bare Nuclei feature; Table 2 demonstrates the shared members of the other features in the cluster 1. The high score number of participated members among Clusters 3 and 5 is Mitoses feature with 85 and 46, respectively. In cluster 4 and 5, the Bland Chromatin feature scored with ten members and ranked as a high score among these cluster members. On the other hand, there is a less number of instances ranking to cluster 5 with 48 instances due to the variation and discrimination of cluster member features. Via these clusters, the Two-Step Clustering algorithm analyzed and described the breast cancer dataset; the main task of different clustering techniques is data description. The clustering algorithm was selected to be hybridized with SVM to enhance the classification and prediction process. The steps of how the clustering was used and combined with the SVM classifier are; first, the TwoStep method conducted to cluster the corpus of data into different groups. The output of these groups and clustering is represented in a new variable feature named label. The values of label feature are the cluster name such as cluster1, cluster2, etc. Each record in the dataset was labeled with the cluster name. Then, the SVM classifier was applied with the label feature for potential generating accurate diagnosis result with high prediction accuracy.

In the prediction part, the SVM algorithm is utilized for achieving accurate prediction cause of its high level of accuracy. Commonly, SVM algorithm adopted to find the predictor as follows [34] and [15]:

$$maximize_x = \left[\sum_{i=1}^{n} x_i - \frac{1}{2} \sum_{ij=1}^{n} x_i x_j y_i y_j k(x_i, x_j) \right] \quad (4)$$

$$subject\ to \sum_{i=1}^{n} x_i y_j = 0, \ \ 0 \leq \forall x_i \leq L. \quad (5)$$

Where x stands for the training vector, y represents the associated label between the training vectors, a denotes the variables vector of hyperplane classifier, K is a kernel function for assessing the distance between the learning vector xi and xj, and L stands for a penalty parameter to manage some misclassifications. For instance, if L is infinity, the predictor supplies an infinite penalty on classification error to prevent classification error from taking place. A higher L ensures a higher precision on learning dataset; simultaneously, it takes extra time to achieve the predictor. A lower L provides additional flexibility on the predictor on the tolerance of fault. In this situation, the results are not much affected by the different kernel function, and sigmoid kernel function has been utilized in the SVM method.

VIII. Experimental Result and Discussion

For the purpose of carrying out an experimental study, breast cancer dataset was learned. As stated earlier discussion, the research used 10-folds cross-validations approach for training and testing the dataset. The experiment applied cross the dataset using SVM classifier without clustering results and with clustering results to investigate the improvement outcomes of the hybrid approach. The cross-validations process obtained computed a diagnosis accuracy results as:

$$\text{Accuracy} = \frac{(\text{TN} + \text{TP})}{(\text{TN} + \text{FP}) + (\text{TP} + \text{FN})} \quad (6)$$

Where,

True Positive (TP): The number of benign and malignant executables correctly classified; False Positive (FP): The number of benign executables classified as malignant; True Negative (TN): The number of benign and malignant executables incorrectly classified; False Negative (FN): The number of malignant executables classified as benign.

In the experiments, the WBC dataset was used in order to determine the breast cancer stage (benign or malignant). The dataset had each instance reported as either a benign or a malignant case. The hybrid technique applied by training and testing the dataset using hybrid TwoStep and SVM method. Using Two-Step algorithm, the dataset then was divided into different clusters with each cluster having different instances. The main objectives of clustering in this study is to extract patterns and structures by collecting the breast cancer samples with similar patterns together thus, the complexity will be reduced and the diagnosis interpretation will be accurate. The achieved performances from the training and testing process on the dataset are illustrated in Table 3 which demonstrates a set of results obtained by SVM classifier technique without clustering and with clustering using the TwoStep algorithm. In the combination process, the output of the TwoSetp is added as a new feature to label each instance in the dataset with a cluster name as discussed in Section 7. This feature can increase the correlation between the instances by grouping the dataset into different clusters, each with similar instances. The SVM classifier employed again with the output of the TwoStep method for possible obtaining high accuracy. A 10-folds cross-validations were applied in the trining and testing process with and without clustering. Each training and testing experiment uses breast cancer dataset features as an input variable to the SVM. Then the target field is a class feature (benign or malignant). The results of the SVM classifier with clustering proved an improvement performance when the SVM technique classified the dataset with TwoStep cluster output. Interestingly, the TwoStep clustering algorithm increases the diagnosis accuracy with 99.1% ratio as shown in Table 3.

Figures 3 and 4 demonstrate both training and testing output of the SVM without clustering and with clustering using Two-Step Clustering. The 10-folds cross-validations were calculated, and the average classification results using SVM without clustering obtained 96.19% and 95.23% for training and testing experiments respectively. The figures also represent the achieved results of the SVM classifier with clustering using a TwoStep algorithm with 99.39% in the training and 99.1 in the testing experiments. The training and testing high-performance results without clustering achieved in folds number 6 and 7 with 97.30% accuracy ratio.

TABLE. III. RESULTS ON THE WBC DATASET USING SVM TECHNIQUE

Fold No	SVM Accuracy Results Without Clustering		SVM Accuracy Results With Clustering Two-step Algorithm	
	Training Results %	Testing Results%	Training Results %	Testing Results%
Fold 1	96.8%	96.6%	99.30%	98.7%
Fold 2	95.5%	95.7%	99.40%	98.9%
Fold 3	94.9%	94.3%	98.90%	98.6%
Fold 4	95.3%	95.6%	99.60%	99.5%
Fold 5	96.6%	96.3%	99.80%	99.3%
Fold 6	97.3%	93.9%	99.30%	99.2%
Fold 7	96.4%	97.3%	99.50%	99.3%
Fold 8	96.3%	95.5%	99.20%	99.0%
Fold 9	95.9%	94.1%	99.30%	99.1%
Fold 0	96.9%	93.0%	99.60%	99.4%
Average	**96.19%**	**95.23%**	**99.39%**	**99.10%**

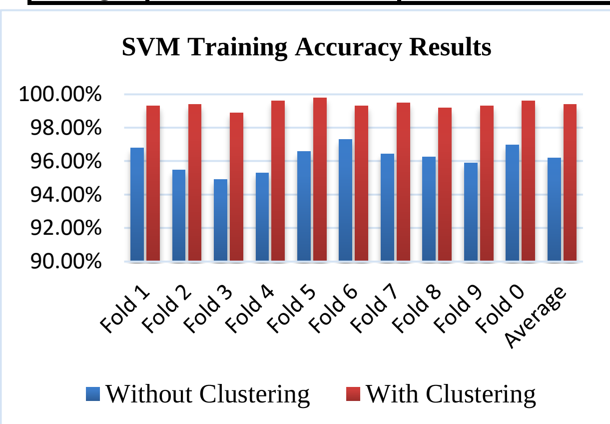

Fig. 3. SVM Training results

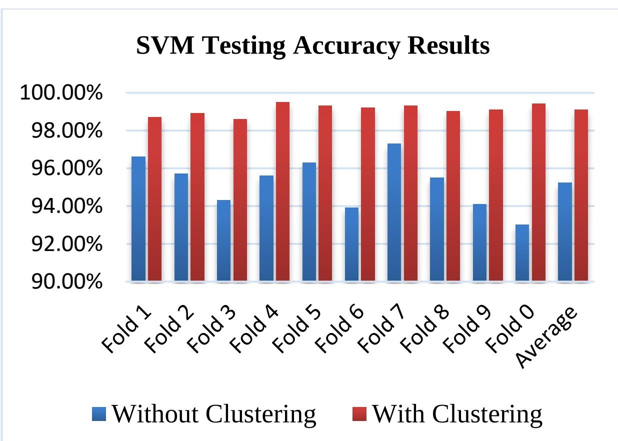

Fig. 4. SVM Testing results

On the other hand, the prediction results with clustering were achieved in folds number 5 and 4 in training and testing experiments respectively. The conclusion is that there is an enhancement while using the TwoStep clustering algorithm. The result of the SVM with clustering is better, and the breast cancer diagnosis is more accurate when using a combination of the SVM output with the Two-Step Clustering algorithm.

This research performed *T-test* algorithm as statistical significance test between the obtained results from the first experiment using SVM and second experiment using the TwoStep-SVM method, and it presented the enhancements obtained by using the Two-step-SVM technique. The small significance result for the T-test (normally below 0.05) specifies that there is a significant change between the two variables. Base on the obtained results in Table 4, regarding the accuracy of values (0.014), this condition was emphasized in assessment measures. It indicates that the TwoStep-SVM achieved significant improvement on the accuracy and there is a significant difference between the SVM with clustering and vice-versa.

The Comparison between Two-step-SVM technique and current approaches demonstrates in Figure 10. The proposed TwoStep-SVM obtained high accuracy value by 99.1.

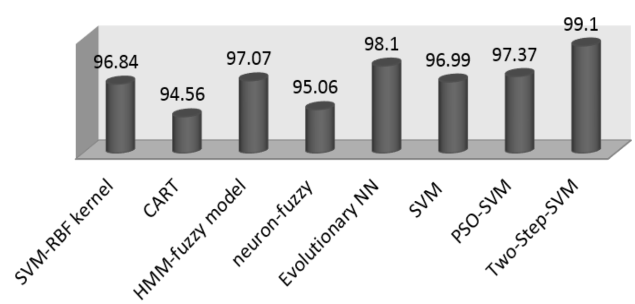

Fig. 5. Accuracy comparison between the Two-step-SVM technique and current breast cancer classifier method

TABLE. IV. T-TEST COMPARISON RESULTS

	Differences between accuracy result in 50%, 60%, and 70%, before and after the improvement					t	df	Significant Value
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
SVM & SVM-Two-Step	-0.0387	0.01409	0.000199	-0.048783	-0.028617	-8.68	18	0.000011

The time complexity of the hybrid TwoStep-SVM was also computed based on machine time efficiently. Due to the WBC dataset structure (Vector of data) that consist of number of columns (*n*) and number of rows (*m*), the time complexity can be computed as (*n*m*) and it is belong to the (*n*m*) class. Where *(n)* is represents the breast cancer features and *(m)* represents the breast cancer patients. The computational time of the previous studies such as [21] and [22] was calculated based on the machine time complexity (execution time/ CPU time) where the complexity time of the proposed hybrid method is calculated based on the mathematical computation.

IX. CONCLUSION AND FUTURE WORK

This research considered a major challenge in the health sector today the problems surrounding cancer disease detection. Significantly, this study has pioneered the use of the hybrid Two-Step-SVM method for predicting cancer disease. Moreover, the research investigated the hybrid algorithm on a WBC-UCI dataset which is a standard dataset utilized in the diagnosis of breast tumour. It has been proved that the SVM with the Two-Step algorithms can significantly improve the prediction accuracy rate and decrease the miss-classification error in cancer disease. More importanlly, the hybrid method improved the prediction accuracy following the methodology explained in section 6. In the future work, an optimization method will be combined with the SVM-two-step clustering algorithm to enhance the diagnosis accuracy.

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Automatic Recognition of Medicinal Plants using Machine Learning Techniques

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***Abstract*—The proper identification of plant species has major benefits for a wide range of stakeholders ranging from forestry services, botanists, taxonomists, physicians, pharmaceutical laboratories, organisations fighting for endangered species, government and the public at large. Consequently, this has fueled an interest in developing automated systems for the recognition of different plant species. A fully automated method for the recognition of medicinal plants using computer vision and machine learning techniques has been presented. Leaves from 24 different medicinal plant species were collected and photographed using a smartphone in a laboratory setting. A large number of features were extracted from each leaf such as its length, width, perimeter, area, number of vertices, colour, perimeter and area of hull. Several derived features were then computed from these attributes. The best results were obtained from a random forest classifier using a 10-fold cross-validation technique. With an accuracy of 90.1%, the random forest classifier performed better than other machine learning approaches such as the k-nearest neighbour, naïve Bayes, support vector machines and neural networks. These results are very encouraging and future work will be geared towards using a larger dataset and high-performance computing facilities to investigate the performance of deep learning neural networks to identify medicinal plants used in primary health care. To the best of our knowledge, this work is the first of its kind to have created a unique image dataset for medicinal plants that are available on the island of Mauritius. It is anticipated that a web-based or mobile computer system for the automatic recognition of medicinal plants will help the local population to improve their knowledge on medicinal plants, help taxonomists to develop more efficient species identification techniques and will also contribute significantly in the protection of endangered species.**

Keywords—leaf recognition; medicinal plants; random forest; Mauritius

I. INTRODUCTION

The world bears thousands of plant species, many of which have medicinal values, others are close to extinction, and still others that are harmful to man. Not only are plants an essential resource for human beings, but they form the base of all food chains. To use and protect plant species, it is crucial to study and classify plants correctly. Identifying unknown plants relies much on the inherent knowledge of an expert botanist. The most successful method to identify plants correctly and easily is a manual-based method based on morphological characteristics. Thus many of the processes involved in classifying these plant species is 'dependent on knowledge accumulation and skills of human beings' [1]. However, this process of manual recognition is often laborious and time-consuming. Hence many researchers have conducted studies to support the automatic classification of plants based on their physical characteristics [2][3]. Systems developed so far use varying number of steps to automate the process of automatic classification, though the processes are quite similar. Essentially, these steps involve preparing the leaves collected, undertaking some pre-processing to identify their specific attributes, classification of the leaves, populating the database, training for recognition and finally evaluating the results. Although, leaves are most commonly used for plant identification, the stem, flowers, petals, seeds and even the whole plant can be used in an automated process. An automated plant identification system can be used by non-botanical experts to quickly identify plant species quite effortlessly.

II. RELATED WORKS

Several studies have been conducted in order to develop tools for the identification of plants during the last 10 years. One of the most authoritative works in the field of plant classification has been done by Wu *et al*. [2]. From five basic geometric features, twelve morphological features are derived and then Principle Component Analysis (PCA)) is used for dimension reduction so that fewer inputs could be sent to a probabilistic neural network (PNN). They achieved an average accuracy of 90.3% with the Flavia dataset, which is their own creation. Using a different dataset but the same classifier, Hossain and Amin (2010) achieved a similar level of accuracy with similar features [4]. Using similar features but a different dataset with only 20 species, Du *et al*. (2007) attained 93% with the k-nearest neighbour classifier [5]. Using a new distance measure called '*isomap*', Du *et al*. (2009) reached an accuracy of 92.3% on a dataset of 2000 images containing 20 different types of leaves [6].

Herdiyeni and Wahyuni (2012) used a fusion of fuzzy local binary pattern and fuzzy colour histogram and a probabilistic neural network (PNN) classifier on a dataset of 2448 leaf images (270 *240 pixels) obtained from medicinal plants from the Indonesian forests to achieve a classification accuracy of 74.5% [7]. Prasvita and Herdiyeni (2013) developed a corresponding mobile application based on the previous research [8]. Using the kernel descriptor (KDES) as a new feature extraction technique, Le *et al*. (2014) developed a fully automated plant identification system [9]. The proposed technique was tested on a dataset of 55 medicinal plants from Vietnam and a very high accuracy of 98.3% was obtained with a support vector machines (SVM) classifier. Furthermore, their algorithm achieved an accuracy of 98.5% on the Flavia dataset, which is the best result published so far on this dataset [9].

Using the discrete wavelet transform to extract translation invariant features from a collection of 8 different ornamental plants in Indonesia, Arai *et al*. (2013) achieved an accuracy of 95.8% using a support vector machines (SVM) classifier [10]. The size of each image was 256*256 pixels. Du *et al*. (2013) proposed an approach based on fractal dimension features based on leaf shape and vein patterns for the recognition and classification plant leaves [11]. Using a k-nearest neighbour classifier with 20 features, they were able to achieve a high recognition rate of 87.1%. Using a volumetric fractal dimension approach to generate a texture signature for a leaf and the Linear Discriminant Analysis (LDA) algorithm, Backes *et al*. (2009) was able to beat traditional approaches which were based on Gabor filters and Fourier analysis [12].

TABLE. I. SUMMARY OF RELATED WORKS

Reference	**Features**	**Classifier**	**Accuracy (%)**	**Dataset**	**Training**	**Testing**	**Species**
Wu *et al*. (2007)	Shape, Veins	PNN	90.3	1800	1480	320	32
Du *et al*. (2007)	Shape	kNN, MMCH	93, 90	400	200	200	20
Du *et al*. (2009)	Shape	kNN	92.3	2000+	1000	1000+	20
Backes *et al*. (2009)	Texture	LDA	89.6	2000	1200	800	10
Hossain and Amin (2010)	Shape	PNN	91.4	1200	Ten-fold cross-validation		30
Du *et al*. (2013)	Curvature, Veins	kNN	87.1	2422	1695	727	30
Amin and Khan (2013)	Curvature	kNN	71.5	1600	1120	480	100
Herdiyeni and Wahyuni (2012)	Texture, Colour	PNN	74.5	2448	1938	510	51
Arai *et al*. (2013)	Wavelets	SVM	95.8	120	96	24	8
Hernandez-Serna and Jimenez-Segura (2014)	Shape, Texture	ANN	92.9	1800	1620	180	32
Le *et al*. (2014)	Kernel Descriptor	SVM	98.5	1905	1585	320	32
			98.3	1312	649	663	55
Munisami *et al*. (2015)	Shape, Colour	kNN	87.3	640	Leave-one-out cross-validation		32
Chaki *et al*. (2015)	Shape, Texture	NFC	97.6	930	310	620	31
Siravenha and Carvalho (2015)	Shape	ANN	97.5	1865	Ten-fold cross-validation		32
Carranza-Rojas and Mata-Montero (2016)	Curvature, Texture	kNN	87.2	2345	Leave-one-out cross-validation		66

Using a k-nearest neighbour (kNN) classifier, Munisami *et al*. (2015) achieved an accuracy of 87.3% on a dataset of 640 leaves taken from 32 different plant species [13]. They used shape and colour information only. The images were acquired using a smartphone camera with a resolution of 1980*1024.

Hernandez-Serna and Jimenez-Segura (2014) reached an accuracy level of 92.9% using the Flavia dataset [14]. Sixteen inputs (6 geometrical, 8 texture and 2 morphological features) were fed to an artificial neural network (ANN) with 60 nodes in the hidden layer and a learning rate of 0.1 over 50000 generations. Using the same dataset, Chaki *et al*. (2015) achieved an overall accuracy of 97.6% using a Neuro-Fuzzy classifier (NFC) with a 44-element texture vector and a 3-element shape vector [15]. Using shape features only on the Flavia dataset and Pattern Net (a flavour of neural network), Siravenha and Carvalho [16] reached a similar accuracy as Chaki *et al*. [15]. Their feed-forward neural network had two hidden layers with 26 neurons in each and it was trained over 100 epochs.

An interesting work was done by Carranza-Rojas and Mata-Montero (2016) in which they created two datasets: a clean one and a noisy one [17]. They implemented the Histogram of Curvature over Scale (HCoS) algorithm to extract contour information and the local binary pattern variance (LBPV) to extract texture information. In the best case, the clean dataset outperformed the noisy dataset by only 7.3%. This suggest that images taken directly using a smartphone can produce satisfactory levels of accuracy compared with images which are manually processed in a lab and then classified. Earlier, Amin and Khan (2013) have used a distributed hierarchical graph neuron (DHGN) to capture curvature information using 64 feature vectors and the k-nearest neighbour classifier with Canberra distance to obtain an accuracy of 71.5% [18].

Table I summarises some of the works that have been done in the automated recognition of medicinal and non-medicinal plant species during the last decade. Babatunde *et al*. (2015) has done a good survey on different computer vision techniques and machine learning classifiers that have been used in this field during the last ten years [19]. Furthermore, Mata-Montero and Carranza-Rojas (2016) has provided a good introduction to the field and also discussed the challenges and opportunities in this domain [20].

III. METHODOLOGY

A database of medicinal plants which are available on the tropical island of Mauritius was created. Using a Samsung Galaxy J1 Mini smartphone, thirty (30) images of different leaves were taken for twenty-four (24) different plant species. The petiole of each leaf was removed and then placed one by one on a sheet of white paper before being photographed. The size of each image was 1024x600 pixels. The images are stored in the jpeg format.

No manual pre-processing was done on the images in order to enhance them. However, a number of post-processing operations were performed automatically on each image. From the basic attributes (width, length, area, perimeter, area of white space, area of bounding box, area of hull, perimeter of hull), 40 different attributes were derived for each leaf. These values are stored in a csv file. A Java programming environment with the open source Weka machine learning workbench was then used to assess the performance of the system [21].

A. *Automatic pre-processing steps*

One drawback of taking pictures using a camera, instead of using a scanner, is the presence of shadows on the image. If the shadow is not removed, this will affect all measurement. Thus, to remove the shadow, the image must first be converted to the HSV format and then split into its different colour channels. Only the second channel (saturation) is kept. This has the effect of removing the shadow from the image. To reduce noise in the image, a median blur filter with a window size of 25 is applied to the resulting image.

The next step is to perform a thresholding operation which will convert the image into a binary image with only two values: black and white pixels. This is achieved using the Otsu thresholding method. An opening operation is then performed on the images. This is an erosion operation followed by a dilation. Erosion has the effect of reducing the size of foreground (white) pixels while dilation enlarges them. This operation is important in order to clear the image from many small noisy pixels, which are the artefacts of the thresholding operation.

Fig. 1. Original Giant Bramble Leaf

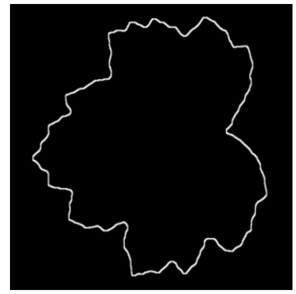

Fig. 2. Binary Image of Leaf

B. *Feature extraction*

A number of base features were extracted from the images in Figures 1 and 2. These are: length, width, area of the bounding box, area of leaf, perimeter of leaf, hull area, hull perimeter, number of vertices, horizontal & vertical distance maps, 45^{o} radial map and the original RGB values of each pixel.

Fig. 3. Bounding Box & Contour

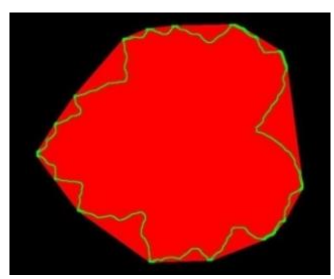

Fig. 4. Area & Perimeter of Hull

Figure 3 shows the bounding box (in red) and the contour line (in green) around a giant bramble leaf. Using the bounding box, the length and the width of the leaf can easily be computed. The perimeter of the leaf is obtained from the contour line. The area of the leaf corresponds to the white space inside the green contour line. Figure 4 shows the convex hull which can be used to compute the hull perimeter and the hull area. The hull is the smallest polygon that can contain the leaf. The convex hull is also used to calculate the number of vertices in the leaf. Although the algorithm which is used to calculate the number of vertices is not very accurate, it was still a good differentiator. This is mainly because it is a raw attribute which is independent of the size of the leaf.

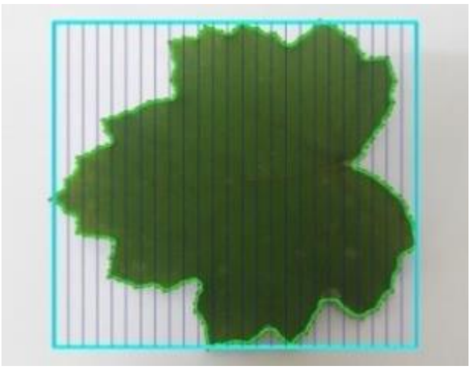

Fig. 5. Vertical Distance Map

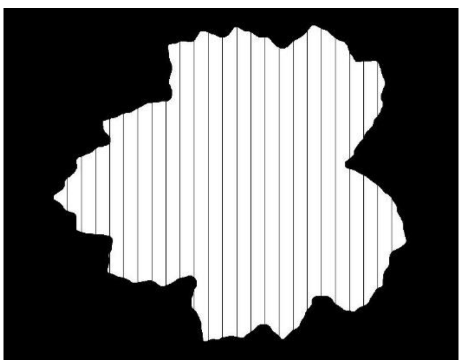

Fig. 6. Vertical Distance Map

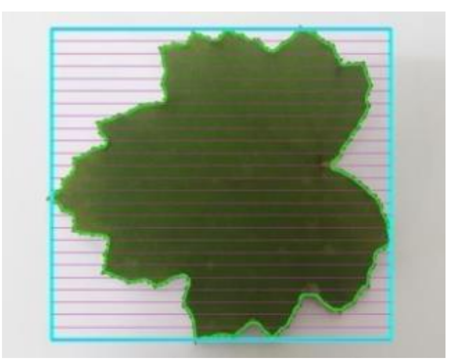

Fig. 7. Horizontal Distance Map

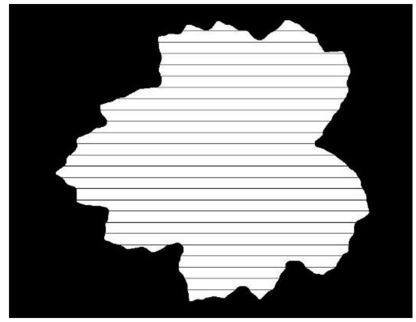

Fig. 8. Horizontal Distance Map

Figure 5 shows the vertical distance maps in which the image is divided into 24 equal strips. The aim is to find where each vertical line intercepts the contour line of the leaf. The distances between the intercepts are then computed. This is shown in Figure 6. Figure 7 shows the horizontal distance maps in which the image is divided into 24 equal strips. Again, the objective of this procedure is to locate where each horizontal line touches the boundary of the leaf, as displayed in Figure 8. To avoid overfitting, only 12 alternate values are used for both directions. Similarly, the radial distances are computed as shown below in Figure 9 and Figure 10.

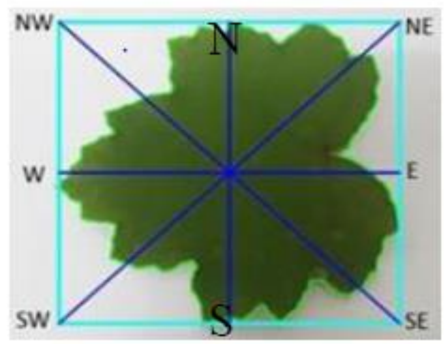

Fig. 9. Radial Map

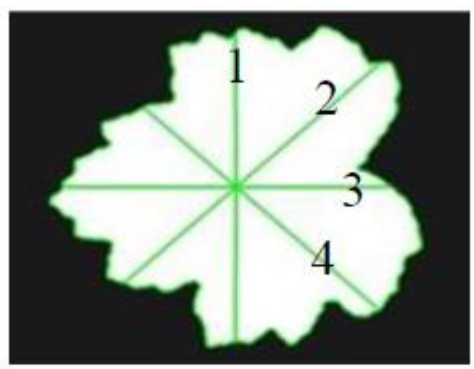

Fig. 10. Radial Map

C. Derived features

Using the base features which are extracted directly from the image, a number of derived features are calculated [22]. Ratios are more suitable for comparison as they are independent of the actual size of the image in pixels. The ratios are shown below in Table II. The different plant species studied are summarized in Table V.

TABLE. II. DERIVED FEATURES

#	Derived Feature	Method
1	aspect ratio	width/length
2	circularity/roundness	area/(perimeter*perimeter)
3	solidity	area/hull area
4	convexity	hull perimeter/perimeter
5	rectangularity	width*length/area
6	hydraulic radius	area/perimeter
7	lobidity	perimeter/(width+length)
8	white area ratio	(area of bounding box–area)/area of bounding box
9	hull ratio	hull area/hull perimeter
10	red to green ratio	red/green
11	red to blue ratio	red/blue
12	blue to green ratio	blue/green
13	N_S ratio	1/N_S (refer to Figure 9 & 10)
14	NE_SW ratio	2/NE_SW (refer to Figure 9 & 10)
15	E_W ratio	3/E_W (refer to Figure 9 & 10)
16	SE_NW ratio	4/SE_NW (refer to Figure 9 & 10)
17	vertical distance ratios (12)	length of line in leaf/width
18	horizontal distance ratios (12)	length of line in leaf/length

IV. RESULTS AND DISCUSSION

Medicinal plants have received much attention since they are generally perceived as safe and accessible for human utilization. However, the proper identification of plant species has major benefits for a wide range of stakeholders ranging from consumers, forestry services, botanists, taxonomists, physicians, pharmaceutical laboratories, organization fighting for endangered species, government, and the public at large.

Five different machine learning classifiers were used to assess the recognition rate. The results are shown in Table III. The Random Forest classifier achieves the best performance with an accuracy of 90.1%, i.e., out of 720 leaves, 649 leaves were classified correctly while 71 were not.

The Multilayer Perceptron produced the second best accuracy at 88.2%. However, due to resource constraints, the potential of neural networks has not been fully exploited and it is still possible to achieve even higher accuracy with this classifier. The k-Nearest Neighbour (kNN) classifier had the lowest accuracy. A 10-fold cross-validation technique was used in all the experiments. The main parameters of each classifier was varied to find the ones producing the highest accuracy.

TABLE. III. PERFORMANCE OF MACHINE LEARNING CLASSIFIERS

#	Classifier	Accuracy (%)
1	Random Forest (numTrees=100)	90.1
2	Multilayer Perceptron Neural Network (Epochs=500)	88.2
3	Support Vector Machine (PolyKernel and c=4.0)	87.4
4	Naïve Bayes	84.3
5	k-Nearest Neighbour (k=1)	82.5

Figure 11 shows the confusion matrix obtained when using the Random Forest classifier with 100 trees and 6 attributes in each iteration. The value 25 (first number in the second row) in the matrix indicates that 25 Antidesma leaves were correctly classified. Out of the five remaining leaves, one was incorrectly classified as an Avocado leaf, one as a Fandamane leaf, another as a Jackfruit, and last two as Guava. From the first column, it can be seen that two Bigaignon Rouge and one Pomegranate leaves were misclassified as Antidesma. The high values in the diagonal line indicate that the recognition was very successful. Another important observation is that six Coriander leaves were misclassified as Bitter Gourd and the only two Bitter Gourd leaves that were not correctly carried were predicted as Coriander leaves. These observations could be explained by the fact that both these plants have highly lobed leaves.

```
  a  b  c  d  e  f  g  h  i  j  k  l  m  n  o  p  q  r  s  t  u  v  w  x   <-- classified as
 25  1  0  0  0  0  0  0  0  0  0  0  0  1  1  0  0  0  0  0  0  0  2  0 |  a = Antidesma
  0 28  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  1  0  0  0 |  b = Avocado
  0  0 30  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 |  c = Ayapana
  0  0  0 29  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0  0 |  d = Balloon Plant
  2  0  0  0 24  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0  3  0  0  0 |  e = Bigaignon Rouge
  0  0  0  0  0 28  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0  0  0  0 |  f = Bitter Gourd
  0  0  1  0  0  0 25  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  3  0 |  g = Bois Carrote
  0  0  0  0  0  0  0 27  0  0  0  0  0  0  0  0  0  0  3  0  0  0  0  0 |  h = Bois Cerf
  0  0  0  0  0  0  0  0 26  0  0  0  0  3  0  1  0  0  0  0  0  0  0  0 |  i = Bois de rat
  0  0  0  0  0  0  0  0  0 30  0  0  0  0  0  0  0  0  0  0  0  0  0  0 |  j = Bramble
  0  0  0  0  0  0  0  0  0  0 30  0  0  0  0  0  0  0  0  0  0  0  0  0 |  k = Chinese Okra
  0  0  0  0  0  6  0  0  0  1  0 21  2  0  0  0  0  0  0  0  0  0  0  0 |  l = Coriander
  0  0  0  0  0  0  0  0  0  0  0  0 26  1  0  0  1  0  0  0  0  0  1  1 |  m = Curry Leaf
  0  0  0  0  0  0  0  0  0  0  0  0  0 27  0  0  1  0  0  0  0  2  0  0 |  n = Fandamane
  0  0  0  0  0  0  2  0  0  0  0  0  0  0 23  0  0  0  0  0  0  2  3  0 |  o = Jackfruit
  0  0  0  0  0  0  1  1  3  0  0  0  0  0  0 24  0  1  0  0  0  0  0  0 |  p = Mango
  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0 28  0  0  0  1  0  0  0 |  q = Moringa
  0  0  0  0  0  0  0  2  0  0  0  0  0  0  0  1  0 27  0  0  0  0  0  0 |  r = Neem
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 30  0  0  0  0  0 |  s = Orange Climber
  0  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 29  0  0  0  0 |  t = Parsley
  0  0  0  0  1  0  0  0  0  0  0  0  1  0  0  0  0  0  0  0 28  0  0  0 |  u = Peppermint
  1  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0 27  0  0 |  v = Pomegranate
  0  0  0  0  0  0  1  0  0  0  0  0  0  0  1  0  0  0  0  0  0  0 28  0 |  w = Strawberry Guava
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0 29 |  x = Tulsi
```

Fig. 11. Confusion Matrix for Random Forest with 100 Trees

Besides the overall accuracy, the performance of the automated system was also assessed on a class-wise basis. Recall is the proportion of leaves, for each class, that was correctly picked out from the entire set. Precision is the proportion of correctly identified leaves out of all the leaves that are predicted to be of a specific plant while F-measure can simply be considered as the average of these two values. Table IV shows that Ayapana, Bramble, Chinese Okra and Orange Climber has a perfect recall of 100% while Coriander has the lowest recall of 70%. Only the Chinese Okra and Parsley has a precision value of 100% while the Strawberry Guava has the lowest precision at 76%. Thus, Table IV provides us with much useful information which can be used to both gauge the strengths of the system and address its weaknesses as well. Plants which have low recall and low precision must be relooked into. For example, new features must be designed and extracted that bring out the uniqueness in such leaves and are determinative of their species.

TABLE. IV. PERFORMANCE ASSESSMENT BY SPECIES USING A RANDOM FOREST WITH 100 TREES

#	Species	Precision	Recall	F-Measure
1	Antiderma	0.89	0.83	0.86
2	Avocado	0.97	0.93	0.95
3	Ayapana	0.97	1.00	0.98
4	Balloon Plant	0.97	0.97	0.97
5	Bigaignon Rouge	0.96	0.80	0.87
6	Bitter Gourd	0.82	0.93	0.87
7	Bois Carotte	0.81	0.83	0.82
8	Bois Cerf	0.90	0.90	0.90
9	Bois de rat	0.90	0.87	0.88
10	Bramble	0.97	1.00	0.98
11	Chinese Okra	1.00	1.00	1.00
12	Coriander	0.91	0.70	0.79
13	Curry Leaf	0.87	0.87	0.87
14	Fandamane	0.84	0.90	0.87
15	Jackfruit	0.89	0.77	0.82
16	Mango	0.89	0.80	0.84
17	Moringa	0.93	0.93	0.93
18	Neem	0.93	0.90	0.92
19	Orange Climber	0.88	1.00	0.94
20	Parsley	1.00	0.97	0.98
21	Peppermint	0.85	0.93	0.89
22	Pomegranate	0.84	0.90	0.87
23	Strawberry Guava	0.76	0.93	0.84
24	Tulsi	0.97	0.97	0.97
Average		0.91	0.90	0.90

Besides investigating the effect of different classifiers, the effect of the number of plant species in the dataset on the overall accuracy of the system was also studied. As expected, with only eight features, a very high accuracy of 97.9% is obtained, as shown in Figure 12. Next, the number of plant species is doubled to 16 but the accuracy decreases by only 3.1%. After an additional set of eight new types of leaves are added, the accuracy drops by 4.7%. Munisami *et al*. (2015) reported very similar results but with a different dataset containing 32 plants [13].

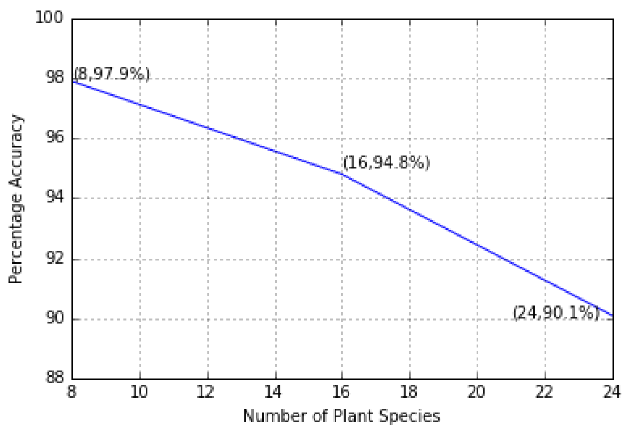

Fig. 12. Number of Plant Species v/s Percentage Accuracy

As shown in Figure 13, increasing the number of leaves per plant species has a positive impact on the classification accuracy. The peak performance is achieved when using 25 leaves per plant. There is no improvement in accuracy beyond this threshold. This is an important result which can be used by researchers and scientists to decide on the number of samples that they must collect in their studies. Munisami *et al.* (2015) performed a similar assessment [13]. However, they collected only 20 samples per species and therefore they could not arrive at this threshold value [13].

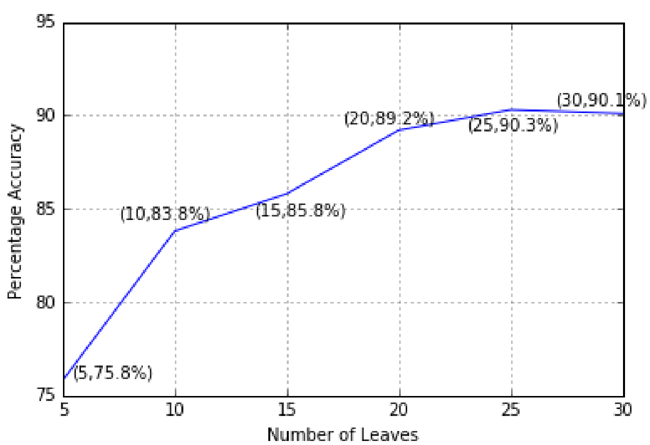

Fig. 13. No. of Leaves per Plant v/s Percentage Accuracy

Using the chi-squared ($\chi2$) statistical test in Weka, the *k* best features from the dataset were selected. The results are shown in Figure 14. The eight (*k*=8) best features were: white area ratio (first position), rectangularity, number of dents, hull ratio, hydraulic radius, aspect ratio, lobidity, and solidity at the eight position. An accuracy of 77.1% was obtained using these 8 features. The next best features were: convexity (ninth position), NE_SW ratio, SE_NW ratio, N_S ratio, E_W ratio, circularity, blue to green ratio and the red to green ratio (sixteenth position). Using the 16 best features lead to a significant boost in accuracy by 12.1%. The accuracy was only minimally better with the 24 best features and using more than 32 features did not bring any improvement in the accuracy.

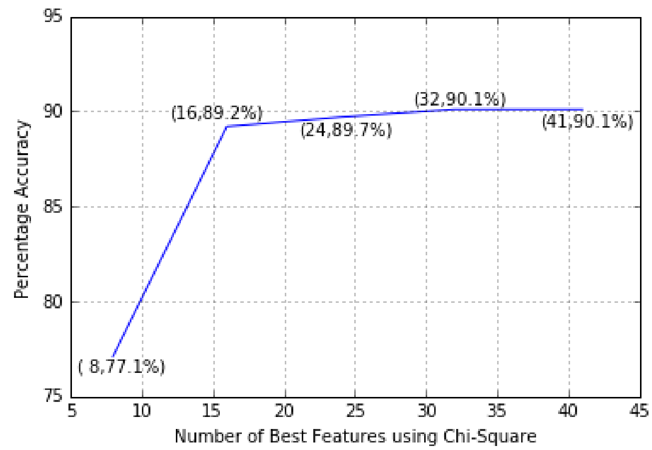

Fig. 14. Number of Best Features v/s Percentage Accuracy

Although literature on leaf-based recognition of plant species using image processing and data mining techniques are abundant, only a handful of researchers have applied these techniques on medicinal plants. Countries like China, India, Indonesia, Malaysia, and Vietnam have vast repositories of medicinal plants and therefore it is no wonder that many of the research works on medicinal plants come from these countries [23]. The novelty of this work resides in the creation of a unique image dataset for medicinal plants that are available on the island of Mauritius.

A new measure called lobidity has also been proposed. This is the seventh best differentiating feature according to the chi-squared test. Although the majority of researchers have been able to achieve accuracies above 90%, improvements are still possible. The work of Mata-Montero and Carranza-Rojas (2016) outlines the different approaches that have been used for plant classification, including morphometrics (curvature, texture and venation), DNA barcoding, and crowd sourcing [20]. More importantly, they outlined the challenges of collecting, classifying and sharing huge datasets and discuss the opportunities that crowd sourcing and deep learning offer to this community of researchers.

V. Conclusion

A new dataset on medicinal plants of Mauritius has been made publicly available on the machine learning repository portal. In this paper, computer vision techniques have been used to extract several shape-based features from the leaves of medicinal plants. Machine learning algorithms were then used to classify the leaves from 24 different plant species into their appropriate categories. The highest accuracy of 90.1% was obtained from the random forest classifier. This excellent performance indicates the viability of such computer-aided approaches in the classification of biological specimens and its potential applicability in combatting the '*taxonomic crisis*'. A web-based or mobile computer system for the automatic recognition of medicinal plants will help the local population to improve their knowledge on medicinal plants, help taxonomists to develop more efficient species identification techniques and will also contribute significantly in the protection of endangered species. For future research, in an attempt to achieve even higher accuracies, probabilistic neural networks and deep learning neural networks would be investigated.

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TABLE. V. PLANT SPECIES

Image	
Scientific name	*Antidesma madagascariense*
English name	Antidesma
Mauritian name	Bigaignon batard
Medicinal uses	Effective against dysentery and skin infections
Image	
Scientific name	*Persea americana*
English name	Avocado
Mauritian name	Avocat
Medicinal uses	Reduce the risk of eye cataract; Control cholesterol level
Image	
Scientific name	*Ayapana triplinervis*
English name	Ayapana
Mauritian name	Ayapana
Medicinal uses	Stomachic; anti-ulcerous; Fights cough
Image	
Scientific name	*Cardiospermum halicacabum*
English name	Balloon plant

Mauritian name	Pocpoc
Medicinal uses	Management of Type II diabetes mellitus; Healing skin infections
Image	
Scientific name	*Psiloxylon mauritianum*
English name	Bigaignon wood/Red bigaignon
Mauritian name	Bois bigaignon/Bigaignon rouge
Medicinal uses	Treatment and management of amenorrhea, dysentery and Type II diabetes mellitus
Image	
Scientific name	*Momordica charantia*
English name	Bitter gourd
Mauritian name	Margose
Medicinal uses	Management of Type II diabetes mellitus
Image	
Scientific name	*Pittosporum senacia*
English name	Not available
Mauritian name	Bois carotte
Medicinal use	Treatment of stomach disorders
Image	
Scientific name	*Olea lancea*
English name	Not available
Mauritian name	Bois cerf
Medicinal uses	Effective against cough and hypertension
Image	
Scientific name	*Coptosperma borbonicum*
English name	Not available
Mauritian name	Bois de rat
Medicinal uses	Treatment of fever
Image	
Scientific name	*Rubus alceifolius*
English name	Giant bramble/Wild raspberry
Mauritian name	Framboisier/Piquant loulou

Medicinal uses	Management of Type II diabetes mellitus
Image	
Scientific name	*Luffa acutangula*
English name	Chinese okra/Silky gourd
Mauritian name	Pipengaille
Medicinal uses	Prevention of cardiovascular disease; Effective against hypertension
Image	
Scientific name	*Coriandrum sativum*
English name	Coriander
Mauritian name	Cotomili/Coriandre
Medicinal uses	Management of Type II diabetes mellitus
Image	
Scientific name	*Murraya koenigii*
English name	Curry tree
Mauritian name	Cari poulet
Medicinal uses	Management of hypertension
Image	
Scientific name	*Aphloia theiformis*
English name	Fandamane
Mauritian name	Fandamane
Medicinal uses	Management of Type II diabetes mellitus; Prevention of eye cataract
Image	
Scientific name	*Artocarpus heteophyllus*
English name	Jackfruit
Mauritian name	Jack
Medicinal uses	Management of Type II diabetes mellitus
Image	
Scientific name	*Magnifera indica*
English name	Mango
Mauritian name	Mangue
Medicinal uses	Management of Type II diabetes mellitus

Image	
Scientific name	*Moringa oleifera*
English name	Moringa
Mauritian name	Brede mouroum
Medicinal uses	Management of Type II diabetes mellitus; Control cholesterol level
Image	
Scientific name	*Azadirachta indica*
English name	Neem
Mauritian name	Neem
Medicinal uses	Management of Type II diabetes mellitus
Image	
Scientific name	*Toddalia asiatica*
English name	Orange climber
Mauritian name	Patte poule
Medicinal uses	Treatment of asthma
Image	
Scientific name	*Petroselinum crispum*
English name	Parsley
Mauritian name	Persil
Medicinal uses	Management of Type II diabetes mellitus; Control cholesterol level; Treatment of kidney diseases

Image	
Scientific name	*Mentha x piperita*
English name	Peppermint
Mauritian name	Menthe
Medicinal uses	Effective against indigestion
Image	
Scientific name	*Punica granatum*
English name	Pomegranate
Mauritian name	Grenade
Medicinal uses	Prevention of cardiovascular disease; Control cholesterol level; Effective against diarrhea
Image	
Scientific name	*Psidium cattleyanum*
English name	Guava
Mauritian name	Goyave de chine
Medicinal uses	Management of Type II diabetes mellitus; Control cholesterol level
Image	
Scientific name	*Ocimum tenuiflorum*
English name	Holy basil/Tulsi
Mauritian name	Tulsi
Medicinal uses	Management of Type II diabetes mellitus; Control cholesterol level

E-exam Cheating Detection System

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***Abstract*—With the expansion of Internet and technology over the past decade, E-learning has grown exponentially day by day. Cheating in exams has been a widespread phenomenon all over the world regardless of the levels of development. Therefore, detection of traditional cheating methods may no longer be wholly successful to fully prevent cheating during examinations. Online examination is an integral and vital component of E-learning. Students' exams in E-learning are remotely submitted without any monitoring from physical proctors. As a result of being able to easily cheat during e-exams, E-learning universities depend on an examination process in which students take a face-to-face examination in a physical place allocated at the institution premises under supervised conditions, however this conflicts with the concept of distant E-learning environment. This paper will investigate the methods used by student for cheating detection in online exams, through continuous authentication and online proctors. In addition, we have implemented an E-exam management system, which is used to detect and prevent the cheating in online exams. The system used fingerprint reader authenticator and eye tribe tracker in exam session. We researched two parameters that can define the examinee status as cheating or non-cheating during exam. Through these two parameters: the total time on out screen and the number of times on out screen were computed.**

Keywords*—online exam; cheating; continuous authentication; online proctor; fingerprint; eye tracking

I. Introduction

In recent years, information and communication technologies (ICT) witnessed rapid developments and had direct impacts on human life, especially in the field of education. As a result, E-learning has become increasingly popular over the last few years and widely adopted by educational institutions. It enables to deliver information whenever students need at anytime and anywhere over the web. For this reason, it also called web-based learning or online learning. "Assessment for Learning is the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go and how best to get there" [1]. Assessment is one of the main tasks of the education process. It takes an important weight during the development of any e-learning course.

Exams are most widely used to assess student learning. However, exams can be classified into three types: traditional exams, online exams and distance exams (D-exams). Traditional exam defined as a set of questionnaires given in the class. They are created based on static questions per student. As a result, students must begin and end the exam within the same time limits. Online exams, sometimes referred to as e-examination, are Internet based questionnaire. They are created randomly from questions set per student with a preset time limits by which the exam is to be completed. Furthermore, students should attend to a classroom for performing an exam.

D-exams are a way of delivering questions to students who are not physically present in a traditional setting such as a classroom. They are created randomly from questions set per student with a preset time limit by which they should be answered. Furthermore, they save or reduce time required for paper checking, as well as, they save papers, and printing, thus saving environment. D-exam present a new challenges for teachers; notably, how to prevent students from cheating. As a result, e-learning institutions depend on an examination process in which students take a face-to-face examination in a physical place located at the institution premises and under supervised conditions to ensure the student identity. However, that conflicts with the concept of E-learning, which eliminates the temporal and spatial dimensions between the students and the learning process. Each student must be physically present in the classroom in order to take the exam.

This paper investigates all types of methods used for cheating in D-exam, and resolves this problem by either detection or prevention. Detecting and preventing cheating require a human intervention (i.e. the presence of a proctor). The proctor needs to physically authenticate students' IDs before starting the exam. However, this is not enough; we need continuous authentication all over the exam session. In addition, we need a continuous process of monitoring and controlling over all students during the exam period.

The rest of this paper organized as follows: Section II describes cheating, Section III depicts authentication, Section IV describes online proctor, Section V introduces the e-exam management system architecture, Section VI presents the e-exam management system algorithm, Section VII presents the implementation of e-exam management system, Section VIII presents the experimental results, Section IX provides conclusions, and Section X provides future work.

II. Cheating

Cheating on exams has been a widespread phenomenon in the world regardless of the levels of detection development. Many studies have been conducted over the past decade about cheating activities performed by students and the means by which university could attempt to combat this problem [2]. In the U.S., it was revealed that 80% of the higher achieving secondary school students admitted to cheat in during exams, 95% of secondary school students who admitted cheating said that they had not been caught, 51% of secondary school students did not believe cheating was wrong, 85% of college students said cheating was necessary to get ahead, 75% of college students admitted cheating in exams, and 90% of college students did not believe cheaters would be caught [3].

The most common reasons that motivate students to cheat include: pressure from parents to do well, fear of failure, unclear instructional objectives, desire for a better grade, everyone else is doing it, there is no punishment if being caught, there is little chance of being caught, and no time to study and easy access to online information [4].

Many students still use traditional cheating methods that are defined as each student can be cheating by own self or others. Cheating that appears in online exam is called online cheating. A student can be cheating via the Internet.

Table I illustrates the different types of cheating in traditional exams and in online exams. In addition, it presents some of the suggested solutions to prevent cheating. By proctor, we mean a person who monitors or invigilates exams.

TABLE. I. TYPE OF CHEATING

Type of cheating	**Traditional Cheating**		**Online Cheating**	
	Prevention	***Detection***	***Prevention***	***Detection***
Using cheating sheets: prewritten cheat sheets, usually in small font, hidden in clothes or under wrist watch [5]		Seek help from physical proctors		Seek help from physical proctors
Using cheating sheet on the floor: prewritten cheating sheets hidden in books or under folders below the desk [5]	Make sure that books or notes are stored in backpack, not under desk	Seek help from physical proctors	Make sure that books or notes are stored in backpack, not under desk	Seek help from physical proctors
Using numeric devices to communicate a question number or correct answer by text messaging via cell phones [6]	Don't allow cell phones or use a Microsoft Dongle to detect any Devices with Bluetooth technology in the "on" Position	Seek help from physical proctors	Don't allow cell phones or use a Microsoft Dongle to detect any Devices with Bluetooth technology in the "on" Position	Seek help from physical proctors
Listening to the ipod which has recording abilities; It is possible to hide earphone wires behind long hair [5]	Don't allow examinees to use ipods	Seek help from physical proctors	Don't allow examinees to use ipods	Seek help from physical proctors

D-exam is an efficacious manner to conduct an examination. Students can study from any convenient place. Moreover, there is no need for physical transfer. However, it faces the problem of cheating during examinations since there are no physical proctors invigilate and control the exam. This referred to as distance cheating. Distance cheating includes all previously mentioned kinds of cheating. In addition, there are other forms of cheating, such as: taking an examination for another student or having someone take an examination for one, using applications that help to solve the exam questions, copying test questions and sending them to an expert to send back the answers, and downloading resources from the Internet, for example, using an e-book .

III. AUTHENTICATION

Authentication is one of the methods that are designed to protect personal identity [7]; also, it attempts to verify that the users are those who claim to be. Unlike face-to-face examinations, D-exam have no proctors or invigilators. They are held at a different and an uncontrolled remote environments. As a result, authentication goals in D-exam are important to check the identity of online students since it plays a key role in security [8, 9].

There are two kinds of authentication [7]: static authentication and continuous authentication. Static authentication refers to authentication that takes place at the beginning of accessing the examination, and will also be valid during the whole period until the user logs off from that examination. The continuous authentication refers to authentication that will be continued after the start of the examination, and will verify whether the current user is the same as the user who initiated the exam or not.

A. Continuous Authentication Technique

1) Fingerprint

Fingerprint authentication refers to the automated method of verifying a match between two human fingerprints. Fingerprint identification is one of the most well-known and publicized biometrics, because of its uniqueness and consistency over time. No two people have exactly the same fingerprints. Even identical twins, with identical DNA, have different fingerprints. This uniqueness allows fingerprints to use in all sorts of ways, including background checks [10]. Fingerprint offers many advantages such as uniqueness, convenience, non-repudiation and non-transferable.

Fingerprint recognition operates in two distinct modules, as shown in Fig 1, [11]. First, the enrollment module: an application to be used by a user to capture multiple fingerprints for at least two fingers by a fingerprint reader. In addition, it checks image quality to ensure that a good quality scanned image is captured. In addition, it extracts the fingerprint minutiae and saves the entire fingerprint images and/or minutiae in a database. The verification module: an application that verifies users. It can capture a fingerprint from a fingerprint reader. In addition, it extracts the fingerprint minutiae. In addition, it compares fingerprint with stored fingerprints to identify a user from a list or verify a specific user.

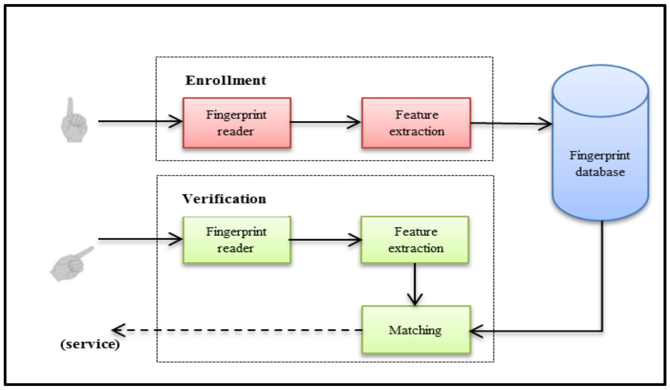

Fig. 1. Fingerprint Recognition

2) Eye Tracking

Eye tracking is a technology that calculates the eye gaze point of a user as he or she looks around. The eye gaze coordinates are calculated with respect to a screen the person is looking at, and are represented by a pair of (x, y) coordinates given on the screen coordinate system [12].

Eye tracking can be used in a wide variety of applications, typically categorized as active or passive. Active applications involve device control, for example aiming in games, eye activated login or hands-free typing. Passive applications include performance analysis of design, layout and advertising. Other examples are vehicle safety, medical diagnostics and academic research [13].

IV. Online Proctor

Online proctor (e-proctor) is another technique, which is planned to be investigated for the objective of monitoring a student while he/she is taking a D-exam. The e-proctor role is to detect any cheating activities during a D-exam session.

E-Proctor is an integrated solution that brings academic integrity to distance learning exams. The e-proctor requires a fingerprint scanner to authenticate the identity of a student, and it requires an eye tracker that contains a camera to track the user's eyes movements, as shown in Fig 2. The camera tracks even the most minuscule of movements of the users' pupils, by taking the images and running them through computer-vision algorithms. The algorithms read, "On-screen gaze coordinates", and then, help the software to determine where on the screen the user is looking. E-proctor is connected to the student' computer, it locks the computer system to only the exam application while simultaneously prohibiting access to all other applications or pre-existing information which could be used for cheating during an exam.

The student must successfully pass through the ID authentication process that entails placing the finger on a scanner and will match the biometrics with the information gathered during the initial registration process. In addition, student needs a personal calibration process. Each person has different eye characteristics. The eye tracking needs to locate the gaze accurately. The calibration consists of a circular target that displayed at different locations of the screen on a blank background for around 2 seconds each. The user needs to look at the target as it is displayed on the screen. Once all the calibration targets displayed on the screen, the calibration process is completed.

Once the student identification authenticated and the calibration process completed successfully, E-proctor launches the exam application for the student while locking his computer until the exam completed. During the exam, e-proctor will record changes in the eyes movement.

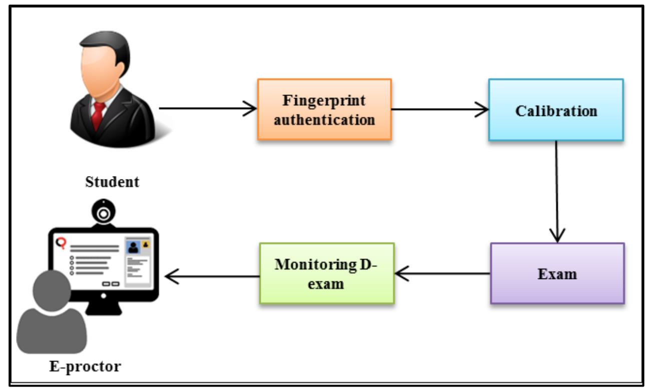

Fig. 2. Online Proctor

V. E-Exam Management System Architecture

The work of e-exam management system can be divided into two phases as depicted in Fig 3. The first phase is before being permitted to perform the E-exam session, username/password and fingerprints must be used to authenticate the examinee. The second phase is during the exam session, it is required to continuously guarantee that the examinee is the one who is claiming to be. Eye tracking is utilized during the E-exam session.

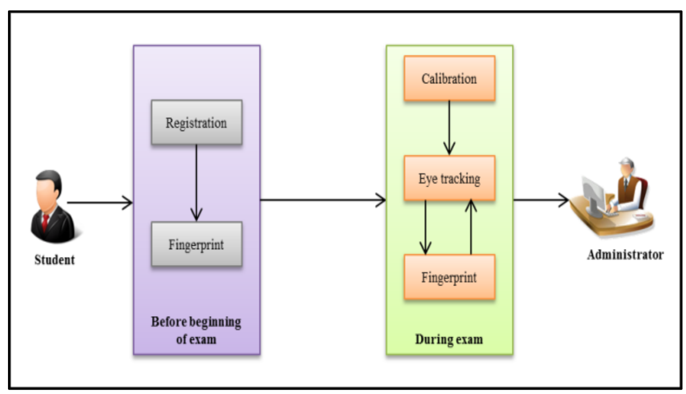

Fig. 3. The Architecture of E-Exam Management System

Before starting exam session, the system's user, i.e. examinee, first must create an account. The user will be required to provide his/her examinee user name and password. After registration, the examinee will be able to enroll the fingerprint into the system.

In the second phase, the examinee is continuously authenticated through an eye tracking to prevent any cheating situation. Eye tracking is the process of using sensors to locate features of the eyes and estimate to where the examinee is looking (point of gaze). The tracker must be placed below the screen and pointing at the examinee. The examinee needs to be located within the tracker's trackbox. A trackbox is a small graphical component that illustrates an examinee's position relative to the sensor. This is useful to see if examinee is within the range of the sensor and the tracking is fully functional. Afterwards, the examinee will now be ready to the calibration process. The calibration process requires of examinee to look at a series of calibration targets distributed evenly throughout the screen. Each target will appear one after the other and they are displayed for a predefined periods. The process usually takes about 20 seconds to complete. After successful completion of the calibration process , the examinee will be able to log into the E-exam. The examinee will be continuously authenticated through an eye tracker; eye trackers may be able to prevent any cheating status during E-exam.

To achieve the continuous authentication in E-Exam Management system via eye tracker, the system needs to distinguish between three scenarios as shown in Fig 4.

- Scenario 1: The examinee is in front of the screen and his frontal eyes view is available to the camera.
- Scenario 2: The examinee is sitting in front of the screen, but he is looking down.
- Scenario 3: The examinee has moved away from the screen.

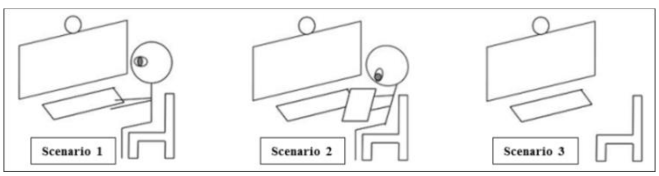

Fig. 4. Scenarios of Eye Tracking

In scenario 1 ; the system is unlooked the exam , because examinee is active and in front of the screen , also the system can be monitoring the examinee via eye tracker .In scenario 2 and scenario 3, the system locked the exam; because user is not active or moves away from the screen , furthermore the system must be re-authenticate examinee automatically.

VI. E- Exam Management System Algorithm

E-exam management system that we suggested in this paper consisted of several modules that perform the functions of the system. Fig 5 demonstrates flowchart of the algorithm of the E-exam management system.

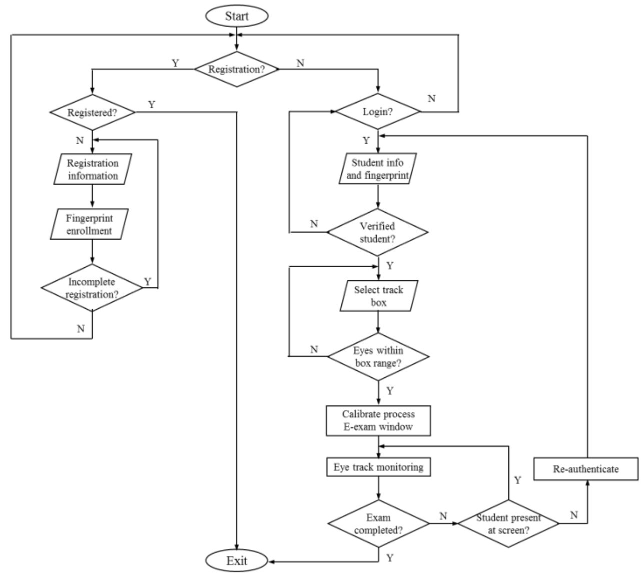

Fig. 5. Flowchart of E-Exam Management System

VII. Implementation of E-Exam Management System

E-Exam Management system is implemented using visual C# 2012 and SQL server 2008 database. In addition, we used some tools such as digital persona U.Are.U 4500 HD USB Fingerprint Reader, and Eye Tribe Tracker. The following is a snapshot of the E-exam window of the eye tracker monitoring. Any time the E-system recognizes that the examinee is no longer present in front of the screen; the system is locked and must re-authenticate the examinee automatically via fingerprint, as shown in Fig 6.

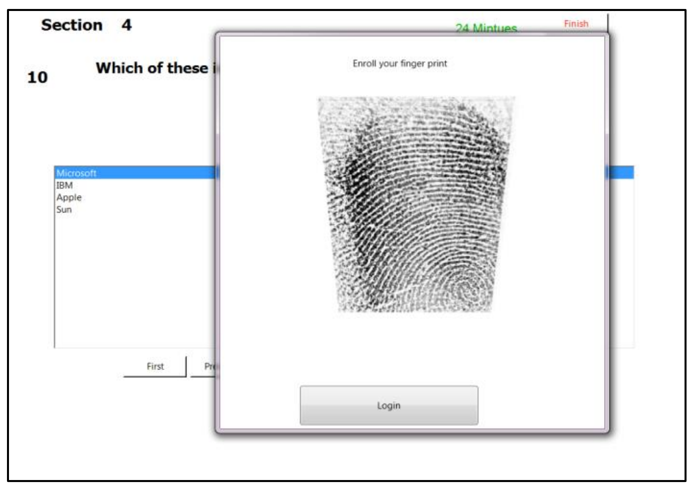

Fig. 6. E-Exam Windows

VIII. ANALYSIS AND EVALUATION

The E-exam management system is utilized to detect any status of cheating in D-exam. We used the fingerprint reader for continuous examinee authentication and the eye tracker for the observation of the examinee through the D-exam session.

The experiments involved 30 participants with a diverse range of jobs, backgrounds and education levels. Participants were divided into two groups: the first group consisted of 15 participants who were in status of cheating during the D-exam, and the second group was 15 participants who were in status of non-cheating during the D-exam. In addition, each participant repeated the experiment three times. So the size of data equals 90 samples in this experiment.

We observed the participant in D-exam via the eye tracker. The tracker registers the movements of the participant's eyes in a database. The database contains the user ID of the examinee, the time when the examinee get out of the screen, the time when the examinee come back to the screen, and the cheating status. Tables II show samples of collected data.

TABLE. II. SAMPLES OF COLLECTED DATA

ID	Average time out of the screen (Second)	Average number of times out of the screen	Status
1	0:11:57	19	non- cheating
2	0:12:52	6	non- cheating
3	0:01:38	10	non- cheating
4	0:06:28	28	non- cheating
5	0:02:29	16	non- cheating
6	0:01:31	12	non- cheating
7	0:14:23	32	cheating
8	0:14:50	25	cheating
9	0:12:07	25	cheating
10	0:12:18	21	cheating
11	0:16:55	11	cheating
12	0:15:06	21	cheating

A scatter plot of the data is shown in Fig 7.

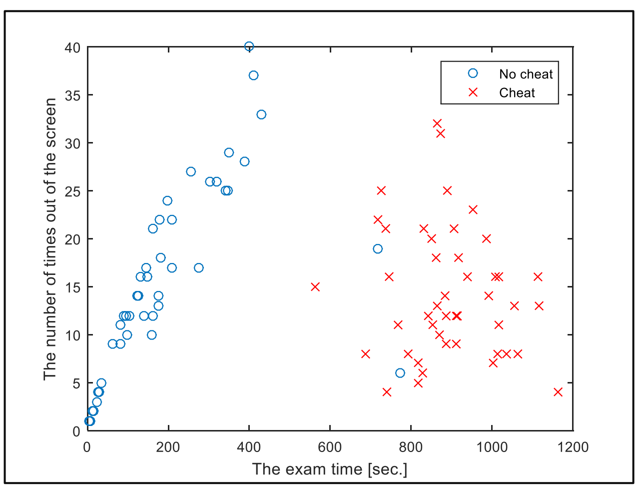

Fig. 7. Scatter Plot of 90 Samples

We can discriminate between "cheating" case and "no cheating" case by dividing the plane into two regions by a line defined by the two points p_1 (300, 0) and p_2 (600, 40) as shown in Fig 8.

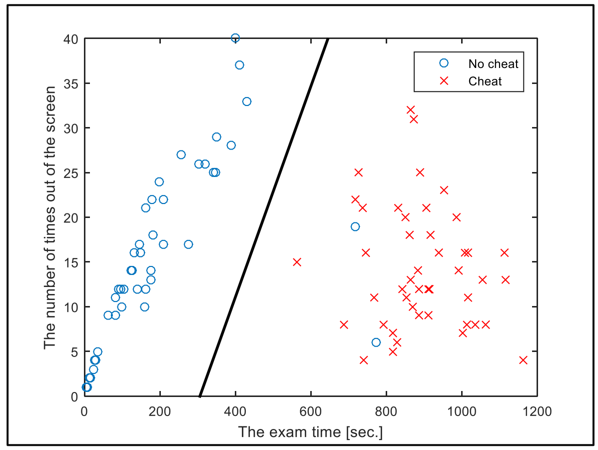

Fig. 8. Scatter Plot of 90 Samples with a Separation Line

Let t be the exam time and n be the number of times out of the screen, then the equation of the line is:

$$n = m\,t + b \qquad (1)$$

Where m is the slope of the line and b is the intercept. They can calculate as follows.

$$m = \frac{\Delta n}{\Delta t} = \frac{40-0}{600-300} = 0.1333 \qquad (2)$$

$$b = n - m\,t = 0 - 0.1333 \times 300 = -40 \qquad (3)$$

Therefore, the equation of the line is:

$$n = 0.1333\,t - 40 \qquad (4)$$

Any sample $s(t_s, n_s)$ can be classified using equation (4) as follows:

$$s \in \begin{cases} no\ cheating & if\ n_s - 0.1333\,t_s + 40 > 0 \\ cheating & if\ n_s - 0.1333\,t_s + 40 < 0 \end{cases} \qquad (5)$$

Using the classifier defined by the equation (5), the 90 samples can classified as shown in Fig 9.

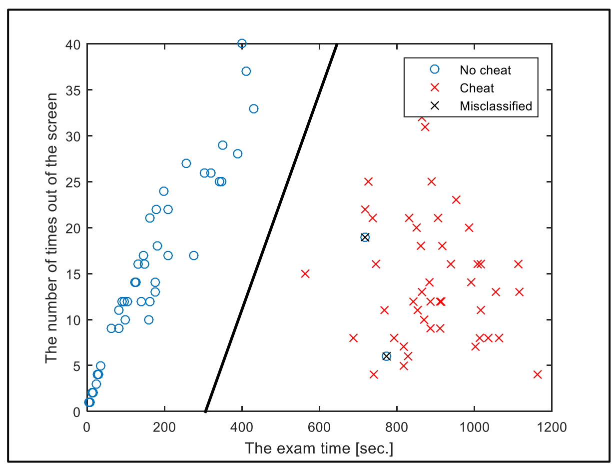

Fig. 9. Classifying the 90 Samples using Equation (5)

A confusion matrix, also known as a contingency table used to indicate the results of the recall, specificity, precision, and accuracy measures [14]. The confusion matrix contains four cells:

- TP: Number of true items on the classified positive samples.

- FP: Number of false items on the classified positive samples.
- TN: Number of true items on the classified negative samples.
- FN: Number of false items on the classified negative samples.

The confusion matrix given by:

TABLE. III. CONFUSION MATRIX

	Predicted No	**Predicted Yes**
Actual No	43	2
Actual Yes	0	45

Therefore, $\mathrm{TN} = 43$, $\mathrm{FP} = 2$, $\mathrm{FN} = 0$, and $\mathrm{TP} = 45$. In addition, the performance of the Table III is measured as follows:

- Sensitivity (Recall) which is measures the proportion of positives that correctly identified, also called the true positive rate.

Sensitivity (Recall) = TP / (TP + FN) = 100 %

- Specificity, which is, measures the proportion of negatives that correctly identified also called the true negative rate.

Specificity = TN / (FP + TN) = 95.56 %

- Precision is the fraction of retrieved instances that are relevant, also called positive predictive value.

Precision = TP / (TP+FP) = 95.74%

- Accuracy is the proximity of measurement results to the true value.

Accuracy = (TP + TN) / (TP + TN + FP + FN) = 97.78 %

- F-measure :A measure that merges both the precision and the recall, also called the harmonic mean.

F-measure = 2*TP / (2*TP+FN+FP) = 97.83%

IX. CONCLUSION

This paper addresses the cheating in online exam. Specifically, it introduced the concepts of cheating and how it can be controlled in online exam. It provides a technique for detecting and preventing student from cheating through continuous authentication and online proctor. E-exam management system is proposed to investigate cheating in D-exam using Fingerprint Reader to authenticate the examinee, and Eye Tribe Tracker to continuously guarantee that the examinee is the one who is claiming to be. This system was developed in visual C# and SQL server database. As a result, the system classified the examinee status as cheating or non-cheating based on two parameters: the total an examinee time on out screen and the number of times, the examinee is out of screen. To evaluate this proposed work, a series of experimental tests were conducted. The tests yielded the following results: sensitivity is 100 %, specificity is 95.56%, precision is 95.74%, accuracy is 97.78 %, and f-measure is 97.83% .

There are some limitations for the system that we presented in this paper, such as the handling of the cases of students with special needs.

X. FUTURE WORK

There are several promising directions to extend the work presented in this research. The system can be implemented over the web. Another feature to improve continuous authentication such as voiceprint that is integrated and utilized during the D-exam session can be added to the system. Using face recognition as continuous authentication which can identify a specific individual in a digital image by analyzing and comparing patterns. Still one more enhancement can be made is that, after a student start an exam, the use of keystrokes as continuous authentication that will control whether the current user is the same as the user who initiated the static authentication or not.

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Modeling and Control of a Multi-Machine Traction System Connected in Series using Two Static Converter

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***Abstract*—Power may be segmented either at the converter, using a multilevel inverter, either at the machine, by performing a polyphase winding. Moreover, increasing numbers of phases enables improved power quality and reducing torque ripples with the advantage of fault tolerance related to the loss of one or more phases. This class of system offers a reduction of design time, costs and the optimization of the volume of embedded systems. The objective of this work is to order, model and characterize the behavior of a training system multimachines composed of two five phase synchronous permanent magnet motors connected in series using two static converters.**

***Keywords*—synchronous machine; Multi-machine Multi-inverter; five-phase; vector control**

I. Introduction

Thanks to the advances in technology and the means of calculating the powerful, it is possible to consider the variable speed applications in an efficient manner where the association of electrical machines and of static converters are more and more applications in embedded systems (ships, submarines, vehicles, aircraft...etc.), where the gain in space and weight requires a very particular attention. An example of the systems of drives, which combine the advantages offered by the use of multiphase machines, of the electronic power and the means of calculation, is the SMM which allows you to order in a way completely decoupled several electrical machines whose windings are connected in series.

The traction systems electric railway are complex, they have electrical couplings, magnetic and mechanical solid. These couplings impose a number of constraints that complicate the modeling and analysis of these systems. Multi Machine / System Multi-converter systems (MMS) used to meet the industrial requirements such as the optimization of the system volume and weight. Several configurations are developed and analyzed in order to guarantee the stability of operation when a mechanical disturbance or electric appears.

In this approach, we focus in particular on the modeling and the independent control of the two five phase synchronous permanent magnet motors connected in series.

II. Description and Modeling of the System

The use of a structure composed of two engines powered by a single static converter, allows one hand to reduce the number of components of power and control, and on the other hand, to establish a command for the entirety of the bogie of traction. In this study the overall system consists of two five phase motor synchronous with permanent magnet connected in series. Therefore many configurations are possible. The first consists of a continuous floor which supplies several three-phase inverters mounted in parallel, or each inverter supplies a three phase motors. The control of each engine is independent via its inverter and its control algorithm. The second configuration consists of a single converter, which moreover supplies in parallel several Engines. For this structure, the engines must have the same speed of rotation and suffer the same load torque [5], [6].

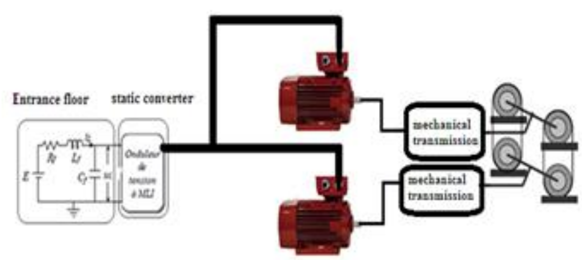


Fig. 1. Block diagram with a command structure of the configuration parallel for the chain of rail traction

A new structure of propulsion is proposed. It consists of a inverter to seven levels of voltage to pulse width modulation, feeding in series with the two five phase motors.

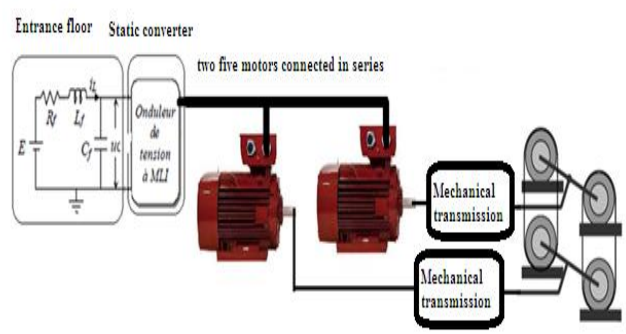


Fig. 2. Block diagram with a command structure proposed for the chain of rail traction

III. Modeling of Two Five Phase Motors Synchronous with Permanent Magnet Connected in Series

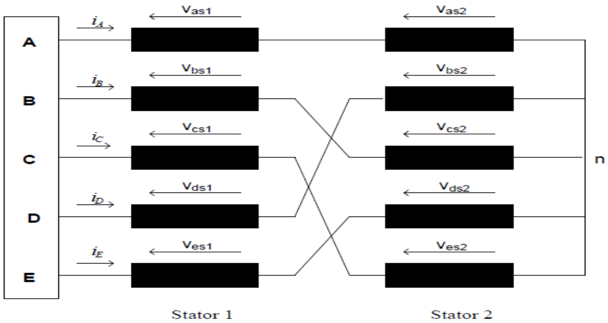


Fig. 3. Description of two five phase motor connected in series

According to the connection diagram of the fig(3), where the phase voltages of the two machines are defined, voltages of the inverter phase-neutral (A, B, C, D, E to NEUTRAL (N) and the relationship between the output current of the ups and currents of the phases of the two machines are provided with[1] , [2] , [3] , [4] :

$$[V_s]=\begin{bmatrix} v_A \\ v_B \\ v_C \\ v_D \\ v_E \end{bmatrix}=\begin{bmatrix} v_{as1}+v_{as2} \\ v_{bs1}+v_{cs2} \\ v_{cs1}+v_{es2} \\ v_{ds1}+v_{bs2} \\ v_{es1}+v_{ds2} \end{bmatrix} \quad (1)$$

$$\begin{aligned} i_A &= i_{as1} = i_{as2} \\ i_B &= i_{bs1} = i_{cs2} \\ i_C &= i_{cs1} = i_{es2} \\ i_D &= i_{ds1} = i_{bs2} \\ i_E &= i_{es1} = i_{ds2} \end{aligned} \quad (2)$$

The two machines of Fig (3) are assumed to be of the same parameters, the electrical circuit of the model of the fig (3) it can be represented as a matrix form (quantities not linear) by:

$$[V_{\mathrm{ABCDE}}] = [R_s][I_{\mathrm{ABCDE}}] + \frac{d}{dt}[\phi_{\mathrm{ABCDE}}] \quad (3)$$

A. Transformation of decoupling of Clark:

The relationship between the original variables of the phases and the new variables (αβxyo) is given by:

$$f(\alpha\beta)' = [C] f(ABCDE)$$

Where [C] is the transformation matrix to invariant Power:

$$[C_s]^t = \sqrt{\frac{2}{5}}\begin{bmatrix} 1 & \cos(\alpha) & \cos(2\alpha) & \cos(3\alpha) & \cos(4\alpha) \\ 0 & \sin(\alpha) & \sin(2\alpha) & \sin(3\alpha) & \sin(4\alpha) \\ 1 & \cos(2\alpha) & \cos(4\alpha) & \cos(6\alpha) & \cos(8\alpha) \\ 0 & \sin(2\alpha) & \sin(4\alpha) & \sin(6\alpha) & \sin(8\alpha) \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix}$$

Applying this matrix tension vector inverter there will:

$$\begin{bmatrix} v_\alpha^{inv} \\ v_\beta^{inv} \\ v_x^{inv} \\ v_y^{inv} \\ v_o^{inv} \end{bmatrix} = [C]\begin{bmatrix} v_A \\ v_B \\ v_C \\ v_D \\ v_E \end{bmatrix} \quad (4)$$

Using this matrix to the relation (1), the tensions of each machine in this mark:

$$\begin{bmatrix} v_\alpha^{inv} \\ v_\beta^{inv} \\ v_x^{inv} \\ v_y^{inv} \\ v_o^{inv} \end{bmatrix} = [C]\begin{bmatrix} v_{as1}+v_{as2} \\ v_{bs1}+v_{cs2} \\ v_{cs1}+v_{es2} \\ v_{ds1}+v_{bs2} \\ v_{es1}+v_{ds2} \end{bmatrix} = \begin{bmatrix} v_{\alpha s1}+v_{xs2} \\ v_{\beta s1}+v_{ys2} \\ v_{xs1}+v_{\alpha s2} \\ v_{ys1}+v_{\beta s2} \\ 0 \end{bmatrix} (5)$$

The relationship between the output current of the ups and currents α-β, x-y of the two machines is:

$$\begin{aligned} i_\alpha^{INV} &= i_{\alpha 1} = i_{X2} \\ i_\beta^{INV} &= i_{\beta 1} = -i_{Y2} \\ i_X^{INV} &= i_{X1} = i_{\alpha 2} \\ i_Y^{INV} &= i_{Y1} = i_{\beta 2} \end{aligned} \quad (6)$$

As the sub-Space α-β is orthogonal to the sub- space X-Y, it follows that the specific method of the serial connection used in the Fig (3) will allow the vector command independent of the two machines.

$$[V_{\mathrm{ABCDE}}] = [R_s][I_{\mathrm{ABCDE}}] + \frac{d}{dt}([L_s][i_{ABCDE}] + [\phi_{\mathrm{aimant}}]) \quad (7)$$

The component of order zero for the converter can also be well neglected. The Electromagnetic part of the drive system can then be represented with eight equations of the first order. The four equations of the converter are as follows [8], [12], [13]:

$$
\begin{aligned}
v_{\alpha}^{INV} &= (R_{s1}+R_{s2})i_{\alpha}^{INV} + (l_{s1}+\frac{5}{2}m_{s1})\frac{d}{dt}i_{\alpha}^{INV} + l_{s2}\frac{d}{dt}i_{\alpha}^{INV} - \sqrt{\frac{5}{2}}\omega_1\phi_{f1}\sin(\theta_1) \\
v_{\beta}^{INV} &= (R_{s1}+R_{s2})i_{\beta}^{INV} + (l_{sl1}+2m_{s2})\frac{d}{dt}i_{\beta}^{INV} + l_{s2}\frac{d}{dt}i_{\beta}^{INV} + \sqrt{\frac{5}{2}\omega_1\phi_{f1}\cos(\theta_1)} \\
v_{x}^{INV} &= (R_{s1}+R_{s2})i_{X}^{INV} + l_{s1}\frac{d}{dt}i_{x}^{INV} + (l_{s2}+\frac{5}{2}m_{s2})\frac{d}{dt}i_{x}^{INV} - \sqrt{\frac{5}{2}}\omega_2\phi_{f2}\sin(\theta_2) \qquad (8) \\
v_{y}^{INV} &= (R_{s1}+R_{s2})i_{y}^{INV} + l_{s1}\frac{d}{dt}i_{y}^{INV} + (l_{s2}-\frac{5}{2}m_{s2})\frac{d}{dt}i_{y}^{INV} + \sqrt{\frac{5}{2}}\omega_2\phi_{f2}\cos(\theta_2)
\end{aligned}
$$

B. Model in a rotary index

In order to express all sizes in a single frame, the stator variables are projected into a rotating reference frame (d, q) shifted by φ with respect to the fixed coordinate system (α, β), this transformation is calculated from the matrix D rotation as:

$$
D=\begin{bmatrix} \cos(\theta)\ \sin(\theta) & \cdot \\ \sin(\theta)\ \cos(\theta) & \cdot \\ \cdot \qquad \cdot & [I]3*3 \end{bmatrix} \quad (9)
$$

In terms of the different components of the tensions of stator d-q of two machines[1] , [2] , [3] , [4]:

$$
\begin{aligned}
v_d^{INV} &= v_{ds1} + v_{xs2} \\
v_q^{INV} &= v_{qs1} + v_{ds2} \qquad (10) \\
v_x^{INV} &= v_{xs1} + v_{ys2} \\
v_y^{INV} &= v_{ys1} + v_{qs2}
\end{aligned}
$$

Couple relations between the two series-connected machines are given in terms of current components of the inverter:

$$
\begin{aligned}
C_{e1} &= p((L_d - L_q)i_d^{INV}i_q^{INV} + \sqrt{\frac{5}{2}}\phi_{f1}i_q^{INV}) \\
C_{e2} &= p((L_x - L_y)i_x^{INV}i_Y^{INV} + \sqrt{\frac{5}{2}}\phi_{f2}i_y^{INV}) \qquad (11)
\end{aligned}
$$

IV. Vector Control of Two Five Phase Motors Connected in Series

To a voltage supply via a voltage-controlled inverter, the reference voltages are created by adding the reference voltages of each machine are [15], [16]:

For the machine 1:

$$
\begin{aligned}
v_d^{INV} &= (R_{s1}+R_{s2})i_d^{INV} + (l_{s1}+\frac{5}{2}m_{s1})\frac{d}{dt}i_d^{INV} + l_{s2}\frac{d}{dt}i_d^{INV} - \omega_1(l_{s1}+\frac{5}{2}m_{s1})i_q^{INV} \\
v_q^{INV} &= (R_{s1}+R_{s2})i_d^{INV} + (l_{sl1}+\frac{5}{2}m_{s1})\frac{d}{dt}i_q^{INV} + l_{s2}\frac{d}{dt}i_q^{INV} + \omega_1(l_{s1}+\frac{5}{2}m_{s1})i_d^{INV} + \sqrt{\frac{5}{2}}\omega_1\phi_{f1}
\end{aligned}
$$

For the machine 2:

$$
\begin{aligned}
v_x^{INV} &= (R_{s1}+R_{s2})i_X^{INV} + l_{s1}\frac{d}{dt}i_x^{INV} + (l_{s2}+\frac{5}{2}m_{s2})\frac{d}{dt}i_x^{INV} - \omega_2(l_{s2}+\frac{5}{2}m_{s2})i_y^{INV} \\
v_y^{INV} &= (R_{s1}+R_{s2})i_y^{INV} + l_{s1}\frac{d}{dt}i_y^{INV} + (l_{s2}-\frac{5}{2}m_{s2})\frac{d}{dt}i_y^{INV} + \omega_2(l_{s2}+\frac{5}{2}m_{s2})i_x^{INV} + \sqrt{\frac{5}{2}}\omega_2\phi_{f2}
\end{aligned}
$$

Couple relations between the two series-connected machines are given in terms of current components of the inverter:

$$
\begin{aligned}
C_{e1} &= p((L_d - L_q)i_d^{INV}i_q^{INV} + \sqrt{\frac{5}{2}}\phi_{f1}i_q^{INV}) \qquad (12) \\
C_{e2} &= p((L_x - L_y)i_x^{INV}i_Y^{INV} + \sqrt{\frac{5}{2}}\phi_{f2}i_y^{INV})
\end{aligned}
$$

Both equations are completely independent, so we can control each machine with two and vector control using a single inverter.

The couple first machine controlled by the two currents (id, iq) and. for the second machine torque controlled by both current (ix, iy) .Among control strategies, one that is often used is to maintain I_D component and zero i_x. We control couples only by iq iy and currents. Thus rule speeds by ix and iy component.

The overall voltage references are then formed on the wiring diagram of fig (3), whereas:

$$
\begin{aligned}
v_A^* &= v_{as1}^* + v_{as2}^* \\
v_B^* &= v_{bs1}^* + v_{cs2}^* \\
v_C^* &= v_{cs1}^* + v_{es2}^* \\
v_D^* &= v_{ds1}^* + v_{bs2}^* \\
v_E^* &= v_{es1}^* + v_{ds2}^*
\end{aligned}
$$

Use of the matrix with the equation gives:

$$i_{\alpha}^{INV} = i_{\alpha 1} = i_{X2}$$
$$i_{\beta}^{INV} = i_{\beta 1} = -i_{Y2}$$
$$i_{X}^{INV} = i_{X1} = i_{\alpha 2}$$
$$i_{Y}^{INV} = i_{Y1} = i_{\beta 2}$$

A system illustration of the vector control of two five phase motors is given in fig.(04)

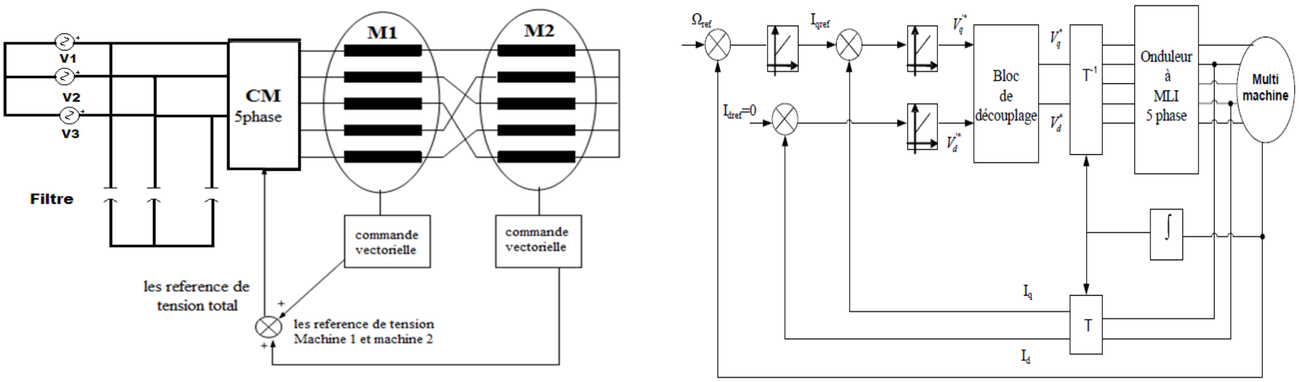
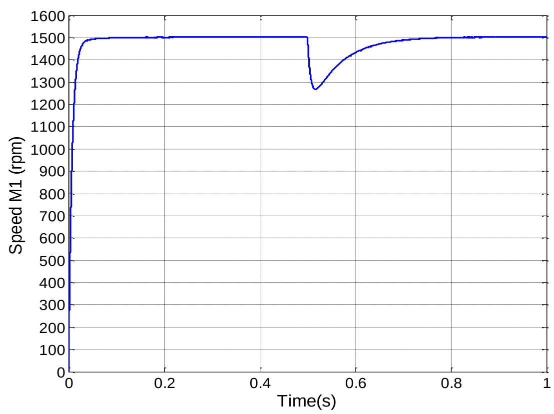
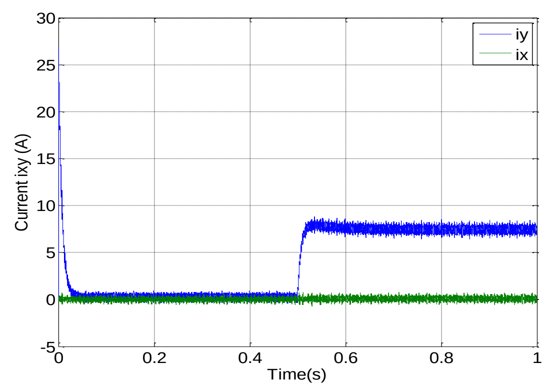
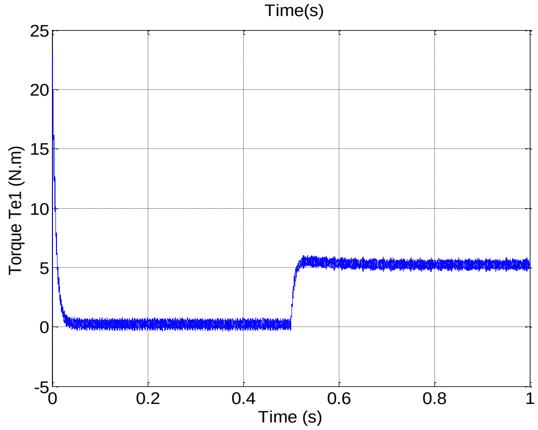


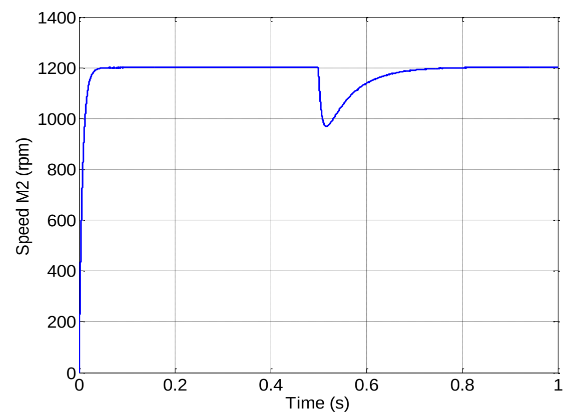
Fig. 4. Block diagram of vector control two five phase motors connected in series powered by five phase inverter and matrix converter

V. Simulation Result









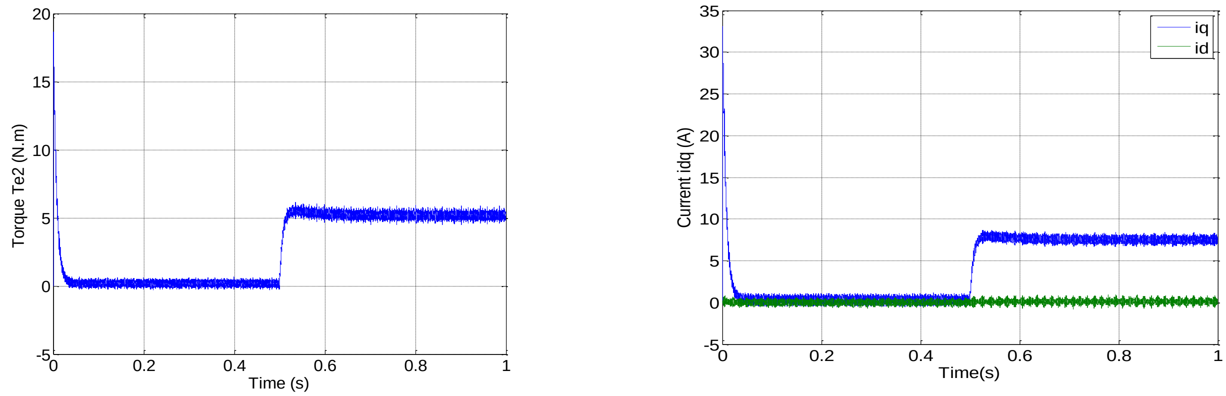


Fig. 5. Responses of the PMSM connected in series powered by five phase inverter with a load of 05 Nm at 0.5s and a step change of two speed order (1500 rpm and 1200 rpm)

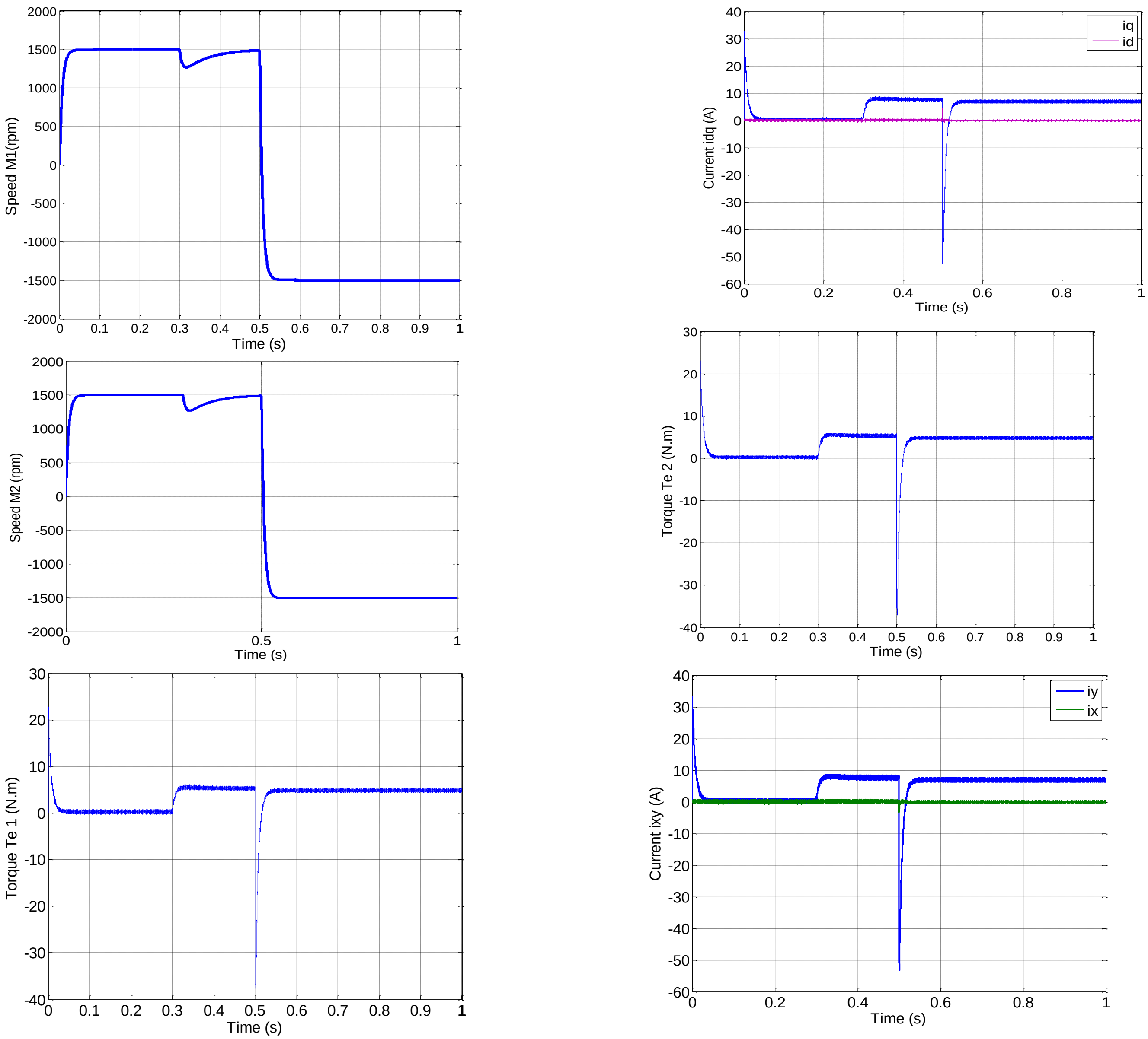


Fig. 6. Responses of the PMSM connected in series powered by five phase inverter with a load of 05 Nm and a step change of the reference speed from 1500 rpm to -1500 rpm at t=0.5s

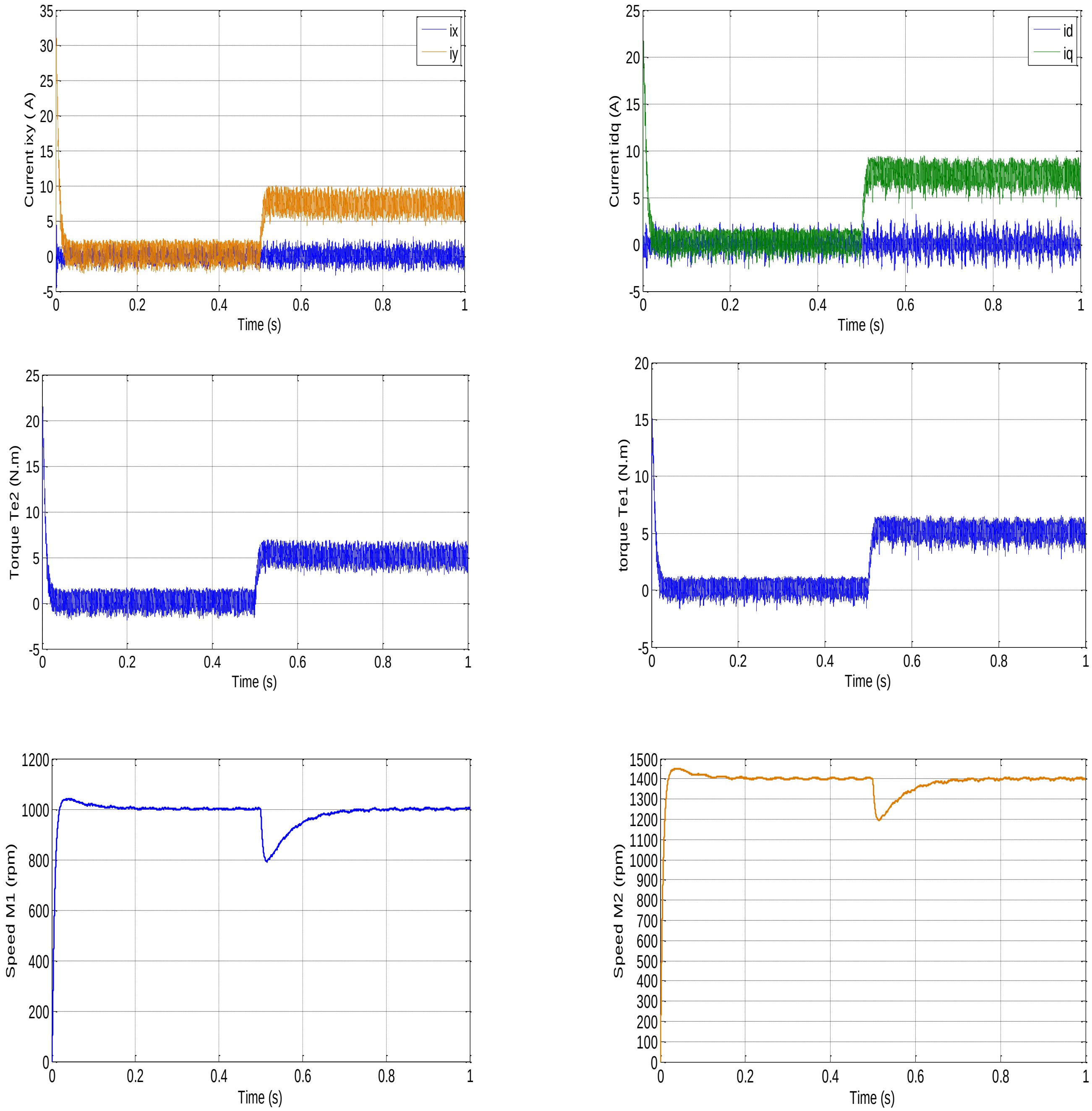


Fig. 7. Responses of the PMSM connected in series powered by five phase matrix converter with a load of 05 Nm at 0.5s and a step change of two speed order (1500 rpm and 1200 rpm)

TABLE. I. FIVE PHASE PMSM PARAMETERS

R_s	L_d	L_q	j	p	φ_f	f_r
3.6 ohm	0.0021 H	0.0021 H	0.0011 kg/m^2	2	0.12 web	0 hrtz

VI. CONCLUSION

In this approach, we tested in simulation vector control applied to two five phase synchronous machines permanent magnets connected in series using two static converter .The transposition of two machines has allowed us to have more degree of freedom on the axes of currents and so ordered two machines independently we note that:

- The pace of speed perfectly follows its reference which is reached very quickly with an acceptable response time. The effect of the disturbance is quickly removed and the electromagnetic torque stabilizes at a value of 5 N.m.
- The response of the two components of the current shows decoupling introduced by vector control of two

five phase machines.

- The current Iq is the image of the torque 1.
- The current Iy is the image of torque2.

The independent vector control two machines gave good results and helped to decouple control flow and torque for both machines. This allowed controlling several machines in series and with different types of polyphase machines.

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Spatial Comprehension Exercise System with 3D CG of Toy Model for Disabled Children

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***Abstract*—Spatial comprehension exercise system with Three-Dimensional Computer Graphics: 3D CG of toy model for disabled children is proposed. In order to improve spatial comprehension in an attractive manner, a toy model is created together with building block model. Through experiments, it is confirmed that the spatial comprehension is improved for the disabled children remarkably.**

Keywords—Spatial Comprehension; Toy model; Augmented reality; Computer graphics

I. Introduction

E-Learning Framework for Learning Disabled Children is well defined [1]. Although there are so many types of the Learning Disability: LD [2]-[4], very few paper deals with learning content spatial comprehension. It's really hard to pick up objects and take a look at the back view of the objects for disabled children. Therefore, there is a strong demand of learning contents which allow improvement of spatial comprehension.

Digital content creation, learning content retrieval, collaborating learning system, learning system utilizing computer input by human eyes only for disabled persons are proposed previously [5]-[20]. Such those contents and systems would be better to be used for disabled children. One of the difficulties for disabled children to learn is spatial comprehension. Spatial comprehension needs practices with physically acting to an object. Although, it is easy to conduct such practices for able children, it is not so easy for disabled children. This paper deals with learning system based on 3D CG for spatial comprehension practices in particular for disabled children.

As for the related research works, National Institute of Special Needs Education: NISNE created Web Based Learning Contents of Japanese characters, numerical counting, recreations for disabled children [1]. Also, Yamaguchi Education Support Center (Prefectural local government) created digital contents for disabled children[2]. Furthermore, Japan Science and Technology Agency: JST provides digital contents of Science and technology for disabled children[3]. Kanagawa prefectural education support center provides digital contents and materials for disabled children[4]. PROP Station provides education software tools, learning contents for a variety of disability[5]. Most of useful digital contents for disabled children can be accessible to the site[6]. Although there are many 3D CG contents, there is small number of 3D CG content for spatial comprehension exercises for disabled children. It is hard to learn spatial comprehension for disabled children.

In order to improve spatial comprehension in an attractive manner, a toy model is created together with building block model. Through experiments with several disabled children, it is confirmed that the spatial comprehension is improved for the disabled children remarkably.

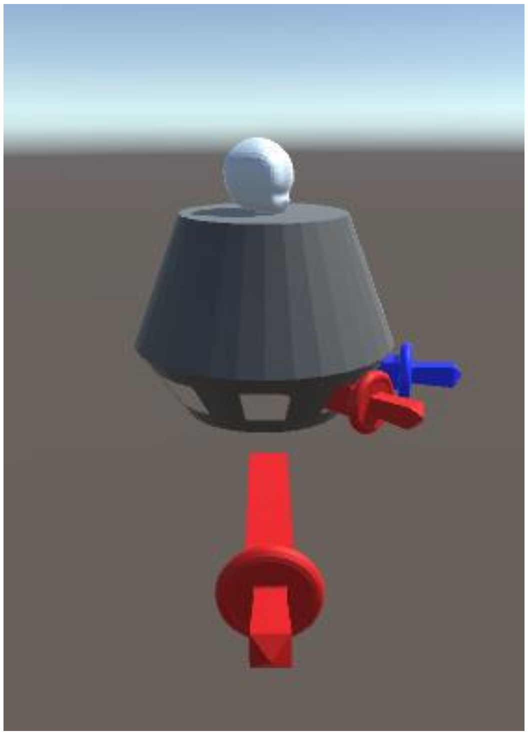
The following section describes the proposed method and system followed by the procedure of experiments. Then the experimental results are described together with some remarks. Finally, conclusion is described together with some discussions and future research works.

II. Proposed Method and System

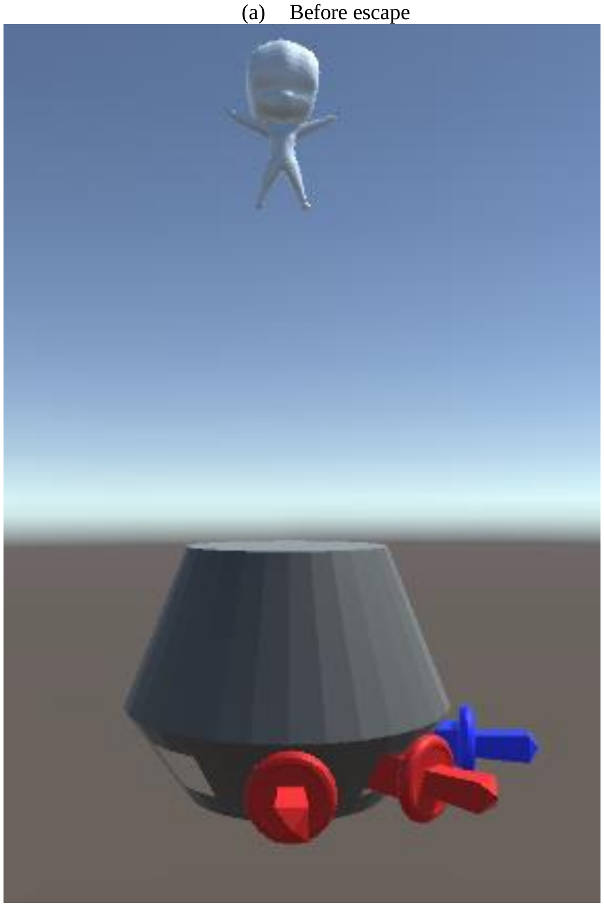
A. Toy Model

Fig.1 shows one of the examples of the proposed toy model. Practice system of spatial comprehension should be attractive. Therefore, toy model is created. Spatial comprehension capability is improved through playing with the toy model. Through this escape game, disabled children are getting familiar with spatial comprehension pleasantly. There are three elements for the escape game, character, sword and capsule as shown in Fig.2. The key components of the proposed toy model are (a) Realistic motion of the objects, (b) Learning in an attractive manner. Therefore, physical model of the objects have to be created precisely. Also, it has to be represented that jumping motion of the character when the sword is inserted into the correct hole. Then the proposed learning content becomes attractive.

[1] http://www.nise.go.jp/wakaru/index.html
[2] http://shien.ysn21.jp/teacher/kyoiku_link.html#spedu
[3] http://rikashien.jst.go.jp/support/index.html
[4] http://www.edu-ctr.pref.kanagawa.jp/kanabox/modules/mydownloads/viewcat.php?cid=1
[5] http://www.prop.or.jp/challenged/open/heart/heart-jp133-1.html
[6] http://www.tenji.ne.jp/kyozai/list.php

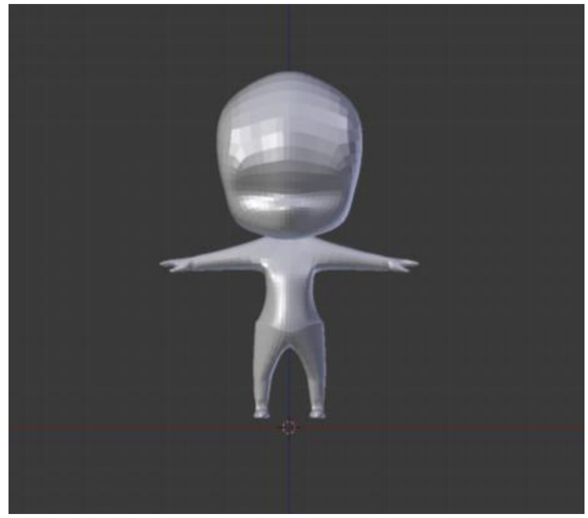


(a) Before escape

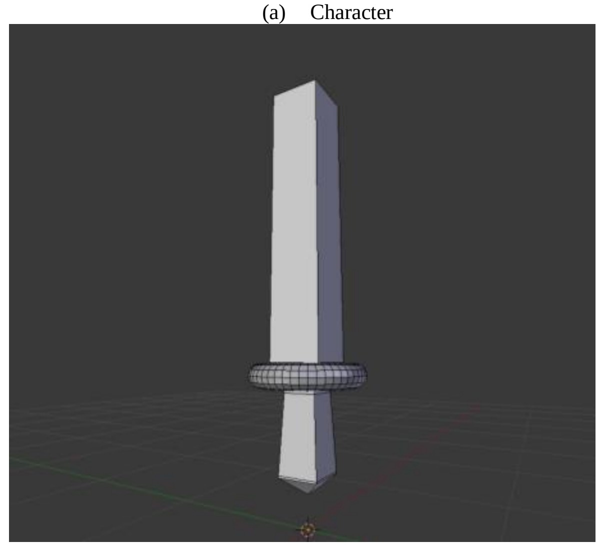


(b) After Escape

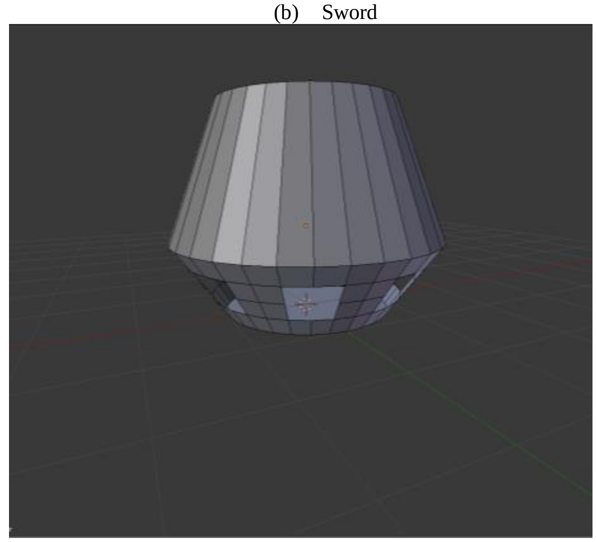
Fig. 1. Toy model



(a) Character



(b) Sword



(c) Capsule

Fig. 2. Elements of the escape game

Rotation of the sword, stab the sword can be selected by clicking the right and the left button as shown in Fig.3. At the beginning, the character is in the capsule. Then the sword appears followed by manipulation of the sword.

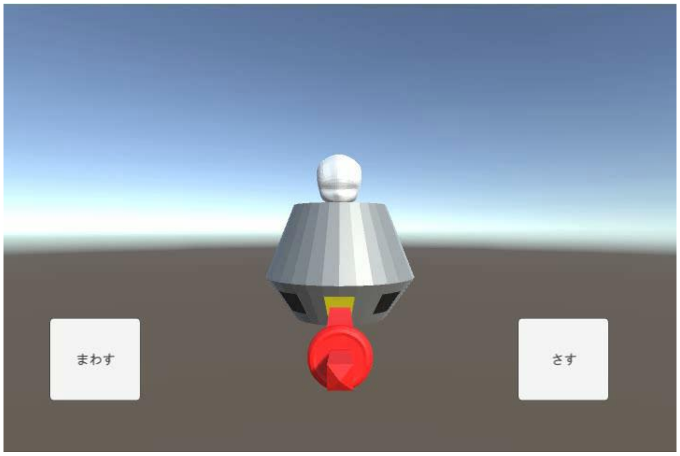


Fig. 3. Escape game

At the bottom of the capsule, there are the holes of which the shape of the hole is matching to the cross section of the sword. Learners manipulate the capsule by rotating for matching the sword to one of the holes, then put the sword in to the hole. If the sword put in bingo hole, then the character jumped out from the capsule. It is not so easy to put the sword in the hole. It is required spatial comprehension for matching the sword to the hole. Through practices with the toy model, spatial comprehension is getting better.

B. Building Block

Another spatial comprehension practice model proposed here is "Building Block". Pile up blocks needs spatial comprehension. Fundamental interface between disabled children and PC is shown in Fig.4.

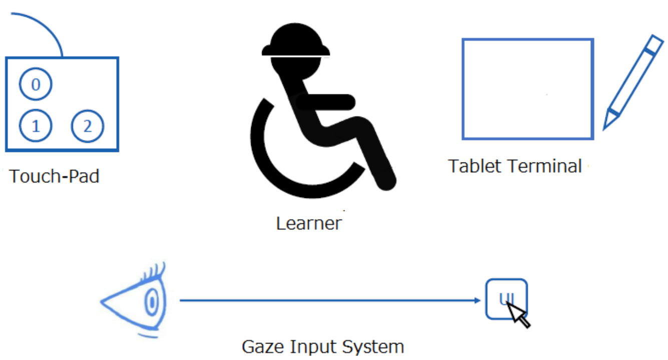


Fig. 4. User interface of the proposed spatial comprehension practices

Namely, touch pad and tablet terminals are available for the disabled children who can use their hands and fingers. Also, gaze input can be used for the disabled children who cannot use their hands and fingers.

Fig.5 shows screen shot image of the menu. At the top-right, there is the radio-button for getting started. The example of the questions is available through the button user the start button. Hold the current situation can be done with the top-left button. If the learner would like to increase another block, the button under the hold button is used.

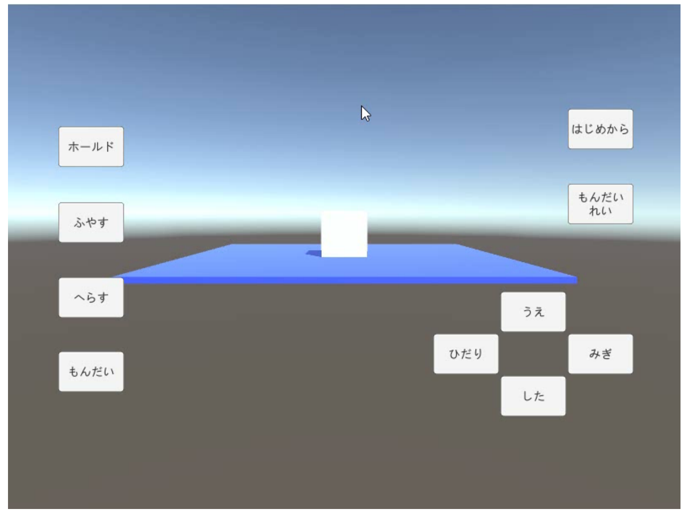


Fig. 5. Screenshot image of the proposed building block practice system

Meanwhile, the number of blocks can be reduced by one by one basis with the button under the increase button. Also, the questions are available with the button under the reduce button. When the increase button is clicked, then one block appears at the top of the screen. It, then is falling to the base plane of which the building blocks are piled up. Physical model is considered. Therefore, felt down block touches down on the base plane or on the previously situated block. Collision occurs between the additional block and the base plane or the previous blocks as shown in Fig.6.

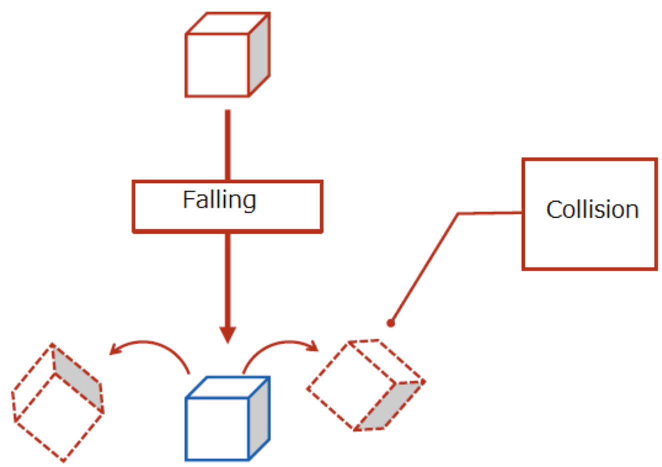


Fig. 6. Additional block is felt down (collision occurs with the other blocks)

The blocks may be translated on the right, the left, the upward and the downward by using the buttons situated at the right bottom of the screen image in Fig.5. Learners may select practice modes by clicking the top left button in the Fig.7. Learners also may restart the building block practice by clicking the top right button in Fig.7.

Questions are available with the bottom left button while the examples of the questions can be referred with the bottom right button in Fig.7. The block in concern can be translated by clicking arrow buttons in the direction of right, left, upward and downward.

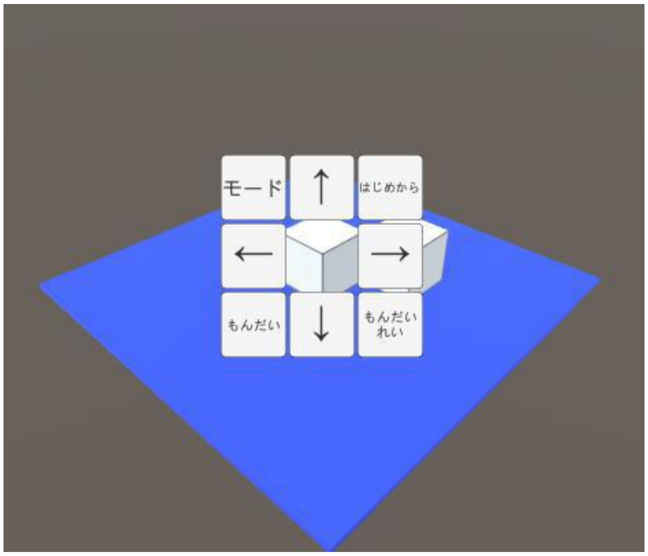
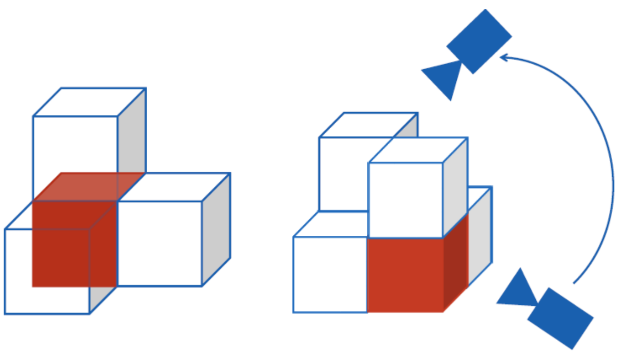
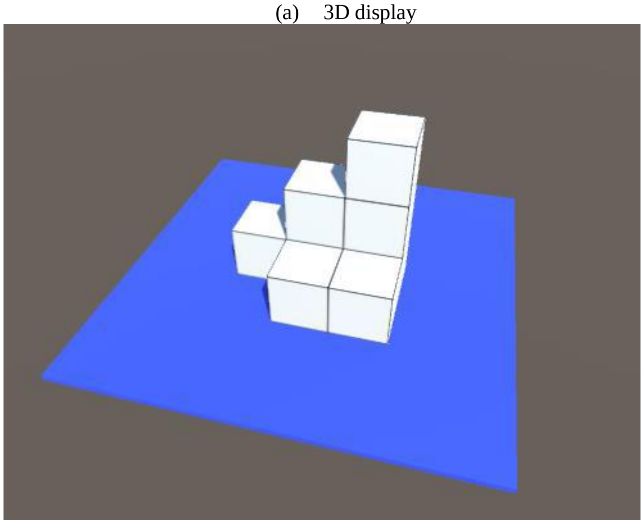


Fig. 7. Screen shot image of the sub menu

It is also available to show the building blocks in the 3D space as shown in Fig.8. The different aspects of view images are available by changing the viewing angles as shown in Fig.8.



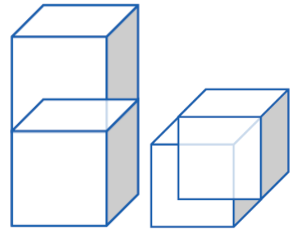
(a) 3D display



(b) Example of 3D representation

Fig. 8. Representation of building blocks in the 3D space

Through building block practices, learners can improve their spatial comprehension such as those situations of blocks which are shown in Fig.9

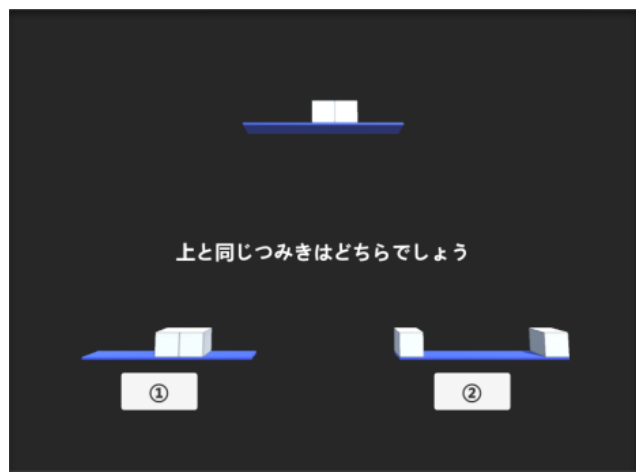


(a) (b)

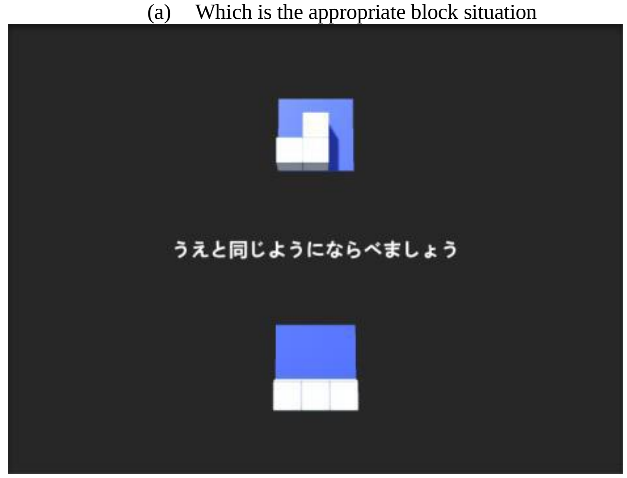
Fig. 9. Improve their spatial comprehension such as those situations of blocks

The block situations which are shown in Fig.9 are not so comprehensive. By representing the building blocks in the 3D space, the block situations can be comprehensive.

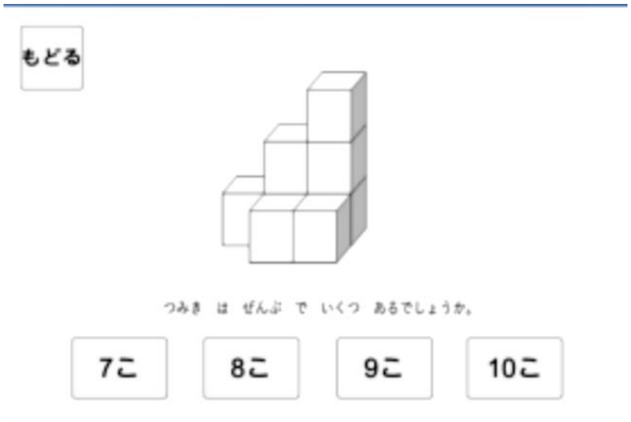
Three examples of the questions are shown in Fig.10. The example of Fig.10 (a) askes which block representation in 3D space is the most appropriate real situation of the block shown at the top. Learner is asked to build the blocks as is matched to the 3D image of building blocks shown in the top of Fig.10 (b). On the other hand, learner is asked the number of blocks in the 3D building blocks as shown in Fig.10 (c).



(a) Which is the appropriate block situation



(b) Put the blocks



(c) Count

Fig. 10. Examples of the questions

The key issues of the proposed learning content creation are (a) Realistic motion of the blocks in accordance with physical model, (b) encouragement for the disabled children with attractive question and answer.

III. Experiments

Photos of the spatial comprehension practices are shown in Fig.11. In the practice, the disabled children can pick up and drop the blocks in the 3D CG world. The block motion is natural in the CG world so that the proposed learning content is attractive. Question and answer is also attractive. They can imagine the blocks which are situated behind the blocks through practices. Disabled children also can see the blocks from the different aspects. This is very helpful to improve their spatial comprehension.

As the experimental results, all the disabled children made correct answer to the questions which are illustrated in Fig.10 (a), (b) and (c) perfectly after the practices. Therefore, it may said that it is confirmed that the spatial comprehension is improved for the disabled children remarkably.

(a)

(b)

(c)

Fig. 11. Photos of the spatial comprehension practices

IV. Conclusion

Spatial comprehension exercise system with Three-Dimensional Computer Graphics: 3D CG of toy model for disabled children is proposed. In order to improve spatial comprehension in an attractive manner, a toy model is created together with building block model. Experiments with building block model are conducted.

As the experimental results, all the disabled children made correct answer to the questions, (a) askes which block representation in 3D space is the most appropriate real situation of the block shown at the top, (b) learner is asked to build the blocks as is matched to the 3D image of building blocks, (c) learner is asked the number of blocks, perfectly after the practices. Therefore, it may say that it is confirmed that the spatial comprehension is improved for the disabled children remarkably.

Further investigations are required for confirmation of improvement of spatial comprehension through achievement tests.

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Gatekeepers Practices in Knowledge Diffusion within Saudi Organizations: KFMC Case Study

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***Abstract*—Gatekeepers in organizations play a critical role in terms of disseminating and transferring outside knowledge into their groups. This research contributes in identifying the gatekeepers' practices in terms of gathering, selecting, and diffusing knowledge. In the context of Saudi organizations, the exploratory case selected in this research is King Fahad Medical City (KFMC). This research is conducted on Health Informatics and Information Technology employees. A mixed-method design is applied on this research to provide a deep understanding of knowledge interactions structure and the process of knowledge interactions across the organization network. Both methods; questionnaires and interviews are conducted in order to investigate the context. Social Network Analysis method is also used in this research to capture the "brokerage" network structure position using Flow Betweenness Centrality algorithm. The findings reveal that gatekeepers use different knowledge sharing mechanisms which are: information retrieval, information pooling, pushing, diffusion, collaborative problem solving, and thinking along. In addition, the results present the distinct methods and technologies used by the gatekeepers to collect and share their knowledge with others. The findings of this research help managerial decision makers and strategic managers among start-up organizations and also well-structured organizations to provide valuable insights and decisions in terms of policies, strategies, and the appropriate collaborative tools that foster collaborative working.**

Keywords—Knowledge sharing; gatekeepers; brokerage; knowledge transfer; and SNA

I. Introduction

Organizations viewed knowledge as a significant strategic resource because it represents the core of organizational learning, managerial cognition, and the management of technology [1]. Knowledge could be embedded in the organization’s identity and culture, policies, routines, systems, and documents, as well as the employees of the organization [2]. Nonaka defined the term “Knowledge” as; “*Dynamic human process of justifying personal believes as part of an aspiration for the truth.*” [3]. Managing knowledge in organizations is important for organizational innovation [4][5]. This research focuses on the informal knowledge interactions on virtual communication tools within the organization. In particular, informal interactions in the organization network cause “weak ties” between teams, groups, units, and divisions which affecting transferring knowledge among the organization [2][6]. As informal networks affect the working life in organizations [7], studying the informal networks in organizations can clarify the structural gaps and led to have a good insight for successfully constructing formalized networks [8]. It is important to mention that informal knowledge and information exchange routes developed based on the local needs of the organization [9]. Weak ties or weak connections in the organization network represent structural holes in the network structure [9][10][11]. The existence of structural holes in the organization network doesn’t mean that there is a gap in knowledge and information flow between two groups or clusters, but it means an area of weak connections [12]. Creating a link to bridge the gap in the network structure in order to connect those groups is called “brokerage” connection [9]. In the context of organization network structure, employees on the "brokerage" position can play different roles based on knowledge flow between and within different groups: Gatekeeper, Coordinator, Liaison, Representative, or Itinerant broker [13]. Tushman defined Gatekeepers as; *“Individuals in the communication network who are capable of understanding and translating contrasting coding schemes.”* [14]. Capturing the gatekeeper employees is very important because gatekeepers are professionally oriented, technical performers, overrepresented at lower levels of the organizational hierarchy, and they are not formally recognized by the organization [15]. Also, highlighting their practices in knowledge diffusion gives an insight of the best practices in disseminating knowledge across groups within the organizations [16]. Studies mentioned that individuals on the "brokerage" network structure position have the capacity to ease social interactions and information flow, and dismissing knowledge among connections [6][9][12]. Moving to Saudi organizations context, the limited local researches captured the fact that local organizations are still in the stage of understanding the environment requirements (challenges, opportunities, and taxonomies) in the knowledge management (KM) field [17][18][19][20][21][22][23][24][25]. However, the researchers in this study capture gatekeeper employees in King Fahad Medical City (KFMC) using social network analysis (SNA) method. Additionally, they conduct in-depth interviews with the gatekeepers in order to understand the combined views of the structure and the process of knowledge sharing (KS) among groups' knowledge interaction network. The findings of this study introduce gatekeepers’ practices in knowledge collection and it capture gatekeepers' KS mechanisms, which are assisting the decision makers in the organizations in terms of policy, decision, and behavior creation.

The rest of this paper is organized as the following: the second section presents the literature review by introducing the main concepts related to this research. A brief description of the selected case of this research, pilot study, data collection and analysis are included in the Research Methodology section. The Results and Discussion section introduces the qualitative and quantitative results and it provides critical analysis of the research results from different aspects. The conclusion of this research is covered in the last section.

II. Literature Review

The theme of the literature review of this research is related to three research directions which are: Knowledge Sharing, Social Capital, and Gatekeepers.

A. Knowledge Sharing

There are three major processes in the integrated cycle of KM that support managing knowledge in organizations which are: Knowledge Capture and/or Creation, Knowledge Sharing and Dissemination, and Knowledge Acquisition (KA) [26]. Knowledge Sharing and Dissemination which means provide or receipt information, know-how, and feedback regard something [27]. Gatekeepers could use the KS mechanisms for transferring knowledge with others. KS mechanisms such as [28]:

- Diffusion: storing the information on intranet to be accessible by others.
- Information retrieval: means that the content of the shared knowledge is associated with transferring factual information.
- Information pooling: concerns about questions, suggestions, and instructions not only consist of transferring factual information.
- Collaborative problem solving: consists of developing new information related to a shared problem. This mechanism associated with suggestions, new ideas, and questions.
- Pushing: try to provide some knowledge without asking your assist.
- Thinking along: means thinking about opportunities in group meetings or developing ideas for someone else's problem.
- Self-suggestion: means thinking about someone's own problem during the interaction.

The following section provides more details in order to understand knowledge flow and interactions between the members.

B. Social Capital

Social capital is a core concept in organizational behavior, business, political science and sociology [29]. Nahapiet defined Social capital as; *"The sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit."* [30]. The concept of social capital used in organizations to explain the role of relational resources involved in social network relationships [31]. The term "Society Network" means activists of society and the aggregation of the relations between social elements. Aggregation is composed of number of points and lines connected together. Points in the network could be individuals, companies, units, cities and countries, etc. [32]. The social network is a representation of the relations in society. In the same society, a number of social networks exist based on the type of the relations [33]. Social capital assists in knowledge creation and has positive effects on knowledge sharing among members of organizations [31][34]. for better understanding of the knowledge flow among the organization network, SNA is an innovative method that makes embedded relations in the organization social network visible to the key mangers [7][35][36]. SNA is; *"The disciplined inquiry into the patterning of relations among social actors, as well as the patterning of relationships among actors at different levels of analysis."* [37]. Moreover, Haythornthwaite pointed out the basic principles used in SNA to identify the relation properties between actors in the social network as the following [9]:

- Cohesion: Actors' grouping is based on strong common relations between them.
- Structural equivalence: Actors' grouping is based on similarity in relations.
- Brokerage: identifying the "bridging connection" actors to another network.
- Prominence: indicating the "accountable" or "in charge" actors.
- Range: indicating the span of actors' relations in the network.

This research focuses on "brokerage" network principle. This is because the power of the members on this network structure position in terms of facilitating the information flow and dismissing knowledge within connections [6][9][12]. Additionally, tighter and smaller networks can be less useful to their members than networks with weak ties to members outside of the main network [38]. However, brokerage measures are related to Betweenness centrality family. Betweenness centrality extend to which an individual lies between other individuals in the network. The measure reflects the number of individual actors connected indirectly through their direct links [38][39][40]. In such cases, an individual can be a "Gatekeeper" who has a potential control over others.

C. Gatekeepers

Gatekeepers is identified as individuals who are both strongly connected to internal colleagues and strongly linked to external domains [13][14][41]. Gatekeepers play a major role in information control and knowledge gathering and diffusion into their groups [14][16][42]. Evidence suggests that gatekeepers do more than mediate external information; they facilitate effective communication for their groups within the organization and provide potential paths to outside world [14][41][43]. Moreover, gatekeepers in the organizations contribute to the organizational technical goals [41]; and they evolve to fulfil the need in which the formal organization is in capable to deal with [44]. In addition, there is no evidence of informal role of gatekeepers that may exist due to the formal organizational hierarchy [44]. Gatekeepers play different roles in the organizations which are based on the context. There are three situations of gatekeeper role which are [16][45]:

1) Monitoring: in situations where all collaborators have sufficient previous knowledge to grasp external information, as the external information related to ongoing activities, the role of the gatekeeper could be limited to environment monitoring.

2) Monitoring and translating: when the knowledge gap between individuals inside the organization and external actors is high, a gatekeeper is needed to monitor the environment and translate the technical information to be understandable to his/her group.

3) Centralizing: centralizing the interface with the environment may reduce organizational absorptive capacity; this happens when information flows are random.

Furthermore, gatekeepers, through their strategic position, affects organizational innovation levels positively [46], they reduce uncertainty situation [47]. External information, held by the gatekeepers, can be channelled within two-step process: First, the gatekeepers gather and understand outside information, and then they translate it into terms that are more meaningful to their groups [14][43][46]. Gatekeepers are responsible of the gatekeeping process. Gatekeeping process is not only filtering things but it is also making them more appeal to the final receiver [48]. Barzilai-Nahon suggests that network gatekeeping process is best conceptualized via information control, and it holds three main goals which are the following [15]:

1) “Locking-in” of gated inside the gatekeeper’s group network;

2) Protecting information, norms, gated, and subnets from unwanted entry from outside;

3) Maintaining ongoing activities within network boundaries without disturbances.

Gatekeeping is one of the three power mechanisms (gatekeeping, decoupling and resource allocation) which form the basis of a model of network power dynamics [49]. Gatekeeping itself has different bases; which are [15]:

1. Selection. 8. Manipulation.
2. Addition. 9. Repetition.
3. Withholding. 10. Timing.
4. Display. 11. Localization (including translation).
5. Channeling. 12. Deletion.
6. Shaping. 13. Integration.
7. Selection. 14. Disregard.

Moreover, studies in the literature mentioned the role of gatekeepers in transferring outside knowledge into their groups [15][50][51][52]. Social interactions foster close and intensive knowledge exchange [53][54]. Furthermore, Haas mentioned that identifying gatekeepers’ practices that allow them to gather, select and diffuse outside knowledge and information into the organization is a future research direction [16]. Thus, the researchers attempt to identify the gatekeepers those controlling knowledge flow into their groups and capturing their practices in knowledge diffusion.

However, the following section provides a detailed description in terms of the methodology used in this study in order to capture the gatekeepers and their practices in knowledge diffusion.

III. Research Methodology

The methodology of this research is based on a single exploratory case study. The researchers follow the Deductive approach [55]. The exploratory case in this research is KFMC. KFMC belongs to the healthcare sector in Saudi Arabia. Selecting a single case for this research context is following the studies in [56][57]. A mixed-method design is used in this research for data collection and data analysis. The key members such as the researchers in the field and managerial decision makers are required to have "out-side" view which is related to the structure and "in-side" view which is related to the process in order to understand the context in depth [58]. Moreover, SNA method is used to understand the "out-side" view which is related to the knowledge flow across the organization network structure. On the other side, in order to interpret the "in-side" view which is related to the process, interviews are conducted in this study for deep understand of the context.

A. Case Study

KFMC is the selected organization to be the exploratory case organization in this research. KFMC is a critical case because it represents the Ministry of Health hospitals in Saudi Arabia. Also, it has number of achievements which reflect the power of their infrastructure on both IT and business sides. KFMC has eight hospitals and the organization structure of KFMC consists of fifteen administrations. In KFMC hospitals and administrations, there are around seven-thousand employees distributed there. The sample of this research is selected from the Administration of Health Informatics and Information Technology (HIIT). This is due to projects complexity and dynamic changes in the Information Technology (IT) sector which makes the context suitable for KS among KFMC employees. Another reason of selecting employees from Administration of HIIT, is because the IT background of the employees in this administration makes them aware of virtual communication tools. The Administration of HIIT has five main departments which are: IT Infrastructure Department, Customer Care Centre Department, Non-Clinical System Department, Clinical System Department, and Enterprise Architecture Department. The Customer Care Centre Department include two sub-departments which are: Telecommunication System Department and Technical Support Department. However, the research's institutional review board (IRB) is got from KFMC research center for official application of this research on KFMC employees. Additionally, regarding employees' confidentiality complains, the researchers use alias instead of participants' real names in this study.

B. Pilot Study

A pilot study is conducted in this research to make sure that there is no problem with the questionnaire instrument and to ensure that it is designed to work in an effective manner. The questionnaire of this study is evaluated by six experts who are interested in the Information Systems domain. The Telecommunication System Department is the selected group for the pilot study. In the Telecommunication System Department, there are nine employees who represent the total employees in the department. The questionnaire is sent to the employees' work emails by SurveyMonkey website. Email reminders are used to remind the employees who are not responding. After collecting the data, the data are exported to Excel sheets and processed. Then they are entered into the SPSS software to calculate internal reliability and internal validity measures using Cronbach's alpha score. This is to insure the consistency in scores and items homogeneity for the measured variables. The accepted score of Cronbach's alpha in general should be 0.70 or higher [59]. For the items in the questionnaire, Cronbach's alpha equals 0.926. Which means that this scale is accepted to measure the "brokerage" network structure position.

C. Data Collection

Semi-structured interviews are conducted face to face with five managers in the Administration of HIIT for fifteen minutes. This is to identify the collaborative tools used for inter-group communication, group context, and knowledge sharing environment in KFMC. However, the questionnaire of this research is built using five knowledge interactions ranking questions. This is to measure the employees' "brokerage" network structure position. The questions are derived from studies in [7][35]. The questionnaire of this research is sent to one-hundred-six employees in the five departments in HIIT using SurveyMonkey website with % 68.8 response rates (seventy-three participants). It is important to highlight that the questionnaire of this research is targeting full groups which means all employees in the department have to participate rather than random individuals. This is because each department represents a population in this research. However, the collected data are cleaned by eliminating partial groups and dummy responses. For these reasons the response rate decreased into % 33 response rates (thirty-five participants). The thirty-five employees are representing three full groups or departments in the Administration of HIIT:

1) Telecommunication System Department (nine employees).

2) Non-Clinical System Department (eleven employees).

3) Enterprise Architecture Department (fifteen employees).

Triangulation data collection is used in this research to increase the validity in this research results [59]. Moreover, in this research the data are collected within two rounds within one month. The first round is for Test and the second round is for Retest. The two rounds are separated by one week. The questionnaire is customized based on the employees in each department. For each department, the employees' names are presented in a list within each question. The respondent asked to rank the interactions with the employees based on his/her communication preference. As a result, the data collected in a form of Socio-matrixes, because the questions are related to social interactions domain. The sampling method used in this research is full social network, which means presenting all the actors names in the network in a list to the respondent to overcame the bias of free recall (snowball). After conducting the questionnaire, face to face semi-structured interviews for fifty to sixty minutes are conducted with the employees on the "brokerage" network structure position. The interview questions are derived from the studies in [27][60]. The interview questions investigate the gatekeeping bases, the technologies used for sharing documents, practices of collecting the knowledge, knowledge sharing mechanisms, and initiative and couching characteristics. Also, the interviewer checks some archival documents to increase the research results validity. Furthermore, the reason of checking the gatekeeping bases is to make sure that the selected employees acting as gatekeepers. Therefore, the interviewer investigates his/her practices in collecting and disseminating knowledge.

D. Data Analysis

Mixed- method analysis is used to analyze the data in this research. The data are analyzed qualitatively and quantitatively respectively. For the quantitative analysis UCINET 6 software is used in order to analyze the Socio-matrixes. Flow Betweenness Centrality algorithm is used to measure the "brokerage" network structure position. The reason of selecting this measure over other measures in the Betweennees centrality family is that measure focuses on the information flow rather than the brokerage only [61]. However, for each department there will be five Socio-matrixes which are representing the knowledge interaction relations. The Mean of Flow Betweenness Centrality is calculated for each employee in the department. The employee with the highest Mean is selected to be on the "brokerage" network position. In this research, fifteen Socio-matrixes are analyzed for the three departments those are participated in the questionnaires. Moving to the qualitative analysis, content analysis type is used to analyze the interviews data in this study [55]. Moreover, secondary data such as archival documents are checked and they were helpful in supporting the data interpretation for the validity of the research results.

IV. Results and Discussion

From the pre-interviews that are conducted at the early stage of this research, the researchers get a general view of KFMC knowledge sharing environment as well as they get a view of the tools used for work collaboration. The HIIT top management in KFMC gives attention of knowledge codification and diffusion, as the chairman of Enterprise Architecture Department states; "*The top management organized a competition between the employees. The competition is based on how many technical notes an employee can create per year*". Also, they support the knowledge sharing environment by conducting seminars and conferences, as the IT Infrastructure Department chairman declares; "*Yes, KFMC supports the knowledge sharing environment by conducting seminars and conferences*". The top management, also, gives attention of building knowledge database, as the Technical Support manager says; "*There is a library, yet, not activated for some issues*". The departments in KFMC use different tools for inter-group communication and work collaboration, such as: SharePoint, Outlook, Lync, What'sApp, text messages. The chairman of Enterprise Architecture Department says; "*For* *group communication, we use SharePoint to achieve work integration. Emails, Lync and What'sApp are used, also, for communication and ideas sharing…What'sApp is easier than Lync*". The chairman of Non-Clinical System Department explains the reason of using What'sApp in inter-group communication; "*…for example, SharePoint is used for managing documents, Outlook is remarkably used for work documentation through emails…text messages…What'sApp especially for standby on critical tasks as it is easy to be set on devices, and it is handy. We use Lync but it is not easy to be set on different devices types of different version*".

However, the results of this research are presented for Telecommunication System Department, Non-Clinical System Department, and Enterprise Architecture Department.

A. Telecommunication System Department Results

1) Brokerage results: The Mean of the Flow Betweenness Centrality of the five Socio-matrixes of knowledge interactions is calculated.

As presented in Fig.1, Hashim has got the Max Mean of Flow Betweenness Centrality which equals 13.0666. This means that Hashim on the "brokerage" network structure position. However, an interview is conducted with Hashim in order to investigate how do gatekeepers gather, select, and diffuse outside information and knowledge into their groups in the organization.

2) Interview results: The interview results organized in the following parts.

a) Gatekeeping Bases: Hashim analyzes and shapes his knowledge using flow charts to make it understandable. Hashim says; "I prepare presentation materials when required…I use flowcharts for explaining the information". Based on the current context of Hashim's team, there is no need for translating, filtering, and deleting any part of the sent knowledge. he explains; "There is no need for different translations of the information to make them understandable because my colleagues understand what I send…There is no need to filter the sent information or delete the unnecessary information because I know my colleague understand the purpose of the information". In addition, Hashim selects the suitable time and the suitable person for providing the knowledge and repeating the sent knowledge verbally. He states; "I try to select the suitable moments for providing ideas. I try to select the suitable person to make sure that the idea will not delay the current tasks…I send the information to the suitable person. I use email reminders to remind myself to send this information once this person is available…I do not re-send the information to the same receiver, but I may talk about it again face to face".

Empl	KI1	KI2	KI3	KI4	KI5	Sum	Mean
Samar	8.55	7.783	7.383	8.55	8.95	41.216	8.2432
Khaled	9.533	9.55	10.95	10.95	8.2	49.183	9.8366
Shatha	8.8	5.7	8.8	8.8	13.2	45.3	9.06
Faris	8.8	7.033	7.633	9.55	8.95	41.966	8.3932
Basem	3.133	3.133	3.133	0.8	0	10.199	2.0398
Semon	4.3	2	3.3	3.3	5.5	18.4	3.68
Arfan	3.5	1.45	3.5	3.5	2.5	14.45	2.89
Fadhel	5.5	10.85	6.75	5.5	4.45	33.05	6.61
Hashim	14.433	16.35	15.6	13.6	5.35	65.333	13.0666

Fig. 1. Mean of Flow Betweenness Centrality of Telecommunication System Department Employees

b) Technology and Knowledge Collection Practices: Hashim is a 13years-work-experience staff member. He collects his knowledge by professional internet searching, videos, self-development, filtering and codifying the knowledge using word documents. Then, he saves in a hard desk and private cloud in order to be accessible anywhere. Also, he marks some professional websites as favorite, and saves the important links in the email to be accessible anywhere, Thus, he has got a federated knowledge base; "I collect the information by internet searching, I couch myself, and I try to filter and write the collected information in a word documents, so I refer to them when needed…I send web links, screen shots for configuration, for example…and videos from YouTube…I send the preferred links to my email, once I want to refer to them, it is easy from anywhere…also, I mark the important links as the favorite…I use Google drive to store my documents, to be accessible anywhere…regularly, I save my emails and documents every 6 months in a hard disk". Hashim mentions the need of chatting tool supported by photos attachment to support the virtual communication between the employees; "Photos facilitate understanding the technical problems, hence, when technical problems I send a photo to the technician, so the damage area is to be understandable".

c) Knowledge Sharing Mechanisms: Hashim uses information retrieval mechanism for knowledge sharing with his colleagues such as professional links, screen shots, and You tube videos to describe the confused information or to clarify concepts; "To clarify the confused information to my colleagues, I send web links, screen shots for configuration, for example…and videos from YouTube". Regarding the information pooling, Hashim says; "Always, I give my suggestions and instructions but they are unnecessary to be applied because of financial issues, for example". For the collaborative problem solving, Hashim explains; "Yes, due to my 13 years of experience in KFMC, I know the place very well, once a problem occurs, there might be 2 conditions: the first condition, it could be a new problem. In this case, I google it and solve it. Then, I send the solution through the email. However, if I have had the issued problem, I take the technician to the spot and show him how to fix it". In addition, Hashim uses pushing mechanism for sharing his knowledge. He says; "I try to select the suitable person to make sure that the idea will not delay the current tasks…I send the information to the suitable person. I use email reminders to remind myself to send this information once this person is available". Also, he Thinking along his colleagues' work problems as his problem. Hashim says; "Yes, I try to solve my colleagues' work problem even if it is not of my duties, I try to do my best based on my knowledge, Also, I try searching to find the solution…I prepare presentation materials when required".

d) Initiative and Couching Characteristics: Hashim is an initiative taker and trainer by his nature. He says; "I consider myself as an initiative taker because I try to solve my colleagues' work problem even if it is not of my duties when necessary…When a new technician, whom I feel is not understanding any work issue, is applied to the work, I specify part of my time training and couching him in the spot, or I might, sometimes, train him in the office during the working hours…even if nobody is asking for assistance". The Telecommunication system manager declares; "Hashim is interested in learning, doer, and overall cooperative person…He is the top in my team".

B. Non-Clinical System Department Results

1) Brokerage results: The Mean of the Flow Betweenness Centrality of the five Socio-matrixes of knowledge interactions is calculated.

As presented in Fig.2, Noura has got the Max Mean of Flow Betweenness Centrality which equals 14.4432. This means that Noura on the "brokerage" network structure position. The following section presents Noura's interview results.

Empl	KI1	KI2	KI3	KI4	KI5	Sum	Mean
Reem	6.033	8.667	7	10.633	12.467	44.8	8.96
Rasha	13.15	10.75	13.317	15.067	11.267	63.551	12.7102
Talal	10.533	8	12.783	8.2	18.167	57.683	11.5366
Ahmad	14.933	9.617	11.817	13.533	13.433	63.333	12.6666
Nawara	8.817	5.6	5.633	8.133	6.533	34.716	6.9432
Nouf	11.7	7.167	9.617	9.2	8.767	46.451	9.2902
Basmah	7.183	7.033	7.85	6.667	6.7	35.433	7.0866
Sahar	4.767	7.8	4.733	5.333	6.3	28.933	5.7866
Maisa	5.117	6.85	5.617	0	3.3	20.884	4.1768
Noura	11.733	26.5	13.617	9.033	11.333	72.216	14.4432
Anas	8.067	15.95	11.283	12.733	10.567	58.6	11.72

Fig. 2. Mean of Flow Betweenness Centrality of Non-Clinical System Department Employees

2) Interview results: The interview results organized in the following parts.

a) Gatekeeping Bases: Noura analyzes and shapes her knowledge using flow charts and steps to be understandable. Noura says; "I try to modify the code of the shared function to be understandable and I use flowcharts, steps to explain the provided information" -The interviewer asks her to provide a document of her work for the sake of checking-. Also, she translates and filters the sent knowledge. Noura explains; "Yes, I translate the new concept to a concept that my team is familiar with, or I try to match the new concept with a common one…I try to summarize the shared information, for example, I summarize long paragraphs that contain additional information…I send web links, screen shots with a summary of information". Noura states that she does not delete unnecessary information; "No, I do not try to delete part of the information; once I want to share something, I have two choices: sending it as it is, or summarize it".

b) Technology and Knowledge Collection Practices: Noura is a staff member of about 2years work-experience. Noura collects her knowledge by internet professional searching, and blogs. She summarizes and codifies the collected knowledge in points using notebook. Noura scans the notes for sharing. She may write the points in a word document. Also, she marks some professional websites as favorite, and downloads resources to the PC from email. She says; "I collect the information by searching in the internet and blogs. If somebody sends me resources, I download it to my PC, and I try to summarize the information in points and write it in an external notebook. I scan the notes for sharing. If I have time I type these notes in a word document…I mark the favorite links".

Empl	KI1	KI2	KI3	KI4	KI5	Sum	Mean
Wafa	21.654	14.375	13.923	17.789	18.732	86.473	17.2946
Ebtisam	10.643	16.642	13.077	11.202	9.982	61.546	12.3092
Najwa	18.404	17.91	17.911	15.611	17.708	87.544	17.5088
Noura	6.619	11.262	16.5	9.708	13.696	57.785	11.557
Rana	19.679	20.261	15.429	17.421	22.601	95.391	19.0782
Ghady	11.523	15.125	15.31	27.296	10.821	80.075	16.015
Fawza	16.304	13.975	8.435	13.236	16.75	68.7	13.74
Fadia	12.107	14.054	12.185	11.518	10.196	60.06	12.012
Aseel	13.683	16.768	15.827	16.027	12.399	74.704	14.9408
Sara	19.821	11.357	13.589	9.582	12.667	67.016	13.4032
Foz	5.125	9.363	6.833	10.16	5.042	36.523	7.3046
Asma	8.964	10.386	12.375	9.618	13.012	54.355	10.871
Hind	14.036	13.274	13.262	13.671	12.506	66.749	13.3498
Aleen	13.386	13.25	17.054	12.564	15.958	72.212	14.4424
Nouf	3.286	8.071	4.792	3.917	2.679	22.745	4.549

Fig. 3. Mean of Flow Betweenness Centrality of Enterprise Architecture Deparment Employees

c) Knowledge Sharing Mechanisms: SharePoint as intranet which is mainly used by Non-Clinical System members for sharing knowledge, as the team manager says; "…for example, SharePoint is used for managing documents". Therefore, for knowledge diffusion, Noura says; "I collect my work in a folder, then, upload it to the SharePoint server to be saved…I prefer SharePoint for sharing reports and documents. I like to use it because of file sharing and work integration properties…I use the DropBox for large documents". Also, she points out one disadvantage of the SharePoint searching feature; "It will be helpful if the search in the SharePoint is supported by categorization rather than searching all the files". Noura uses information retrieval mechanism for knowledge sharing with her colleagues such as professional links and screen shots to describe the confused information or to clarify concepts. She says; "I send web links, screen shots with a summary of information". Regarding the information pooling mechanism, Noura says; "I give my suggestions verbally in meetings". In addition, Noura uses collaborative problem solving mechanism in order to share her knowledge. She explains; "Yes, I give my idea face to face. If the others are interested, I send a reference by email, so, they have the ability to read and understand". Noura pushes her knowledge to her colleagues. Noura states; "Yes, once my colleague is talking about a work problem, I try to help her even if she is not asking for assistance". Moreover, Noura uses thinking along KS mechanism in order to share her knowledge. She says; "Yes, I try to solve my colleagues' work problem, I search about links and asking for others knowledge… I do my best until the problem is solved".

d) Initiative and Couching Characteristics: Noura is an initiative taker. Also, she tries couching her colleagues. She says; "I like helping others…Yes, once my colleague is talking about a work problem, I try to help her even if she is not asking for assistance…Yes, I try to solve my colleagues' work problem, I search about links and asking for others knowledge…I do my best until the problem is solved…once I learn something new, I try to coach my colleague in the office. I show her how I apply the new method…this is done during the working hours".

C. Enterprise Architecture Department Results

1) Brokerage results: The Mean of the Flow Betweenness Centrality of the five Socio-matrixes of knowledge interactions is calculated.

As presented in Fig.3, Rana has got the Max Mean of Flow Betweenness Centrality which equals 19.0782. This means that Rana on the "brokerage" network structure position. However, the following section presents Rana's interview results.

2) Interview results: The interview results organized in the following parts.

a) Gatekeeping Bases: Rana analyzes and shapes her knowledge using brief descriptions, flow charts, and infographics to make it understandable, she says; "If there is a specific flow for the shared information. I use flow charts or Infographics. I have to send something appeal and understandable…If there is a task, I write a brief description about the task with an infographic, if available, in addition to a source link". Moreover, she translates and filters the sent knowledge in regards to the recipient. Rana says; "Yes, I translate the sent information regarding the receiver. If the receiver is a manager, I never provide details, unlike if the receiver is a team member…Yes, I filter the things that are given by my manager. For example, if my manager sends me something related to work, I try to clarify some points, and add screen shots and steps. Therefore, when I send it to my team members they understand the requirements…For general resources, I share the resources regarding each team member interest…I send it through email, What'sApp, or Lync". Rana mentions that she is a time-selector when sending knowledge. Regarding repetitions, she is purpose-oriented based on the situation of the receiver. She says; "Yes, normally, referring to my (to do list), I decide what to do. I check my team's current tasks, therefore I do not send them things that make them confused or put them in conflict with their current tasks. It is important to choose the suitable time…If there is a need to resend the information for this person, I resend the information with a detailed description…I do not like duplication". Rana states that she is deleting unnecessary information; "Yes, when I select certain resources and then send them to my email, I integrate them with the list that I have previously, then I review all the resources in the list…I delete unnecessary ones due to the confusion that may made to my team…I share the list with my team after adding a brief description of each link".

b) Technology and Knowledge Collection Practices: Rana is a team leader in her group with 4years work-experience. She collects her knowledge by internet professional searching, blogs, videos, scientific papers, accessing online libraries such as iOS and Android libraries, and course training materials. Rana's searching method is based on "how to do?" things rather than "what to do?". She stores the scientific papers in her PC, saves web links in the email. She uses SharePoint and Dropbox for storing and sharing documents with her team and she marks professional links as favorite. Also, she summarizes and codifies her knowledge using videos, mind maps, infographics and flow charts in attractive ways. Rana says; "I collect the information by searching in google. I search different applications of ideas for visual feeding. I check different practices, then, picks up the best of them in application…Stackoverflow is helpful. Also, iOS and Android libraries…once I have a specific topic, I usually have a background supported by theories, due to my interest in scientific papers reference…I send course training links, articles, and videos…SharePoint is used for sharing the official reports and documents…SharePoint stores the documents for a long time. As a result, everybody has the ability to go through it anytime…I prefer using email, Dropbox for storing things because they are accessible anywhere…I mark the favorite links…I use iMindMap application for scoping the work -you can say (scope management)- and I share it with my team…I use ivideo application for designing videos to summarize the information which are presented. I prefer using videos specially in short time presentations for fast description…If there is a specific flow for the shared information. I use flow charts or Infographics. I have to send something appeal and understandable. I do my job with love" -The interviewer asks her to provide a document of her work for the sake of checking-.

c) Knowledge Sharing Mechanisms: SharePoint as intranet which is mainly used by Enterprise Architecture members for sharing knowledge, as the team manager says; "We use SharePoint for work integration". Therefore, for knowledge diffusion, Rana says; "I use SharePoint for documents sharing even if these documents are sent to the group emails". Also, Rana uses Dropbox for knowledge diffusion. She declares; "I use Dropbox for documents sharing with my team especially large documents…we do not utilize the SharePoint storage for large documents, but we should…The searching feature in Dropbox is good, whereas in SharePoint, it is good on the list level, but it does not give precise results on the site level". Rana uses information retrieval mechanism for knowledge sharing with her colleagues such as online articles, scientific papers, professional videos, and training courses links, to describe the confused information or clarify concepts. Rana explains; "Once I have a specific topic, I usually have a background supported by theories, due to my interest in scientific papers reference…I send course training links, articles, and videos…My help to my colleagues is based on the condition of the problem…I send an email with options supported by source links…Yes, usually, I provide steps supported by links and I send them by email". Regarding information pooling mechanism, Rana says; "Yes, usually, I provide steps supported by links and I send them by email…I send an email with options supported by source links". Moreover, for collaborative problem solving, Rana present her idea verbally in the workshops, and group meetings. Also, she sends emails to share her knowledge. She explains; "Yes, I present my ideas in workshops…I prepare presentations for my ideas…we discuss the idea verbally in the weekly meetings…I send an email with options supported by source links…In workshops, I use white board, colored sticky notes, highlighters, pens for preparing the ideas. Then, I do brain storming with my team to solve the problem. Each member writes a solution in the sticky note, then we discuss the suggested solutions". Rana pushes her knowledge verbally and using virtual communication tools such as emails, What'sApp, imessage, and Lync. She says; "Yes, I send links and online courses by email and What'sApp…I firstly provide solutions…My help to my colleagues is based on the condition of the problem. For major problems; if I have the knowledge I soon explain it either by visiting my colleague's office, by phone, What'sApp, Lync, or sometimes using imessages. However, for minor problems, I send an email with options supported by source links". Furthermore, Rana uses thinking along mechanism to share her ideas with her colleagues. Rana says; "Yes, Always I do, at the end we are working as a team. my team problems are mine…I do presentations for my ideas. For discussion, verbal communication is preferable".

d) Initiative and Couching Characteristics: Rana, is an initiative person. Also, she couches her colleagues. Rana states; "Absolutely I am an initiative person because I like being initiative in solving problems, and I proact in suggesting solutions…initiative is the reason behind my success…Yes, I normally teach. I send training course through email, and I do verbal communication during working hours. If my colleague is in need for training after the working hours, I never mind". The chairman of Enterprise Architecture Department says; "I consider Ghady, Foz, and Rana as initiative takers and proactive members in my team because they are cooperatives and they have the basic of sharing knowledge with others. They know this help them in their work".

TABLE I. SUMMARY RESULTS OF GATEKEEPERS' INTERVIEWS

Participated Groups	Employees with Max Flow Betweeness Centrality score	Gatekeeping Bases	Practices of Knowledge Collection	Knowledge Sharing Mechanisms	Initiative	Coaching
Telecommunication System (9 members)	Hashim	• Analyzing • Shaping • Timing • Repetition	• Professional links searching • Self-development • Filtering and codifying knowledge	• Information retrieval • Information pooling • Collaborative problem solving • Pushing • Thinking along	yes	yes
Non-Clinical System (11 members)	Noura	• Analyzing • Shaping • Manipulation • Translating	• Professional links searching • Summarizing and codifying knowledge	• Diffusion • Information retrieval • Information pooling • Collaborative problem solving • Pushing • Thinking along	yes	yes
Enterprise Architecture (15 members)	Rana	• Selection • Analyzing • Shaping • Manipulation • Translating • Timing • Repetition • Display	• Professional links searching • Course materials • Scientific papers • Summarizing and codifying knowledge	• Diffusion • Information retrieval • Information pooling • Collaborative problem solving • Pushing • Thinking along	yes	yes

In order to have a single view of the interviews results, TABLE 1 summarizes the results. It presents each participated department results. for each department, the table captures the employee on the "brokerage" network structure position, the gatekeeping bases, practices of knowledge collection, KS mechanisms, and initiative and couching characteristic. The researchers observe that the selected employees on the "brokerage" network structure position are acting as gatekeepers. This is because they have gatekeeping bases such as (analyzing, display, shaping, timing, manipulation, repetition, selection, and translating) [15]. Furthermore, based on the interview results, the gatekeepers are using different KS mechanisms such as (diffusion, information retrieval, information pooling, collaborative problem solving, pushing, and thinking along) -which are depending on the context- in order to share their knowledge with their colleagues [28]. They collect and gather their knowledge using different ways based on their preference. They are searching professional links (e.g. blogs, videos, and websites), accessing course materials, reading scientific papers, and they filter, summarize, and codify the collected knowledge. Therefore, Gatekeepers use distinct methods and technology to serve their needs. They provide their knowledge in a way to be understandable and looking appeal [48]. However, the results capture the way that gatekeepers codify their knowledge. They are using videos, mind maps, info-graphics, steps, and flow charts in order to share their knowledge with others. Moreover, they store their knowledge using organization's intranet, external internet locations, and hardware storages. Gatekeepers also have initiative and couching characteristics. This is observed in their proactive and reactive attitudes in terms of assisting their colleagues in the work place.

On the other hand, the researchers observe that KFMC is an open environment that is adaptive to changes. KFMC supports KS environment, this is seen in their strategy with their employees. They are fostering their employees in terms of knowledge codification, attending public speaks and online training courses, and conducting internal team meetings and workshops. Furthermore, KFMC employees require social interaction media that supports the collaborative work from anywhere. The employees need something "handy", and easily set on their mobiles. Moreover, there is a need for knowledge base with advanced searching feature, hence, the KFMC employees can effectively utilize the codified knowledge.

V. CONCLUSION

This research contributes in discovering gatekeepers' practices in terms of gathering, collecting, and diffusing knowledge into their groups. Combining both the structure view and process view gives deep understanding of the context. The findings of this study highlight the gatekeepers bases and how they are collecting their knowledge using different technologies to serve their need [15]. Also, the results reveal that gatekeepers use different KS mechanisms, in order to share their knowledge with their colleagues [28]. The findings of this research assist managerial decision makers and strategic managers among start-up organizations and also well-structured organizations in terms of policy, decision, and behavior creation. Therefore, they provide valuable insights and decisions in terms of policies, strategies, and the appropriate collaborative tools that foster the collaborative environment in the organizations. In such cases, employees can get faster answers for "What if?" and "How to do?" questions. Furthermore, applying this research in the local area and driving results directly from the practical environment gives evidences of strong outcomes in KM field.

The limitation of this study occurs in the area of using static SNA. The results might change when applying dynamic SNA.

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Observation of Scintillation Events from GPS and NavIC (IRNSS) Measurements at Bangalore Region

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***Abstract*—Ionosphere scintillation is a random phenomenon of the ionosphere, causing abrupt fluctuations in the amplitude and phase of the signals traversing the medium, significantly impacting the performance of navigation systems, signifying the need to take up scintillation studies. Scintillation events are monitored on L5, S and L1 band signals of IRNSS and GPS navigation system respectively over low latitude Bangalore region during moderate and low solar activity period, 2015 and 2016 respectively. Investigations into scintillation variability with respect to local time, solar activity and seasonal variations are conducted to draw a trend of scintillation pattern. Comparison of L5 and L1 band scintillation events demonstrate similar scintillation pattern with varying scintillation magnitude. With S band signals exhibit minimum scintillation, suggesting the scintillation-free link for effective navigation.**

Keywords—Ionosphere scintillation; Navigation; carrier to noise ratio; solar activity; equinox

I. Introduction

The ionosphere extending from 50 to 1000 km from the Earth's surface is formed of ionized particles. The RF signal transmission from satellite, traversing through the ionosphere as shown in Fig.1 undergoes refraction and diffraction. The refraction changes the velocity and direction of an EM wave, introducing delay in the received signal [1]. The diffraction causes mutual interference of the Electromagnetic waves, giving rise to random fluctuations in the amplitude and phase of the radio signal [2] referred to as ionosphere scintillation. The velocity of propagation of radio wave in the ionosphere is determined by density of electrons which is measured in Total electron count (TEC) units, 1TEC unit is equal to 10^{16} electrons / m^2. The TEC is defined as the number of electrons measured along a vertical shaft of area $1m^2$ connecting satellite and receiver. The TEC is mathematically computed as $\int_p Nds$. N is the electron density, p is the propagation path. TEC is be computed $\frac{1}{40.3}\left[\frac{f_1^2 f_2^2}{f_1^2 - f_2^2}\right](p_2 - p_1)$.where p1 and p2 are group path lengths and f1 and f2 are high and low frequency signals respectively.Ionosphere scintillation is a random phenomena exhibiting high level of variability with respect to seasons months and solar activity.

The scintillation activity extends upto ± 30^0 N and S of geomagnetic equator and severe scintillation is observed in auroral zones and in the regions close to equator in the belt of ± 10^0 of equator. Moderate levels of scintillation are monitored in low latitude regions and low or rare events over mid latitude regions. Several studies have reported scintillation occurrence as a night-time phenomenon occurring between local sunset and midnight and rarely extends until post-midnight hours. Scintillation events tend to increase with increase in solar activity as solar radiation intensifies the ionization process and greatly increasing the electron density in the ionosphere.

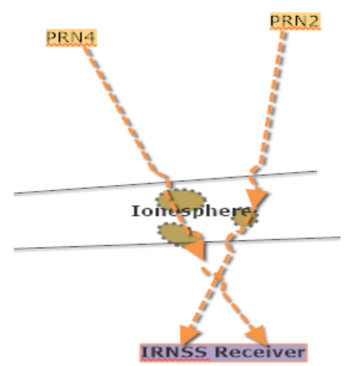


Fig. 1. Pictorial representation of Ionosphere scintillation

The objective of this article is to provide statistical analysis of scintillation occurrence over Bangalore zone. Drawing a pattern of scintillation variability with respect to months, seasons and solar activity. Investigating the Vulnerability of satellites links to scintillation and lastly the comparison of scintillation occurrence on L5, S and L1 band.

Section 2 describes the methodology adopted to carry out this study with some samples of C/No plots. Section 3 presents statistical analysis of scintillation occurrence with respect to various parameters (local time, months, seasons, solar activity)

A. *The Cause of Scintillation*

The background electron density of the ionosphere undergoes severe variation from low solar activity to high solar activity period and from equator to anomaly crest sites. Further due to plasma instability processes during the post sunset period in the equatorial region, triggers several night-time phenomena such as equatorial spread F (ESF) [3] which are prominent factors controlling the occurrence of ionosphere scintillation. Several experimental research and studies are carried out to draw pattern of scintillation activity in the stations close to and away from equator to characterize variability in scintillation activity.

B. *Impact of scintillation on navigation systems*

Ionosphere scintillation significantly impacts the performance of navigation systems: GPS and IRNSS. Amplitude and phase scintillation of the signal causes signal fading which is witnessed as fluctuations of carrier to noise ratio in the order 15 to 20dB.Hz. The signal goes undetected if the signal fading exceeds fade margin of the receiver, thereby increasing signal acquisition time. Further signal distortion, data loss, cycle slips [4], loss of lock on the signal are some of the degrading effects of scintillation on the receiver performance. This study is further extended to investigate the adaptability level of the system to scintillation environment [5].

C. *Related work*

The detailed study on various aspects of scintillation has been carried out in various locations of India particularly in Equatorial Ionization anomaly (EIA) crest regions [20-25^0 geo magnetic latitude]: Calcutta [6], Delhi [7], Varanasi [8] and Ahmadabad [9] as these sites are the origins of precursors of onset of scintillation activity. Scintillations events are monitored in Udaipur region on 244/250MHz radio beacon signals [10] exhibit nighttime characteristics associated with equatorial spread F (ESF) phenomenon. Spatial and temporal variability pattern of scintillation occurrence is monitored and recorded from 240MHz geostationary satellite signals [11].The scintillation Studies has also been conducted in the regions close to the equator in Ascension Island [12], Africa and India. All these studies attempted to draw a definite pattern of scintillation variability relative to solar activity, seasonal fluctuations and other factors. In all these studies reported, scintillation is a nighttime phenomenon and occurs in discrete patches of irregular interval. It is significant to monitor scintillation activity pattern and its variability over Bangalore region, to estimate scintillation activity pattern and confirm the findings with similar work carried out at various regions of India and other countries

II. Data Analysis

Scintillation occurrence is monitored on IRNSS navigational signals from geostationary IRNSS satellites (1A, 1B, 1C, 1D, 1E, 1F, 1G) at L5 and S band signals over Bangalore region –JGI campus, Jain University, kanakapura (**12.643° N, 77.0044° E**) from 2015 to 2016 time period using IRNSS receiver which continuously tracks IRNSS/GPS signals. The carrier to noise ratio (C/No) of the received signal is investigated for the occurrence of scintillation.

The seasonal variation of scintillation is monitored by grouping month wise data into 3 seasons, viz equinoxes (March, April, September & October), winter months (January, February, November and December) and summer months (May, June, July, August). To assess the influence of solar activity on occurrence of scintillation, scintillation analysis is carried out for the year 2015 as this year experiences moderate solar activity (100-140 solar flux units)and the year 2016, experiences low solar activity (80-100 solar flux units).

It is observed that during day time, the nominal variation of C/No is 5dB.Hz while rapid and abrupt fluctuations in the order on 8-20dB Hz are observed during night hours, is one of the characteristics of scintillation. Some typical records of C/N0 recorded at Bangalore is shown in the Fig.2. As is apparent, scintillation is primarily a night-time phenomenon, identified as rapid fluctuations of C/No in the order 8-20dBHz against nominal variation of 5dBHz.

III. Results and Discussion

From Fig.2, it is observed that scintillation being a night time activity starts 3 to 4 hrs of local sunset time 6.30pm and reaches peak values any time between 22 to 22.30 hrs and persists for short duration in post-midnight and declines in activity towards dawn. It is also observed that the Scintillation occurs in discrete patches of irregular intervals in pre and post-midnight hours as reported in [10, 11]. S band signals observe nominal variation of 5dBHz in C/No as shown in the Fig. 3.

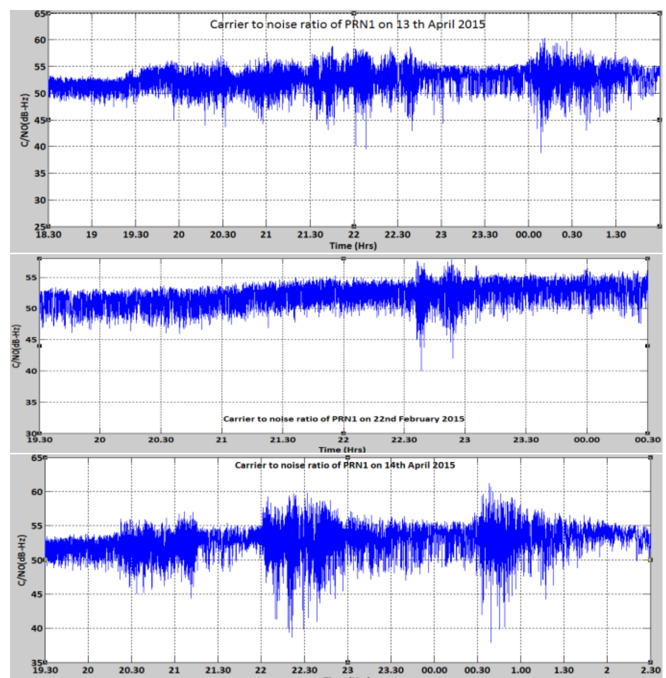


Fig. 2. Carrier to noise ratio of the signal at L5 band from geostationary IRNSS satellite recorded at Bangalore

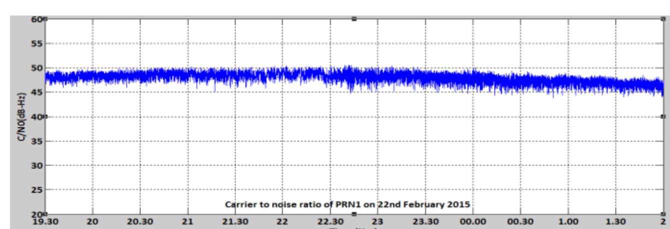


Fig. 3. Carrier to noise ratio of the signal at S band from geostationary IRNSS satellite recorded at Bangalore

Fig. 4 illustrates month wise, percentage of scintillation for the year 2015 and 2016, characterized as moderate and low solar activity period respectively. Highest percentage of scintillation is witnessed during moderate solar activity period (2015) and highest percentage recorded in the April month (63%) followed by March (45%). The percentage of scintillation has declined to 16% in low solar activity period which is recorded in the April and March month of the year 2016. May, June, November and December month has not witnessed any scintillation irrespective of the solar activity. From Fig. 5, scintillation activity observed for equinoxes complements the Fig. 4 and its observations. The observations reported very well agree with findings of [10].

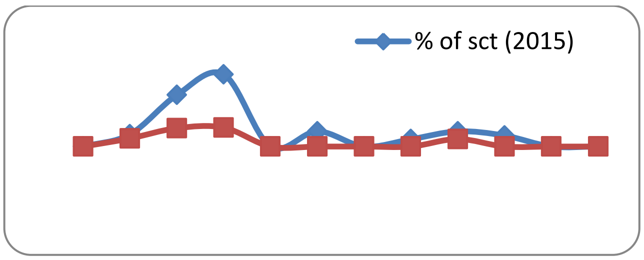


Fig. 4. Percentage occurrence of scintillation for moderate and low solar activity period (2015-2016)

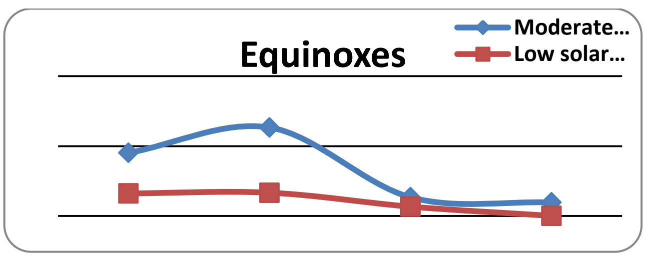


Fig. 5. Percentage scintillation for equinoxes of moderate and low solar activity period (2015 & 2016)

Percentage scintillation witnessed for equinox months in moderate and low solar activity is illustrated in Fig. 6, it is evident that the scintillation activity started at local sunset and gradually increased in intensity and attained peak values (20-25%) at around 21.30-22.30 Hrs, after attaining peak values, the percentage scintillation decreased from midnight to post midnight. The percentage of scintillation has decreased to 5-7% during low solar activity period.

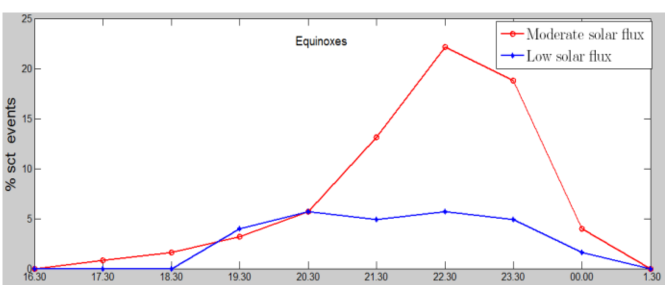


Fig. 6. Nocturnal variation of percentage of scintillation over Bangalore region in equinoxes of the moderate and low solar activity period (2015-2016)

The highest percentage (20-25%) of scintillation occurrence is observed in equinoxes, less in winter (2.5%) and least in summer (2.2%) in moderate solar activity period. Peak occurrence of scintillation activity is between 22:00 and 23:00 hrs as apparent from Fig.7. During low solar activity period, the percentage of scintillation has declined to (5-6%) in equinoxes and 1-2% in winter and summer months witnessing zero scintillation events. Thus solar activity has direct influence on the scintillation activity as the year 2015 witnesses high percentage of scintillation events than the year 2016. However irrespective of solar activity, equinoxes witnesses high scintillation events compared to winter and summer seasons.

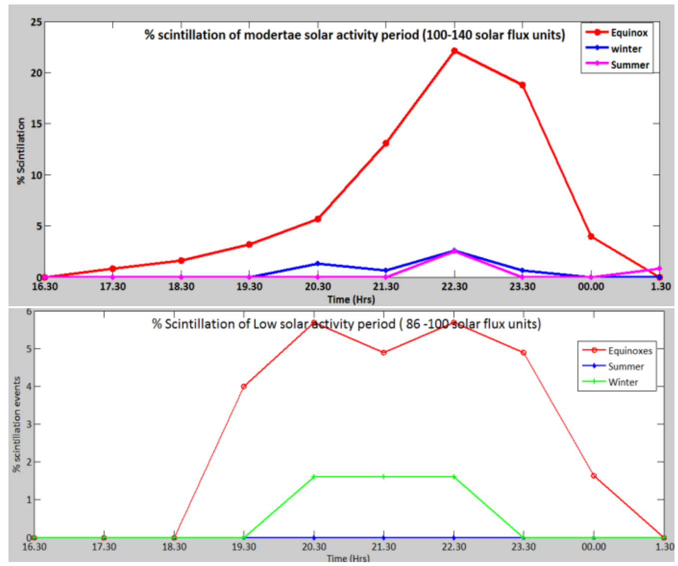


Fig. 7. Percentage of scintillation for seasons during moderate and low solar activity period (2015-2016)

The satellites of IRNSS constellation of the period 2015, prone to scintillation in equinox months with varying level of percentage scintillation experienced with respect to time as illustrated in the Fig.8. The satellites are experiencing varying level of scintillation in night hours and go hand in hand with scintillation activity. However all satellite links are not simultaneously prone to scintillation except at around 22:00 - 23:00 hrs, satellites PRN1 to PRN4 experiences high percentage (25-35%) of scintillation in equinox months (17.30-20.30)

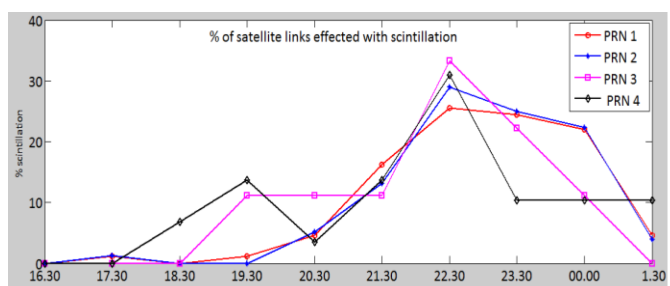


Fig. 8. Percentage of IRNSS satellites links vulnerable to scintillation in the post sunset period of moderate solar activity (2015)

C/No undergo rapid fluctuations in scintillation phase. The variation in C/No is categorized as 8-10, 10-15, 15-18, 18-20 dB Hz. The percentage variation in C/No with respect to night time hrs is illustrated in the Fig. 9. Mild variation in C/No (8-12dB) in low percentages (<10%) is observed in pre midnight hrs) while large variation in C/No (15-20dB) is observed in

40-50% at around 22.30-23.30 Hrs. Hence variations in C/No are direct influence of scintillation activity.

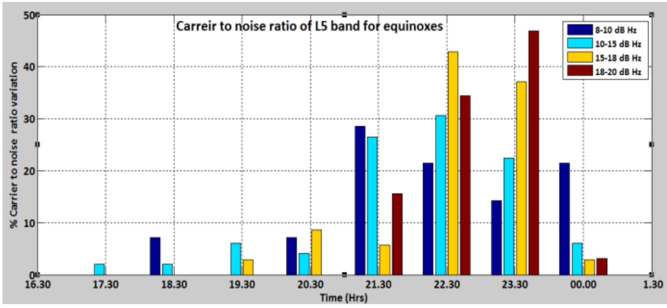


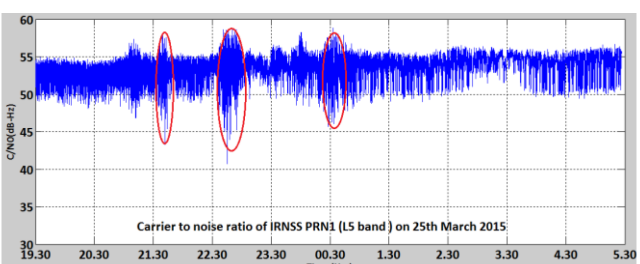
Fig. 9. Percentage variation in carrier to noise ratio for equinox months of moderate solar activity period (2016)

Duration of scintillation occurrence is monitored for April month of moderate solar activity period (2016).It is observed that scintillation occurrence in time duration ranges from 3-50 minutes. As investigated, scintillation occurrence is sometimes continuous for time duration of 30-45 minutes while also exhibiting discrete patchy nature of occurrence for time duration ranging from 5, 20 to 30 minutes. Further scintillation occurrence in varying time duration is observed during both pre and post-midnight hrs.

IV. Observation And Comparison of Scintillation Occurrence on IRNSS (L5 And S) and GPS (L1) Bands

Irregular, patchy and rapid fluctuations of C/No is observed in the order 15-20 dB Hz on L5 band signals while similar pattern fluctuations in the order 10-15dB Hz observed on L1 band signals and 6-8 dB variations on S band signals as illustrated in the Fig.10 implying the low frequency signals are more prone to scintillation than high frequency signals.

High percentage (1.6-22.2%) of nocturnal scintillation is observed on L5 band signals followed by L1 (0.8- 11.5%) and least percentage (1.6%) on S band signals during equinox months of moderate solar activity period. The trend of scintillation being minimum in the post sunset hours increases gradually and attain peak maximum in the pre-midnight hours and gradually decreases in post-midnight to zero as observed for both L5 and L1 band and pattern differing for S band as shown in the Fig.11.



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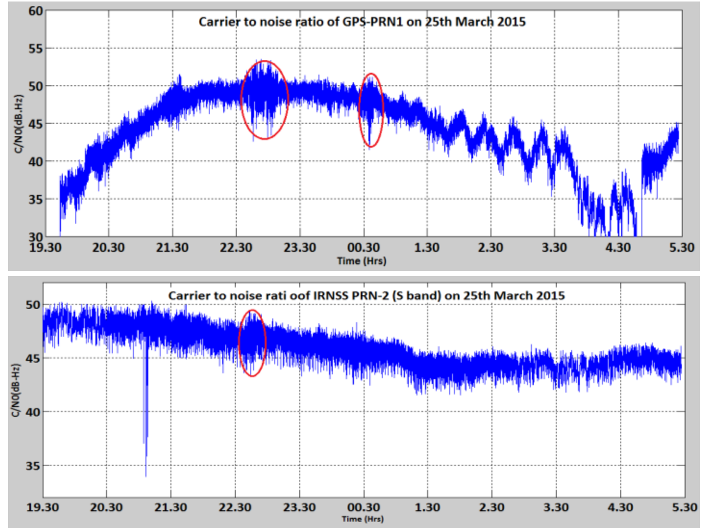

Fig. 10. Plot of Carrier to noise ratio of L5, L1 and S band signals

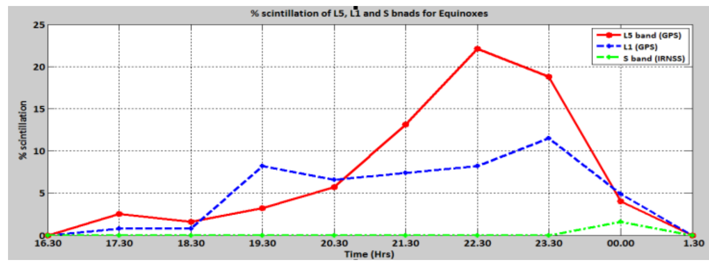

Fig. 11. Comparison of percentage of scintillation of L5, L1 and S band during equinoxes

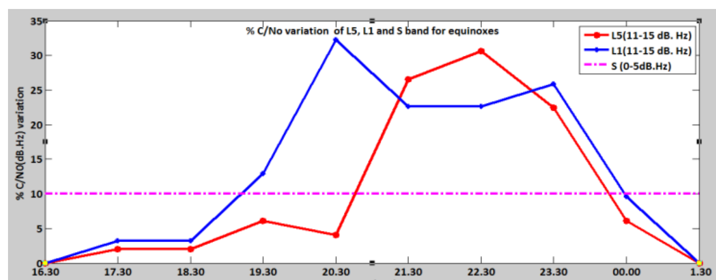

Fig. 12. Percentage of nocturnal C/No variation in the range 11-15dB Hz of L5, L1 and S band

The percentage variation of C/No, more or less follows similar pattern for both L5 and L1 band signals except peak percentage is observed at different timings in the pre-midnight hours. The variation attains maximum percentage of 32.2% at around 20.30 and 30.6% at around 22.30 for L1 and L5 signals respectively while S band signals experiences a constant 0-5 dB Hz variation in C/No. The summary of above observations are tabulated in Table.1

TABLE. I. COMPARISON OF % OF SCINTILLATION OCCURRENCE FOR EQUINOX MONTHS

Solar activity (*solar flux units*)	**Frequency bands**	**Equinox months**	
		% of Scintillation	***C/No variation (dB Hz)***
Moderate (100-140)	*L5*	20-25	15-20
	L1	0.8-11.5	10-15
	S	<1.6	6-8
Low (80-100)	*L5*	5- 6	1-5
	L1	<1	1-5
	S	0	1-5

V. CONCLUSION

In this paper, observed characteristics of night time scintillation on L5 band signals over low latitude Bangalore region has been discussed in terms of month to month, seasonal and solar cycle variation. During moderate solar activity period, scintillation occurrence is more frequent with highest percentage recorded in equinoxes. The percentage occurrence of scintillation decreases with solar activity and scintillation recorded in low solar activity period is 1-5% in equinoxes, less and least events are recorded in winter and summer months respectively. Irrespective of solar activity, equinox months witnesses the scintillation events with percentage occurrence comparatively higher than that witnessed during low solar activity period. The scintillation events start at or after 3 to 4 hrs of local sunset time depending on the solar activity level and attain maximum peaks around (22:00- 23:30) Hrs. Post-midnight scintillations are also observed in equinoxes in discrete patches. Random variation of C/No in the order of 8-20 dB is observed during night scintillation hours as compared to nominal variation of 5dB.Hz during day time. About 25-35% of scintillation at L5 band is experienced by all satellites of IRNSS constellation in the moderate solar activity period (2015) during equinoxes around 22:00-23:00 hrs while an S band IRNSS signal experiences zero or less scintillation. Comparison of L5 and L1 band scintillation shows that though L1 experiences low percentage of scintillation follows similar pattern of scintillation activity as that of L5 band signals as also expected.

Next phase of the work: consequent to the observations of the scintillation events, the work will be extended to study the impact of scintillation on GNSS Receiver performance and also address the scintillation mitigation techniques.

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A RDWT and Block-SVD based Dual Watermarking Scheme for Digital Images

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***Abstract*—In the modern era, digital image watermarking is a successful method to protect the multimedia digital data for example copyright protection, content verification, rightful ownership identification, tamper detection etc. In this paper for improving the robustness and security, a Dual watermarking approach using Redundant Discrete Wavelet Transform (RDWT), block based singular value decomposition (SVD) and Arnold transform is presented. There are two gray scale watermarks, one is Prime watermark and other is Arnold scrambled Second watermark. Second watermark is embedded into the RDWT transformed Prime watermark in all sub bands to get the processed watermark image. After that transformed gray scale cover image is partitioned into non-overlapping blocks for embedding the processed watermark image by modifying the SVD coefficients of each block to obtain the resultant watermarked image. Now a reverse algorithm is developed to takeout the Prime and Second watermark from noisy image. Analysis and experimental outcomes show that the presented method is more robust against numerous image processing attacks and perform better as compared to previously introduced schemes related to presented work.**

Keywords—Digital image watermarking; Redundant Discrete wavelet transform; Singular value decomposition; Arnold transform; NCC and PSNR

I. INTRODUCTION

Due to volatile revolution in the communication digital multimedia, internet and computer technology, the transportation of multimedia digital information/data over the internet are not safe and also suffers by unlawful operation such as unauthorized copying, duplication, editing, modification, replication, tampering and alterations by the inducers. So there is strong need for protection the digital content for ownership verification, copyright protection, content identification and temper detection etc. Now, it is a challenging task but watermarking is an important tool, which solve all these intellectual property rights problems. Watermarking is the process by which, the secret digital data information can hide into the digital multimedia (Audio, Image and Video) without any visible changing in the cover digital information and only true and real owner can extract the secret information. The concept of watermarking can also be used in various applications such as digital multimedia security, certification, Broadcast Monitoring, medical application, finger printing, data hiding etc. [1-3]. The elementary requirement of watermarking is imperceptibility, Robustness, Security. Robustness means that the watermarking procedure should be curbed beside several image processing attacks such as filtering, histogram manipulation, noise addition and geometric attacks such as translation, scaling, rotation, cropping etc. Imperceptible means sameness between original image data and watermarked image data. Security means resistance against malicious attacks.[3] For embedding the secret digital information in to the digital media is scaled by factor called scaling factor, if scale factor is high then more distortion in the image but the robustness is increased and vice versa. Watermarking techniques can be divided as spatial domain and frequency domain techniques. Spatial domain has high data capacity, less robust and transform domain techniques such as Discrete wavelet transform (DWT) Discrete Fourier transform (DFT), Discrete cosine transform (DCT), Singular value decomposition (SVD) are more robust and good imperceptibility [4-7]. The method of changing the location of picture pixel by way of matrix transforms to get an image whose visible effect is ailment known as scrambling. There are numerous scrambling methods of the image such as Hilbert fractal curve, Fibonacci-Q transform, Affine transform, Arnold transform [8-11].The hiding information embedding into the singular values of the source image data in SVD [12-15]. The RDWT based watermarking has the properties shift invariant directionality and overcome the DWT problem [16-19].Dual watermarking procedure in which two watermarks are embedded into the cover image in different ways for enhancing the robustness, imperceptibility and security [20-29].

The rest of the paper organized as in segment II literature survey, SVD, RDWT and Arnold transform are briefly described. Then in segment III embedding and extracting process are explained. The outcomes and the comparative analysis of our approach are shown in segment IV, and the conclusion of this paper is described in segment V.

II. LITERATURE SURVEY

This section briefly explains the previous works on block based dual watermarking. Lin *et al*. [20] suggested a dual watermarking procedure using just noticeable distance method for invisible and visible watermark. Lee and Lin [21] presented a dual watermarking method for temper detection in which two replicas of watermark embedded in to each block of the image and improve the security and robustness. Hu *et al*. [22] offered a dual watermarking procedure for gray scale and binary watermark image and also improve the security and robustness. Dhanalakshmi and Thaiyalnayaki [23] suggested a DWT-SVD and chorus encryption based dual watermarking scheme but the robustness and imperceptibility results are not satisfactory. Amini *et al*. [24] proposed a DWT, block by block SVD dual watermarking scheme using principal component analysis. In this scheme embedded a binary watermark in best sub band on the basis of intensity variance of each block and also improve the robustness and security. Xiao *et al*. [25] presents a DWT based blind, dual watermarking method for color images. This scheme is used for invisible and fragile watermark for copyright protection and image authentication respectively. But the tamper localization is not satisfactory. Mohanty *et al*. [26] proposed a combination of visible and invisible block based dual watermarking scheme and embedding of watermark is done by finding the mean and variance of every block. Navas *et al*. [27] presented a DWT block based scheme and improve the imperceptibility as well as robustness. Lu and Liao [28] suggested a dual watermarking method for robust and fragile watermarks but tamper localization is not satisfactory. Ghazy *et al*. [12] proposed a block based SVD techniques, this scheme has very low embedding capacity. Bhatnagar *et al*. [29] provide a DWT-SVD base dual watermarking scheme in which a gray scale secondary watermark is embedded in the primary watermark and this primary watermark image is embedded in the host image but from the result analysis it is found that for some image processing attacks, the primary and secondary watermark are seriously degrade. In our presented scheme, a dual RDWT block-SVD based watermarking has high capacity and little degradation due the properties of RDWT and SVD and also enhances the robustness and imperceptibility.

A. SVD

Singular value decomposition(SVD) is a mathematical tool to dissolve any $n \times n$ matrix A in to three matrices U, D and V as $A = UDV^T$ where U and V are left singular and right singular matrices which are orthogonal and $D = diag(\alpha_i)$ is a diagonal matrix, where α_i , $i = 1,2,3 \dots .n$ are the singular values and satisfies $\alpha_1 > \alpha_2 > \alpha_3 > \cdots \cdots > \alpha_n$.The matrix U and V identify the geometric information and also singular matrix S contains the intensity information of the image [12]. The SVD matrix both may be square or rectangular. It can be factorized as

$$A = UDV^T \tag{1}$$

$$= [u_1, u_2, \dots u_n] \times \begin{pmatrix} \alpha_1 & 0 & \cdots & 0 \\ 0 & \alpha_2 & \cdots & 0 \\ \vdots & 0 & \ddots & 0 \\ 0 & 0 & \cdots & \alpha_n \end{pmatrix} \times [v_1, v_2, \dots v_n]$$

$$= \sum_{i=1}^{r} \alpha_i u_i v_i$$

Where, 'r' represents the rank of matrix A. The SVD has good constancy property that means the minor deviation of singular values do not disturb the visual characteristics of the digital information[13,14] It is also used in various application such as noise reduction, image watermarking, noise and hiding of the image etc.

B. Arnold Transform

Vladimir Arnold proposed cat mapping called Arnold transform in the research of Ergodic theory. Arnold transform is one the method to achieve encryption algorithm in image transform domain [8,10]. It is 2D chaotic map, when it applied on digital images, then the original pixel position become irregular and the image seem to be imperceptible or distorted image (scrambled image). Arnold transform can be described as:

$$\begin{vmatrix} a' \\ b' \end{vmatrix} = \begin{vmatrix} 1 & 1 \\ 1 & 2 \end{vmatrix} \begin{vmatrix} a \\ b \end{vmatrix} (mod\ M) \tag{2}$$

The inverse Arnold transform can be defined as

$$\begin{vmatrix} a \\ b \end{vmatrix} = \begin{vmatrix} 2 & -1 \\ -1 & 1 \end{vmatrix} \begin{vmatrix} a' \\ b' \end{vmatrix} (mod\ M) \tag{3}$$

The value of *a, b*= {0, 1, 2…………….*M*-1}

Where *(a, b)* are the original image pixel coordinates and $(a'b')$ indicates the coordinates of the image pixels after applying Arnold transform. The size of square matrix is *M*. Each pixel of the image is passed over by Arnold transform equation and after several iterative calculations the distorted image (scrambled) is obtained. The image is recovered after certain number of permutation due to periodicity of Arnold transforms [11].

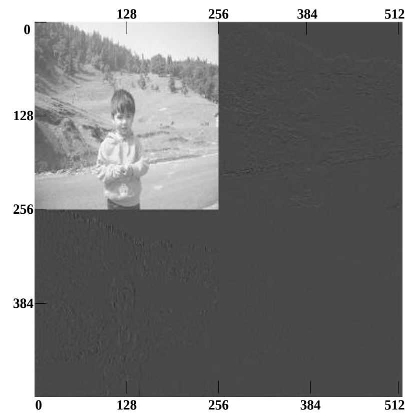

Fig. 1. 1-level Haar DWT (Rudra Image size is 512×512 and decompose each sub-band size is 256×256)

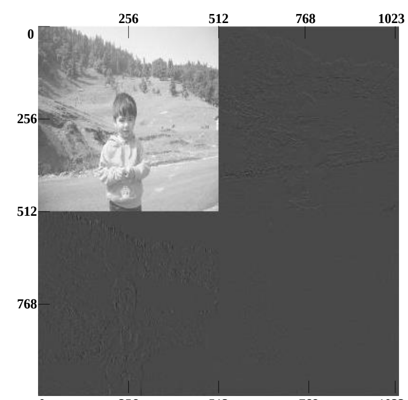

Fig. 2. -level Haar RDWT (Rudra Image size is 512×512 and decompose each sub-band size is 512×512)

C. RDWT

In the image processing application, for transforming the image in to transform domain from spatial domain, generally DWT is mostly using common transform because it has spatio-frequency localization property. It affords sufficient statistics to investigate and synthesize the data with a substantial decrease within the computational complexity. The down sampling approach in DWT attains shift variant even for a slight shift in the entire image. Due to shift variant a major changes occur in the image wavelet coefficients as well as slight shifts occur in the input image [16,17]. Due to this, there is an incorrect extraction of watermark image and cover image data. This is main shortcoming of DWT based watermarking. To overcome the problem of DWT, the RDWT techniques have been proposed because it has directionality, shift invariant properties [18,19]. From Fig.1and2, at the same decomposition level the size of sub band is decrease in DWT but in RDWT is same as the host image.

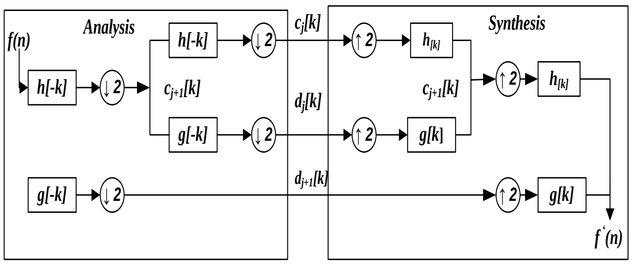

Fig. 3. Analysis and Synthesis filter banks of I D DWT

Fig.3 and Fig.4 represents the 1D DWT and 1D RDWT and their inverse transform respectively. Where $f(n)$ and $f`(n)$ shows the 1D input, reconstruct the signal. *h[-k]* and *g[-k]* represents analysis filters, *h[k]* and *g[k]* shows synthesis low pass, high pass filters respectively. c_j and d_j are low and high band output coefficients at *j* leve*l.* Difference between DWT and RDWT are demonstrated by the equation (4-12) and Fig.3 and 4.

DWT analysis and synthesis equations can be expressed as

Analysis equation

$$c_j[k] = \left(c_{j+1}[k] * h[-k]\right) \downarrow 2 \tag{4}$$

$$d_j[k] = c_{j+1}[k] * g[-k] \downarrow 2 \tag{5}$$

If $y[n] = x[n] \downarrow 2$

Then $y[n] = x[2n]$ (6)

Synthesis equations given as

$$c_{j+1}[k] = \left(\left(c_j[k] \uparrow 2\right) * h[k] + \left(d_j[k] \uparrow 2\right) * g[k]\right) \tag{7}$$

If $y[n] = x[n] \uparrow 2 \quad , then$ (8)

DWT can be described by

$$y[n] = \begin{cases} x\left[\frac{n}{2}\right] & , n \; is \; even \\ 0 & , n \; is \; odd \end{cases} \tag{9}$$

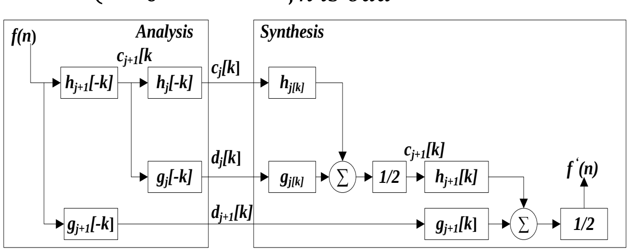

Fig. 4. Analysis and Synthesis filter banks of I D RDWT

RDWT analysis and synthesis equations can be expressed as

Analysis equations

$$c_j[k] = (c_{j+1}[k] * h_j[-k] \tag{10}$$

$$d_j[k] = (c_{j+1}[k] * g_j[-k] \tag{11}$$

Synthesis

$$c_{j+1}[k] = \frac{1}{2}\left(c_j[k] * h_k[k] + d_j[k] * g_i[k]\right) \tag{12}$$

Where * means convolution and ↓2 means down sampling and ↑2 means up sampling at each level of iteration in DWT. Size of each sub band decrease due to down sampling and increase in levels of decomposition. RDWT discard down sampling as well as up sampling of coefficients. At every stage the output coefficient two times that of the input. Due to shift invariant, directionality, spatio-frequency localization property RDWT based digital image processing techniques is more robust than DWT based techniques.

III. PROPOSED SCHEME

The proposed scheme embeds the dual watermarking method for enhancing the robustness and security. In this scheme there are two invisible watermarks, one is Prime watermark $'P_R\,'$ and other is Second watermark $'S'$ both are same size (128×128) gray scale images and $'H'$, is a gray scale cover image of size 512×512. First the Arnold scrambled Second watermark embedded into Prime watermark and get the processed watermark image and this processed watermark image is considered as a watermark image for the cover image. The Embedding and extracting steps are given below.

A. Watermark Embedding

a) Second Watermark Embedding Steps

For embedding of Second watermark $'S'$ into the Prime watermark $'P_R\,'$ is given as.

1) Second watermark $'S'$ is scrambled by the Arnold transform and get Arnold scrambled watermark image S_{NA}.

2) Apply SVD Process on this scrambled watermark image S_{NA} such as.

$$S_{NA} = I_s SW_s V_s^T \tag{13}$$

3) Perform one level RDWT transform on the Prime watermark (P_R) to divide it into 4-sub bands and get the P_{Rj} image, where $j = \{\, LL, LH, HL \; and \; HH \; sub \; bands.$

4) Apply SVD Process on Prime watermark of all sub bands such as.

$$P_{Rj} = UW_{Pj} SW_{Pj} VW_{Pj}^T \tag{14}$$

5) Now modified the singular values of the Prime watermark by adding the singular values of the Second watermark in all sub bands such as.

$$SW_{Pj} + \alpha \, SW_s = SW_j^* \tag{15}$$

6) Now find the new RDWT coefficient matrix by applying inverse SVD transform for all sub bands.

$$P_{Rj}^* = UW_{Pj} SW_j^* VW_{Pj}^T \tag{16}$$

7) Now apply inverse RDWT and modified the coefficient of all sub bands and get the processed watermark image as.

$$PW_R^* = RDWT^{-1} \tag{17}$$

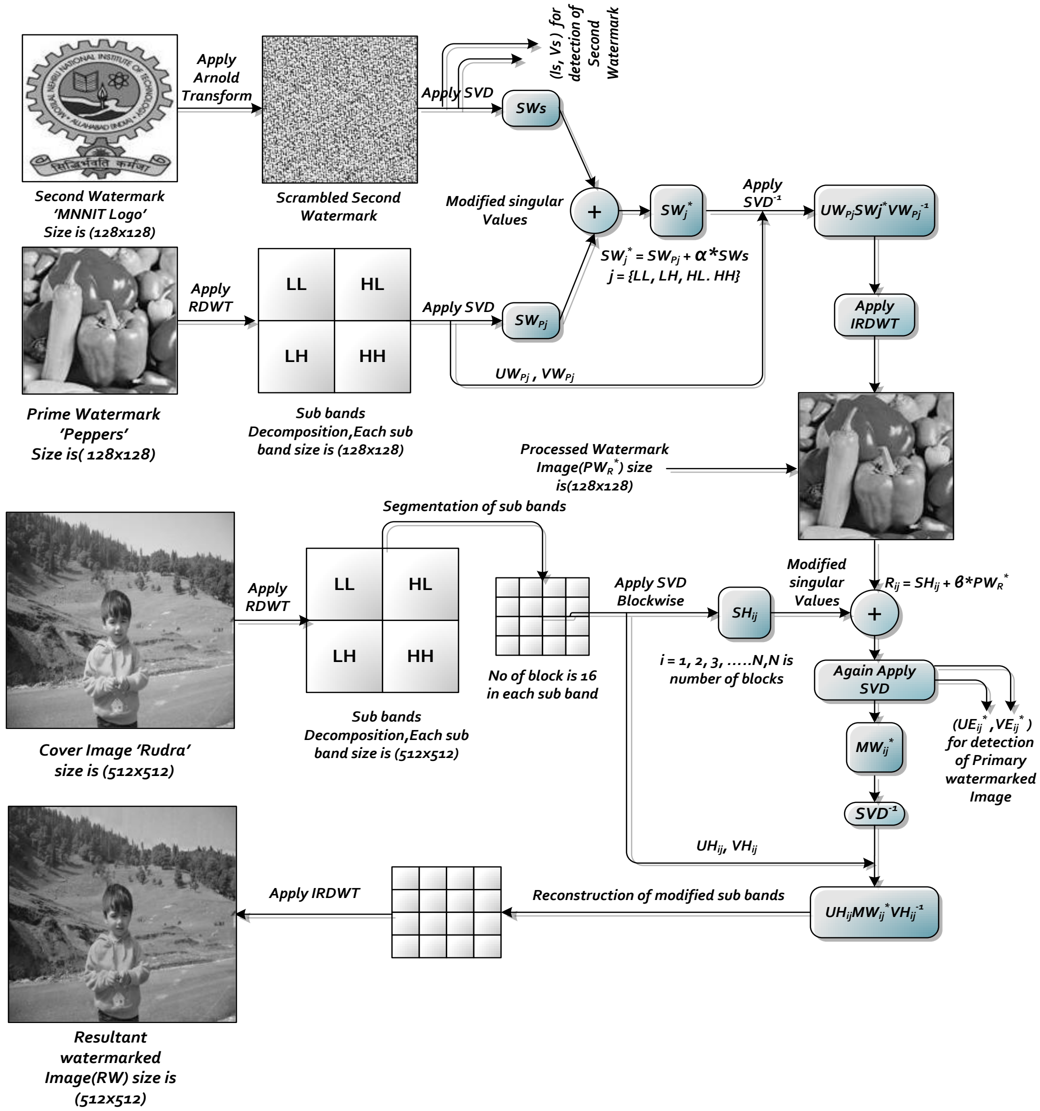

Fig. 5. Watermark Embedding Process

b) Embedding of Prime watermark image

Now the processed watermark image PW_R^* use as watermark for the cover image and the embedding steps are given bellow.

1) One-level RDWT transform is carried out on the cover image for obtaining four sub bands (LL, LH, HL and HH).

2) Divide the approximation and details part into non overlapping blocks.

3) An SVD process is applied on every block sub bands and gets the SH_{ij} matrix of singular values. Where *i =1,2,3…..N, N are the no. of blocks and j = {LL,LH,HL, and HH} sub bands.*

$$C_{ij} = UH_{ij}SH_{ij}VH_{ij}^T \quad (18)$$

4) Now modified cover image singular values, directly by adding the processed watermark image PW_R^* such as.

$$SH_{ij} + \beta\, PW_R^* = R_{ij} \quad (19)$$

5) Again SVD process is applied on the modified matrix R_{ij} such as.

$$R_{ij}^* = UE_{ij}^* MW_{ij}^* VE_{ij}^{*T} \quad (20)$$

6) Now perform the operation such as.

$$L_{ij} = UH_{ij}MW_{ij}^*VH_{ij}^* \quad (21)$$

7) Now at the end apply IRDWT and reconstruct the all watermark image in each bands and get the resultant watermarked image RW.

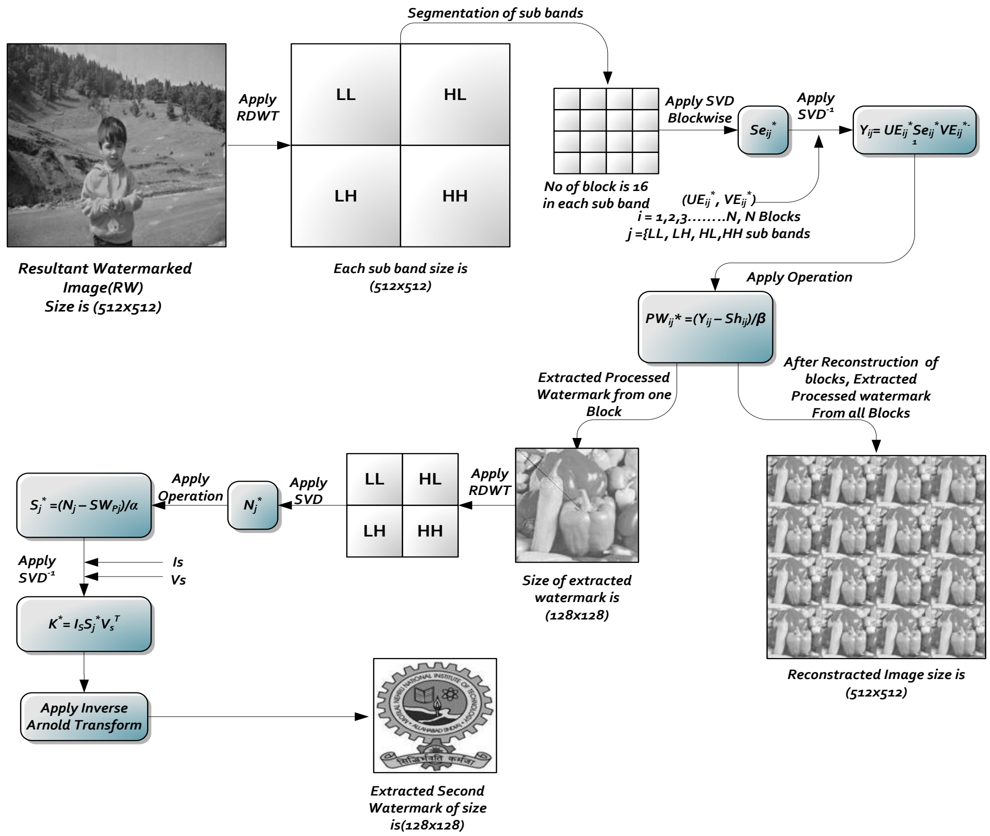

Fig. 6. Watermark Extraction Process

B. Watermark Extraction

For extraction the inverse process of embedding is applied, first extract the processed watermark image from the cover image which is known as watermark for the cover image and then extract the second watermark from this image. The extraction steps are given below.

a) Extraction of Prime Watermark

1) First apply RDWT on noisy corollary watermarked image RW and four sub bands (LL, LH, HL and HH) are obtained.

2) After that segmented these sub bands in to non-overlapping blocks.

3) Now SVD transform is applied on each block of all sub bands such as.

$$EW_{ij} = E_{ij} Se_{ij}^{*} H_{ij}^{T} \tag{22}$$

4) Now applying inverse SVD transform such as.

$$Y_{ij} = UE_{ij}^{*} Se_{ij}^{*} VE_{ij}^{*} \tag{23}$$

5) Now applying this operation

$$PW_{ij}^{*} = \left(\frac{Y_{ij} - SH_{ij}}{\beta}\right) \tag{24}$$

6) Now rearrange all extracted processed watermark in each block of all sub bands and get the combine image.

b) Extractions of Second Watermark Image

Now finally takeout the Second watermark from processed watermark image. The extraction steps are given as:

1) Processed watermark image which has highest correlation coefficient is decomposed into four sub bands using RDWT.

2) Perform SVD process on each sub bands such as

$$D = G_j N_j^{*} B_j^{T} \tag{25}$$

3) Apply this operation

$$S_j^{*} = \frac{N_j^{*} - SW_{Pj}}{\alpha} \tag{26}$$

4) Now obtain the extracted scramble Second watermark such as.

$$\breve{K} = I_s S_j^{*} V_s^{T} \tag{27}$$

5) At the end apply inverse Arnold transform and get the Second watermark image $\breve{K}^{*}$.

$$\breve{K}^{*} = IAT(\breve{K}) \tag{28}$$

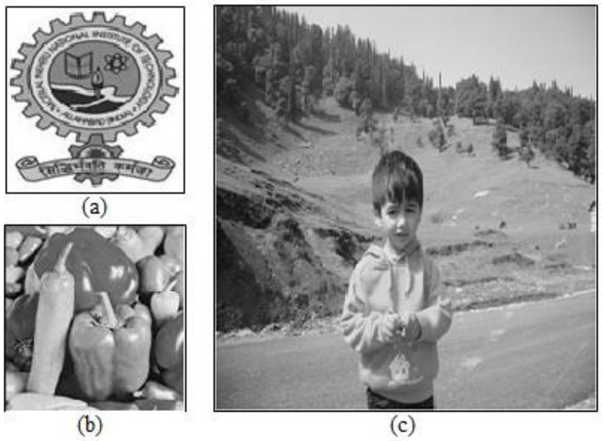

Fig. 7. Input Images (a) Second Watermark 'MNNIT Logo' (b) Prime Watermark 'Peppers'(c) Cover Image 'Rudra'

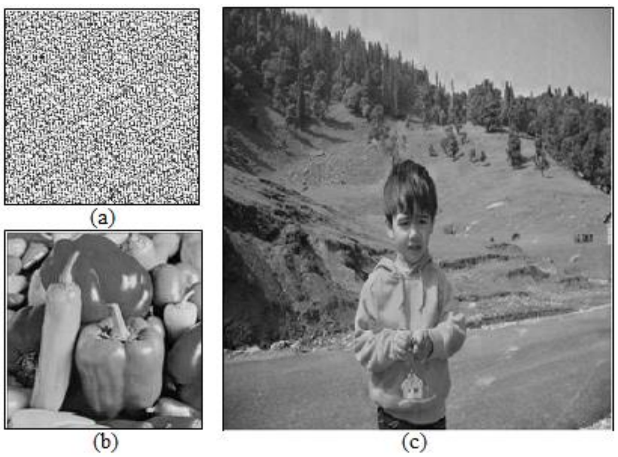

Fig. 8. Images after embedding (a) Scrambled Second Watermark Image 'MNNIT Logo' (b) Processed Watermark Image 'Peppers' (PSNR=43.381db, NCC=0.9886) (c) Resultant watermarked Image 'Rudra' (PSNR=49.564db, NCC=0.9991)

IV. Experimental Results

In this segment experiments are executed to evaluate the performance of proposed method by using the MATLAB 13a. In our experiments there are three gray scale images have been taken, one is prime watermark 'peppers' of size 128x128 and other is second watermark 'MNNIT Logo' of same size and third one is cover image 'Rudra' of size 512x512 respectively. Now decompose the cover image into one level RDWT by using 'Haar' mother wavelet filter bank and segmented in to non-overlapping blocks and then embedded the processed watermark image 64 times into the cover image. For extraction of Second watermark, those processed watermark images have been taken whose correlation coefficient is highest. Different block size can be use but this size has less complexity. Fig.7 shows the source images (a) Second watermark (MNNIT Logo) (b) Prime watermark (peppers) (c) cover image (Rudra) and Fig.8 shows the (a) scrambled Second watermark (b) Processed watermark and (c) resultant watermarked image. For preserving the imperceptibility and robustness, here two scaling factor one is 0.05 for embedding the Second watermark into the Prime watermark and other (0.02) for embedding the processed watermark image in the cover image have been taken. The PSNR(peak signal to noise ratio) is calculated to analysis the imperceptibility of the image. The acceptable value of PSNR is 30 db.

The PSNR can be calculated by the given formula as.

$$PSNR = 10\log_{10}\left[\frac{max\big(x(i,j)\big)^2}{MSE}\right] \tag{29}$$

MSE (Mean square error between host image x and watermarked image y can be calculated as

$$MSE = \frac{1}{m \times n}\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j) - y(i,j)]^2 \tag{30}$$

The robustness can be calculate by finding the normalize correlation coefficient (NCC) by given formula.

$$NC(w,\overline{w}) = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[w(i,j) - \mu_w][\overline{w}(i,j) - \mu_{\overline{w}}]}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}[w(i,j) - \mu_w]^2}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}[\overline{w}(i,j) - \mu_{\overline{w}}]^2}} \tag{31}$$

Where N and M indicates the no of pixel of watermark. $w, \overline{w}$ are real and extracted watermark.$\mu_w, \mu_{\overline{w}}$, represent the mean values of real and extracted watermark respectively. The value of NCC should be in the range between −1 and 1. If the value of NCC closes to +1 then the extracted watermark is very much correlated. If it's far close to −1, the extracted watermark is also very much correlated, however it happens to be a negative images. And if it's value is equal to 0, the extracted watermark is absolutely uncorrelated, generally the NC acceptable value is 0.75 or above. To examine the robustness and imperceptibility of propose method, different image processing attacks for example Gaussian noise, salt and pepper noise, speckle noise, rotation, resizing, compression, cropping, median filtering are applied on the resultant

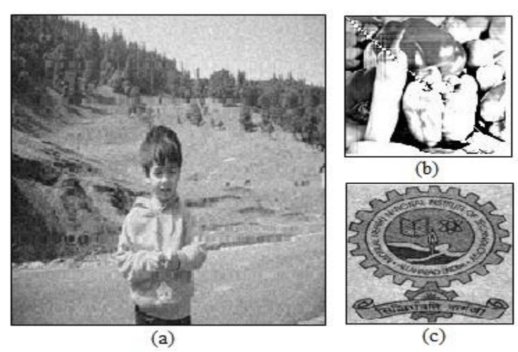

Fig. 9. Gaussian Noise (0.5) (a) Attacked Cover image (b) Extracted Prime Watermark (c) Extracted Second Watermark

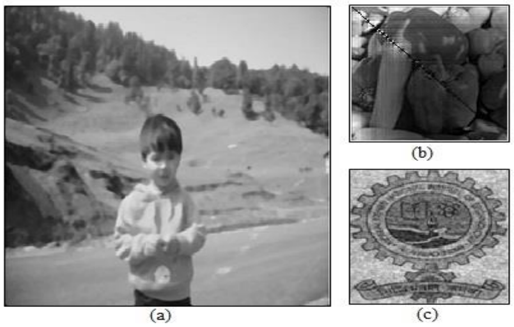

Fig. 10. Median filtering (7×7) (a) Attacked Cover image (b) Extracted Prime Watermark (c) Extracted Second Watermark

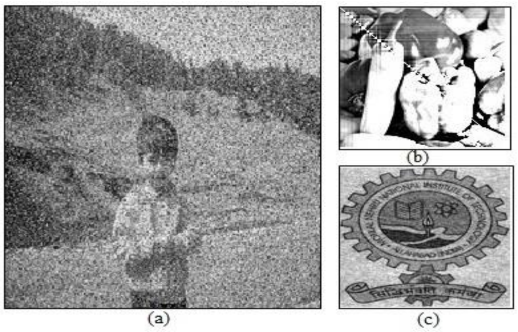

Fig. 11. Salt & Pepper Noise (0.4) (a) Attacked Cover image (b) Extracted prime watermark (c) Extracted Second Watermark

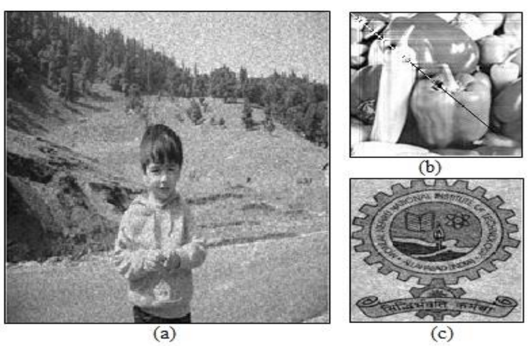

Fig. 12. Speckle Noise (density0.4) (a) Attacked Cover image (b) Extracted Prime Watermark (c) Extracted Second Watermark

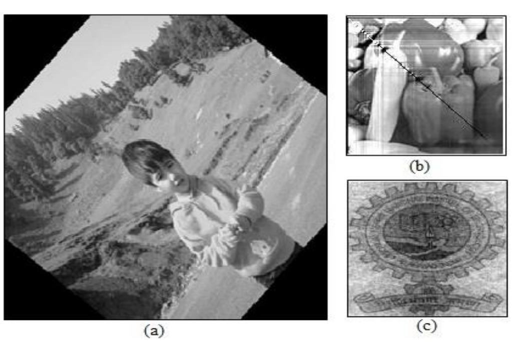

Fig. 13. Rotation (50^0) (a) Attacked Cover image (b) Extracted Prime Watermark (c) Extracted Second Watermark

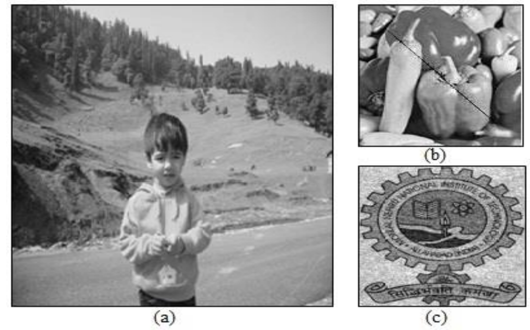

Fig. 14. Compression (a) Attacked Cover image (b) Extracted Prime Watermark (c) Extracted Second Watermark

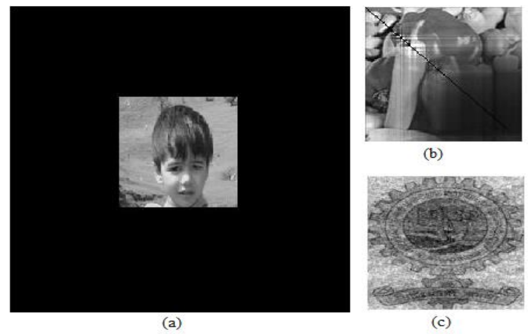

Fig. 15. Cropping (30%) (a) Attacked Cover image (b) Extracted Prime watermark (c) Extracted Second Watermark

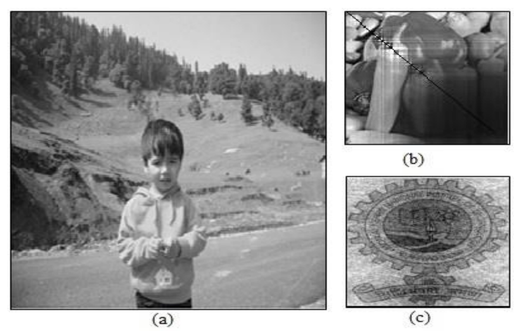

Fig. 16. Resizing (512-256-512) (a) Noisy Cover image (b) Extracted Prime watermark (c) Extracted Second watermark

watermarked image and see the correlation between extracted watermarks and original image by finding the correlation coefficient using equation (31) in Table 1and 5. The PSNR (peak signal to noise ratio) of processed watermark image and resultant watermarked image are (43.381db, 49.564db) respectively can be calculated by using the equation(29),30. The outcomes of extracted watermark after applying attacks gaussian noise (mean=0,var=0.5), pepper and salt noise(0.4), speckle noise(0.4), median filtering (7x7), rotation(50^0), cropping(30%), compression(75:1), resizing (512-256-512) are shown in Fig. 9-16. and also have been depicted in the Table 1. Table 1 presents the minimum correlation coefficient value after applying attacks which is greater than (0.5) so the presented method is accaptable.

TABLE. I. CORRELATION COEFFICIENT VALUE OF PRIME AND SECOND WATERMARK IMAGE AFTER APPLYING ATTACKS IN LL SUB-BAND

Attacks	NCC	
	Prime Watermark	Second Watermark
(a) Gaussian Noise(M=0,V=0.5)	0.6377	0.5365
(b) Salt & Pepper noise(0.4)	0.5954	0.5131
(c) Speckle noise(0.4)	0.5998	0.5117
(d) Median filtering(7×7)	0.5676	0.4989
(e) Rotation(50^0)	0.6083	0.4991
(f) Cropping (30%)	0.6187	0.5091
(g) Resizing(512-256-512)	0.6365	0.5783
(h) Compression	0.6963	0.5998

Now also check this proposed scheme for different standard images like Lena, Penguin, Baboon, and Boat and also find out the numerical analysis values. After embedding the watermark the values of correlation coefficient and PSNR (peak signal to noise ratio), for these images as well as extracted watermark are shown in Table 2 and 3. The highest correlation coefficient of Prime and Second extracted watermark after applying attacks shown in the Table.5 After analysis of received outcomes, conclude that the provided method is wealthy in terms of robustness, security and imperceptibility.

TABLE. II. NCC AND PSNR VALUE AFTER EMBEDDING THE PROCESSED WATERMARK IN DIFFERENT IMAGES

Images		NCC	PSNR
Baboon		0.9894	54.973
Lena		0.9991	57.184
Bird		0.9881	53.142
Boat		0.9792	51.872

TABLE. III. NCC AND PSNR VALUE AFTER EXTRACTING THE PRIME WATERMARK IN DIFFERENT IMAGES

Images	Prime Watermark	
	NCC	PSNR
Baboon	0.9773	58.991
Lena	0.9792	60.347
Bird	0.9669	59.144
Boat	0.9632	60.891

TABLE. IV. NCC AND PSNR VALUE AFTER EXTRACTING THE SECOND WATERMARK IN DIFFERENT IMAGES

Images	Second Watermark	
	NCC	PSNR
Baboon	0.9665	48.898
Lena	0.9689	50.387
Bird	0.9614	45.557
Boat	0.9558	47.149

A. Comparative Study

In this segment, compare the results of the presented method with Bhatnagar *et al.* [29] shown in Table 5.Bhatgnar *et al.* [29] proposed a DWT-SVD based dual watermarking method in which a gray scale secondary watermark is embedded in the primary watermark and this primary watermark image is embedded in the host image by using zigzag sequencing but from the result analysis it is found that for some image processing attacks, the primary and secondary watermark are seriously degrade.

TABLE. V. COMPARISON OF HIGHEST CORRELATION COEFFICIENT VALUE OF PRIME AND SECOND WATERMARK IMAGE AFTER APPLYING ATTACKS IN LL SUB-BAND BETWEEN PROPOSED SCHEME AND BHATNAGAR *ET AL.* [29] , '-' MEANS ATTACKS ARE NOT APPLY

Attacks	NCC comparison			
	Bhatnagar *et al.*[29]		Prosed Scheme	
	Prime Water-mark	Second Water mark	Prime Water-mark	Second Water mark
(a) Gaussian Noise(M=0,V=0.5)	0.4728	0.3527	0.7832	0.6598
(b) Salt & Pepper noise(0.4)	-	-	0.6945	0.5937
(c) Speckle noise(0.4)	-	-	0.6783	0.6214
(d) Median filtering(7×7)	0.5432	0.3314	0.6685	0.5963
(e) Rotation(50^0)	0.5627	0.2822	0.7538	0.6018
(f) Cropping (30%)	0.5366	0.3249	0.7128	0.5382
(g) Resizing(512-256-512)	0.7776	0.2863	0.8193	0.6185
(h) Compression	0.9887	0.7393	0.8189	0.7841

In our proposed method, a 128×128 Arnold scrambled gray second watermark image is embedded in to the prime watermark image of same size and get processed watermark image, this processed watermark image is embedded in to the RDWT transformed cover image of size 512 × 512. RDWT has shift invariant, directionality property due to this, RDWT based watermarking method is more robust than DWT based watermarking. The comparison between our method and Bhatnagar scheme for Prime and Second watermark are also shown by comparative chart in Fig.17. By seeing the NCC values in Table 1,5, Fig.9-16 and comparative chart, we can analyze that the presented techniques is more robust against distinct image processing attacks and geometric attacks and have high embedding capacity, more imperceptible and robust than previously proposed techniques.

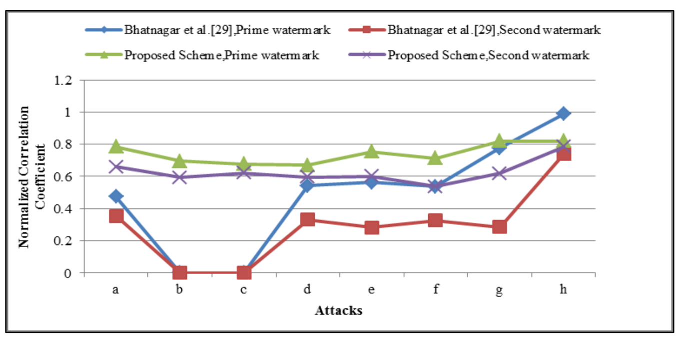

Fig. 17. Comparative Chart between Bhatnagar et al.[29] and proposed scheme

V. CONCLUSION

This paper presents a dual image watermarking method based on RDWT and block-SVD, to embed an Arnold scrambled Second watermark image. The watermarking process is carried out by modifying the singular values of prime watermark to obtain a processed watermark image, which is then embedded by modifying the singular values of each block with all RDWT sub bands of the gray scale cover image. For extraction the left and right singular matrices are used at the receiver end.This scheme has the high embedding capacity and a little degradation in the image due to the RDWT-SVD properties and scrambled watermark by Arnold transform to enhance its privacy. The considerable contribution of this presented scheme is for copyright protection and authentication of the digital images. The future scope of this scheme is an optimization method can also be used for different images to make it adaptive. Experimental results show that it sustain the noise and various image processing, geometric attacks and also improve the performance in terms of imperceptibility, capacity robustness, and security.

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Optimized Routing Information Exchange in Hybrid IPv4-IPv6 Network using OSPFv3 & EIGRPv6

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***Abstract*—IPv6 is the next generation internet protocol which is gradually replacing the IPv4. IPv6 offers larger address space, simpler header format, efficient routing, better QoS and built-in security mechanisms. The migration from IPv4 to IPv6 cannot be attained in a short span of time. The main issue is compatibility and interoperability between the two protocols. Therefore, both the protocols are likely to coexist for a long time. Usually, tunneling protocols are deployed over hybrid IPv4-IPv6 networks to offer end-to-end IPv6 connectivity. Many routing protocols are used for IPv4 and IPv6. In this paper, researchers analyzed the optimized routing information exchange of two routing protocols (OSPFv3 & EIGRPv6) in hybrid IPv4-IPv6 network. Experimental results show that OSPFv3 performs better than EIGRPv6 in terms of most of the parameters i.e. convergence time, RTT, response time, tunnel overhead, protocol traffic statistics, CPU and memory utilization.**

Keywords—EIGRPv6; OSPFv3; Hybrid IPv4-IPv6; Route Redistributio; Route Summarization; Tunneling

I. INTRODUCTION

The Internet is growing day by day throughout the world. Everyday, different types of devices are becoming part of the Internet. All these devices require IP address for communication with each other over the network. In Internet, "Internet Protocol" (IP) is the most broadly used routed protocol [1]. There are two versions of IP: IPv4 and IPv6. IPv4 protocol uses 32-bit addressing structure. It was introduced in 1981. Due to the anticipated shortage of its addresses, IPv6 protocol was designed by the "Internet Engineering Task Force" (IETF) in 1990 [2]. IPv6 uses 128-bit addressing scheme. The future is of IPv6 [3]. It will gradually replace IPv4 throughout the world. IPv4 is comparatively easy to configure, however, IPv6 is more complicated due to its nature of complex addresses [4]. Furthermore, IPv6 has more advantages than IPv4 in terms of header format simplification, efficient routing, built-in security, QoS and route optimized mobility [5, 6]. There are millions of devices around the world which are being used in IPv4; therefore, it is not easy to transit at once. A study report shows that after twenty-five years, it has replaced approximately 10 – 15 % around the world [7]. The core issue is compatibility and interoperability between the two protocols. Therefore, both the protocols are needed together for a long time. Multiple transition solutions i.e., dual stack, tunneling and translation techniques have been designed to work in the hybrid IPv4-IPv6 network [8].

Routing becomes a challenging task in case when both IPv4-IPv6 protocols are co-existed in a network. The co-existence of IPv4 and IPv6 at "Internet Service Providers" (ISPs) bring the major challenges for the users. Packet traversing is one of the main challenges, in which communication is between two IPv6 hosts over an IPv4 network. Packet traversing is achieved through tunneling. There are multiple tunneling standards [9]. These two IP protocols are not interoperable with one another. Each supports different kinds of routing protocols. For example, (RIP, IGRP, EIGRP, OSPF and BGP) are routing protocols of IPv4 network while (RIPng, EIGRPv6, OSPFv3 and BGPv4) are routing protocols of IPv6 [10]. EIGRP and OSPF are widely used in corporate and enterprise networks. However, their configuration method, metrics, administrative distance, convergence speed and performance are differed to each other.

In a corporate network, there are many routes in a routing table of the router. It can be million in case of IPv4, while it can be billion in case of IPv6. Some routes are directly connected while the remaining are transported by other routers. These transferred routes in a router may stretch by using "Route Redistribution". After that, the size of the routing table is increased. In dynamic routing, it will increase the convergence time over the network. More convergence time will require more bandwidth and it affects the performance of the router. "Route Summarization" is used in routing protocols to minimize the convergence time and to reduce the size of the routing table. Both routing protocols (EIGRP & OSPF) support route summarization and route redistribution in hybrid IPv4-IPv6 network [10].

This study focuses on the performance analysis and comparison of optimized routing information exchange in hybrid IPv4-IPv6 network by using EIGRPv6 and OSPFv3 based on convergence time, tunnel overhead, protocol traffic statistics, end-to-end delay, response time, packet delivery ratio, CPU and memory utilization. We deploy and configure this mechanism on CISCO routers by using "Graphical Network Simulator" (GNS). To achieve these goals, we test these two routing protocols in hybrid IPv4-IPv6 network with the help of a simulator and conclude the results either, which one is more suitable for the "Next Generation Network" (NGN). The rest of the part of this paper is structured as follows: Section II presents related work and compares this research work to existing studies. Section III highlights a brief description of the routing protocols and their differences. Section IV gives the brief description of transition mechanisms. In section V, we display the experimental results. Finally, section VI concludes the paper.

II. Related Work

Performance of routing protocols have been analyzed in many papers [11, 12, 18, 22, 23]. The authors have examined and compared the performance of different routing protocols (RIP, EIGRP and OSPF) by using multiple simulators. The researchers tested the different applications based on several parameters and concluded the results that EIGRP performed better in terms of convergence time, CPU utilization, throughput, end-to-end delay and bandwidth control as compared to RIP and OSPF. In [22], researchers observed and compared the performance of two routing protocols (EIGRP and OSPF) in three different networks with same topologies. One network is configured with EIGRP, second is configured with OSPF and third is configured with EIGRP and OSPF. This research study shows that EIGRP consumed fewer system resources as compared to OSPF in real time applications. Although, in these related works, researchers compared routing protocols with IPv4. However, these studies lack the evaluation for the IPv6.

Other closely related works are presented in [4, 13, 14, 15, 24, 26] in which authors compared and analyzed two routing protocols (OSPFv3 & EIGRPv6) based on their performance in a small network. In [4], the researchers focused on configuration analysis and compared IPv6 configuration commands with IPv4 configuration commands and analyzed that IPv6 configuration commands are more complex than IPv4 configuration commands because of IPv6 addresses complexity. Research study [15] showed that IPv6 provided better QoS as compared to IPv4. In [13, 27] studies, the researchers tested routing protocols in IPv6 network and examined that EIGRPv6 has the advantages over OSPFv3 in term of convergence time in a small network with the help of multiple simulators. These studies did not specifically evaluate the performance of the routing protocols in the hybrid IPv4-IPv6 network.

Further very close related works of this paper are [1, 16, 17, 19, 28, 29] in which the researchers compared and analyzed the performance of dissimilar routing protocols in hybrid IPv4-IPv6 network based on user traffic. Research studies [19, 28, 29, 31] focused on transition methods. Researchers discussed in detail the pros and cons of different transition methods in terms of QoS and security perspective. In [16], the researchers investigated the video protocols traffic in dual-stack and tunneling (IPv6to4 and IPv6in4). Results showed that EIGRPv6 gave better performance in terms of packet loss and CPU utilization in dual stack transition method. Dual-stack is a transition mechanism in which a network or a host runs both IPv4 and IPv6 addresses. Both versions of IP protocol are configured and operated simultaneously on the device. In [17], the researchers experimented EIGRP and OSPF in different topologies of dual-stack network. Their study showed that EIGRP is much better than OSPF in packet loss performance.

Although, the researchers evaluated the performance of routing protocols (EIGRP & OSPF) in IPv4 networks, in pure IPv6 networks and in dual-stack networks based on numerous parameters like (RTT, packet loss, throughput, end-to-end delay, convergence time, jitter, CPU and memory utilization) for user traffic. To the best of our knowledge, these two protocols and their behavioral are not tested in tunneling. It is strongly needed to investigate the interoperability of these two routing protocols (EIGRP & OSPF) in tunneling regarding routing information exchange in terms of others parameters like (response time, tunnel overhead, end-to-end delay, hello messages exchange and memory utilization). Our focus in this research paper is to relate the performance of routing protocols (EIGRPv6 & OSPFv3) based on optimized routing information exchange in hybrid IPv4-IPv6 network by using a tunneling technique.

III. Routing Protocols

Routing protocols are classified into two categories: distance vector routing protocols and link state routing protocols. Distance vector routing protocols use “Bellman-Ford” algorithm to calculate the best path, while link state routing protocols use “Dijsktra” algorithm to calculate the best route. RIP, IGRP and BGP are distance vector routing protocols, while IS-IS and OSPF are link state routing protocols. Moreover, EIGRP is considered a hybrid. EIGRP uses “Diffusion Update Algorithm” (DUAL) to calculate the best routes. Routing table consists of calculating best paths in the form of network ID called routes. If the destination route is not in the routing table, then router discards the packet. ISPs use routing protocols per their need to keep the routing tables updated [18]. When IPv6 has been successfully launched as a next generation network, routing protocols have also been upgraded for next generation network.

A. EIGRPv6

Enhance Interior Gateway Routing Protocol (EIGRP) is a CISCO proprietary protocol. It is said to be a hybrid routing protocol, which means it is a crossover between link state and distance vector routing proctors. EIGRP was introduced in 1993 and it is IPv4 supported [19]. EIGRPv6 is the advance version and it is IPv6 supported. It works in the “Autonomous System” (AS). AS is a group of similar routers exchanging routes under the same administrative control [20]. It is said to be a classless routing protocol and supports “Variable Length Subnet Mask” (VLSM). VLSMs enable you to allocate required host bits on a granular basis. The main feature of this routing protocol is its unequal load balancing.

There are three tables in the EIGRPv6 routing protocol, which help to routing decisions. Neighbor table, topology/database table and routing table. By default, “bandwidth and delay” are the metrics of EIGRPv6 to determine the best path, however, reliability, load and MTU may also be used as metrics. It sends “hello messages” to its neighbors after every 5 seconds on the links (Ethernet and FDDI) and after 60 seconds on the links (Frame Relay and SMDS) [21]. Its administrative distance is 90. It uses as multicast updates instead of broadcast. FF02::A is multicast address [3].

B. OSPFv3

Open Shortest Path First (OSPF) is a link state routing protocol. It is an open standard and the most popular routing protocol proposed by IETF in 1988. IETF published a revised version of OSPFv3 for IPv6 in 1999. It is characterized by stability and scalability. Due to open standard, its specification is freely available [21]. It divides the network into areas to group similar routers together for better management. If there are multiple areas, then one area is said to be a "backbone area". Backbone area is referred to as "area 0". Multiple areas are connected to the backbone through virtual links. It is also a classless routing protocol and supports VLSM [22]. It also supports load balancing up to 16 equal paths. Cost is the metric to determine the best path. Its administrative distance is 110.

In OSPFv3, there are also three tables. Neighbor table, topology table and routing table. The topology information is carried in "Link State Advertisement" (LSAs). There are several types of LSAs. Some are normally used. "Router link LSA" (LSA type 1) describes the state of the router's interfaces, "network link LSA" (LSA type2) represents a broadcast in LAN and describes the routers connected to the LAN, "network summary LSA" (LSA type3) is for Area Border Router (ABRs), "Autonomous System Border Router (ASBR) summary LSA" (LSA type4), "external LSA" (LSA type5) and "Not So Stubby Area (NSSA) external LSA" (LSA type7) [23]. Five types of packets: Hello, Database Description (DBD), Link State Request (LSR), Link State Update (LSU) and Link State Acknowledgment (LSACK), which are used in the normal operation of OSPFv3 [24]. It sends "hello messages" after every 10 seconds to its neighbor for establishing and maintaining the relationship.

In OSPFv3, the method of Hello packets has changed. The ID of interface must be copied into the Hello packet before the Hello packet is sent [25]. If a neighbor does not reply within 40 seconds (dead interval time) then the neighbor is considered as dead. Neighbor can be in a different state. There are seven states in OSPFv3 and they are (Down, Init, 2Way, ExStart, Exchange, Loading and Full) [26]. In multi-access network, it works as "Designated Router" (DR) or "Backup Designated Router" (BDR). In OSPFv3, DR/BDR routers are identified by their routers ID's instead of their IP addresses. DR is the responsible for making adjacencies with all neighbors on a multi-access network (such as Ethernet or FDDI). BDR is used to provide redundancy in the network. If DR fails, then the BDR immediately becomes the new DR. Multicast LSAs are used to communicate with each other. LSAs are sent to the DR/BDR at FF02::6 and other routers at FF02::5 [3].

C. *Route Redistribution*

Route redistribution is the process of advertising routes from one routing protocol to another routing protocol [9]. When a router relates to two dissimilar routing protocols, then the routes cannot be advertised from one routing protocol to another routing protocol without redistribution. Static and directly connected routes may also be advertised into routing protocols through redistribution [10]. During the redistribution process, metric is used by the routing protocol in which the routes would be advertised [26]. Redistributed routes become external routes into the routing table. In our scenario, there are 15 static routes and 15 loopback interfaces on "Router-1" as it has shown in figure 1 and these routes can be advertised into routing protocol through redistribution. EIGRPv6 and OSPFv3 both support redistribution for IPv4-IPv6.

D. *Route Summarization*

Route summarization, also termed as route aggregation is the optimization process in which different advertised routes can be consolidated during convergence between routers. There can be millions of routes in a routing table. Route summarization decreases the number of routes in the routing table. It advertises a single route that is called summary [24]. It will increase the speed of convergence, decrease the size of the routing table in memory and reduce the routing update traffic. In our scenario, there are 15 static routes and 15 loopback interfaces on a "Router-1" as it is shown in figure 1 and these routes can be advertised into routing protocol as a summary address through summarization. EIGRPv6 and OSPFv3 both support summarization for IPv4 and IPv6. During experiments, we will perceive the impact of summarization in these protocols.

E. *Protocol Comparison*

OSPFv3 and EIGRPv6 have many similar features: both support VLSM and "Classless Inter-Domain Routing" (CIDR). CIDR is also known as "prefix routing". It just identifies the number of bits of the network ID and host ID. Both use 32-bit router ID's. Both maintain three tables. Both send partial routing updates when any change occurs instead of periodic [12]. Both support route summarization and redistribution.

EIGRPv6 is only supported on CISCO routers because of CISCO proprietary while OSPFv3 is an open standard and easily configured on all brands that's why it is also known as the industry standard [27]. EIGRPv6 usually uses a combination of metrics to calculate the best path while OSPFv3 uses only one metric and that is cost. An administrative distance of EIGRPv6 is 90 while OSPFv3 is 110. Lower administrative distance means high priority if both routing protocols are running on the same device. EIGRPv6 is designed for flat network while OSPFv3 is designed for large flat network, its hierarchical nature gives an advantage over EIGRPv6. EIGRPv6 is simple to be configured while the configuration in OSPFv3 is difficult because it works in areas and there are numerous types of areas, each of them can be stubby, transit or not so stubby. Differences in these areas and their purposes may increase the level of understanding and difficulty of configuration [4].

1) Configuration Point of View: Some comparisons are given below per their configuration. Both protocols (EIGRPv6 & OSPFv3) are same configured in interface mode. Both protocols require 32-bit router IDs and it is configured in global configuration mode. OSPFv3 demands enter its router ID before its configuration while EIGRPv6 does not require its router ID before its configuration. Route redistribution is configured in global configuration mode in both protocols. In OSPFv3, route summarization is configured in global configuration mode while in EIGRPv6, it is configured in interface mode. When we advertise external routes in EIGRPv6 as a summary address, it displays in routing table with code “D” as an EIGRP route as shown in figure 3 while when we advertise external routes in OSPFv3 as a summary address, it displays in routing table with code “OE2” as an OSPF external route as shown in figure 5.

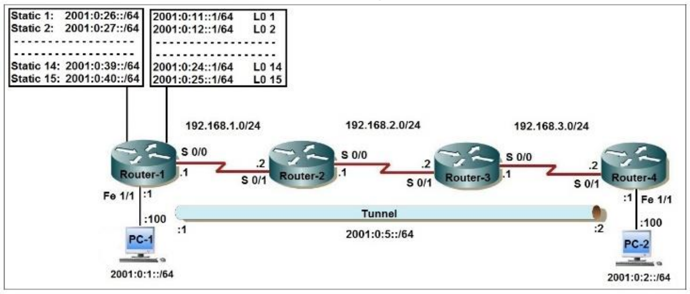


Fig. 1. IPv6 tunnel over IPv4

IV. Hybrid IPv4-IPv6 Network

IPv4 and IPv6 are not compatible with each other. ISPs must provide services in both IPv4/IPv6 network because users can be mixed. Some users are only in IPv4 network, some are in dual-stack and in future, there would be only IPv6 network users [28]. The primary reason for the transition is that the user may need to access data that will only be available in IPv6. There are multiple modes of transition:

- Dual-Stack
- Tunnelling
- Translation

A. Dual-Stack

In dual-stack mechanism, IPv4 and IPv6 are established and operated simultaneously on the device. It is a transition technique. It allows to IPv4 supported device to communicate with only IPv4 supported while IPv6 based nodes can communicate explicitly with IPv6 based nodes [16]. However, IPv6 based nodes can’t communicate with IPv4 nodes. It is the easiest technique but it also has some complex network management and troubleshooting issues.

B. Tunneling

Tunnel is a logical connection which is created over the existing network. In tunneling mechanism, IPv6 traffic is sent over existing IPv4 network by encapsulating in IPv4 header at one end [29]. At the second end of the tunnel, node extracts the IPv6 datagram from the IPv4 header and forwards it to its actual IPv6 network. Interesting part of the tunneling is that the start and end nodes of the tunnel are dual-stack enabled. There are multiple tunneling approaches and some of them are:

- Configured Tunnelling
- 6to4 Tunnelling
- GRE Tunnelling

1) Configured Tunneling: It is a static and point-to-point tunnel. In this tunnel, both ends are manually configured. A permanent virtual link is built between two IPv6 networks over the IPv4 network. Both end nodes of the tunnel have IPv4 route able addresses and an IPv6 address is required to configure a tunnel. This tunnel is not scalable because it must be configured manually. It is easy to deploy and available on most platforms.

2) 6to4 Tunneling: It is an automatic and point-to-multipoint tunnel. In this tunnel, both ends are automatically configured with IPv6 global address prefix “2002:wwwxx:yyzz::/16”. The “wwwxx:yyzz” is the colon-hexadecimal representation of a public IPv4 address and is obtained dynamically from the IPv4 address embedded in the IPv6 destination address. It is not only a tunneling technique but an address assignment as well. It is used to assign global IPv6 address in the network [30]. It is introduced to provide the configuration simplicity. It is less secure than static tunnel.

3) Generic Route Encapsulation (GRE Tunneling): It is also a static and point-to-point encapsulation tunnel. In this tunnel, both ends are manually configured. Like a configured tunnel, it is also configured between two points with a separate IPv6 address over the IPv4 network. In GRE tunnel, end-points are authenticated by a simple key. This simple key is transmitted in clear text during the setup of the tunnel. In GRE, IP protocol type 47 traffic would must be opened for inbound/outbound.

C. Translation

It is a simple method. It translates the IPv6 traffic to IPv4 traffic without encapsulation. In this method, the traffic is simply converted into destination form. There are two translation methods:

- NAT-PT
- NAT64

1) NAT-PT: “Network Address Translation-Protocol Translation” (NAT-PT) method converts IPv6 traffic to IPv4 and vice versa. It is configured as statically or dynamically. This method is like NAT function but protocol translation function is additional in it. NAT-PT is attached with an “Application Layer Gateway” (ALG) functionality that can convert “Domain Name System” (DNS) mappings between protocols. ALG consists of a security components that enhances a firewall or NAT. It allows customized NAT traversal filters to be plugged into the gateway.

2) NAT64: One drawback in NAT-PT was its attachment with ALG. It is said to be a burden to deployment. NAT64 also originated DNS64. Both are configured independently. NAT64 can be deployed as stateless or state-full.

V. Experiments and Results

In this study, GNS3 simulator is used for all experiments. GNS3 is a network emulator software and it is used to simulate complex network. It uses dynamips emulation software to simulate CISCO IOS. Dynamips is an emulator computer program and can emulate the hardware of the CISCO series routing platforms by directly booting an actual CISCO IOS image into the emulator. That’s why its results are very close to the results obtain by real routers and it can valid for decisions. Figure 1 shows the topology of our network design. Topology consists of four CISCO 7200 series routers connected to each other with serial link with an IPv4 addresses. By default, serial link provides 1.5 mbps bandwidth. Two virtual hosts (PC-1 & PC-2) are also connected through fastEthernet link with edge routers with IPv6 addresses. By default, the fastEthernet link supports 100 mbps bandwidth. Table-1 shows the description of devices.

Router-1 and Router-4 are dual-stack routers. An IPv6 tunnel is established between two edge routers (Router-1 & Router-4) over IPv4 network. We used static tunnel because studies show that it is more secure and its working is better than others. We advertised all static routes and loopback interface routes as a summary address through this tunnel and then gather results. Data will be collected by using router's commands. Whireshark tool is also used for packets capture and analysis. In this study, all experiments are repeated 5 times during different times of the day and the reported results are averaged over these runs. Performance evaluation of OSPFv3 and EIGRPv6 is measured for this topology based upon convergence time, round trip time (RTT), response time, protocol traffic, tunneling overhead, CPU and memory utilization.

TABLE I. DEVICES & DESCRIPTION

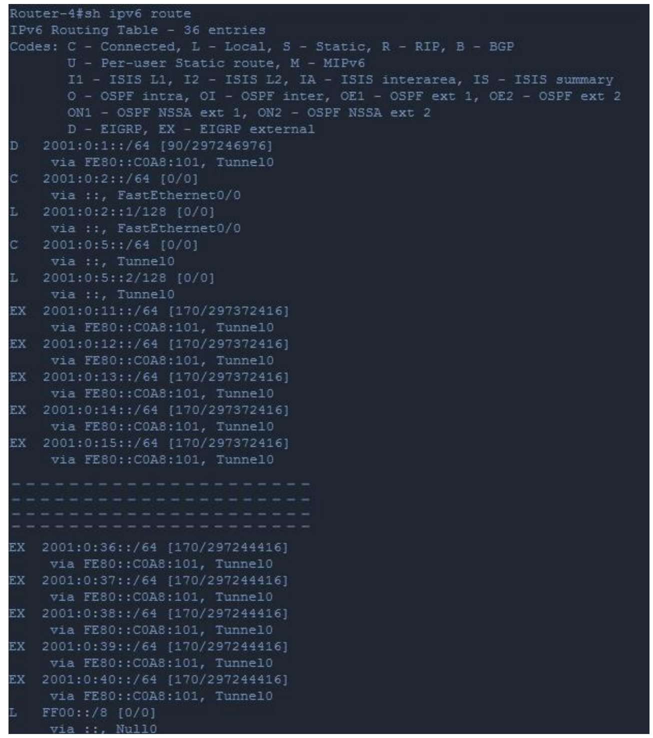
S#	Device	Description
01	Router	GNS3 based CISCO 7200 series, IOS v. 12.4(11)T1, c7200-adventerprisek9-mz.124-11.T1.bin Total = 4
02	PC	GNS3 based IPv6 Client Machines Total = 2

A. EIGRP Configuration

Our testbed is a hybrid IPv4-IPv6 network. So, we need to configure both versions of routing protocols as well as routed protocols in our scenario. Router-1 and Router-4 are dual stack routers. First, make sure IPv6 routing is enabled on these two routers then assign IP addresses on all interfaces per topology. EIGRP works in AS. We configured AS 10 for EIGRP and AS 100 for EIGRPv6.

Now create a tunnel interfaces on edge routers and assign IP addresses per figure 1. Configure source and destination IP addresses in tunnel interface. Finally, select tunnel mode and configure EIGRPv6 with AS 100.

1) EIGRPv6 Route Redistribution: In our scenario, there are total 15 static routes and 15 loopback interface routes. Create all static routes in global configuration mode. Create all loopback interfaces and then assign IPv6 addresses. Now redistribute all these routes into EIGRPv6. Both versions of EIGRP are redistributed routes in global configuration mode. We can see the advertised routes as external routes in routing table as shown in figure 2 given below.



```
Router-4#sh ipv6 route
IPv6 Routing Table - 36 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
D   2001:0:1::/64 [90/297246976]
     via FE80::C0A8:101, Tunnel0
C   2001:0:2::/64 [0/0]
     via ::, FastEthernet0/0
L   2001:0:2::1/128 [0/0]
     via ::, FastEthernet0/0
C   2001:0:5::/64 [0/0]
     via ::, Tunnel0
L   2001:0:5::2/128 [0/0]
     via ::, Tunnel0
EX  2001:0:11::/64 [170/297372416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:12::/64 [170/297372416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:13::/64 [170/297372416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:14::/64 [170/297372416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:15::/64 [170/297372416]
     via FE80::C0A8:101, Tunnel0

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EX  2001:0:36::/64 [170/297244416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:37::/64 [170/297244416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:38::/64 [170/297244416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:39::/64 [170/297244416]
     via FE80::C0A8:101, Tunnel0
EX  2001:0:40::/64 [170/297244416]
     via FE80::C0A8:101, Tunnel0
L   FF00::/8 [0/0]
     via ::, Null0
```
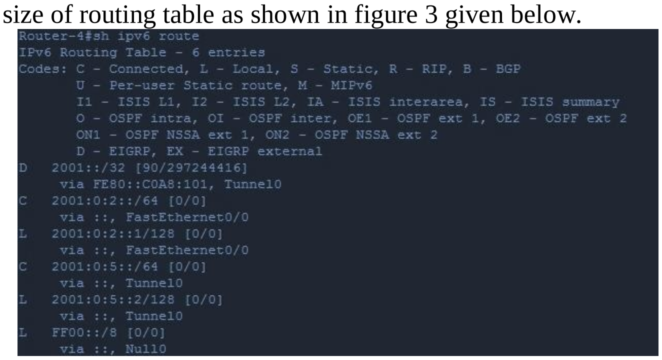

Fig. 2. EIGRPv6 Route Redistribution

2) EIGRPv6 Route Summarization: Multiple external routes are advertised in routing protocols. Routing table size will increase if they are not summarized. Configure summary address in tunnel interface. Route summarization decreases the size of routing table as shown in figure 3 given below.



```
Router-4#sh ipv6 route
IPv6 Routing Table - 6 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
D   2001::/32 [90/297244416]
     via FE80::C0A8:101, Tunnel0
C   2001:0:2::/64 [0/0]
     via ::, FastEthernet0/0
L   2001:0:2::1/128 [0/0]
     via ::, FastEthernet0/0
C   2001:0:5::/64 [0/0]
     via ::, Tunnel0
L   2001:0:5::2/128 [0/0]
     via ::, Tunnel0
L   FF00::/8 [0/0]
     via ::, Null0
```

Fig. 3. EIGRPv6 Route Summarization

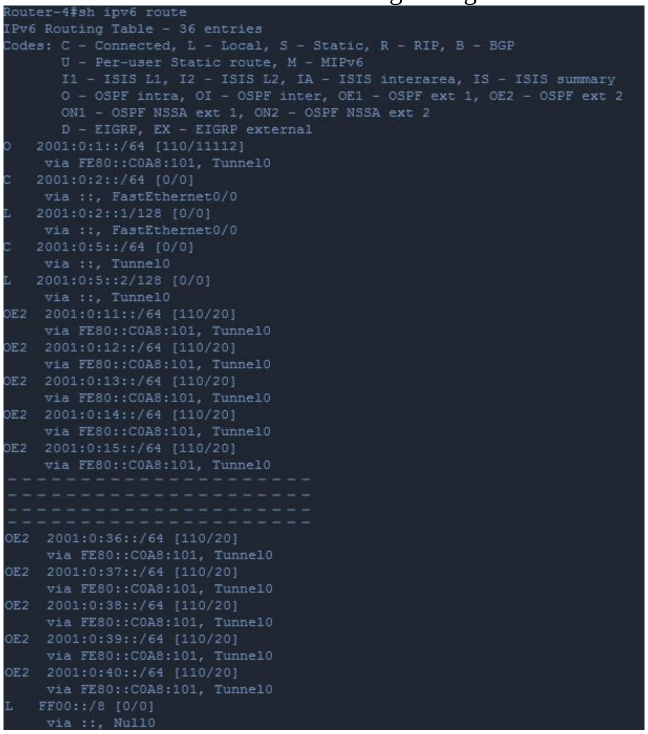
B. OSPF Configuration

OSPF works in different areas. We configured area 0 for OSPFv2 and area 0 for OSPFv3. OSPFv2 is configured in global configuration mode while OSPFv3 is configured per interface.

Now create a tunnel interfaces on edge routers and assign IP addresses per figure 1. Configure source and destination IP addresses in tunnel interface. Finally, select tunnel mode and configure OSPFv3 with area 0.

1) OSPFv3 Route Redistribution: Create all static routes. Create all loopback interfaces and then assign IPv6 addresses. Now redistribute all these routes into OSPFv3. Both versions of OSPF are redistributed routes in global configuration mode.

We can observe that all these routes are present in routing table as external routes as shown in figure 4 given below.


```
Router-4#sh ipv6 route
IPv6 Routing Table - 36 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
O   2001:0:1::/64 [110/11112]
     via FE80::C0A8:101, Tunnel0
C   2001:0:2::/64 [0/0]
     via ::, FastEthernet0/0
L   2001:0:2::1/128 [0/0]
     via ::, FastEthernet0/0
C   2001:0:5::/64 [0/0]
     via ::, Tunnel0
L   2001:0:5::2/128 [0/0]
     via ::, Tunnel0
OE2  2001:0:11::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:12::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:13::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:14::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:15::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
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OE2  2001:0:36::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:37::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:38::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:39::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
OE2  2001:0:40::/64 [110/20]
     via FE80::C0A8:101, Tunnel0
L   FF00::/8 [0/0]
     via ::, Null0
```

Fig. 4. OSPFv3 Route Redistribution

2) OSPFv3 Route Summarization: Configure summary address in global configuration mode. Routing table after summarization is given below in figure 5.

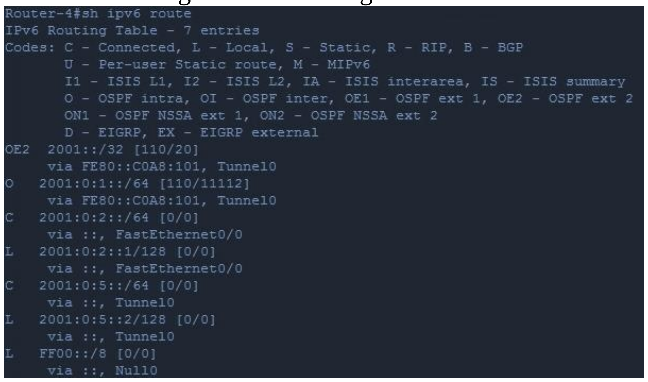

```
Router-4#sh ipv6 route
IPv6 Routing Table - 7 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
OE2  2001::/32 [110/20]
     via FE80::C0A8:101, Tunnel0
O   2001:0:1::/64 [110/11112]
     via FE80::C0A8:101, Tunnel0
C   2001:0:2::/64 [0/0]
     via ::, FastEthernet0/0
L   2001:0:2::1/128 [0/0]
     via ::, FastEthernet0/0
C   2001:0:5::/64 [0/0]
     via ::, Tunnel0
L   2001:0:5::2/128 [0/0]
     via ::, Tunnel0
L   FF00::/8 [0/0]
     via ::, Null0
```

Fig. 5. OSPFv3 Route Summarization

C. Convergence Time

When a router is exchanging its topological information with other routers within the network and try to complete its routing table, it is said to be a convergence state. In convergence state, only routing information is exchanged. Convergence time is the measure of how fast a set of routers reach the state of convergence. It is an important performance indicator for routing protocols. The size of the network also plays an important role. A large network will converge slower than small network. In our experiments, we calculated convergence and re-convergence time of both routing protocols (EIGRPv6 & OSPFv3) over the IPv6 tunnel before and after summarization as shown in figures 6 & 7.

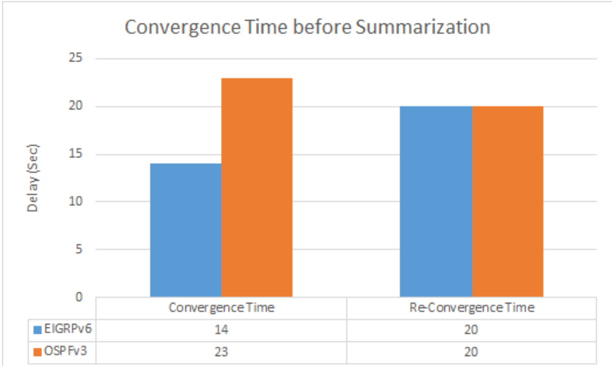


Fig. 6. Convergence Time before Summarization

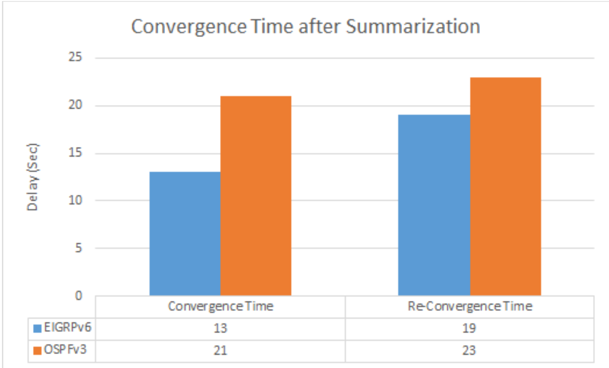


Fig. 7. Convergence Time after Summarization

In the figures 6 & 7, average convergence time for multiple rounds (5 times) is noted for both routing protocols from “up state of serial interface” to “adjacent state of tunnel interface” on Router-4. We observed that EIGRPv6 provides fast convergence as compared to OSPFv3 in before and after summarization. We also observed that summarization plays an important role in fast convergence for both protocols.

D. Round Trip Time (RTT)

It is the total time taken by a packet to travel from source to destination and time taken by an acknowledgement back. RTT is a key parameter in the network layer. “Transmission Control Protocol” (TCP) protocol is used on top of the “Internet Control Message Protocol” (ICMP) to ping messages to get the RTT results between sender and receiver. Figure 8 shows the average RTT statistics for multiple rounds by using two routing protocols (OSPFv3 & EIGRPv6) without summarization over the IPv6 tunnel. Results are calculated from PC-2 to Loopback-1.

For validating the results, we calculated “coefficient of variation” (CV). General formula of CV is given below (1). Where S is the standard deviation and $\overline{X}$ is the mean. In this experiment, calculated CV of EIGRPv6 is 63 ms while CV of OSPFv3 is 37 ms. Results show that the RTT of OSPFv3 is much better than EIGRPv6 without summarization.

$$\mathrm{CV} = \frac{\mathrm{S}}{\overline{\mathrm{X}}} * 100 \qquad (1)$$

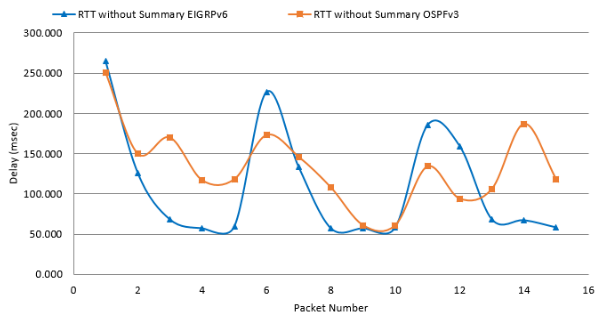


Fig. 8. Round Trip Time before Summarization

Figure 9 shows the average RTT statistics with summary address over the IPv6 tunnel. Results are calculated from PC-2 to Loopback-1. CV of EIGRPv6 is 45 ms while CV of OSPFv3 is 51 ms in this experiment. Results show that EIGRPv6 provides better performance than OSPFv3 with route optimization.

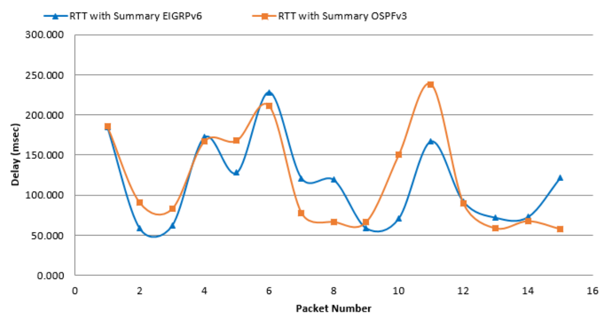


Fig. 9. Round Trip Time after Summarization

E. Response Time

It is the total time that it takes to respond to a request for the service. In our experiments, response time is measured for both OSPFv3 and EIGRPv6 over the hybrid IPv4-IPv6 network before and after summarization. Figure 10 shows the average response time for different rounds without summarization. Results are calculated from PC-2 to Loopback-1. CV of EIGRPv6 is 81 ms while the CV of OSPFv3 is 79 ms. Results show that OSPFv3 has an advantage over EIGRPv6 in this experiment.

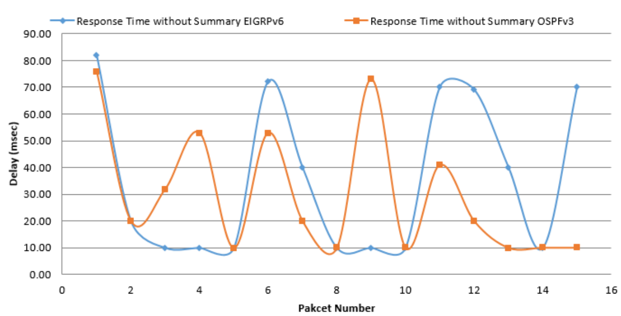


Fig. 10. Response Time before Summarization

Figure 11 shows the average response time with summary address over the IPv6 tunnel. CV of EIGRPv6 is 57 ms while CV of OSPFv3 is 72 ms. Results show that the response time of EIGRPv6 is much better than OSPFv3 with summarization.

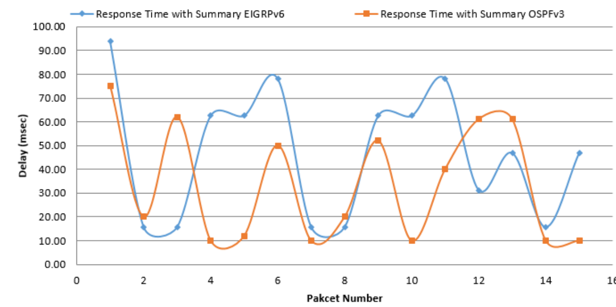


Fig. 11. Response Time after Summarization

F. Tunnel Overhead

Figure 12 displays the status of tunnel in OSPFv3 and EIGRPv6 with same time slot (9 mints) on Router-1 before summarization. Statistics show that Router-1 sent 131 packets to its neighbor and received 118 packets through tunnel by using EIGRPv6 while with OSPFv3, it sent only 75 packets and received 65 packets.

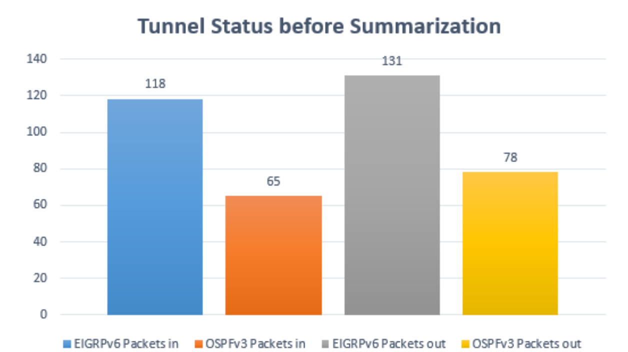


Fig. 12. Tunnel Overhead before Summarization

Figure 13 displays the tunnel overhead after summarization. It can be observed that after summarization, OSPFv3 packets are reduced while EIGRPv6 packets are increased. Results show that in EIGRPv6, total 126 packets are received by tunnel and 134 packets are sent through the tunnel while in OSPFv3, total 61 packets are received and 75 packets are sent. It means EIGRPv6 has approximately 50% higher tunneling overhead than OSPFv3.

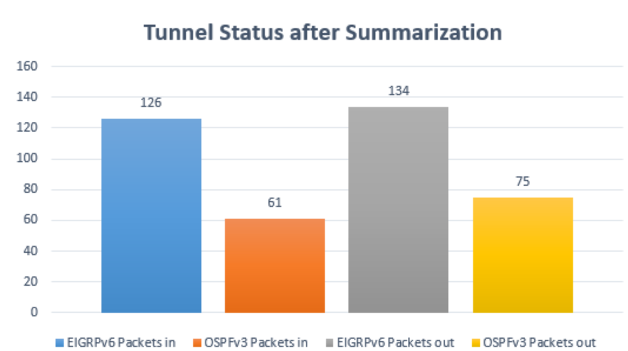


Fig. 13. Tunnel Overhead after Summarization

G. Protocol Traffic Statistics

Figure 14 highlights the traffic statistics of EIGRPv6 and OSPFv3 with same time quantum (6 mints) on Router-1 without route summarization. Statistics show that during this time interval EIGRPv6 has sent 144 "Hello" packets and received only 71 Hello packets while OSPFv3 has sent and receive only 33 Hello packets. It means EIGRPv6 has a higher ratio of Hello packets than OSPFv3 in hybrid IPv4-IPv6 network.

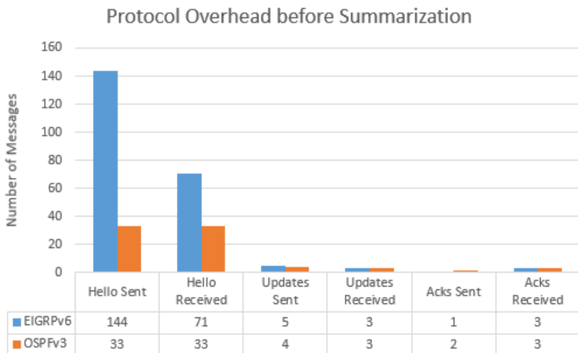


Fig. 14. Protocol Traffic Statistics before Summarization

Figure 15 shows the traffic statistics of EIGRPv6 and OSPFv3 with same time quantum (6 mints) on Router-1 with route summarization. Results show that EIGRPv6 has sent 169 Hello packets and received only 83 Hello packets while OSPFv3 has sent and receive only 33 Hello packets. It means, after summarization, EIGRPv6 has a higher ratio of Hello packets while Hello of OSPFv3 remains same. It can be observed that performance of OSPFv3 is much better than EIGRPv6 in summarization.

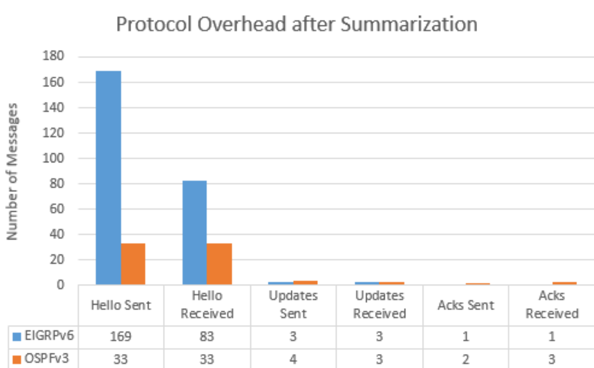


Fig. 15. Protocol Traffic Statistics after Summarization

H. CPU & Memory Utilization

CPU utilization means the percentage of CPU time taken by a running process. CPU utilization is measured using the command "show process cpu" in routers. High CPU utilization may cause the packet loss, delay and slow processing of packets. Memory utilization means the sum of the memory used by all processes listed. Memory utilization is measured using the command "show process memory" in routers. High memory utilization may cause to increase the CPU utilization. Figure 16 shows the comparison of CPU utilization of EIGRPv6 and OSPFv3 without route summarization with same time quantum (2 mints) in hybrid IPv4-IPv6 network. Statistics show that OSPFv3 has better performance of CPU utilization as compared to EIGRPv6.

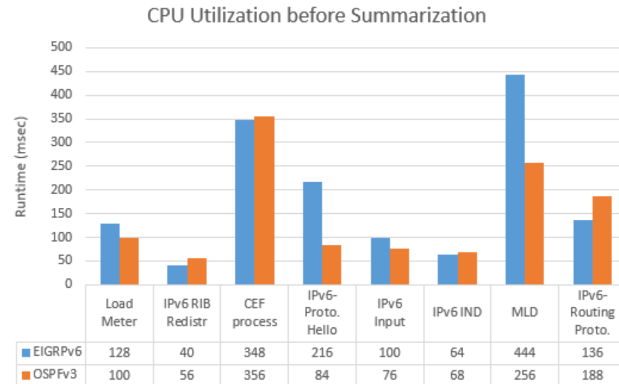


Fig. 16. CPU Utilization before Summarization

Figure 17 shows the comparison of CPU utilization of EIGRPv6 and OSPFv3 after route summarization with same time quantum (2 mints) in hybrid IPv4-IPv6 network. Statistics show that OSPFv3 has better performance of CPU utilization as compared to EIGRPv6. It can be observed that running processes of OSPFv3 consumed CPU in less time than EIGRPv6.

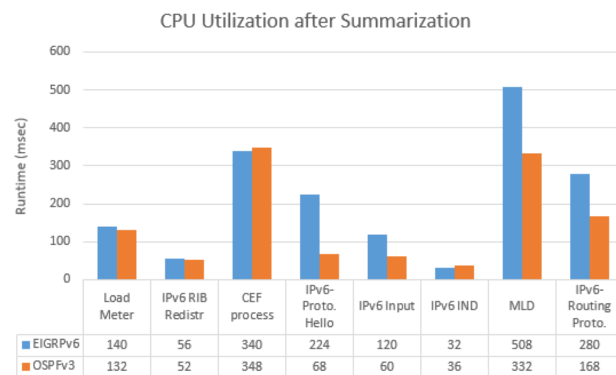


Fig. 17. CPU Utilization after Summarization

Figure 18 shows the comparison of memory utilization of EIGRPv6 and OSPFv3 without route summarization with same time quantum (2 mints) in hybrid IPv4-IPv6 network. Statistics show that OSPFv3 has better performance of memory utilization as compared to EIGRPv6.

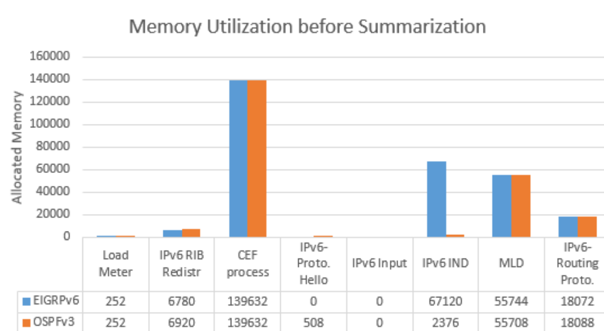
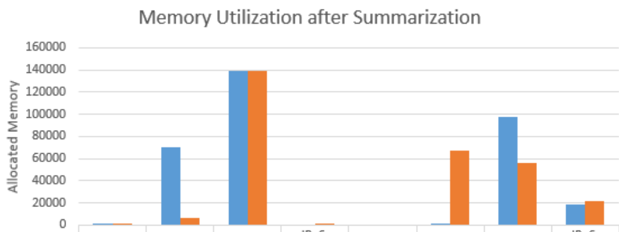


Fig. 18. Memory Utilization before Summarization

Finally, figure 19 displays the comparison of memory utilization of EIGRPv6 and OSPFv3 after route summarization. Statistics show that OSPFv3 has better performance of memory utilization as compared to EIGRPv6.



	Load Meter	IPv6 RIB Redistr	CEF process	IPv6-Proto. Hello	IPv6 Input	IPv6 IND	MLD	IPv6-Routing Proto.
EIGRPv6	252	70208	139632	0	0	1620	97740	18544
OSPFv3	252	6780	139632	508	0	67188	55752	21140

Fig. 19. Memory Utilization after Summarization

VI. CONCLUSION

This study focused on optimized routing information exchange in IPv6 tunnel over IPv4 network by using routing protocols (OSPFv3 & EIGRPv6). Performance of these routing protocols is measured for the parameters like convergence time, RTT, response time, tunnel overhead, protocol traffic statistics, CPU and memory utilization. Experimental results indicated that the performance of OSPFv3 is better than EIGRPv6 with route summarization for most of the parameters like response time, tunnel overhead, protocol traffic statistics, CPU and memory utilization, while EIGRPv6 has shown better performance for convergence time and RTT with summarization. It means, route summarization has an impact to increase the performance of routing protocols. Our future work is to perform the behavioral analysis of OSPFv3 in terms of interoperability between other tunneling protocols like 6to4, GRE and GRE over IPSec.

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Critical Success Factors In Implementing ITIL in the Ministry of Education in Saudi Arabia: An Exploratory Study

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***Abstract*—This paper engages with the ITIL framework for IT service delivery within the specific context of the Ministry of Education in the Kingdom of Saudi Arabia (KSA). A literature review process is used to develop a critical success factors (CSFs) for the implementation of the ITIL framework in an organisation, based on a series of models like TAM and UTAUT, and then put into an overall conceptual model of use behaviour towards ITIL described by [1]. The conceptual model is then deployed in the field through a series of interviews with IT professionals within the Ministry of Education in the KSA. The interviews are semi-structured, and were intended to draw out the corresponding factors for success and the factors that have hindered the implementation of ITIL within this organisation. The data confirm the view of the literature that strong leadership and management involvement is essential both as a success factor in its own right, and as the means by which other success factors are enabled. The findings of paper make two observations. First, the literature sets out a series of quite precise success factors that relate to project management, communication, and quality control. The data presented in this research project demonstrate that in practice it is hard to make clear all of these factors to such a level of detail within the Ministry of Education in Saudi. Second, the implementation of ITIL is more reflexive than the literature and the conceptual model would initially demonstrate.**

Keywords*—*Information Technology Infrastructure Technology (ITIL); Information Technology Service Management (ITSM); Ministry of Education (MoE); the Kingdom of Saudi Arabia (KSA)

I. Introduction

The purpose of this paper is to analyse the factors that affect ITIL implementation in the KSA, specifically in the Ministry of Education, and to enable identification of variables influencing its implementation. Reference [2] analysed the Information Technology Infrastructure Library (ITIL) and found that it is an appropriate framework for best practice, which guides IT Service Management (ITSM) and suggested numerous advantages to an organisation such as it mitigates risk, reduces cost, and improves quality. However, ITSM provides a platform for the construction of IT operations, enabling organisations to deliver quality IT services meeting business requirements and other obligations such as service-level agreements (SLAs). Which is a written agreement documenting the required levels of service.

As we know that education is the most important parts in any country and specially emerging countries like Saudi Arabia. Therefore, the MoE in KSA implemented ITIL and IT managers and experts may be faced with some problems such as meeting customer requirements, poor understanding of dealing with the new operation, poor communication with other departments requesting the operation's execution, the culture of work on the new operations whether that of the employees or the heads of departments in general. Lack of maintenance of new specialist skills for properly implementing this new technology. Thus the aim of this research is to find out and explore what happen there. However, there is no research that has been investigated the implementation of ITIL in MoE.

The aim of this study is to explore concept of critical success factors (CSFs) influencing the implementation of an ITIL framework. Focusing on the Ministry of Education, and adopts an exploration approach. However, the current study takes a different direction which is optimisation of e-services systems in the KSA's Ministry of Education, and variables associated with effective implementation and management of ITIL. Lack of extensive information on the implementation of ITIL in the KSA generally, and the Ministry of Education in particular, has contributed to the decision to carry out this study. The research achieves these aims through answering the following research questions:

RQ1: How is the Ministry of Education implementing ITIL in the KSA?

RQ2: What are some of the crucial factors for successful implementation of ITIL in the Ministry of Education in the KSA?

The research contributes to increase the body of ITIL implementation knowledge in new context which is e-services in Saudi Arabia. The results of paper will enable IT managers and experts in the MoE in Saudi Arabia to better implement, understand, evaluate, and explore success factors of ITIL for their work. The paper includes useful information of ITIL implementation that helps executive management, academics and other organisations to understand ITIL process. This paper framework adopted the concept of CSFs of ITIL which are applied to study the linkage between CSFs and the UTAUT model proposed by [1] to measure users' behaviour impacts toward the use of ITIL implementation. The paradigm of the research employs a qualitative approach through the use of semi-structured interview instruments that were administered over Skype and recorded.

This study employs the thematic analysis technique in order to analyse the data that has been collected from the recorded interviews. The technique also is premised on research and describes the process of identification of data, the coding of the data, creating and discovering themes, the reviewing and the naming of the themes, and the writing of the report.

II. Literature Review

A. Implementation of ITSM

Reference [3] defined ITSM is a framework for delivery of IT that concentrates on the management field of IT processes such IT services and products. The benefits expected from implementing an ITIL framework such as ITSM are: "alignment with business needs, negotiated achievable service levels, predictable consistent processes, efficiency in service delivery, measurable, improvable services and processes, alignment of IT services with current and probable future business needs, improved quality of IT services, a reduction in the long-term costs of service provision, better communication between suppliers and customers, and a common language where terms are defined" [2, 4-6]. The benefits of ITSM can be different based on the objective of the system and administrative aims. Hence, one should determine the aims of IT and a business to obtain a high level of effectiveness and understanding of the organisational needs, directors, and stakeholders who are affected by an organisation's behaviour and policies. The requirements of business apply through the investment of IT made by IT management or stakeholders. These requirements include customer satisfaction by providing IT services to them, improved quality, quick response to customers' needs, and evaluation of service delivery, specifically.

Fig. 1. The components of ITSM (Source: [3])

B. Implementation of ITIL

According to [7] "The concept of ITIL emerged in 1972 when IBM undertook research into the quality of services delivery in order to release its Information System Management Architecture (ISMA). In the 1980s, the first version of ITIL was released by a British public body called the Central Computer and Telecommunication Agency, now known as the UK Office of Government Commerce, with the aim of improving the quality of IT services and best practices observed in the industry. ITIL v2 was released between 2000 and 2002; in that time, Microsoft used it as a foundation from which to develop its operation framework."

The year 2011 saw the publication of ITIL v3. Figure 2 shows the five phases of this were: "Service Strategy," "Service Design," "Service Transition,", and "Continual Service Implementation." The advantage of this new version has been said to be that it "provides a framework for IT governance and proscribed best practice in IT service management" [8].

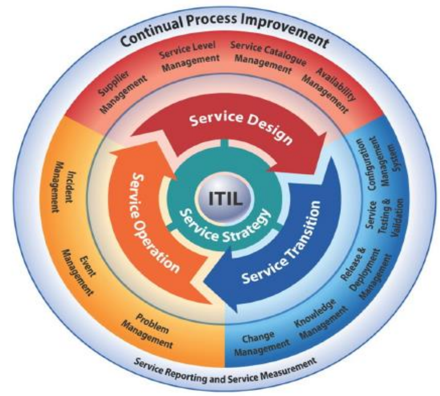

Fig. 2. Service life cycle phases of ITIL (Sources: [7-9])

"**Service strategy**" Service strategy provides the guidance that enables an organisation to define business strategy and is supported by IT strategy effectively through some key activities such as defining the market.

"**Service design**" According to [8], this "provides guidance for the planning and architecting services that fall within a business's strategy."

"**Service transition**" Reference [8] explain that this "provides the guidance for the improvement of capacities, to transfer new and changed services into operations" through recognising the service requirements in service design to be effective and achieved in a service operation, and to control failure risks and disruptions.

"**Service operation**" Service operation manages the services currently utilised by a business, focuses on the practices in service management, and ensures that the delivery of services to the customer by the service provider are achieved effectively.

"**Control service improvement**" Control service improvement (CSI) is something that helps guide how people can identify possible areas for improvement across all service lifecycle stages by measuring and improving efficiency, effectiveness, service levels, technology, and processes used in the whole of services management.

C. Previous Research of ITIL implementation

1) ITSM Based on the ITIL

Reference [9] conducted a systematic review of previous research studies related to ITSM and ITIL implementation. They discussed the implementation from two perspectives: strategies and methods, and implementation status. The authors adopted the categorisation structure of [10]. They used the primary categories of empirical and conceptual approaches. They identified 37 studies. Of these, 21 were published in academic journals, and another 16 were in the form of publications of the proceedings of conferences. Empirical views were captured by means of the use of experiments, case studies, interviews, and multi-method research. Conceptual research was used in order to find relevant studies. The authors used 11 articles based on research in Australia, seven articles based on research in North America, and 17 articles based on research in Europe.

Nine articles discussed the implementation status of ITSM and ITIL based on surveys conducted to address implementation on a broad scale in the US, Brazil, and Europe. This research demonstrated surveys of participant companies from nine articles in 2009. The findings were that 45% of participating corporations were using ITIL, and that 15% were planning for implementation in the US. In Brazil, 21% of the firms were using ITIL and 51% planned to use ITIL. In Europe, 20% of companies in developed countries were using ITSM, and only 8% of companies in transition countries were using ITSM. Furthermore, the research presented CSFs, which include drivers and barriers identified in previous studies for effective implementation of ITSM. Using the Delphi method, this research found that five articles mentioned CSFs. Reference [11] indicated that success factors that influence the implementation of ITIL and ITSM include senior management involvement, communication with employees and stakeholders, and different cultures. In addition, this research found that previous studies focused on top management support as a main factor in the success of projects. However, training of employees, broad organisational participation in process design and providing resources, and readiness to change are all factors in the successful implementation of ITIL and ITSM. Another key finding of the research was that significant outcomes or benefits of both ITIL and ISM included better customer satisfaction and better quality of service [4, 5, 12].

Despite the previous studies that focused on the implementation status of three different levels of analysis worldwide, this research did not explore success factors in developing countries by focusing on the importance of IT functions such as process management and ensuring the implementation or planning of ITIL in enterprises. Further, it did not focus on the organisational level in terms of evaluating the overall implementation status in an organisation and the process level by checking each ITIL process to be implemented in an organisation.

2) ITIL CSFs

Reference [13] discussed CSFs for the implementation of ITIL by using the analytical hierarchy process (AHP) as a systematic approach to improving solutions for the decision problem. The research mentioned that most previous studies have examined ITIL in organisations by using multiple case studies in their projects [2, 5, 11, 14]. Hence, this study applied qualitative analysis to identify CSFs that affect ITIL implementation. The research method used surveys and interviews of 15 experts from a financial company in the United Arab Emirates due to their knowledge about best practices implementation through compliant strategies with other enterprises skilled in IT service management. Data analysis was based on all participants' opinions on this research, and such participants included the IT team, the end users, and top-level managers. The findings were arrived at by using the AHP model to calculate and compare the experts' priorities for each of the existing criteria and then by combining them into groups based on survey results. Table 1 presents the survey results based on the criterion and ranking of participants' priorities. As can be seen in Table 1, the study indicated that IT staff and top-level managers agreed that top management support is a significant factor for the success of ITIL implementation through correct project management [9, 15]. However, the end users considered communication and cooperation to be essential factors for top management to achieve by delivering ITIL to employees and asking them for feedback during the process. However, while this research has illustrated critical factors for ITIL implementation as a systematic approach, the focus on organisational culture was scant and the researchers needed to do more exploration to ascertain the benefits delivered after the implementation of ITIL.

3) Concepts that Influence the Successful Implementation of ITIL

Reference [4] discussed CSFs that influence successful implementation of ITSM with concentration on ITIL organisations in Iran as a developing country. The factors that might affect the implementation of ITSM in organisations include: staff training, top management, communication between departments, usage of consultants and experts, careful selection of software, organisational culture, and customer satisfaction. In addition, processes are essential success factors of ITSM and managers should consider that appropriate techniques and tools should be applied [5, 12].

Reference [4] defined ITSM as a framework for constructing IT operations that enable organisations to "deliver quality IT services" and "to meet business needs" and obligation to SLAs. However, ITIL offers a complete framework of best practices for ITSM, and ITIL has been becoming more common due to the pressure to reduce costs, to push service management into excellence, to introduce SLAs to measure user experience, and because of IT's requirement to conform with regulations [5, 12]. References [4] and [16] identified several challenges that might face an organisation when establishing an ITIL framework. These include resistance of cultural change by staff, resource management problems such as employees, time, and money, and delays in the selection of the right tools.

Reference [4] used a mixed method of research by using a survey and semi-structured interviews and previous studies, and identified 22 success factors to investigate in ITIL implementation.

TABLE I. SURVEY RESULT BASED IN THE CRITERION AND RANKING OF PARTICIPANTS' PRIORITIES (SOURCE: [13])

Criterion		Ranking		
		IT Staffs	Management	Users
F1	Top management support	1	1	4
F2	Change management and organizational culture	7	4	3
F3	Monitoring and evaluation	6	6	7
F4	Communication and cooperation	4	3	1
F5	Project management and governance	5	2	6
F6	Training and competence of involved stakeholder in ITIL project	2	5	2
F7	ITIL process implementation and applied technology	3	7	5

In addition, they used a qualitative approach to get responses from experts through interviewing 13 project managers who were implementing ITIL; 112 questionnaires were used for the analysis.

They also conducted data analysis by applying a robust exploratory factor analysis (EFA) model, which is a measurement scale for analysis of the classic factors that help a researcher choose from many options and to minimise the number of observed variables to fewer factors in order to promote interpretation and reveal hidden structures in the data [17]. The findings classified the concepts based on extracted factors using robust EFA into five groups: "organisational, human resources, project management, managerial, and processes." These concepts affect the success of ITIL implementation. Table 2 shows the extracted components of ITIL and their associated factors.

TABLE II. COMPONENTS OF ITIL AND THEIR ASSOCIATED FACTORS (SOURCE:[4])

Component ID	Component Name	Factor ID	Factor Name
C1	Organizational	OR01	Change-friendly culture
		OR02	Project governance
		OR03	Achieving agreement among different stakeholders
		OR04	IT and business alignment
C2	Human Resources	HR01	Staff awareness
		HR02	Staff training
		HR03	Involving employees in the project
C3	Project Management	PM01	Proper vendors
		PM02	Proper consultants
		PM03	Good relationships with project consultant
		PM04	Proper project management
		PM05	Good project team
C4	Managerial	MG01	Top management support
		MG02	Management belief in project outcomes
		MG03	Optimized budget allocation
C5	Processes	PR01	Continuous performance assessment
		PR02	Continuous monitoring and evaluation of processes
		PR03	Process as a priority
		PR04	Customer focused metrics
		PR05	An integrated process and service based approach

Despite this research contributing to investigating the CSFs in the implementation of ITIL in Iranian organisations, there are some factors which need in-depth information and more exploration, such as management, processes, structure, human resources, and technology: these factors may affect ITSM. Therefore, this research cannot lead to generalisations in developing countries based on its content.

III. ITIL IN SAUDI ARABIA

Historically, the reception of IT in the Gulf Cooperation Council (GCC) was poor, but the current focus is embracement of the technology. In the GCC, the KSA has the highest gross domestic product (GDP) of $653 billion in 2015 and GDP per capita is estimated at $20,813 [18]. The importance of ICT is well understood, and the government continues to finance and support programs and policies for government transactions and services in an electronic manner. The investment in ICT will continue to increase to reflect the demand for information and communication requirements. In addition, numerous organisations continue to adopt ITIL practices such as ITSM solutions in supporting ITIL practices. For example, the Ministry of Defence, the Ministry of Finance, and the Ministry of Education in the KSA continuously invest in and adopt ITIL practices. In the Ministry of Education, the IT department and associated network are dependent on outsourcing service contracts, meaning ITIL is important in the accomplishment of strategic requirements. Network quality and operational efficiencies have continued to improve in the KSA after the standardisation of the Managed Services Unified Platform (MSUP).

IV. THEORIES

In this paper, the framework adopted the concept of CSFs of ITIL which are applied to study the linkage between CSFs and the UTAUT model proposed by [1] to measure users' behaviour impacts toward the use of ITIL implementation. The conceptual framework is the use of ITIL in different contexts and areas previously discussed within the contexts of the Unified Theory of Acceptance and Use of Technology (UTAUT) variables, ITIL critical success factors, and the Technology Acceptance Model (TAM).

A. *Conceptual Framework of Use Behaviour Towards ITIL*

Reference [19] defined ITIL model, and the current study employs this framework that shows in figure 3. To accomplish the study requirements, the conceptual framework in relation with CSFs is discussed, and the focus of the study is a linkage between UTAUT variables and ITIL CSFs founding in figure 3 [1]. Furthermore, the applied technology factor and ITIL implementation are eliminated because these can be seen together as a component of the project management. The proposed conceptual framework disregards the moderators of UTAUT as proposed by [20]. The moderators disregarded "include voluntariness of use, experience, age, and gender." Reference [1] also disregarded these moderators in developing their version of UTAUT. The proposed model contains attitude, which enables measurement of behavioural intention about the requirements of the study. It is premised on the understanding that behavioural intention plays a crucial role viewed from the original TAM. Reference [20] have addressed attitude but have not included these variables in the model because it is directly linked with other cognitions. The proposed model for the current study is the reintroduction of attitude toward using measures in behavioural intention. Figure 3 summarises the proposed model for the conceptual framework of use behaviour towards ITIL.

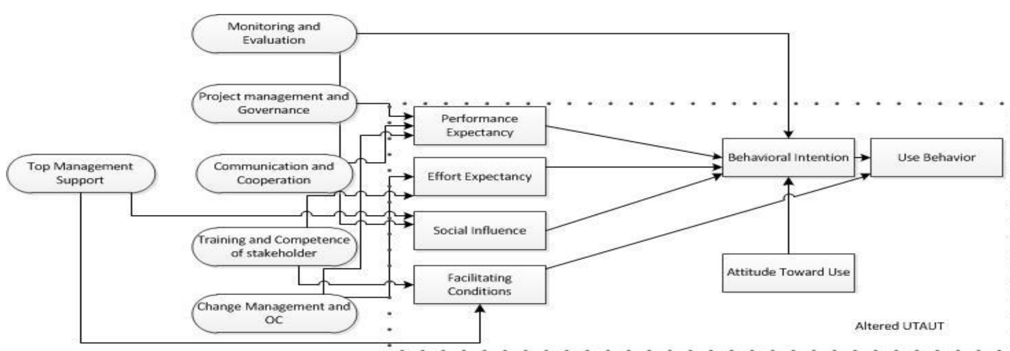

Fig. 3. Proposed model for the conceptual framework of use behaviour towards ITIL (Source: [1])

V. RESEARCH METHODOLOGY

A. *Qualitative Methods*

The appropriateness of the qualitative approach is promised on the description of phenomena approach dependent on the case study data. In addition to the qualitative approach, a case study methodology is utilised with the help of semi-structured interviews to identify ITIL implementation factors in the Ministry of Education in the KSA. Reference [21] defined a case study as "an empirical inquiry" enabling investigation of "a phenomenon within its real-life context" and in depth, particularly in situations whereby the "boundaries" between context and phenomenon are not clear. In the implementation of ITIL in the Ministry of Education, the case study provides and obtains crucial data that relates to users' experiences. Hence, a case study is a preferred approach because of the nature of the study and the sources of the data.

B. The Research Paradigm (Epistemology)

Reference [22] stated that epistemology is the quality of knowledge study and the determination of appropriate methods for acquisition of knowledge. For the purposes of the current study, the approach taken is the interpretivist philosophy, which is explored later on. The reason for adopting this strategy is to analyse the assimilation of human knowledge and behaviour in the ITIL implementation context in the KSA's Ministry of Education. The ultimate expectation is learning the best ITIL knowledge and practices as a determinant in understanding the current IT managers' framework.

C. The Philosophy of Interpretivism

Numerous authors such as [23] and [22] stated that interpretivism targets the recognition of social phenomena through studying the behaviours of individuals and groups who are tasked with a specific activity. In the implementation of e-services ITIL, many employees and managers are involved. These individuals have different perspectives and perceptions of ITIL, and the appropriate strategy to gain knowledge on ITIL implementation is to understand and learn these different perceptions. The study involves the collection of information from four participants who are IT managers and certified in ITIL.

D. Unit of Analysis and Sampling

In accomplishing the requirements of the study and the nature and circumstances of the KSA, a researcher is required to examine massive amounts of data. The data sampling was included four participants of the MoE in the final analysis. Reference [24] further the analysis of interviews through highlighting interview methods including linking elements, recording, and interview venue, and the introduction and conclusion of the interviews

The aim of the interviews is to collect information on the perceptions of certified ITIL experts and IT managers about the component of CSFs in the implementation of ITIL. The appropriate strategy for collecting the data is asking open-ended questions through Skype regarding the experiences of the respondents in ITIL projects.

E. Participants

In this paper four participants were involved, where the participants were required to complete semi-structured interviews: the interviews were carried out for around 30 minutes via Skype since the Skype application enables recording of online information. In determining the participants, the research submitted a request to the head of the Information Technology Department with the aim of identification of individuals involved in the ITIL project and individuals tasked with coordinating and operating e-services system. . The researcher obtained five names at the beginning from the MoE and, emails all of them and got four respondents and, after analysis, the researcher chose four respondents because they agreed to participate in the current research. These participants played an important role in the ITIL project in the Ministry of Education. The positions of these four respondents include Architectural Engineer, Program Manager, Computer Engineer, and Incident Manager. The positions were targeted because of the experiences and exposure of these individuals in ITIL project and ITIL implementation compared to other individuals within the departments or the organisation.

F. Data Analysis (Thematic Analysis)

The current study utilised the inductive approach to analyse the data, the specific transactions, people, and circumstances, to gain an understanding of the relationship between different meanings and contexts [25]. It is important to remember the purpose of the study, which is the identification of the concept of CSFs influencing ITIL practices and ITIL implementation in the Ministry of Education in the KSA. In analysing the data, a thematic analysis approach was also employed. The implementation of the thematic analysis involves numerous stages, and the stages include:

- **Transcribing the collected data:** This stage must be accomplished without consideration of the research tool and data collection methods. The significant component is understanding the collected data and creating ideas, which contribute to the facilitation of coding. The researcher used Skype application to record online information.
- **Producing early codes:** From the collected data, it is imperative to produce early codes. Early codes are used in instances where important content is acquired because of easiness of identification of the nature of the content. For the purposes of this study, the manual approach has employed. After each interview, numerous codes have been identified, such as top management support and monitoring and evaluation.
- **Exploring themes:** The researcher explores the possible themes from the previously analysed data from the previous stage. The themes relate to the early coding and sometimes have to be combined to create themes having stronger links.The same strategy is employed in the current study, and the themes were grouped into a table to appreciate themes, such as leadership, project management abilities and aligning with customer/EndUser.
- **Reviewing themes:** This phase is integral after the data are grouped into appropriate themes. The stage requires rereading the themes created and determining whether the developed themes have appropriate data. For example, the concept of top management support releated to leadership theme.
- **Describing and labeling themes:** Reference [26] explain that this step involves defining and refining the themes through assigning each theme to the correct research phenomenon. For instance, the particpant A noted that "The Manager of the Department of Application Development is a specialist of ITIL, and he is the one who supported the decision to apply ITIL, together with a number of ITIL specialists."
- **Writing the report:** It is the last stage of the thematic analysis. The results are analysed, and conclusions are

drawn. Reference [27] mentioned that the data analysis should be deep and the results should be supported with clear arguments.

G. Reliability and Validity in Qualitative Research

Reliability indicates to reproduce the same findings if the study were repeated [28]. Reference [28] suggest that validity is the interpretation of the accurate findings which reflects understanding of phenomena. However, selection of interviewees carefully is significant due to the validity of interviews that is identified by the extent to which participants are interesting to offer knowledgeable data [29]. Since strategies such as randomisation were not applicable to the current study, the researcher employed different strategies including semi-structured interview questions, data-driven coding, and accurate transcriptions to enhance the accuracy of the information and ensuring that the findings represent reality [30]. The sample sizes of participants were also considered to reflect the study requirements and purpose of this study. The validity of the current study was achieved through obtaining appropriate answers and information of four participants for the research questions that reflect ITIL implementation factors in the MoE in Saudi. Also, the current study ensured that data collection and using of thematic analysis were adopted accurately by using Skype application to record online information [31].

VI. The Case Study Analysis

A. Identification of Themes

The conceptual model of the CSFs [1], which can broadly be put into four stages: top management support, project management and oversight, expectations and conditions, and finally attitudinal responses. The first critical element of the model that shows in table 3 would be the support of senior leadership; something indicated by all the respondents. There would appear to be a very clear sense of direction and involvement from the senior management involved; this was not referenced in great volume in the transcripts, but it was one of the CSFs from the conceptual model that was referred to with comfortably the most clarity in the transcripts. The largest percentage of the respondents' feedback was devoted to stage two of the model, which relates to project management, training, change management, and the quality control of the system. Each of these elements was referenced by the respondents, but there was some difficulty in clarity the different CSFs among the responses. One element that was particularly evident was that it is hard, on the basis of the data, to make clear between the ideas of quality control, project management, and change management. Each of the respondents had a slightly different idea about what each of these stages constituted, and how they should be labelled. It was clear that they were referring to the same sorts of practices, in terms of planning and monitoring, but the way that the ideas of project management and change management were merged together were quite complex; there is a need for a degree of clarity over how the systems fit together into a coherent whole [32, 33]. However, this issue with confusion between these different CSFs brought forward a much more interesting point in terms of analysing the way the model might work, in that there was considerable evidence that the implementation of ITIL is much more reflexive than the structuring of the model currently accounts for. However it is termed, there is a quality control mechanism operating within ITIL that allows for the service ultimately delivered to the end user to be the best it can be at the time; the respondents indicated that either change management teams or other people charged with quality control would check the quality of the work before it was returned to the end user, and send it back for further refinement if the requirements had not been met, which resonates with the literature to an extent [34-36]. In the conceptual model, this issue of reflexivity is hidden because the type of project management, change management, and quality control appears to be happening in parallel rather than reflexively. That is not to say that the model is ignorant of this kind of reflexivity in design, just that it does not describe what is happening in the correct dynamic sequence.

A final point of analysis from the four themes emerging from the results that presented in table 3 is that the attitudinal element of the model is similarly difficult to engage with on the basis of this data. None of the respondents really addressed this in direct terms, but instead mentioned it in passing while referring to other issues; notably with regard to change management and training. The change management issue was presented as an issue in preparation for the implementation of ITIL, in that there was identifiable 'resistance to change'; though what form this resistance took was not specified, as other literatures have [37, 38]. This was then extrapolated into an analysis that training is the route to preventing or at least overcoming this resistance to change. In some ways, this is an unsatisfactory element of the results, in that it is not possible to further differentiate out this issue into the specific of the concept CSFs indicated in the conceptual model that presented in figure 3, and hard to relate to literature [39]. Despite this, the issues with resistance to change and the general attitudinal response to the implementation of ITIL did not seem to diminish its efficacy, and in the sense that there does seem to be something of a departure from the literature [19].

VII. Findings and Discussion

RQ1: How is the Ministry of Education implementing ITIL in the KSA?

The research data suggest that there are several important cultures that underpin the way that the Ministry of Education is implementing ITIL in the KSA. The key point is that the Ministry of Education is really driving the process. The literature review that generated the conceptual model indicated that the attitudinal aspects of the organisations involved would play a major role in whether ITIL implementation would be a success [19]; many institutions had reported that they were unsatisfied in regards to the fact that ITIL was not meeting their expectations. One of the reasons assumed for that was because of key people not accepting the implementation of ITIL as shows in table 4, therefore damaging the effectiveness of the whole [2, 38, 40].

A number of methods for overcoming this were suggested in the literature, principally that there had to be a very clear commitment from senior management to making ITIL work, and to providing training or support to help improve attitudes toward its implementation. The remarkable thing about the data in this report was that, despite one or two references being made to people being unwilling to accept change, there seemed to be relatively few instances of attitudinal problems [38]; that there was clear senior management involvement seemed to be almost assumed, none of the respondents focused on it, but it was very clear, see table 4. Therefore, it seems that the Ministry of Education has been driving ITIL forward in a very clear way, as the literature would suggest [2, 5, 41].

TABLE III. CONCEPT OF CSFS, THEMES AND ANALYSIS INTERVIEWS DISCOVERED FROM CASE STUDY

Concept of CSFs	**Themes**	**The case study Analysis**
Top Management Support	Leadership	*"The Manager of the Department of Application Development is a specialist of ITIL, and he is the one who supported the decision to apply ITIL, together with a number of ITIL specialists."* *"The upper management's support is the first factor for a successful implementation of ITIL. This is reflected in maintaining the current technology and developing the operations whenever the system needs an update. It is responsible for making decisions, obliging the offices with the implementation, and also an exciting cooperation the departments."*
Monitoring and Evaluation	Project Management Abilities	*"Changing the current technology framework of the ministry, so the project management becomes independent from the Change Management, it fully supervises the projects and their execution process, and is connected to the general IT management."*
Project Management & Governance	Project Management Abilities	*"The current project management receives applications to execute new projects and to put new plans for that. I see it responsible for placing and implementing any new system in the ministry."*
Communication & Cooperation	Project Management Abilities	*"This happens either because of poor understanding of dealing with the new operation, or poor communication with other departments requesting the operation's execution."*
Training & Competence of Stakeholders	Project Management Abilities	*"Continuously changing the human resources, and therefore, lack of maintenance of new specialist skills for properly implementing this new technology. This is a challenge to the process of continuous training of the employees on the way of implementing ITIL processes, and developing them to assure a service quality for the client."* *"Lack of employees' knowledge about ITIL operations because of no repetition of specialist courses."*
Change Management & Organisational Culture	Project Management Abilities	*"When a new project is required to be executed, if the change management believes it's not worth execution, such a request would not be activated, and it would stop at this stage."*
Performance Expectancy	Aligning with Customer/EndUser	*"Help Service providers to focus their attention on the needs of the customers and user experience rather than focussing too much on the technology issues. Also, ITIL provides processes and models to help service providers to meet their business."*
Effort Expectancy	Aligning with Customer/EndUser	*Not Addressed Directly*
Social Influence	Attitudinal	*Not Addressed Directly*
Facilitating Conditions	Leadership	*"Training the employees was conducted by the upper management, and specialist consultants were brought to provide courses on ITIL basics and the way to deal with new operations and technological tools."*
Behavioural Intention	Attitudinal	*"There is a desire among the employees to learn ITIL technology, and to continue developing their skills for a proper and faultless implementation."*
Attitude Toward Use	Attitudinal	*"Employee resistance to change, which requires that the employees need training on new operations, and what benefits they would acquire after implementing ITIL for example."*
User Behaviour	Attitudinal	*"Among the problems we faced on, during ITIL implementation, was the culture of work on the new operations whether that of the employees or the heads of departments in general."*

In table 4 the respondents noted that there were some issues with the way that it was being implemented, in terms of there being issues with the old culture and way of doing things, a lack of knowledge and training about ITIL, and references to a high staff turnover and changes in human resources that made it difficult to maintain momentum. In this sense the research at present has captured an organisation in transition; it appears to have made substantial progress in implementing ITIL and delivering training, but is not yet gaining the full benefits of the program; a subsequent research project in a year or two years' time might reveal more quantifiable benefits and outcomes, with some of the cultural issues receding in importance [2, 15, 42, 43].

TABLE IV. SUMMARY OF CONCEPTS INFLUENCE CSFS ADOPTION AT MOE IN SAUDI ARABIA

Concept of CSFs	Themes	analysis	Interviewer's Notes
Training & Competence of Stakeholders	Project Management Abilities	"Continuously changing the human resources, and therefore, lack of maintenance of new specialist skills for properly implementing this new technology. This is a challenge to the process of continuous training of the employees on the way of implementing ITIL processes, and developing them to assure a service quality for the client." "Lack of employees' knowledge about ITIL operations because of no repetition of specialist courses."	There was a clear focus on training as a mechanism through which obstacles could be removed, acceptance improved, and performance improved. Again, this was linked to the attitude of management, who both conducted and commissioned training in order to drive the process.
Facilitating Conditions	Leadership	"Training the employees was conducted by the upper management, and specialist consultants were brought to provide courses on ITIL basics and the way to deal with new operations and technological tools."	Referenced directly in terms of the management of the institution driving the process, providing training and impetus to maximize the chances of acceptance and the efficacy of the ITIL implementation as a whole.
Behavioural Intention	Attitudinal	"There is a desire among the employees to learn ITIL technology, and to continue developing their skills for a proper and faultless implementation."	This was referenced by way of the fact that there was generally a forward-looking approach among the staff, and they were willing to undergo training to help the process along.
Attitude Toward Use	Attitudinal	"Employee resistance to change, which requires that the employees need training on new operations, and what benefits they would acquire after implementing ITIL for example."	The behavioural intention part was referenced to the fact that some people were initially resistant to change, as was the organizational culture as a whole, but this was largely ascribed to a natural part of organizational culture and there was nothing particular to ITIL that gave rise to this; and it was easily dealt with through training and leadership.
User Behaviour	Attitudinal	"Among the problems we faced on, during ITIL implementation, was the culture of work on the new operations whether that of the employees or the heads of departments in general."	As above

RQ2: What are some of the crucial factors for successful implementation of ITIL in the MoE in the KSA?

Of the factors in the conceptual model, there is merit to them all, but there is some difficulty in following that mapping in practice; the way that CSFs are named in each organisation is not necessarily that clear. Therefore, there is some initial value in reducing the number of CSFs in the overall conceptual model, since they cannot be distinguished effectively at that level, see table 5. Therefore, the model could be reduced to a series of factors that commence with strong leadership involvement as demonstrated by the current research, but then focus on simple three-stage set of CSFs: training, project management, and reflexivity [34, 36]. Recasting the model in this form would allow the CSFs to be more clearly referenced against what is happening as the Ministry of Education seeks to implement ITIL as shows in table 5.

This may seem to unnecessarily compress such proposed CSFs as communication abilities and the facilitation of the right conditions, but the data from these respondents would appear to show that it might not be preferable to have these as independent CSFs, but rather to suggest that in order for the CSFs of leadership, training, effective project management, and reflexivity, then these qualities need to be present, see table 5 [44-46]. Communication is not something that should be isolated into its own CSF, it is something necessary to ensure that all core CSFs are delivered effectively.

However, this would need to be set against the findings of the literature at large that would not recommend such a simplification process [47]. Other studies in organisations with less direct leadership styles than the Ministry of Education demonstrate that these factors relating to attitude and culture are important, particularly when it comes to matching the expectations of the user and delivering customer satisfaction, presented in table 5 [36, 48]; therefore, this research project has probably demonstrated quite an abnormal case with a leadership style not possible to replicate in other organisations; therefore, simplifying the model based solely on this data would not be wise [49].

TABLE V. SOME OF THE CRUCIAL FACTORS FOR SUCCESSFUL IMPLEMENTATION OF ITIL IN THE MOE IN THE KSA

Concept of CSFs	Themes	analysis	Interviewer's Notes
Top Management Support	Leadership	"The Manager of the Department of Application Development is a specialist of ITIL, and he is the one who supported the decision to apply ITIL, together with a number of ITIL specialists." "The upper management's support is the first factor for a successful implementation of ITIL. This is reflected in maintaining the current technology and developing the operations whenever the system needs an update. It is responsible for making decisions, obliging the offices with the implementation, and also an exciting cooperation the departments."	There was a very strong impression from the respondents that ITIL was being driven hard in the organization, in that management were very much behind it, and working hard to both lead and create the right context for it to be rolled out. Everything else has to be read through this lens; when they were talking about the project management techniques etc, it was in the context of a strong organizational desire to implement ITIL.
Project Management & Governance	Project Management Abilities	"The current project management receives applications to execute new projects and to put new plans for that. I see it responsible for placing and implementing any new system in the ministry."	As above, this was a complex area – all the factors in the conceptual model were present, but in a muddled form. There was a notable degree of reflexivity, whereby there could be feedback loops built into the process whereby work could be continually amended dependent on quality control and client feedback.
Communication & Cooperation	Project Management Abilities	"This happens either because of poor understanding of dealing with the new operation, or poor communication with other departments requesting the operation's execution."	This was cited mainly in the context of potential obstructions, but again, it has to be seen in the context of the organizational will to implement ITIL; cooperation seemed to be expected and demanded.
Performance Expectancy	Aligning with Customer/EndUser	"Help Service providers to focus their attention on the needs of the customers and user experience rather than focussing too much on the technology issues. Also, ITIL provides processes and models to help service providers to meet their business."	This seemed to be implicit in much of what the responses talked about; in that the discussions about some of the project management and quality control tools were predicated on the expectation that they would deliver a better fit with the client expectations.
Effort Expectancy	Aligning with Customer/EndUser	Not Addressed Directly	
Social Influence	Attitudinal	Not Addressed Directly	
Facilitating Conditions	Leadership	"Training the employees was conducted by the upper management, and specialist consultants were brought to provide courses on ITIL basics and the way to deal with new operations and technological tools."	Referenced directly in terms of the management of the institution driving the process, providing training and impetus to maximize the chances of acceptance and the efficacy of the ITIL implementation as a whole.

VIII. CONCLUSION

The conceptual model in figure 3 was deployed into the research environment associated with the Ministry of Education in the KSA, through a series of interviews, in order to understand how ITIL was being used, the CSFs, and the outcomes of the process. The concept of the CSFs model in the current study were broadly borne out by the data, though it was found that the mechanics of project management and quality are more reflexive than the model describes, and the individual components of it become difficult to make clear. Therefore, on the basis solely of the evidence within this study, it might be appropriate to develop a simplified version of the model, but this would be over-fitted to the peculiar circumstances of the KSA and would not have any wider explanatory power beyond the specific context of this study. Therefore, it would be appropriate to conclude that the project has demonstrated that, in the unique context of the Ministry of Education in the KSA, certain aspects of the model like the concept of communication and cooperation support become more critical than others CSFs, probably due to the strong leadership shown in implementing ITIL, which in turn reduces or nullifies many of the attitudinal issues that are noted in other contexts. Even excluding this, the data demonstrate that the concept of CSFs in this study is the central important of reflexivity in the effectiveness of ITIL, which is perhaps the most important contribution of this research to the literature as a whole and achieved the objectives of this research. Furthermore, this research has demonstrated that where there is very strong leadership, a lot of the CSFs such as communication and cooperation, and training and competence of stakeholders become less relevant because the attitudinal issues are smoothed away before they begin to disrupt the process. The overall of ITIL process is important because the evidence of this project, and a key conclusion, is that ITIL is working effectively in this context; the IT service delivery seems to have been improved both in terms of the service given to the end user, and the costs of delivering that service by the Ministry of Education in KSA.

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QR Code Recognition based on Principal Components Analysis Method

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***Abstract*—QR (Quick Response) code recognition systems (based on computer vision) have always been challenging to be accurately devised due to two main constraints: (1) QR code recognition system must be able to localize QR codes from an acquired image even in case of unfavorable conditions (illumination variations, perspective distortions) and (2) The system must be adapted to embedded system platforms in terms of processing complexity and resources requirement. Most of the earlier proposed QR code recognition systems implemented complex feature descriptors such as (Harris features, Hough transform which aim at extracting QR code pattern features and subsequently estimating their positions. This process is reinforced by pattern classifiers e.g. (Random forests, SVM) which are used to remove false detected patterns. Those approaches are very computationally expensive. Thus, they are not able to be run in real-time systems.**

In this paper, a streamlined QR code recognition approach is proposed to be efficiently operable in systems characterized by a limited performance. The evoked approach is conducted as follows: the captured image is segmented in order to reduce searching space and extract the regions of interest. Afterwards a horizontal and vertical scans are performed to localize preliminarily QR code patterns, followed by Principal Component Analysis (PCA) method which allows removing false positives. Thereafter, the remaining patterns are assembled according to a constraint so as to localize the corresponding QR codes. Experimental results show that the incorporation of PCA decreases notably the processing time and increase QR code recognition accuracy (96%).

Keywords—QR code; Image segmentation; Principal Components Analysis; Perspective rectification; Pattern similarity measurement

I. Introduction

Nowadays, Quick response code (QCR) has become one of the most relying data storage tools by coinciding the enormous growth of the E-Commerce and mobile phone market. QRC combines notably between robustness and cost effectiveness. Thence, it knows increasingly a widespread demand in diverse fields (e.g. industry, commerce, etc.) and for various purposes, such as objects tracking and products labeling [1,2] for which it is attached, this by giving their corresponding information. The latter is stored using a reliable error correcting codes (Reed-Solomon) as well as a vision-based decoder for data extraction. The QRC decoder must be rigorously designed while taking into account number of unavoidable factors. By nature, QCRs are mostly placed on complex environments which are characterized by irregular textures, and illumination changes. This renders QRC recognition quite challenging. In this regard, many competitions have been conducted by inviting computer vision researchers to invent accurate QRC recognition algorithms which can prove their ability in overcoming the evoked obstacles.

QRC recognition algorithms are mostly devised to be implemented in mobile phones or in embedded system platforms, the two latter are distinguished by limited resources as well as a real-time execution. By such factors, the architecture of the proposed algorithms must not be computationally expensive. In contrast, when we analyze the earlier proposed approaches which exist in the literature, we notice that most of them rely on voluminous feature descriptors which generate pattern descriptions of high dimension. These features are used to feed complex pattern classifiers (implemented as false positives removal). Although the accuracy of the earlier proposed QRC recognition algorithms, most of them turned out inappropriate for embedded systems due to their high resource requirements and time consuming.

In this paper a variant QCR recognition system is devised exclusively with accordance to embedded system performance limitation. The proposed approach is based on Principal Components Analysis which is implemented as pattern classifier which basically helps reducing the original data dimension before proceeding to the effective processing. In addition, PCA function receives a set of training pattern images as well as those related to the extracted candidate patterns as input data and subsequently generates loading coefficients matrix in which each row refers to a given pattern. Afterwards, each extracted pattern coefficients are compared separately with those of the training patterns by means of Euclidian similarity measurement. An extracted pattern is considered as a true positive if it has at least one similarity which is less or equal to a predefined threshold.

The remainder of this paper is organized as follows. In section II the existing methods of QR code recognition systems are discussed. The background of this paper is presented in section III. The proposed approach is explained in section IV. The obtained results are displayed in section V. The conclusion accompanied with an outlook of the future improvements are reported in section VI.

II. Related Works

Many QR code recognition approaches have been earlier proposed in the literature, basing upon different distinctive techniques. In this regard, G. S. Vardhan et al [3] used QRC as RFID tag which is therefore recognized through frequency domain reflectometry. N. Bhardwaj et al [4] and Z. Yang et al [5] proposed RGB color segmentation along with luminance enhancement to reduce searching space of QRC. Y. L. Lin et al [6] implemented the histogram of oriented gradients as QRC feature descriptor combined with AdaBoost classifier.

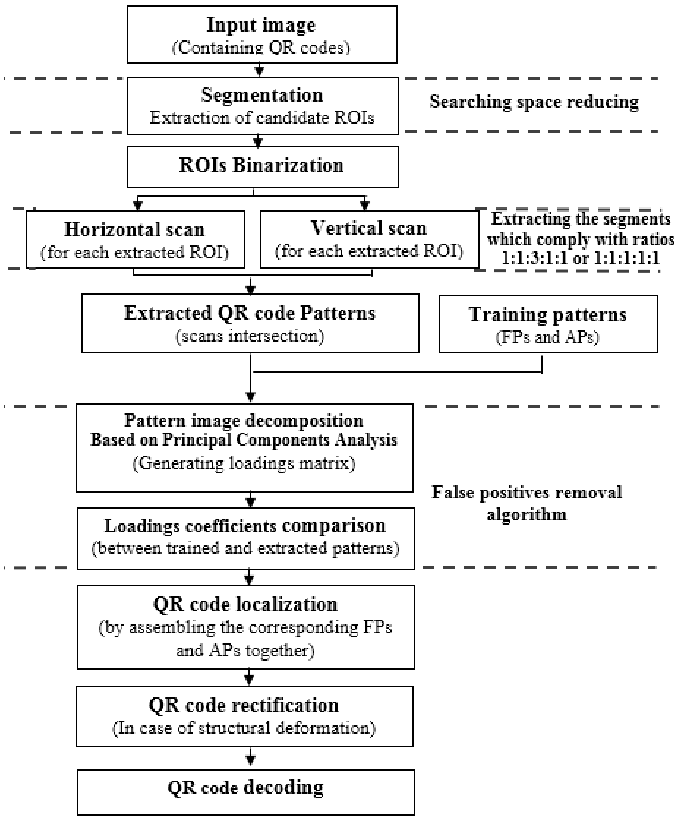

Fig. 1. Overall diagram of the proposed QR code recognition system

M. Ostkamp et al [7] used the raytracing technique which allows recognizing and retrieving QRC even with curved distortions. M. Ahn et al [8] recognition approach is based on cloud-based pre-generated image matching. Y. Kato et al [9] used basic QRC features and a sliding window detector to recognize QRC from image of low resolution, this by constructing an image of high resolution. Z. l. Liao et al [10] relied on vertex point characteristics which aim at localizing the corners related to the finder patters of the QRC. Y. Liu et al [11] focused mainly on the binarization stage using multi-level thresholding as well as a global scanning of the binary image. Once achieved, QRC positions can be estimated. I. Szentandrasi et al [12] implemented Hough transform since they considered QRC as a set of perpendicular segments. Hough transform and one dimensional wave scanning are also implemented by Liu Huijuan [13] for both QRC recognition and structure retrieval in case of geometric distortions. L. Zhong et al [14] exploited spectral space analysis by means of Fourier Transform through which both QCR recognition and deblurring are achieved. P. Bodnar et al [15] implemented a combination of cascading classifiers trained separately by Haar-like features, Local Binary Patterns and Histogram of Oriented Gradient features. K. Suran [16] based on Harris corner detector and convex hull algorithm.

III. Background

QR code is an efficient type of 2D barcode (standardized by the norm ISO/IEC 18004). It allows storing and reading an important amount of data of different types: up to 7089 numeric values, 4296 alphanumeric characters, 2953 binary values and 1817 kanji. QRC is also available in 40 different versions (varying between 1 and 40) as well as various module sizes (21x21 up to 177x177). Each module can handle up to four data error correction levels (L, M, Q and H). These levels can respectively retrieve up to 7%, 15%, 25% and 30% of QRC structure in case of structural damage [17]. Moreover to its technical advantages, QRC is economically viable in consideration that it can be printed in a small piece of paper or exploited directly in electronic format, unlike RFID tags which require specific and costly equipment.

Mainly, QR code localization is conducted through a well-defined patterns characterized by distinctive texture. These patterns help the scanner to preliminarily locate a QR code even if it is placed on complex texture. The evoked patterns can be categorized into two categories: **Finder pattern** (FP) and **Alignment pattern** (AP). The former allows a preliminary estimation of the QRC position, whereas the latter is used to determine the orientation and geometric deformations of the QRC. A structural survey of QRC is displayed in Fig 2.

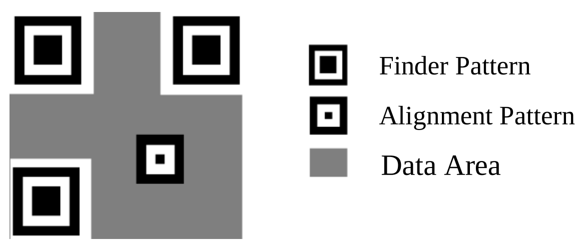

Fig. 2. Structural survey of QR code

IV. Proposed Approach

A. *Searching-space reducing*

Most of QCR recognition systems are devised to be implemented either in handheld devices (e.g. mobile phone, tablet) or in embedded system platforms (Arduino, Raspberry Pi). These equipment are characterized by resources of limited capacity and basically run in real-time. To overcome these restrictions, a searching-space reduction is inevitably required before proceeding to the QRC recognition processing. In this context, various approaches have been proposed. P. Moallem et al [18] implemented edge features and disparity gradient limit technique so as to reduce searching-space during the correspondence of stereo vision areas. E. Cho et al [19] used Quad-tree structure to extract the foreground layer of an image which is assumed containing the regions of interest. The evoked process is a twofold aim, on the one hand it allows reducing computation time along with alleviating resource requirements, and on the other hand it helps increasing recognition accuracy by discarding areas which do not satisfy a predefined constraint. In the current paper, a powerful color-based filter is implemented, which is already proposed by F. zaklouta et al [20] through which a binary mask Fig 3(b) is obtained after scanning all RGB pixels related to the input image and extracting all the areas which are distinguished by an achromatic color (in consideration that QRC texture is characterized by black and white colors). By doing so, a set of candidate regions of interest are extracted. The obtained results are depicted in Fig 3.

$$T_{(x,Y)} = \frac{|R_{(x,Y)} - G_{(x,Y)}| + |G_{(x,Y)} - B_{(x,Y)}| + |B_{(x,Y)} - R_{(x,Y)}|}{K} \quad (1)$$

$$I_{(x,Y)} = \begin{cases} 0 & if\ T(x,y) \leq 1 \\ 1 & otherwise \end{cases}$$

Where K is the achromatic color extraction rate. K is set at 30.

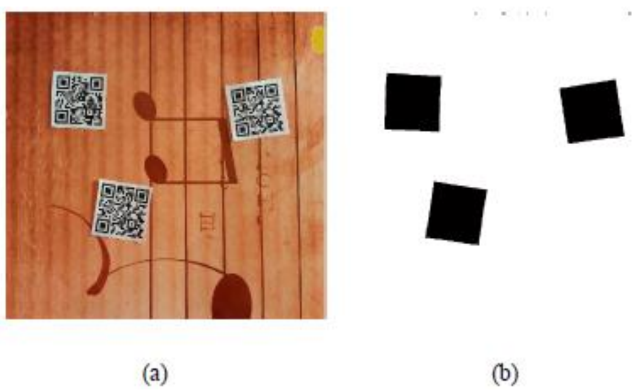

Fig. 3. Regions of interest extraction. (a) Original image (b) Binary mask wherein the black areas refer to the regions of interest

So far, a set of potential QRC areas have been preliminary located by means of the aforementioned binary mask. In order to check out the validity of the obtained ROIs, the latter are passed down to an additional assessment process, in which each ROI is scanned separately into two directions (vertical and horizontal). A valid ROI must contain exactly three FPs and at least one AP. Before proceeding to the evoked process, the set of extracted ROIs are binarized so as to facilitate texture analysis. The algorithm starts first by converting each of them to the grayscale representation using a powerful method which is defined by (2). This equation emphasizes the mean value between the dominant and the minimum intensity related to the three RGB color channels. The mentioned transform outperforms other grayscale ones given that it provides the best contrast. As regards the binary conversion, it is defined by (3). The reached results are displayed in Fig 4.

$$I_{Gray} = \frac{[Max\ P(R,G,B) + Min\ P(R,G,B)]}{2} \quad (2)$$

$$I_{Binary}(x,y) = \begin{cases} 0 & if\ \ I_{Gray}(x,y) \leq T \\ 1 & Otherwise \end{cases} \quad (3)$$

Where P(R,G,B) stands for RGB pixel. I_{Gray} represents a grayscale pixel. I_{Binary} refers to a binary pixel. T is a grayscale threshold.

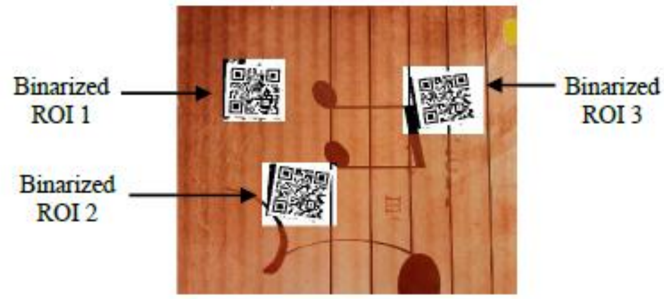

Fig. 4. Candidate regions of interest after Binarization

B. QR code pattern localizations

In order to find the exact location of FPs and APs within the extracted ROIs, three successive processes are performed for each ROI separately. A horizontal scan is launched first, in which the binary area related to each ROI is scanned horizontally. The scan process retains and saves the coordinates (coordinates of the beginning pixel and the end one) of each valid horizontal segment (on a specific matrix denoted **H**) whose the structure complies whether with the ratio 1:1:3:1:1 (related to FP) or 1:1:1:1:1 (corresponding to AP). The structure of the horizontal and vertical segments related to both FP and AP are displayed in Fig 5(a) and (b) respectively. The red perpendicular segments stand for a horizontal and vertical section of a FP and AP. Once the horizontal scan is achieved, a vertical one is launched in the same way as the previous. The vertical scan saves the coordinates of all valid vertical segments (on a specific matrix denoted **V**) which respect the aforementioned ratios.

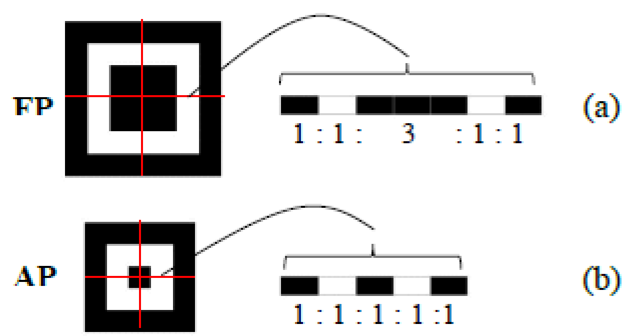

Fig. 5. Longitudinal and transversal sections of a FP and AP. (a) Sections of a FP. (b) Sections of an AP

At the end, the scanning algorithm computes the intersection between the two scan results **(H ∩ V)** i.e. the intersection between the retained vertical segments and the horizontal ones, this process indeed allows extracting the location of the central pixel related to each extracted pattern. Besides true positives (FPs and APs) a set of false ones are extracted. The latter disturb significantly the QR code localizations. In this reason all the extracted patterns are transmitted to a filtering process based on Principal Components Analysis which is used as pattern feature descriptor combined with Euclidian similarity measurement which aim at comparing the resulting pattern features. The implemented filter is sufficiently trained by number of FPs and APs images which are taken under different illumination conditions. The preliminarily extracted patterns are displayed in Fig 6.

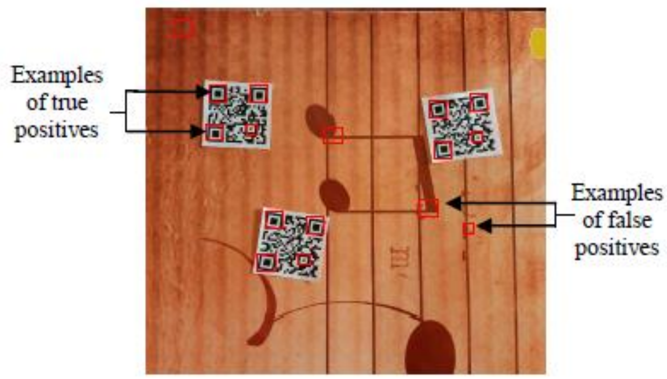

Fig. 6. Preliminarily extracted patterns before removing false positives

C. *False positives removal algorithm*

Most of the false positive removal algorithms are mainly based on three distinct steps. (1) Pattern feature extraction (2) Classifier training. (3) Prediction and Classification. Although the efficiency of this architecture, it is very computationally expensive in terms of computation time and resource requirements, in consideration that the majority of the feature descriptors which are implemented in QR code recognition systems such as SIFT [21], SURF [22], MSER [23] generate huge pattern descriptions, the latter are characterized by high dimension. In addition to that, most of the evoked architectures implement complex classifiers among others, Random forests, K-d trees. These classifiers generally require the building up of an enormous combination of trees which conduct to form a huge decision paths. In order to enhance the performance of the tree classifiers various constraints must be dealt with, especially when it comes to: **(1)** Finding a valid stopping criterion. **(2)** Finding an optimal trees splitting. **(3)** Determining the best trees selection which allows gaining an accurate classification. **(4)** Browsing all the forest paths i.e. starting from the root (main node) until the deepest leaves (terminal nodes). For each browsed path, the probability reflecting the number of feature occurrences must be computed. On the basis of the evoked constraints, the discussed approach turned out inconsistent for embedded system platforms. To get around this problem, a variant approach is proposed which aims at alleviating the QRC recognition complexity. This by implementing the well-known statistical procedure “Principal Components Analysis (PCA)” which is earlier invented by [24] accompanied with the Euclidian similarity measurement. As aforementioned, PCA allows decreasing fairly the original data dimension and generating alternatively a reduced output data in the form of two streamlined matrices i.e. Loading matrix and Score matrix. These matrices are henceforth used to manipulate and analyze the original data. The use of PCA has notably alleviated both complexity and processing time while guarantying a high accuracy. Finally, it is worthwhile to note that the main advantage of the PCA is manifested in that it does not require to be trained with false positives, which decreases notably the size of the training data, unlike SVM and tree classifiers which must be fed with a huge sample of false positives.

It should be noted that the idea of this paper has been inspired from the face recognition system which has known a considerable success in human face identification. In the proposed system, the same principle has been maintained. Namely the evaluation of the extracted patterns validity is divided into three steps. **(1)** Preparing a sample of pattern images as training data e.g. Fig 7(a) and (b) which refer to FP and AP categories respectively. The trained pattern images have been taken under different illumination conditions and have undergone various geometric deformations (e.g. affine and projective deformations). Afterwards, the training patterns accompanied with the extracted ones (e.g. Fig 7 (c) and (d) which refer to a true positive and a false one respectively) will be transmitted to PCA function. The latter will in turn generate the corresponding loading matrix whose each row represents a given pattern. The discussed procedure is explained in detail in the next section.

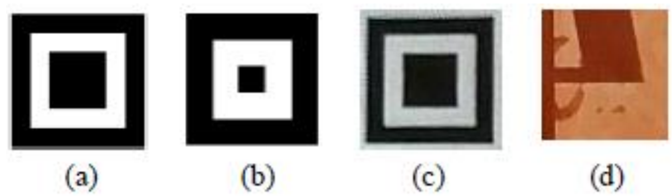

Fig. 7. Sample of training and extracted patterns. (a) Training image of a FP (b) Training image of AP (c) Extracted true positive (FP) (d) False positive

- **Proposed approach steps**

The proposed approach is conducted as follows:

1) At first, the size of each extracted pattern image is rescaled so that it becomes compatible with those of the training patterns. Moreover, each pattern image is converted to a column vector (i.e. by successively concatenating its). The evoked column vectors will be denoted CV_i (for i=1,2,…X) where X stands for the total number of the queried patterns and i represents the column index. If the pattern image size is NxN, then the corresponding column vector size is N^2x1. The process is applied to all the queried patterns (training and extracted patterns). By doing so, a global matrix (denoted A) is obtained whose the size is N^2xX. The matrix *A* is defined as follows:

$$A = \begin{array}{c} \begin{pmatrix} p_{11} & p_{12} & p_{13} & \cdots & p_{1X} \\ p_{21} & p_{22} & p_{23} & \cdots & p_{2X} \\ p_{31} & p_{32} & p_{33} & \cdots & p_{3X} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ p_{N^2 1} & p_{N^2 2} & p_{N^2 3} & \cdots & p_{N^2 X} \end{pmatrix} \\ \begin{array}{ccccc} CV_1 & CV_2 & CV_3 & & CV_X \end{array} \end{array} \tag{4}$$

2) Calculating the mean value (denoted mi) of each column of A. i.e. computing the sum of all coefficients related to each column CVi and dividing the resulting sum by the total number of column coefficients N^2. The evoked mean is defined by the expression (5).

$$\mathrm{m}_i = \frac{1}{N^2}\sum Coef\ (CV_i) \quad for\ i = 1,2,\dots,X \tag{5}$$

Where Coef (CVi) stands for the set of coefficients related to the ith column of *A*. X stands for the total number of columns contained in *A*, and m_i is the mean value of the ith column.

3) Subtracting each column of A by the corresponding mean m_i as defined by the expression (6). This operation allows centering each column of A around its mean. The resulting centered matrix is denoted *A'* and its corresponding structure is defined by (7).

$$CVN_i = CV_i - m_i \ \ for\ i = 1,2,\dots,X \tag{6}$$

Where CVN_i represents the new ith centered column vector of *A'*.

$$A' = \begin{array}{c} \begin{pmatrix} p'_{11} & p'_{12} & p'_{13} & \cdots & p'_{1X} \\ p'_{21} & p'_{22} & p'_{23} & \cdots & p'_{2X} \\ p'_{31} & p'_{32} & p'_{33} & \cdots & p'_{3X} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ p'_{N^2 1} & p'_{N^2 2} & p'_{N^2 3} & \cdots & p'_{N^2 X} \end{pmatrix} \\ \begin{matrix} CVN_1 & CVN_2 & CVN_3 & & CVN_X \end{matrix} \end{array} \tag{7}$$

In this section, the decomposition of the original matrix A is explained from the mathematical point of view basing on PCA method. As aforementioned, the main purpose of the use of PCA is manifested on false positives removal while alleviating the complexity of the comparisons which are performed between the detected patterns and the training ones. In this regard, the matrix A is transmitted as an input to the PCA function which thereafter generates an output in form of two distinctive matrices. The latter are generally known as loading matrix (denoted C_M) and score matrix (denoted S_M). The loading matrix C_M is considered as the main matrix on which the proposed approach relies on to ensure pattern comparisons. The coefficients of C_M reflect the principal variances along the eigenvectors related to the original data as well as the correlation between the queried patterns. Furthermore, the sum of squares of each column of C_M is 1. The loading matrix C_M is obtained after extracting the eigenvectors of the covariance matrix related to the input matrix A. This process is defined by the expression (9). As to the score matrix S_M, it mainly represents the two main orthogonal directions (i.e. the two main principal components) which split optimally the input data through two perpendicular straight lines. The score matrix is obtained by multiplying the centered matrix **A'** by the loading matrix C_M as defined by the equation (10). On the other hand, the decomposition of the original matrix A is conducted according to the equation (8). As previously mentioned, the proposed false positives removal algorithm will exclusively rely on loading matrix coefficients. In consideration that these coefficients provide significant information about the treated patterns. Henceforth, each pattern will be represented by a given row of C_M. Basing on this rule, each extracted pattern coefficients will be compared separately with the coefficients of the training patterns. This comparison is conducted by means of the Euclidian similarity measurement. An extracted pattern is considered as a true positive if it is similar to at least one training pattern.

$$A = S_M C_M^T + E_M \tag{8}$$

$$C_M = Eigenvectors\ (Cov(A)) \tag{9}$$

$$S_M = A'.C_M \tag{10}$$

Where S_M stands for the score matrix. C^T_M refers to the transposed of the loading matrix. E_M is the error matrix which is added to the multiplication result of S_M and C^T_M to reconstruct the original matrix A. Cov(A) stands for the covariance matrix of A. and finally, A' refers to the centered matrix.

D. Extracted pattern assessment and classification

To better understand the proposed approach, a simple demonstration seems useful. In this example the queried data is assumed to contain only 4 training patterns and 2 extracted ones. The two extracted patterns are divided into a true positive and a false one. As previously mentioned, the six patterns are transmitted to the PCA decomposition function after being converted to column vectors. This decomposition in turn yields the corresponding loading matrix C_M as defined in (11). The first four rows of C_M refer to the four training patterns whereas the fifth row (true positive) and the sixth one (false positive) represent the extracted patterns. The classification of the latter requires a comparison of their corresponding loading coefficients with those related to the training ones basing on the Euclidian similarity rate which is denoted E_D. The latter is in turn defined by the expression (12) whilst the pattern classification is obtained through the constraint (13). An extracted pattern is considered as a true positive if and only if it has at least one similarity rate which is less or equal to a predefined threshold (denoted T_D). Otherwise, the pattern is considered as a false positive and consequently removed from the set of extracted candidate patterns. The Table 1 illustrates the obtained results after comparing each extracted pattern coefficients with the training ones. The similarity threshold T_D is set at 0.1. By analyzing the obtained similarity rates, one can observe that the extracted pattern 1 (defined by the fifth row) obtains a similarity rate equals to 0 (according to its comparison with row 1 which refers to a finder pattern), since the evoked similarity is less than 0.1, the extracted pattern 1 is considered as a true positive. On the other hand, the extracted pattern 2 (represented by the sixth row) is considered as a false positive in consideration that none of its obtained similarity rates comply with the classification constraint. This candidate pattern is subsequently removed.

$$C_M = \begin{pmatrix} 0.5803 & 0.3776 & 0.1407 & -0.0238 & 0.0174 \\ -0.2941 & 0.3995 & 0.2070 & 0.7147 & 0.4475 \\ -0.4627 & 0.5750 & 0.3665 & -0.3293 & -0.4610 \\ -0.1566 & 0.2561 & -0.2292 & -0.5887 & 0.7147 \\ 0.5803 & 0.3776 & 0.1407 & -0.0238 & 0.0174 \\ 0.0366 & -0.3989 & 0.8548 & -0.1819 & 0.2752 \end{pmatrix} \quad (11)$$

Where C_M stands for the loading matrix coefficients whose each row refers exclusively to a given pattern of the six queried ones.

$$E_D(i,j) = \sqrt{(a_1 - b_1)^2 + (a_2 - b_2)^2 + \cdots + (a_i - b_j)^2} \quad (12)$$

$$\text{Classification decision} = \begin{cases} \mathit{True\ positive} & \mathit{if}\ E_D(i,j) \le T_D \\ \mathit{False\ positive} & \mathit{Otherwise} \end{cases}$$
(13)

Where $E_D(i,j)$ is the Euclidian similarity rate between the extracted pattern i and the training one j. a_i and b_j stand for the loading coefficients. T_D represents the classification threshold.

TABLE. I. PATTERN CLASSIFICATIONS BASED ON THE COMPARISON OF LOADING COEFFICIENTS

Extracted candidate patterns	Loading rows comparisons	Similarity rate
Extracted pattern 1 (row 5 of C_M)	Row 5 with 1	0
	Row 5 with 2	1.22
	Row 5 with 3	1.22
	Row 5 with 4	1.22
Extracted pattern 2 (row 6 of C_M)	Row 6 with 1	1.22
	Row 6 with 2	1.41
	Row 6 with 3	1.41
	Row 6 with 4	1.41

Given how crucial the implementation of PCA method turns out, the obtained results after applying the false positives filter are displayed in Fig 8. It clearly appears that all the false detected patterns (which were present in Fig 6) have been successively removed. Henceforth the QR code localizations can be performed by grouping adequately the remaining patterns.

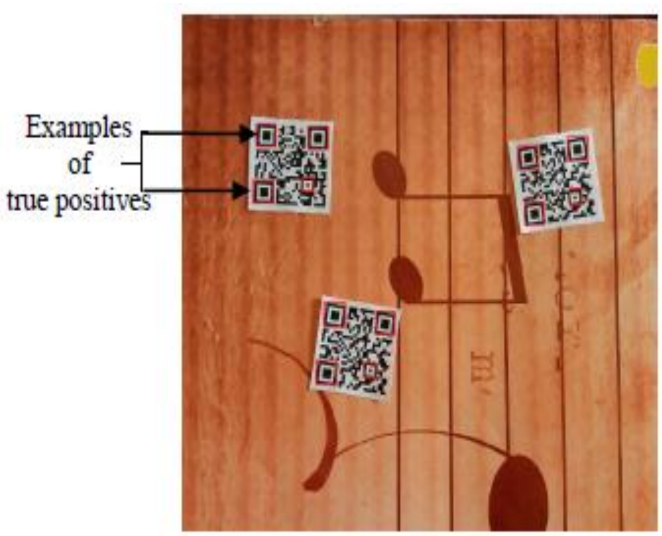

Fig. 8. Obtained results after removing false positives

E. QR code localizations

In this stage, QR code localizations are carried out through the measurement of distances which separate the remaining patterns. To make that possible, these patterns are divided into groups, in which each group must exactly contain three FPs and at least one AP. Basing on this constraint, the algorithm considers that three FPs belong to the same QR code, if the distances separating them satisfy the constraint (14). Once satisfied, the corresponding APs are automatically inferred basing on the principle that APs are usually located within the FPs area. The obtained results are shown in Fig 9 wherein three QR codes are correctly localized.

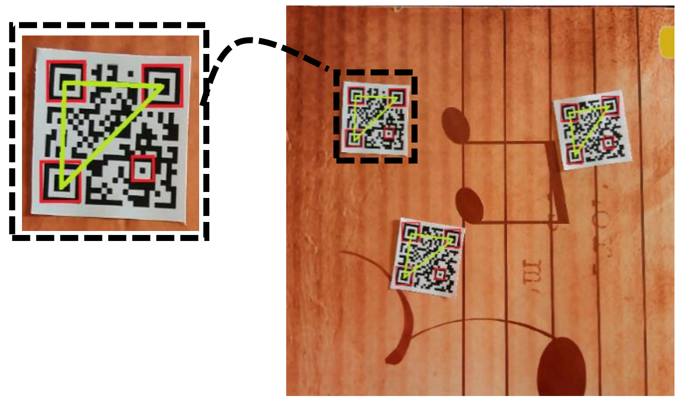

Fig. 9. QR code localizations based on pattern distance measurements

$$D_{ij} = D_T \pm \omega \quad (14)$$

Where D_{ij} stands for the distance which separates two FPs i and j. D_T is a distance threshold and ω designates a marginal acceptable difference.

F. Geometric and color rectifications of QR code

QR code shape evaluation and correction are often deployed in systems wherein the 2D barcode decoder is fixed on a movable object. e.g. the case when mobile phone is used as a QR code decoder, a simple hand motion induces shape deformations of the targeted QR codes, which consequently become unreadable. The most common deformations which may alter the captured QR code can be divided into three categories: (a) Affine deformation, (b) Projective deformation and (c) Lens deformation. As to the affine deformation, the QR code shape is simply rotated or transformed to a well-defined geometric shape e.g. parallelogram, rhombus, etc. Given its linearity, the affine transformation is distinguished by its ability to preserve the main geometric characteristics (parallelism, straight lines) of the transformed objects. For this reason, it does not require a complex processing which aims at retrieving their original structure. On the other hand, the Projective deformation is more complicated to be handled, since it is a nonlinear transformation. This type of deformation renders the QR code trapezoid or in the form of an undefined geometric shape. Both affine and projective transformations are defined by the linear system (15). The only thing that makes difference between them is manifested on the used coefficients f_i related to the Homography matrix. As regards to the lens deformations, they are frequently caused by the use of inappropriate lens calibration, the evoked deformations are generally represented by barrel, pincushion and Mustache distortions wherein the image becomes curved because of its magnification which varies irregularly compared to the optical axis i.e. these deformations occur when the field of view of the lens is much wider or smaller than the size of the image sensor.

The proposed QR code rectification algorithm infers the type of deformation which alters each detected QR code through its four corner coordinates. Once determined, the corresponding Homography matrix is computed (15) and thereafter the corresponding geometric correction is applied to the QR code. This by mapping its pixels to the new positions in the square area.

$$\begin{pmatrix} f_1 & f_2 & f_3 \\ f_4 & f_5 & f_6 \\ f_7 & f_8 & f_9 \end{pmatrix}\begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = \begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} \qquad (15)$$

The sub matrix $\begin{pmatrix} f_1 & f_2 \\ f_4 & f_5 \end{pmatrix}$ is used when the QR code has undergone an affine deformation such as rotation (as shown in Fig 10). In case wherein the QR code is tilted by a given angle θ. The latter is calculated through the basic rules (SOH-CAH-TOA) related to the right triangle. The corresponding Homography matrix is defined as illustrated in (16)

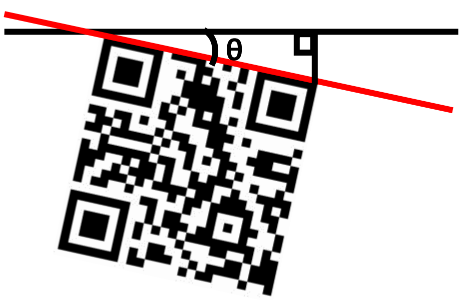

Fig. 10. Tilted QR code by an angle θ

$$\begin{pmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix}\begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = \begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} \qquad (16)$$

When it comes to the projective deformation, a rigorous process must be conducted. The first step consists of defining a square area in which the corrected QR code will be placed. This area is defined by the four corners b1, b2, b3 and b4 as shown in Fig 11(b). Afterwards the projective transformation matrix is computed basing on the relationship between the four corner coordinates (a1, a2, a3 and a4 as shown in Fig 11(a)) related to the deformed QR code with their corresponding ones in the square area in Fig 11(b). Once the projective matrix is computed, all the pixels of the deformed QR code are mapped to the square area, By doing so, the corrected QR code is obtained as shown in Fig 11(b).

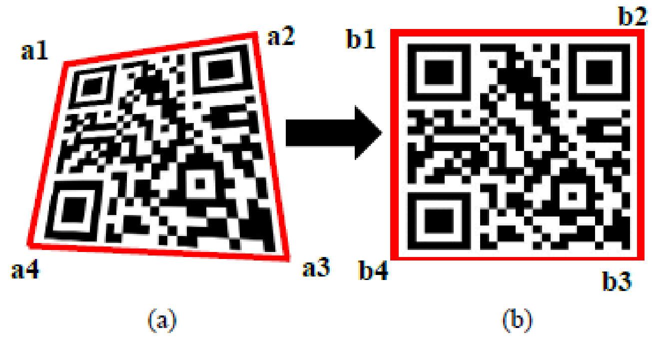

Fig. 11. Shape rectification of the deformed QR code based on projective transformation. (a) Deformed QR code (b) QR code after shape rectification

V. Results and Discussion

The proposed system has been tested in:

- Laptop characterised by an AMD C-60 processor running at up to 1,33 GHz with 2Go of RAM, and an HD camera with USB interface.
- Raspberry pi 2 characterised by quad-core ARM Cortex-A7 processor running at up to 900MHz with 1Go of RAM, and an HD camera offering a resolution of 2560x1536, the evoked equipment are put onboard a robot.

Table 2 displays the obtained results after comparing both the required executing time and performance related to the Principal Components Analysis (**PCA**) with those of the random forests (**RF**), the support vector machine (**SVM**) and the correlation method (**CR**). In order to ensure a good prediction, both RF and SVM require a huge sample of training patterns accomagned with the set of patterns to be classified. Although their high accuracy, the size of their required training data increases notably their processing time (as reported in Table 2). As regards to the correlation method, the pattern comparisons is performed through the correlation between the pixels of the extracted pattern with those of the training one. this method is characterized by its low accuracy and high sensitivity towards image deformations. On the other hand, it clearly appears that the Principal Components Analysis outperforms all the aforementioned methods in terms of accuracy and its low processing time. The tests have been conducted using different pattern image sizes. The latter are set at 11x11, 22x22, 88x88, 176x176 and 352x352.

TABLE. II. Comparison between Principal Components Analysis performance and other methods of pattern classifications

Methods	**352x352**	**176x176**	**88x88**	**22x22**	**11x11**	**Accuracy**
	Processing time (seconds)					
PCA	0.62	0.41	0.30	0.25	0.20	96%
RF	3.67	3.19	2.86	2.38	2.16	92%
SVM	2.60	2.16	1.97	1.85	1.82	85%
CR	1.33	0.71	0.59	0.42	0.39	68%

VI. Conclusion

In this paper, a streamlined QR code recognition system has been proposed to be efficiently run in embedded systems. The implementation of the Principal Components Analysis is opted in order to reduce the dimension of the original data. i.e. the extracted patterns are analyzed and filtered through their corresponding Loading matrix coefficients (generated by the PCA) instead of their original images. The proposed system has been tested under different criteria and taking into account several image deformations. The obtained results were promising.

The proposed QR code recognition system performs a series of treatments. It starts first by the input image segmentation based on an achromatic filter. This segmentation aims at extracting the candidate regions of interest (ROI) which may contain QR codes. Afterwards, the extracted ROIs are binarized and scanned horizontally and vertically in order to localize the candidate QR code patterns within the resulting ROIs. The extracted patterns are then filtered by means of the PCA accompanied with the Euclidian similarity measurement. By doing so, all the false detected patterns are removed. Therefore, the QR code localizations are launched by assembling the remaining patterns into groups. Each group (compounded exclusively by three FPs and at least one AP) allows localizing a QR code. Finally, the obtained QR codes are assessed and rectified in case of structural deformations.

Future directions of research concern the integration of an additional processing which will be implemented at the beginning of the system. This process aims at evaluating the quality of the captured image in terms of blur and photometric distortion. The corrupted images are automatically discarded.

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Segmentation of Brain Tumor in Multimodal MRI using Histogram Differencing & KNN

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***Abstract*—Tumor segmentation inside the brain MRI is one of the trickiest and demanding subjects for the research community due to the complex nature and structure of the human brain and the different types of abnormalities that grow inside the brain. A Few common types of tumors are CNS Lymphoma, Meningioma, Glioblastoma, and Metastases. In this research work, our aim is to segment and classify the four most commonly diagnosed types of brain tumors. To segment the four most common brain tumors, we are proposing a new demanding dataset comprising of multimodal MRI along with healthy brain MRI images. The dataset contains 2000 images collected from online sources of about 80 patient cases. Segmentation method proposed in this research is based on histogram differencing with rank filter. Morphology at post-processing is practically implemented to detect the brain tumor more evidently. The KNN classification is applied to classify tumor values into their respective category (i.e. benign and malignant) based on the size value of tumor. The average rate of True Classification Rate (*TCR)* achieved is 97.3% and False Classification Rate (*FCR)* is 2.7%.**

Keywords—MRI imaging; tumor types; image segmentation; Histogram Differencing; KNN

I. Introduction

Image segmentation is not a hectic task in the field of image processing. Segmentation is a process of extracting the required region from the overall image. Medical image segmentation helps physicians to identify abnormal regions in the body, which tend to save time and efforts of the physicians. Tumor inside a human brain is among the most lethal diseases nowadays. According to the American National Institute [6], almost 3 billion people die annually because of this disease. According to medical study, more than 100 types of tumor have been diagnosed to date, but few of them are most common including Glioblastoma, which is most acute. In this research work four most acute types of brain tumor i.e. Glioblastoma, Meningioma, CNS Lymphoma, and Metastases have been considering.

In the medical study, Tumor broadly categorizes into two classes, tumor in the initial steps consider as primary and tumor with more aggressive in nature known as secondary. Primary tumors are those which spread in the area of their origin and are further divided into benign and malignant.

A benign tumor can be categorized as non-cancerous and in a stage from where a human can recover while malignant is more aggressive and may lead to cancer. Secondary tumors are spread from one organ to other and are normally not recoverable.

There are several techniques used to generate Medical images for medical studies. Amongst them, MRI is the most widely used, because most of the other techniques like Computed Tomography (CT) and X-Rays uses high ultraviolet (UV), rays which are harmful to human health, while the MRI scans use the magnetic field which is comparatively less harmful to UV rays. MRI images have different kinds of modalities like Sagittal, T1, T2, and Flair which represent the different variation of the same organ. Under the research conducted by American Brain Tumor Association [7], around 78,000 new patient cases including 25,000 fundamental and 53,000 non-risky tumors are apparently going to be diagnosed.

Brain Tumor & Types

A Brain tumor is one of the most widely occurred diseases that can threaten human life to death. Like other types of tumors, the brain tumor has about 120 different types [7]. Out of these 120 types, some are acute and some are chronic. In this research work, we will be using the following four types of a brain tumor as they are more severe and grow quickly.

Glioblastoma (GBM)

These types of tumors grow in the glial cells of the brain and are hence called as glioma, one of its types is Gliomablatosma also called astrocytoma, and the cells where it grows are astrocytes [28].

Meningioma

Meningioma is considered as primary, and most of the tumor in Meningioma is benign because of its slow growing nature [29].

CNS Lymphoma

This type of tumor arises in the lymphatic tissues which are the main module of the body immune system; this type of cancer is called CNS Lymphoma (CNSL) or Primary CNS Lymphoma (PCNSL) [30].

Metastatic

The metastatic brain tumor also called secondary brain tumor. A tumor begins in rest of the body and spoils the brain become known as metastatic [31].

MRI Types

The MRI can produce multiple plan or slices of the brain based on the thickness and position of the head. The Fig 1 show different slices and angles generate in the MRI modalities. For diagnosis single type of brain tumor or diseases multiple modalities generated by a physician to study the nature of the diseases [32].

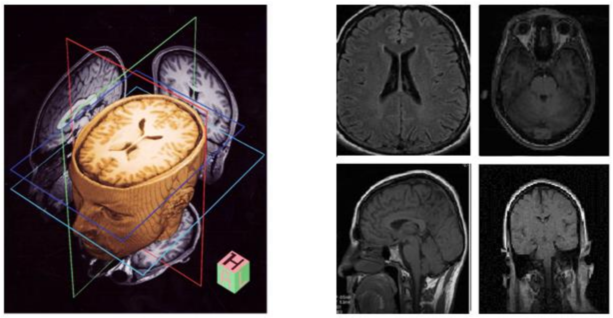


Fig. 1. Brain MRI images with different plane/angles to produce multiple modalities

The rest of the paper is organized as: In section II the relevant literature review is presented. In section III the detail description of the proposed dataset is provided. In section IV the methodology proposed in this research work is presented in detail. In section V the experimental values and detail discussion about the end results are explained. In section VI the conclusion is given of this research work.

II. Literature

The state-of-the-art review and survey literature can be seen in [8], [9], [10], [11], [12], [13], [14], [15], [16].

Shen et al [1] offer an algorithm for segmentation to improve cerebral tumor pattern C (FIMC) between neighbors and neighboring neighbors within each group of each neighboring pixel to try to attract each pixel to its own mass. The results comparing the segmentation of coding algorithms FIMC and MHF in three types of synthetic brain imaging, and brain magnetic resonance imaging exporter (South IBSR General Hospital). Reddy et al [3] present a confidence surface base novel idea on the basis of texture and intensity information from multiple MR images modalities T1(weighted), T2 weighted (T2), and FLAIR to segment brain tumor. The comparison of both proposed and original technique is, that the technique proposed by the authors can also differentiate normal tissues from those which are affected by the tumor. Szilagyi et al [2] present two methods, one for features extraction from images provided by BRATS 2012 dataset and in the second method the features passed to the optimal decision tree for selecting the tumor region. After this, a level-set segmentation is used to separate tumor and edema in the image.

Segmentation obtained with our method is more accurate than before, especially for low-grade tumors. Abdel et al [4] developed a system for the segmentation of tumor using K-means with the combination of Fuzzy C-means (FCM) algorithm to identify brain tumor precisely and as quickly as possible in MRI image. The purpose of combining the two algorithms is the accuracy of FCM and fast computation of K-Mean algorithm is considered. For the evaluation of their method total of 255 MRI images were used. Zhan et al [5] develop a method utilizing the intensity feature of multispectral MRI from both normal and abnormal. The feature is then passed to sparse representation classifier and also to Markov Random Field (MRF) regularization to classify into the tumor and normal tissues of the brain. Selva Kumar et al [17] developed brain tumor segmentation method based on k-mean and fuzzy C-mean (FCM). For getting better results of median filter salt and paper noise is added to suppress the noise for more efficient outcome. The extraction of characteristics is done by thresholding, at the end of the last segmented cluster approximates reasoning method for recognizing the shape and position of the tumor on MRI is obtained. The method is compared with the other segmentation algorithms and found to be more accurate in terms of segmentation.

Aslam et al [18] built up an enhanced sobel edge detection system for brain tumor origin extraction. The improved sobel edge detection technique is used with dependent thresholding to finds different regions in MRI images using closed contour algorithm. The improve sobel edge detection technique is working better for closed counter in tumor extraction. The performance of the technique is tested on 7 MRI images. Azhari et al [19] present a method to recognize and detect tumor in brain MRI images. To enhance the quality of the MRI image, the median filter is used as preprocessing step, the Canny edge recognition method is then applied to smooth the edges and get directions of the edges. Initially, the histogram of the cluster is used to build the image and the detection of cancer. To optimize the system design 50 images were used and 100 outside the sample neuroimaging test, the proposed system of the authors gives an error of 8%. Han et al [20] developed an improved segmentation for brain tumor by combining two methods fuzzy clustering and fuzzy edge enhancement. These study results show that the obscure and complex fuzzy segmentation curve were highly efficient. In the case of a medical image processing algorithm provides promising future application.

Angoth et al [21] present a wavelet base fusion method for brain tumor detection. The images from different Modalities CT and MRI passes through the median filter to improve contrast and brightness. After the filtering process, the images are passing through wavelet analysis followed by wavelet fusion by taking the average minimum or maximum of the coefficients. The algorithm compares with other present methods to show the effectiveness of the proposed algorithm. Nosheen et al [22] developed an automatic method for the detection, segmentation, and for features set evaluation of brain tumor using dataset of NCI-MICCAI 2013. The two methods Gabor Wavelet (GW) and Gray Level Co-occurrence matrix have been used. Firstly, different features like frequency, locality, and orientation extracted through GW from the frequency and spatial domain. Secondly, the GLCM, GLRLM, HOG, and LBP methods are used to extract texture base features. At the end, the comparison of both the features extracted method and based on their comparison statistical features gives better results.

Dahab et al [23] in their research present a modified Probabilistic Neural Network (PNN) based image segmentation technique to detect brain relying on learning vector quantization (LVQ) for automated brain tumor classification. First, the image smoothing and enhancement operations were performed using linear and Gaussian filter. For the edge detection, a vector subtraction algorithm with the ROI and Canny edge detection method is practically applied to identify the edges. These are carried to transform the conventional PNN based on LVQ. The experimental results were carried out on 64 MRI images with the overall accuracy rate of 100%. Ahmad et al [24] present a new yet effective and simple method and dataset of multimodal MRI images for the segmentation of four most commonly diagnose types of brain. The segmentation is consist of four basic steps, at the preprocessing 2D adaptive filter is applied to make the brain MRI image more appropriate for segmentation, after this, in the second step a threshold base segmentation utilizing Otsu's is applied to get the segmented image. In the third step, morphological operation is applied using erosion and dilation to remove the extra particles like Gaussian noise and the remaining skull of the MRI image for getting tumor region more precisely and correctly. At the final step, overlay base image fusion is used to craft the tumor region more noticeable for decision making.

III. PROPOSED DATASET

The proposed dataset consists of multiple modalities and different variations of MRI images. The total number of MRI images in our dataset is 2000 including healthy and tumor affected MRI. The detail about our proposed dataset is given in Table 1.

TABLE. I. DATASET DESCRIPTION

Types of MRI Images	**No of MRI Images**	**Patient Cases**	
CNS Lymphoma	500	Male	10
		Female	8
Glioblastoma	450	Male	10
		Female	6
Meningioma	450	Male	8
		Female	8
Metastases	150	Male	6
		Female	4
Healthy	450	Male	10
		Female	10
Total	2000	80	

The dataset builds from the online available radiological sources Radiopaedia [25] and verified from an FCPS Neurosurgeon for make it more authenticated. The sample of our proposed dataset for the aforementioned types of tumors can be seen in Fig 2.

Fig 2 (a), shows the presence of Primary CNS lymphoma in different modalities of MRI, given the homogeneous vivid enhancement, location, and restricted diffusion. The MRI image related to a male patient case with 79 years of age.

In Fig 2 (b), showing male patient case of age 75 with the most likely high-grade glioma or Glioblastoma (GBM) with significant mass effect.

In Fig 2 (c), shows Meningioma tumor MRI images related to Middle age female patient with a severe headache. There is a well-defined extra-axial and dural based mass lesion, seen in the left frontal region.

In Fig 2 (d), showing multiple cerebral and metastases from lung carcinoma in a 70-year-old man.

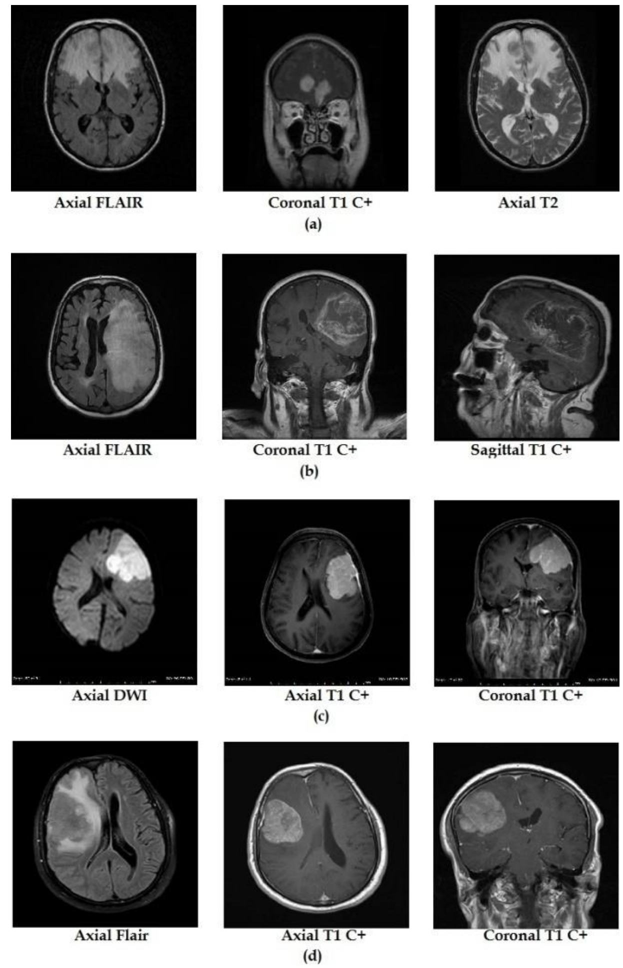


Fig. 2. Sample of MRI Modalities and Tumor Types used in our proposed dataset

IV. METHODOLOGY

In this research work, we proposed a new technique for the segmentation and classification of four basic types of tumors using brain multimodal MRI images. This method is based on the histogram differencing based segmentation and unsupervised KNN classification. In the post processing rank filter is used with morphological analysis to remove the skull and extra particles from the segmented image for making thing easy during the calculation of tumor region. The Tumor Size is calculated from the matrix manipulation of the segmented image. In the Fig 3, shows the step by step implementation of our proposed algorithm.

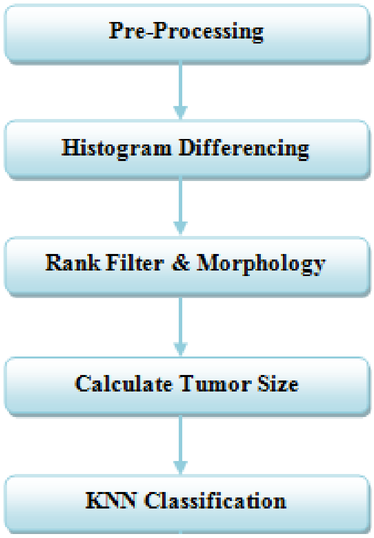


Fig. 3. Proposed algorithm

A. Histogram Differencing

Histogram base segmentation method depends on one of two essential properties of force qualities intermittent and similitude. To start with class is to segment an image in light of sudden changes in force, for example, edges in a picture. Second class depends on parceling an image into locales that are comparative as indicated by predefined criteria. Histogram based approach falls under this class. The Histogram is developed by part the scope of the information into equivalent estimated of canisters/sections likewise called classes. At that point for every cluster, the quantity of focuses from the information set that fall into every canister is numbered. Building the picture histograms, the pixels shape the flat pivot is considered.

First, the histogram of the initial grayscale MRI image is generated. Fig 4 shows the histogram of the original grayscale image.

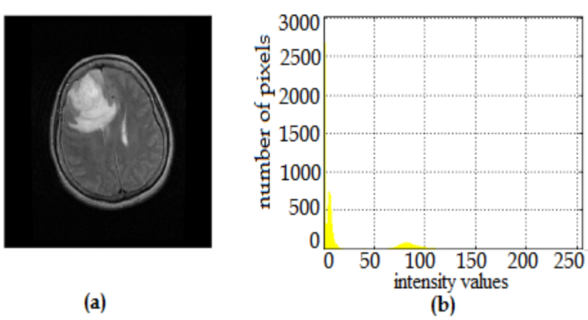


Fig. 4. (a) The original gray scale image (b) histogram of the original gray scale image

After getting the histogram of the initial image. we than calculate number of columns in the gray scale image to extract the left and right side of the image for histogram differencing *HD*, and then separate histograms of left and right side images are computed to find the difference between the two histogram. The steps of the histogram differencing method are as follow.

Histogram differencing basic steps

- Find matrix *M* in gray scale image
- Divide the matrix *M* by 2, *M*/2 for finding
  - Left side of the image "*LH*"
  - Right side of the image "*RH*"
- Subtract *LH* and *RH* to find the difference of histogram "*HD*"
- Apply threshold *T* on . *HD* to get the final segmented image *I*.

The left half of the original grayscale image with the resultant histogram and right half of the image with the resultant histogram can be seen in Fig 5 (a), the resultant display of left half of the original grayscale image is produced with its resultant histogram showing the level of gray scale pixels and number of pixels, In Fig 5 (b) the resultant display of right half of the original grayscale image is produced with its resultant histogram showing the level of gray scale pixels and number of pixels.

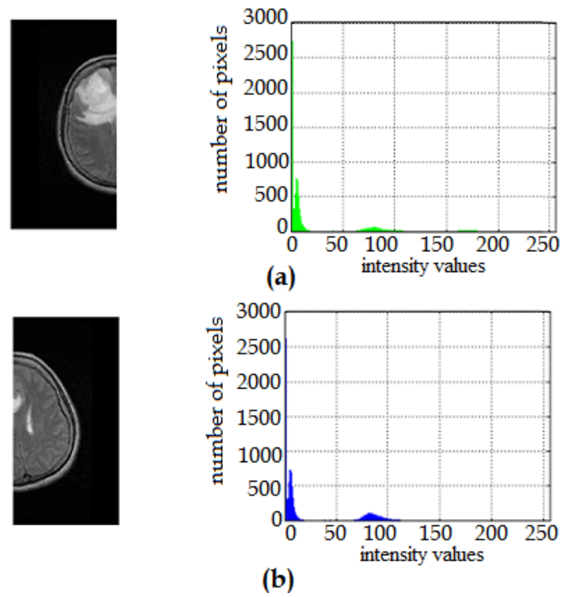


Fig. 5. a) Represent the left half the gray scale image with the resultant histogram, (b) Represent the right half the gray scale image with the resultant histogram

When the two parts, left half of the original gray scale image *LH* and right half of the original gray scale image *RH* with their appropriate histograms are computed from the initial brain MRI image, the difference between the two histogram generated from the two histograms *LH* and *RH*. Difference of both histograms results in segmented image with the affected or tumor region inside the MRI. The resultant image produced by the histogram differencing can be seen in Fig 6. In Fig 6(a) shows the histogram of the two previously constructed histograms, in Fig 6(b) the resultant image produced by the through histogram differencing with the tumor region as foreground.

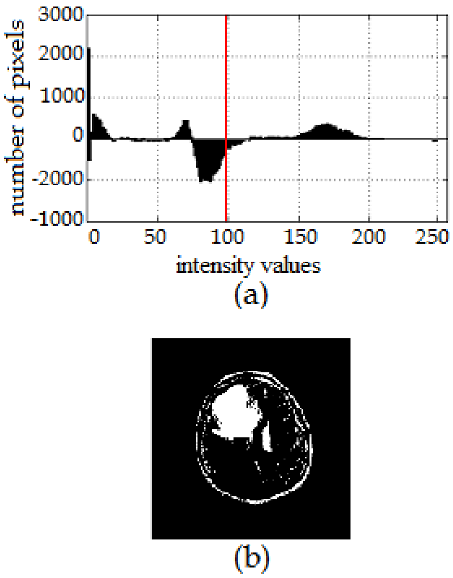


Fig. 6. The resultant display after histogram differencing (a) showing the resultant histogram of Histogram Differencing while subtracting the two histogram (b) shows the resultant image after applying thresholding on the resultant image generated from histogram differencing

B. Post Processing

In the post processing, we combine two techniques, 2-D order statistic filter and Morphological operations for getting better tumor resultant image. The 2-D order statistic filter is applied to support morphology to minimize the size of structure element used in morphology for erosion and dilation.

a) Order statistic filter

The above Fig 6 clearly shows that the extra boundaries affect the shape and the Tumor Size in the resultant image getting after the histogram differencing to remove those boundaries we apply order static filter. The order statistic filter is an order based filter, which defines or estimate the order like first order statistic or min, largest order statistic max etc. Given observations $X_1, X_2, X_3 \ldots\ldots\ldots X_N$ of a random variable X.

The order statistics are obtained by sorting the ascending order. This produces $Y(i)$ satisfying $X(1),X(2),X(3),\ldots..X(N)$. Where X represent the N observation of order statistic filter. So, an Order Statistic Filter (OSF) is an estimator $F(X_1;X_2;X_3\ldots\ldots\ldots..X_N)$.

Filtering using order statistics perform extremely fine in the existence of preservative white noise or impulsive noise if the filter is designed appropriately. One of its property is to preserve the edges and is very much simple in term of computational complexity, their computation can become faster if the algorithm is designed properly [26]. After applying order static filter the tumor shape and size become more prominent, the result of the order static filter can be seen in Fig 7, where the boundary removes without affecting the size and shape of the tumor up to certain level.

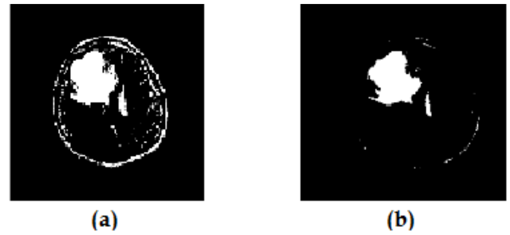


Fig. 7. the figure shows the resultant display of the order static filter, (a) the resultant image of the histogram differencing, (b) the actual resultant image generated after applying order statistic filter

b) Morphological operation

Applying the order static filter gives significant results but still, there is some noise which may affect the size of the tumor during calculation. To get the more precise region of the tumor for size calculation, we apply morphological operations to removes that extra little noise and particles. In combination applying morphology with the order static filter gives significant results. The structure element design for performing the morphological operation is 5*5 for dilation and 7*7 for erosion. In Fig 8, the size and the construction of the structure element developed for this purpose can be seen. Both the structure elements give the desired results as required.

0	0	0	1	0	0	0
0	0	1	1	1	0	0
0	1	1	1	1	1	0
1	1	1	1	1	1	1
0	1	1	1	1	1	0
0	0	1	1	1	0	0
0	0	0	1	0	0	0

(a)

0	0	1	0	0
0	1	1	1	0
1	1	1	1	1
0	1	1	1	0
0	0	1	0	0

(b)

Fig. 8. The two structure elements (SE) used in the morphology steps, (a) diamond shape 7*7 SE, (b) diamond shape 5*5 SE

In Fig 9, we can clearly see that the tumor is coming more prominent after applying morphological erosion and dilation bases on the design structure elements showing in the above Fig 8 after applying morphological operation its becomes easy to calculate the size of the tumor and to classify the tumor based on the size.

Fig. 9. The resultant display image of morphology step, (a) the result of order static filter showing in 7 (b), (b) the resultant image after applying morphology

C. Classification using KNN

KNN (K-nearest neighbor) is a non-parametric, because of its non-parametric approach it's become very useful for the real world problems to classify, KNN used in both classification and regression of data. KNN is a simple algorithm that store all variable or cases and classifies new cases based on some similarity function like distance base using Euclidian distance etc to find the nearest cases. KNN is a statistically based method used for pattern recognition and classification of cases.

The KNN is used for continuous values; applied the various number of *k* values for measuring and to compute the distance between the values of two classes, for this the Euclidian distance is consider based on *k* values from 1 up to 9. In this research work, the KNN classification is used to classify the tumor values into two classes benign or malignant. For the classification, the values of tumor are generated from the segmented image showing the tumor tissues, the value represent different size of tumor in mm^2. The values are generated for the complete dataset of the proposed images and consider for KNN classification.

For the classification of two classes, we have the data in *a* and *b* (a_1,b_1),……………………….,(a_n,b_n).

$a€R^D$, *a* represent the values of classes tumor and non-tumor on the x-axis in *D-Dimensional* plane.

b € *{0,1}*, *b* belongs to finite class representing the classification of values. The *b* will consider values from the two classes for classification it will be either in tumor or non-tumor. Now taking a new values *z* which will represent a new label of a class as k-nearest value to classify the values into their respective category. If the highest numbers of labels from the two classes close to the k-nearest point *z* then the classification results will award the same class as an outcome.

V. Results and Discussion

After segmentation the tumor size will be calculated and will find the percentage of tumor in MRI image. According to WHO report of 2007 [27], the tumor is graded into four different grades from grade 1 to grade 4 based on the size, aggressiveness, and intensity etc of the tumor. To classify the tumor into their respective category, size is one the main features of through which we can easily identify the tumor category. In this research work, the size of the tumor region is calculated through matrix manipulation *(MM)*, the purpose of the matrix manipulation *(MM)* is to find out the total number of foreground/tumor pixels and background/non-tumor pixels.

To find both foreground and background pixels, first we find and calculate the total number of pixels (*TNP*) from the matrix of the final segmented image. After calculating *TNP* through *MM* from the matrix of the segmented image, we then calculate the number of foreground pixels (*NFP*), the foreground pixels is representing by 1 in the matrix and 0 represent background pixels in the matrix. The *NFP* is the indication of tumor pixels which is further used for finding the size of the tumor. In Fig 10 shows the matrix of the segmented image displaying the value of foreground/tumor pixels and the values of background pixels in the segmented image which is further use to calculate the size of the tumor.

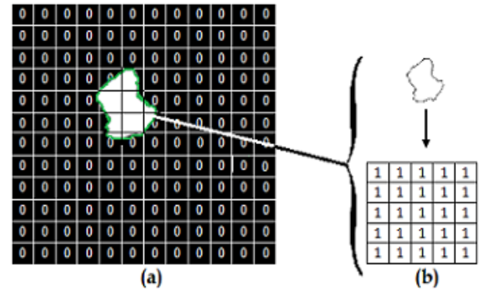


Fig. 10. Shows the matrix of the segmented image, (a) is a full-length matrix of an image representing *TNP*, (b) is the segmented area/tumor area with its desire matrix to find and calculate *NFP* for tumor size

After calculating the *TNP* and *NFP* in the image matrix, we locate and find out the Tumor Size in two modes, in percentage and in millimeter square (mm^2). Firstly, the Tumor Size is calculated in percentage using the parameters generate during the *MM*. In the first mode of calculating the Tumor Size in percentage is as follow.

In the following, divide *NFP* by *TNP* and multiply by 100 to find out the tumor size in percentage.

Mode 1: Tumor Size in percentage (%)

IF
TNP = 80000 pixels
And
NFP = 8000 pixels
THEN
*Tumor Size = NFP/TNP * 100*
*Tumor Size = 1400/8000 * 100*

The tumor Size is 10 % in the segmented brain MRI image

Secondly, after calculating the tumor size in percentage in the first mode, the same number of parameters of *MM* will be utilized in the second mode for calculating the tumor size in mm^2.

The following steps of calculation are used to find out the Tumor Size in mm^2 during the second mode. In the second mode, first take under-the-root of *NFP* and then multiply with a single pixels value in mm^2 which is $0.264mm^2$ (1 pixels = $0.264\ mm^2$).

Mode 2: Tumor Size in mm²

1 pixel = 0.264 mm²

$$Tumor\ Size = [\![(\sqrt{NFP})]\!] * 0.264\ mm^2$$

IF
NFP = 8000
THEN

$$Tumor\ Size = [\![(\sqrt{8000})]\!] * 0.264$$

The Tumor Size is 23.6 mm² in the segmented brain MRI image

After calculating size of tumor from the foreground pixels, the size value calculated in mm^2 is considered to classify the values into two classes benign and malignant using KNN, the size values are calculated for both healthy and tumor MRI images and divided into two classes for classification. Using the KNN for classification, we used the Euclidian Distance in KNN and consider the different variation of *k* values from 1 to 9 for classification to verify the effectiveness of our algorithm.

To get the accuracy rate for different variations of *k* using KNN, the True-Classification-Rate (*TCR*) and False-Classification-Rate (*FCR*) is calculated for the number of values generated from the dataset.

To calculate the *TCR* and *FCR* we use the Total Number of True Classified Values *(TNTCV)* and Total Number of False Classified Values *(TNFCV)* out of the Total Number of Values *(TNV)* used for KNN for classification.

To calculate *TCR*:

$$TCR = (TNTCV / TNV) * 100 \tag{1}$$

To calculate *FCR*:

$$FCR = (TNFCV / TNV) * 100 \tag{2}$$

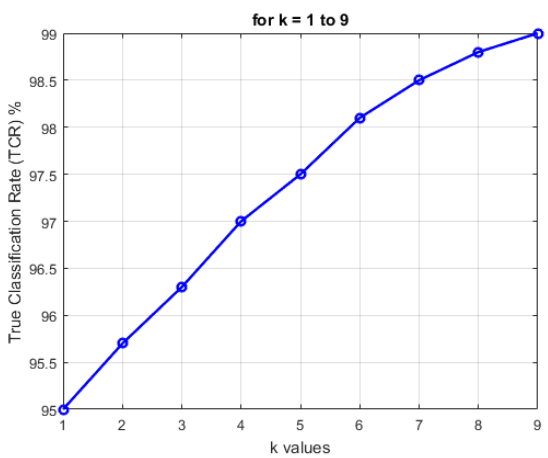
The details results of classification via KNN for the different variation of *k* are presented in Table II. The results can vary on different datasets and may possibly be affected by the number of data being used for classification. The number of 80 patient cases containing 2000 MRI images for the four used types of tumors with healthy MRI images is consider for testing purpose based on *k* values from 1 to 9. If we look into the table II, it is very much clear that every value of *k* gives a different rate of classification, for *k = 1* the *TCR* rate is 95% and for *k = 9* the *TCR* is 99%. The overall results show that taking value of *k* higher than 9 will give results that will become bias for our proposed dataset. So far it is observed from the testing that for the proposed dataset the best suitable *k* value is in between 1-to-9.

The table II shows the overall TCR and FCR for the proposed dataset generated on the basis of *k* values from 1 to 9.

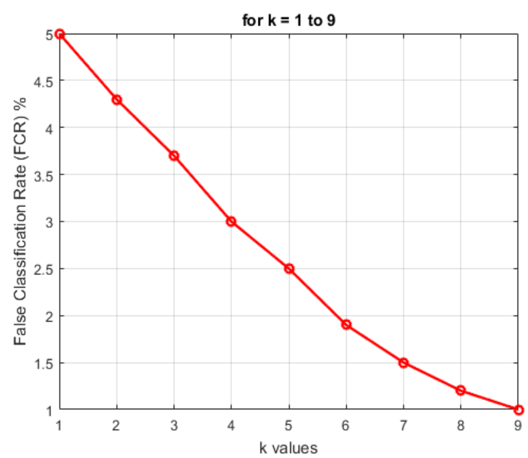
TABLE. II. DETAIL DESCRIPTION OF TCR AND FCR BASED ON *K* VALUES FROM 1 TO 9

k	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
TCR	95 %	95.7 %	96.3 %	97 %	97.5 %	98.1 %	98.5 %	98.8	99 %
FCR	5 %	4.3 %	3.7 %	3 %	2.5 %	1.9 %	1.5 %	1.2 %	1 %

In Fig 11, showing the result for different *k* values. In Fig 11 (a), it can be seen that from different values ranging from 1 to 9 the minimum TCR of is 95% with *k=1* and for *k=9* the *TCR* is 99%. In Fig 11(b) shows the *FCR*, the maximum recorded *FCR* is for *k=5* which is 5% and the *FCR* is decreasing taking higher values of *k*. The *TCR* and *FCR* graphs are clearly explaining the classification achieved by applying different variations of *k* within the proposed method.



(a)



(b)

Fig. 11. Shows the graphical representation of TCR and FCR for *k* values from 1 to 9, (a) representing *TCR*, (b) representing FCR

VI. CONCLUSION

A brain tumor is a kind of mass over the brain, the mass can be either benign or malignant. The nature of brain tumor varies depending on the location, and size of the tumor inside the brain. Image processing helps to diagnose and treat brain tumor successfully using the benefit of MRI imaging technology. In this research work, a technique to segment and classify four most common types of brain tumor has been proposed. The dataset used in this research contains 2000 MRI images with an expert opinion of FCPS Neurosurgeon. To segment tumor pixels from the rest of the brain tissues, the histogram differencing based approach is applied to segment and detect tumor pixels. After applying histogram differencing the order statistic filter and morphology has been applied as post-processing to improve the result of segmentation. After successful segmentation of tumor region through histogram differencing using MRI images, the tumor size is than calculated through matrix manipulation in two different modes percentage and mm^2. The values calculated in *mm*2 are then considered for KNN classification method to classify tumor into benign and malignant. The KNN classification method is based on Euclidian distance with the different variation of *k* values for testing and evaluation of the developed algorithm. The average rate of *TCR* of classification is 97.3% and the average rate of *FCR* is 2.7 for different values of *k.*

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VHDL Design and FPGA Implementation of LDPC Decoder for High Data Rate

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***Abstract*—In this work, we present a FPGA design and implementation of a parallel architecture of a low complexity LDPC decoder for high data rate applications. The selected code is a regular LDPC code (3, 4). VHDL design and synthesis of such architecture uses the decoding by the algorithm of BP (Believe propagation) simplified "Min-Sum". The complexity of the proposed architecture was studied; it is 6335 LEs at a data rate of 2.12 Gbps for quantization of 8 bits at the second iteration. We also realized a platform based on a co-simulation on Simulink to validate performance in BER (Bit Error Rate) of our architecture.**

Keywords*—*error correcting codes; LDPC codes; BP “Min-Sum”; VHDL language; FPGA

I. Introduction

LDPC codes were discovered by Gallager [1][2] in the early 1960. This remarkable discovery has been largely ignored by researchers for nearly 20 years, until the work of Tanner in 1981, in which he provided a new interpretation of the LDPC codes from a graphical perspective. Tanner's work has also been ignored by theorists for about 14 years until the late 1990s, when some coding researchers began to investigate the graphic codes and iterative decoding. Their research led to the rediscovery of Gallager’s codes. They showed that a long LDPC codes with iterative decoding based on the Believe Propagation enable a performance error representing only a fraction of a decibel away from the Shannon limit [3][6][7][8]. This discovery makes the LDPC codes powerful competitors relative to turbo codes for error control when high reliability is required. LDPC codes have the advantage of turbo codes, it does not require a long interleaving to achieve a good error performance. Thus in 2004, an LDPC code was first standardized in a satellite broadcast DVB-S2 [9].

In this work, we are interested in building a regular LDPC code and study its performances in terms of complexity, data rate, latency and BER versus SNR for various iterations and quantifications.

We began by recalling the principle of LDPC codes in the first part; the second part is devoted to the implementation of said decoder and the last one to validate our design.

II. The LDPC Codes

A. Principle Of LDPC Codes

An LDPC code can be represented by its parity check matrix (noted H) or by a bipartite graph (Tanner graph). In the example of Fig. 1, the rows of the matrix are represented by squares and are called check nodes, the columns of the matrix are represented by circles and are called data nodes and the”1” represent the edges in the graph.

$$H = \begin{vmatrix} 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 1 \end{vmatrix}$$

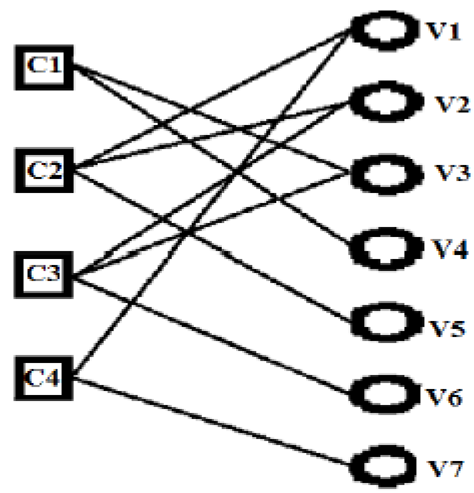

Fig. 1. Example of parity check matrix and its correspondent Tanner Graph

B. Encoding of LDPC codes

The encoding operation consists first in finding a generator matrix G such that $G.H^T = 0$. The work of T. J. Richardson and Urbanke R.L [4] showed that the check matrix must undergo a pre-processing before the encoding operation. The aim of this pre-processing is to put this matrix in a lower pseudo-triangular form, as shown in Fig. 2, using only permutations of rows or columns. This matrix is composed of 6 sparse sub-matrix, referenced A, B, C, D, E and a lower triangular T sub-matrix. The size of T sub-matrix is (m-g)×(m-g) where g is smaller as possible. Once the H pre-processing is completed, the coding principle is based on the resolution of the system represented by the equation (1) [4]. Where C is a code word:

$$C.H^T=0^T \qquad (1)$$

The pre-processing algorithm is described by Jean-Baptist Doré [10].

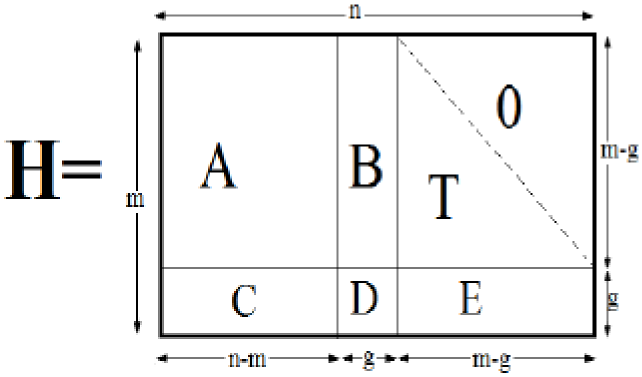

Fig. 2. Parity check matrix represented in lower pseudo-triangular form

C. Decoding of LDPC Codes

Decoding the LDPC codes is done from iterative algorithm; the most used is the BP (Belief Propagation). In our work, we have used the BP "Min-Sum" adapted to the hardware implementation. The algorithm consist to update, first the data nodes after, check nodes at each iteration and at the end make a decoding “Hard” decision that is the most likely codeword [10].

III. FPGA Implementation of LDPC Decoder

LDPC code discussed in this document is characterized by the H parity matrix given in (3), after we made the necessary transformations on H [9] to determine the generator G matrix. This G matrix is the basis of the LDPC encoder which calculates the word C code from the u information as follows:

$$C=u.G \qquad (2)$$

The LDPC decoder is designed in VHDL and implemented on the EPC4CE115F29C7 type of FPGA Altera using the simplified BP "Min-Sum". The decoder circuit is given in Fig. 5. Table I summarizes the complexity (in Logic Elements LE), data rate , and decoder latency for 2nd, 10th and 20th iterations quantized on 5, 6, 7, 8 and 11 bits.

Operators used to update variable nodes and check nodes are illustrated in Fig. 3 and Fig. 4 respectively.

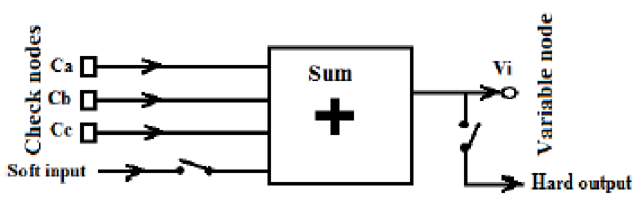

Fig. 3. Data nodes updating operator

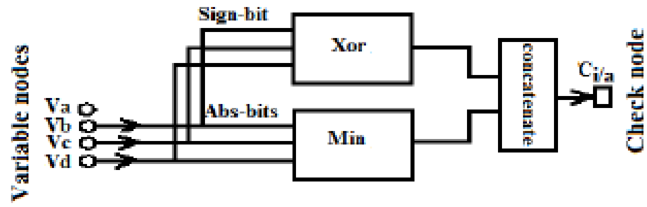

Fig. 4. Check nodes updating operators

The functional simulation on Quartus II tool (see Fig. 6) shows the parallel computing implemented, allowing the updating of outputs after the first active edge of the clock. Where, a maximum latency equals to one clock cycle.

$$H=\begin{bmatrix}
1&1&1&1&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&1&1&1&1&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&1&1&1&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&1&1&1&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1&1&1&1\\
1&0&0&0&1&0&0&0&1&0&0&0&1&0&0&0&0&0&0&0\\
0&1&0&0&0&1&0&0&0&1&0&0&0&0&0&0&1&0&0&0\\
0&0&1&0&0&0&1&0&0&0&0&0&0&1&0&0&0&1&0&0\\
0&0&0&1&0&0&0&0&0&0&1&0&0&0&1&0&0&0&1&0\\
0&0&0&0&0&0&0&1&0&0&0&1&0&0&0&1&0&0&0&1\\
1&0&0&0&0&1&0&0&0&0&0&1&0&0&0&0&0&1&0&0\\
0&1&0&0&0&0&1&0&0&0&1&0&0&0&0&1&0&0&0&0\\
0&0&1&0&0&0&0&1&0&0&0&0&1&0&0&0&0&0&1&0\\
0&0&0&1&0&0&0&0&1&0&0&0&0&1&0&0&1&0&0&0\\
0&0&0&0&1&0&0&0&0&1&0&0&0&0&1&0&0&0&0&1
\end{bmatrix} \qquad (3)$$

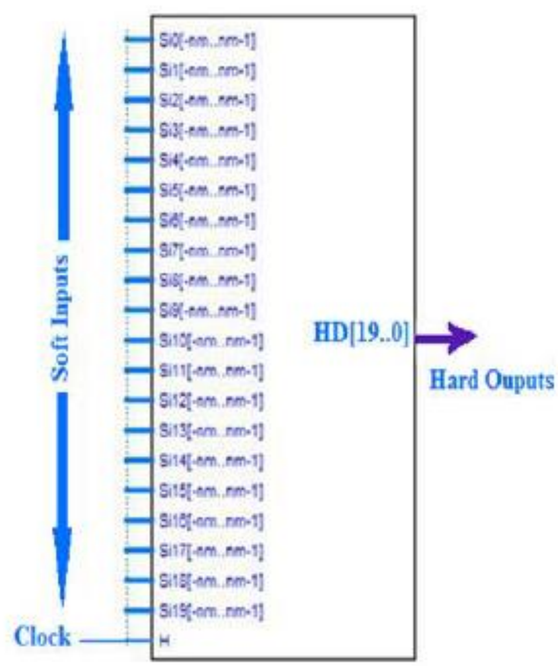

Fig. 5. External scheme of our LDPC decoder circuit

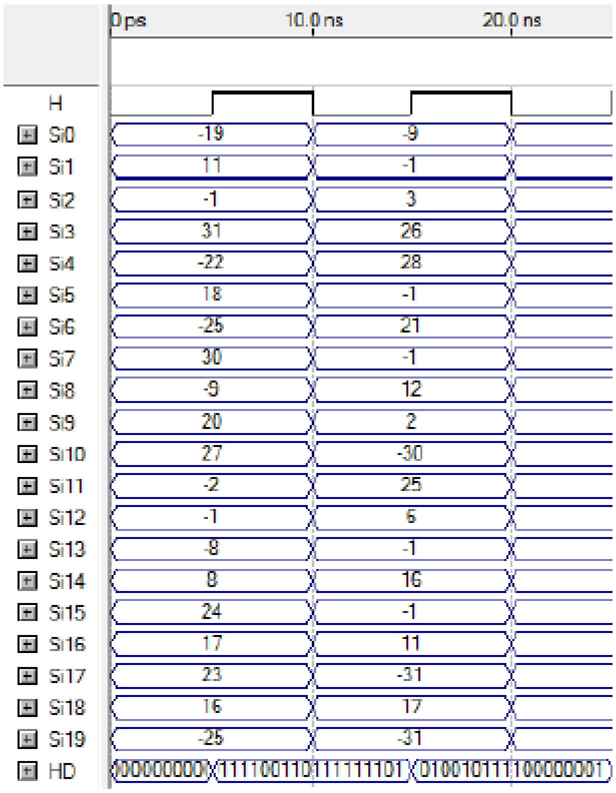

Fig. 6. Example of the decoder functional simulation

The evolution of complexity versus the iterations and the number of quantization bits is shown in Fig. 7. This shows that the complexities of the 10th and the 20th iteration are multiplied respectively by 5 and 10, relative to the 2nd iteration, whatever the number of quantization bits.

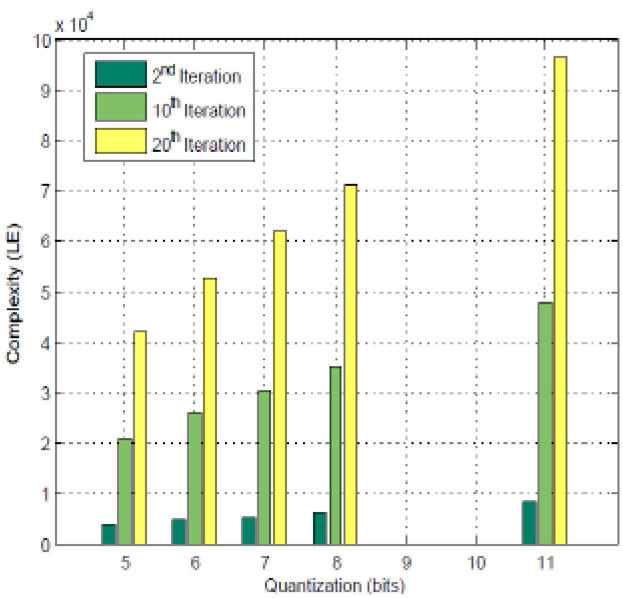

Fig. 7. Complexity evolution depending on the number of iterations and the number of quantization bits

TABLE I. DECODER PEFORMACES FOR DIFFERENT ITERATIONS AND NUMBER OF QUANTIZATION BITS

Iteration	*Characteristics*	*Quantization*				
		5bits	*6bits*	*7bits*	*8bits*	*11bits*
2nd, 10th and 20th	*Pins number*	121	141	161	181	241
2nd	*Complexity (LE)*	3817	4715	5515	6335	8595
	Freq. Max (Mhz)	109.06	108.11	106.61	106.04	99.82
	Latency (ns)	9.17	9.25	9.38	9.43	10.02
	Throughput (Gb/s)	2.18	2.16	2.13	2.12	2.00
10th	*Complexity (LE)*	20881	26035	30595	35151	47755
	Freq. Max (Mhz)	106.94	105.60	104.92	103.84	97.96
	Latency (ns)	9.35	9.47	9.53	9.63	10.21
	Throughput (Gb/s)	2.14	2.11	2.10	2.08	1.96
20th	*Complexity (LE)*	42126	52685	61945	71171	96705
	Freq. Max (Mhz)	105.85	104.83	103.59	102.08	95.79
	Latency (ns)	9.45	9.54	9.65	9.80	10.44
	Throughput (Gb/s)	2.12	2.10	2.07	2.04	1.92

IV. VALIDATION OF THE DECODER

After functional simulation on Quartus II, we validated our decoder in the digital transmission chain designed on the Simulink tool (see Fig. 8)[5]. This chain of Co-simulation also allowed us to measure the BER performance based on the SNR for various iterations and different quantization bits.

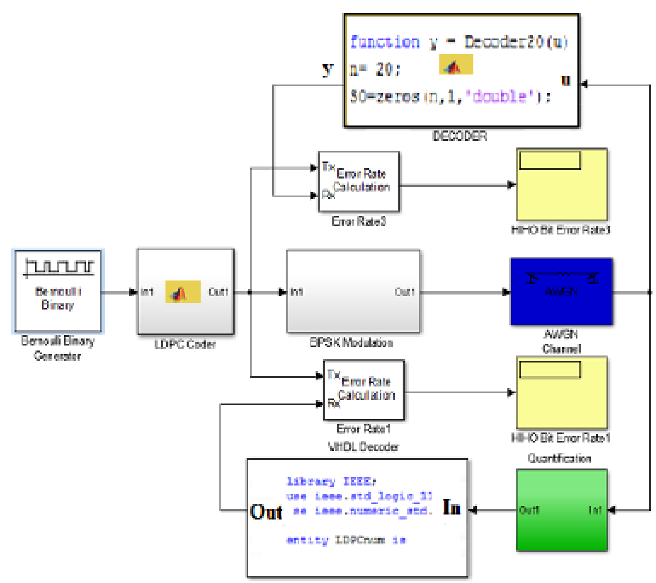

Fig. 8. Validation platform of our decoder circuit on Matlab/Simulink

Fig. 9 shows the BER performance of the decoder for the real data (2nd, 10th and 20th iteration), where one can see that the value of the SNR won in the 10th and 20th iteration, compared with the second iteration for a given BER is negligible in comparison to the complexity, which is multiplied respectively by 5 and10.

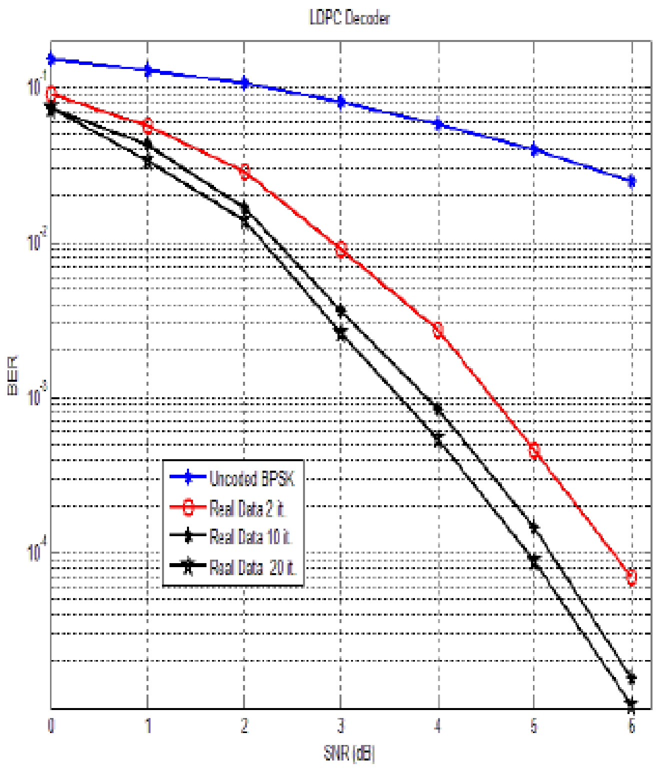

Fig. 9. BER Performances versus the SNR of the decoder for the 2nd 10th et 20th iteration (Real data)

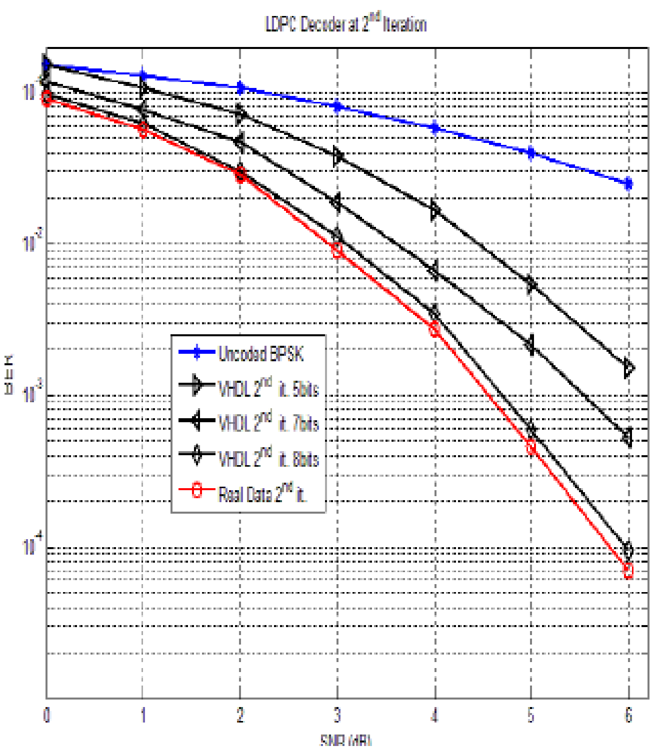

Fig. 10. BER performances for real data and VHDL implementation for the 2nd iteration

Fig. 10 shows this BER performance for the VHDL implementation for the second iteration (with quantifications of 5 bits, 6 bits, 7 bits and 8 bits). The results show that quantification of 8 bits gives BER performance very close to those of real data.

The comparison with other designs (see Table II), shows that our design has a very low complexity, higher data rate and acceptable BER performance.

TABLE II. COMPARISON WITH OTHERS DESIGN

References	**[13] 2013**	**[12] 2009**	**[11] 2012**	**[14] 2008**	**This Work**
LLR bitwidth	1^{U}	7^{U}	5^{U}	9^{U}	8^{U}
Clock (Mhz)	125.71	128	96	-	106.04
FPGA	Altera Cyclone4	Altera Stratix 2	Xilinx Virtex-5	Xilinx Virtex-2p	Altera Cyclone4
Algorithm	Hard decision	Min-sum	Min-sum with correction	Min-sum with correction	Min-sum
Iterations	12	8	10	10	2
Throughput (bps)	8.54G	465M	950M	1.54M	**2.12G**
ELs (k)	39.995	103.67	71.4	1.2	**6.34**
SNR(dB) at BER=10^{-4}	-	1.94	3.02	4.5	5.8
BER at SNR=1.5dB	-	4 10^{-4}	3 10^{-2}	-	4 10^{-2}

^{U}: Uniform quantization

We note that:

For the data rate s in the table II, they are evaluated without removing the parity bits.

For the complexity, some authors have used Stratix and Virtex FPGA circuits, where the complexity is evaluated by different units of LE (Logic Element), which therefore requires an analysis that is performed as follows:

For Stratix FPGA from Altera, where the complexity is expressed in ALUTs: LE=1.25*ALUT.[15].

For Virtex FPGA from Xilinx, the complexity is expressed in Slice and LUT, the approximate formula used is LE = Slice* 4*LUT * 0.83 [16].

V. CONCLUSION

In this paper, we designed in VHDL and implemented on the FPGA circuit an LDPC decoder, starting from its parity check matrix, and the determination of all the necessary means for its implementation, namely the generator matrix and decoding equations using the simplified method BP "Min-Sum". Then we tested and validated it on a platform developed in the Simulink software for the co-simulation with Dsp Builder software.

The results show that our design has a high data rate, low latency and very low complexity. The BER versus SNR can be further improved by the increase in the code size and keeping the same principle of parallelism.

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Resources Management of Mobile Network IEEE 802.16e WiMAX

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***Abstract*—The evolution of the world of telecommunications towards the mobile multimedia following the technological advances has demonstrated that to provide access to the network is no longer sufficient. The need for users is to access value-added multimedia services in their own home environment regardless of how they access the systems. Multimedia services require high transfer rates and have quality service requirements. They must coexist with services with real time constraints such as the voice service which does not tolerate variation of the delay between sending and receiving packets. The guarantee of these services by the operator becomes much more difficult in the technologies that take into account the mobility of the users.**

This paper studies the IEEE802.16e system according to the continuous modeling case. A model of the IEEE802.16e cell is proposed and allows the decomposition of the cell according to the principle of the AMC adaptive modulation and coding technique. The model is based on an admission control mechanism in the presence of two types of real-time and non-real-time traffic. The model is based on a new CAC strategy with intra-cell mobility and gives the same QoS for the calls of this traffic by favoring the calls in progress on the new arrivals.

Keywords—Wireless Networks; IEEE 802.16; WiMAX; Radio Resource Allocation; Mobility; Admission Control

I. Introduction

Mobile communications systems have evolved considerably in recent years. This has encouraged the deployment of several multi-technology cellular systems or networks. Quality of service (QoS) for mobile users improves across systems. Third generation (3G) systems, such as UMTS, offer better quality of service compared to second generation (2G) systems such as GSM. For example, 3.5G (HSDPA) systems improve the 3G network throughput on the downlink to meet the requirements of the new services. In addition, fourth-generation (4G) networks, such as WiMAX (IEEE802.16e) [1], extend cell coverage while delivering superior throughput. This new development further improves the accessibility of Internet services. Migration of services from the Internet to mobile networks is a major challenge for telecommunications research.

In particular, efforts have been made to optimize the quality of service and to differentiate between real-time and best-effort or non-real-time services. It is a service and content subject to constraints of availability of radio resources and network load, while maintaining the semantics and offering a rendering in accordance with users' expectations.

New mechanisms are needed to differentiate services and provide the quality of service required. These mechanisms include admission controls, resource reservation protocols, and packet scheduling policies. The challenge for next-generation networks is to maintain high bit rates and quality of service on radio links (up and down) that are unreliable for transmissions. CDMA is the most advanced technique of multiplexing, intended to be used especially on third generation mobile telephony networks such as UMTS [2]. Whereas the previous techniques of frequency multiplexing (FDMA) and time division multiplexing (TDMA) essentially consisted of dividing a physical quantity (a frequency bandwidth or the time that elapses) into individual "slots", the CDMA does not fix No prior static distribution of these resources and resembles computerized packet transmission techniques.

This technique was chosen because of the constraints specific to the 3G radio interface: variable rate, variable quality of service (multiservice traffic environment). It allows simultaneous access of multiple users at very high speeds and services (sound, image, multimedia, ...). There are nevertheless different CDMA variants. The one on which the UMTS standard called WCDMA is based. The speed promised by UMTS in theory is 2 Mbits/s, but it is never reached in practice because of the 3G network limitations. A WCDMA software extension called HSDPA was introduced to improve the downlink rate where more information will be transported. With the HSDPA [3] technique the throughput can reach 14 Mbps in the 3.5G network or HSP +. To better manage radio resources by the operator with more flexibility in terms of quality of service and throughput, a new OFDMA multiple access method has become the basis for next-generation networks such as IEE80.16e and LTE. The WiMAX network allows a theoretical throughput of 70 Mbits/s over a maximum radius of 50 km while relying on new techniques such as the adaptive modulation and coding scheme depending on the state of the radio channel associated with a mobile. LTE promises a very high bandwidth of up to 100 Mbps as well as wide accessibility of coverage (100 km in rural areas).

In this paper, we introduce a new admission control mechanism into the IEEE802.16e (WiMAX) network with two types of real-time and non-real-time traffic. The continuous case of the multiservice IEEE 802.16e system is studied. We develop a new resource allocation mechanism that takes into account intra-cell mobility of users. We consider a mobility model called RWP (Random Waypoint).

The remainder of this paper is divided into six sections. After introducing, the evolution of communication standards is presented in Section 2. Section 3 describes the standard IEEE802.16 (WiMAX) and its service classes and QoS. Section 4, describes related work on the capacity and admission control models of an HSDPA and IEEE802.16 cell. In section 5, an analysis of the IEEE 802.16e system is presented. Finally, this paper is concluded in Section 6.

II. Mobile Communication Systems

The eighties witnessed the birth of first generation, fully analog cellular mobile phone systems, such as *Nordic Mobile Telephony* (NMT), *Advanced Mobile Phone Service* (AMPS), *Total Access Cellular System* (TACS) or the *Radiocom2000*.

Nevertheless, reduced spectral resources, short battery life and terminal cost were obstacles that limited the early development of first generation mobile phones. The second generation of cellular systems emerged in the early 1990s with DECT (*Digital Enhanced Cordless Telecommunications*), GSM (*Global System for Mobile Communications*, Europe), PDC (Japan) and PCS (United States). Initially designed for speech and data transmission applications at low bit rates (9600 bits/s) around frequencies (935-960 MHz) or (890-915 MHz), this standard has allowed for the growth of mobile communications. The performance (spectral efficiency, safety, functionality) of the second generation of cellular systems is greater than that of the first generation. An important contribution to these systems has been the modification of the method of data access, and the birth of the intermediate generation named 2.5G, embodied by the *General Packet Radio Service* (GPRS) system. Another form of evolution of second-generation cell systems is embodied in EDGE (*Enhanced Data Rate for GSM Evolution*) systems; they use a new modulation, optimizing the effective rate at the GSM interface, allowing to reach speeds of 384 Kbps/s at the maximum. Different continents have developed systems that are fairly similar in principle, but sometimes different in their realization. It is therefore within the framework of a global homogenization of standards that the idea of a third generation of cellular systems was born. The third generation (3G) of cellular systems, often assimilated in Europe to UMTS (*Universal Mobile Telecommunication Services*) [2], has been mainly designed and imagined to satisfy multimedia data routing (Internet access, corporate networks , Courier services, videoconferencing, games, etc.). In the same way as the GPRS and EDGE allowed, without modifying the basic principle of communications, their generation of cellular systems to evolve in terms of efficiency. The HSDPA (*High-Speed Downlink Packet Access*) [3] is already considered the standard 3.5G mobile telecommunications. While the maximum bit rate allowed on a UMTS link is 2 Mbps for a 5 MHz bandwidth, the HSDPA, thanks to its 16-QAM modulation, allows for 10 Mbits/s. Thus, thanks to the introduction of the new 64-QAM modulation in *Release 7*, the theoretical rate of 14 Mbits/s is possible via the HSDPA network.

In the same sense, IEEE802.16 (WiMAX) 4G network allows a theoretical rate of 70 Mbits / s over a maximum radius of 50 km while being based on different modulations depending on the state of the radio channel and New ways of accessing the channel. The performance of the system in terms of throughput is much greater than that provided by the previous systems, thanks to these modulations (QPSK, 16-QAM, 64-QAM). The WiMAX Mobile standard allows services such as VoIP communication (Telephony over IP network) on mobile phones or access to mobile services at high speeds. Its equivalent in Europe is the Hiper-MAN. In addition, the main purpose of new communication technologies is to eliminate cables and allow transmission (voice, data, etc.) via a radio link. Fig. 1 summarizes the evolution of wireless networks.

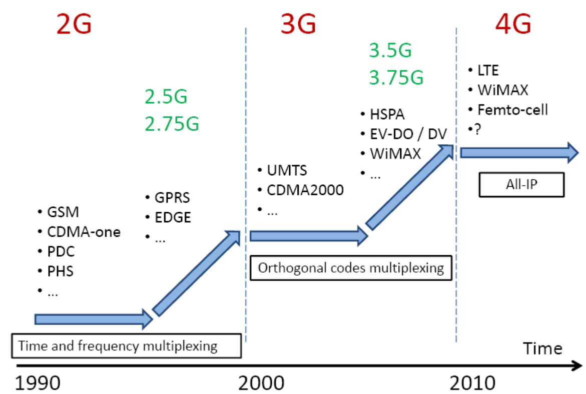

Fig. 1. Evolution of wireless networks

Thus, the rapid development of wireless communications and the emergence of new standards call for convergence towards the fourth generation of mobile communications. Originally planned for the years 2010, it would seem to present its very first commercial achievements slightly earlier. This advance in relation to the forecasts is due in particular to the fact that the fourth generation will not be the outcome of a revolution in communications (as in the second and third generation), but rather the convergence of different Standards, applications and products. Indeed, it seems relevant to consider 4G as the convergence of standards and technologies covered by 3G and wireless local area networks (WLANs). The goal of 4G is to improve the performance of the third generation, without fundamentally changing the content or applications originally planned for 3G.

III. IEEE 802.16e (WiMAX)

A. Presentation of IEEE 802.16e (WiMAX)

The Wimax [1] is a technology mainly used for MAN (*Metropolitan Area Network*). It allows, in particular, rural areas to have a broadband internet connection. The objective of WiMAX is to provide a broadband internet connection over a coverage area several kilometers radius. The theoretical speeds of WiMAX are 70 Mbits/s with a range of 50 kilometers. In practice in the worst case scenario, ie in NLOS

"*Non Line Of Sight*", the rate reaches 12 Mbits/s up to 4.5 kilometers. The WiMAX works in point-to-multipoint mode, that is to say the infrastructure mode known for WiFi or the same functioning as the 2G, 3G technologies of mobile telephony. Fig. 2 presents the IEEE 802.16 network architecture. As in 2G, a base station called BTS (Base Transceiver Station) or BS (Base Station) transmits to the clients and receives their requests and transmits them to the network of the access provider. An overview of a backbone mesh network and connections to WiFi, WiMAX, and wireless cellular networks is presented in Fig. 3. Several variants of standard have been proposed, modified and ratified as summarized in Table 1.

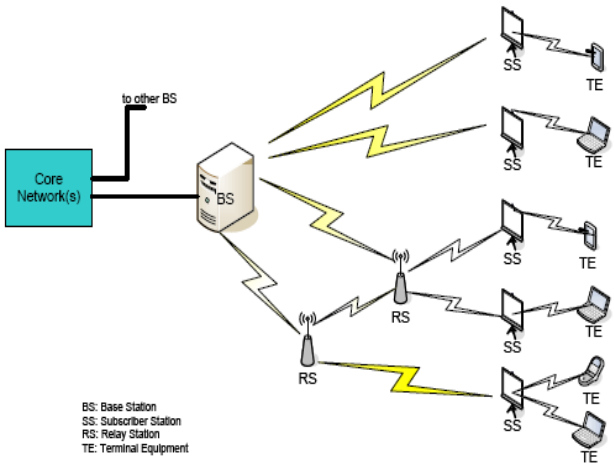

Fig. 2. IEEE 802.16 network architecture

We are interested in the IEEE802.16e standard [4] which uses in its physical layer the OFDMA method initially developed by Sari and Karam [5] as a multiple access method. In order to report specific events, the mobiles transmit *Ranging* signals to the base station. These messages are of different types depending on the type of event to be reported. The signaling transmission uses a set of 256 orthogonal codes (*CDMA codes*) encoded on 144 bits. These codes are distributed among the four possible types of signaling. A mobile unit wishing to transmit one of these signals randomly selects one of the codes available in the subset specific to its signaling family. This code is then transmitted via binary phase modulation (BPSK). The IEEE802.16e standard establishes four signaling categories: *Initial Ranging* (IR) initialization, *Hand-Over Ranging* (HR) migration request, *Bandwidth Request Ranging* (BR) request, and request *Periodic Ranging* (PR).

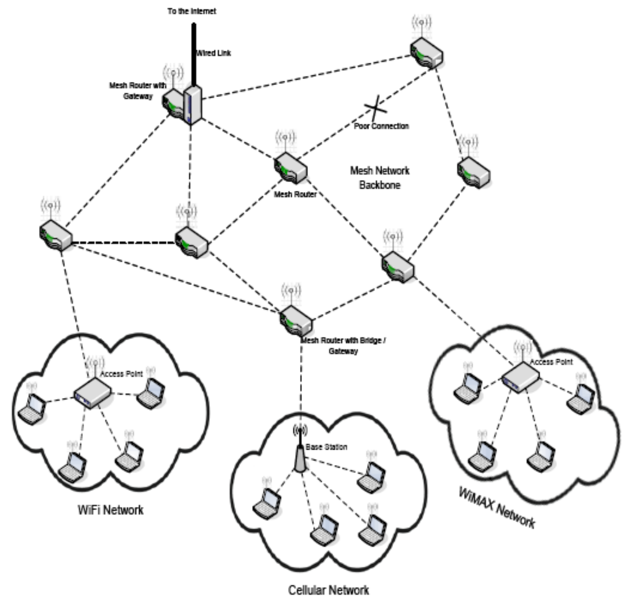

Fig. 3. Connections to Backbones mesh networks

TABLE. I. IEEE802.16 STANDARD HISTORY

Standard IEEE802.16	Frequency Band (FB)
IEEE std 802.16	Metropolitan wireless networks FB greater than 10 GHz.
IEEE std 802.16a	Metropolitan wireless networks FB between 2 and 11 GHz.
IEEE 802.16b	Metropolitan wireless networks FB between 10 and 60 GHz.
IEEE std 802.16c	Metropolitan wireless networks FB in free bands.
IEEE 802.16d (IEEE std 802.16-2004)	Revision integrating standards 802.16, 802.16a and 802.16c.
IEEE std 802.16e	Metropolitan wireless networks with mobile customers.
IEEE std 802.16f	Networks (mesh network).

B. Service classes and QoS defined by the IEEE802.16 standard

Scheduling services consist of the mechanisms supported by the *Medium Access Control layer* (MAC) for data transport. Each connection is associated with a single class of service. These service classes involve a particular set of parameters that define the QoS associated with the connection. Four classes of services are proposed in the standard [4, 6]: the unsolicited acceptance service (UGS), the real-time service (rtPS), the data transfer service (nrtPS) and interactive traffic (BE). In addition, a last class has recently integrated the standard constituting an extension of the real-time service (ertPS). They are defined as follows:

- *Unsolicited Grant Services* (UGS): The UGS class is intended to support real-time data streams characterized by a fixed size of packets received periodically. This class is therefore intended for T1 / E1 services and voice over IP (VoIP) without silence suppression. The associated QoS parameters are then the maximum and minimum traffic to be reserved for traffic (often the same), maximum delay, tolerated jitter, update policy. The mobile maintains an optimal delay by the fact that no request is sent to the contention sub-channel once the service is engaged. This class of traffic therefore eliminates the data and delays caused by repeated bandwidth requests. The BS then periodically reserves to the mobile part of the available radio resources. The reserved quantity is initially equal to the maximum requested flow. This class is dedicated to real-time streams. The frames are of fixed size and emit regularly;

- Real-time service rtPS (*real-time Polling Services*): The rtPS class is designed to handle real-time traffic for which the size of data stream packets is variable and at regular intervals. Also, this class is used for video traffic such as MPEG, H.263. The Quality of Service settings are based on a minimum bandwidth for video traffic, a maximum acceptable bit rate, a maximum delay, and an update periodicity. The rpt-enabled mobile has the ability to update its performance parameters by periodically incorporating new queue resource requests into the data packets. During the restraint interval. This class therefore respects time-sensitive traffics by avoiding the collisions involved in the contention interval to update requests. In addition, the mobile has the opportunity to indicate to the BS what periodicity of updating requires the traffic engaged. It allows real-time flows. The frames are of variable size and the emission may be irregular. This class is suitable, for example, for a video stream;

- Extension of the real time service ertPS (*extended real time Polling Service*): The ertPS class is intended to support real-time data streams characterized by a variable size of packets received periodically. This class is therefore intended for voice over IP (VoIP) services with silence suppression. The Quality of Service settings are based on a minimum bitrate for video traffic, a maximum acceptable bit rate, a maximum delay but no update timing indicator. The SS ertPS traffic has the ability to update its performance parameters by incorporating new resource requests at the queue of data packets or during the contention interval when necessary. This class therefore respects time-sensitive traffic by avoiding the collisions implied by the contention interval to update requests. Additionally, this class of traffic reduces signaling traffic and the delay time for dynamically allocated resources. In addition, variable resource allocation for ertPS calls avoids resource waste on uplink, as may be the case on UGS calls;

- NrtPS data transfer service (*non-real time Polling Service*): the nrtPS class must be able to manage traffic that is insensitive to the delay but requires a minimum throughput. The size of the packets can therefore be variable, as well as the delay between two packet transmissions. This class is therefore very suitable for the file transfer protocol (FTP). The Quality of Service settings are: minimum traffic flow to be reserved, maximum possible throughput for connection and traffic priority. Once the connection is initiated, the SS must imperatively issue a new bandwidth request in order to be able to claim another rate;

- BE (*Best Effort*) Interactive Service: The BE class is dedicated to traffic that does not require a particular level of performance. The QoS parameters are only related to the maximum possible throughput for connection, traffic priority, and query renewal policy. As for the previous class, the class engages a new connection for any new resource need. In this class nothing is guaranteed we send the data without guarantee of reception. Suitable for Internet browsing.

IV. Related Works

This section describes the literature work associated with the models of capacity and admission control address the main means and tools for modeling the capacity of an HSDPA and IEEE802.16 cell with or without the management of resources in relation to mobility of users.

Numerous works have been developed in the literature to study the capacity of wireless networks. In [7], Li et al. Develops a downlink admission control of the broadband network WiMAX and HSDPA based on the adaptation of the radio link of the air interface. They decompose the cell into a finite number of regions taking into account a simple propagation model operating with only a path loss as a function of the distance between the mobile and the base station. They consider in their study a single class of service and model the system by the network of queues of type BCMP [8], [9] whose number of active users is fixed. The authors assume that the arrival rates of calls in each region only depend on the average number of mobile that move in that region. Thus, they consider that the average time of service depends only on the time that the mobile remains in the region.

The authors in [10] are interested in the resource management of HSDPA and WiMAX networks taking into account mobility. They present three RRM (Resource Management) resource management schemes in a cooperative system containing HSDPA and WiMAX and compare the performances in these schemes in terms of probability of blocking new calls, lost calls in progress and time files transfer. The authors rely on a Markov model with game theory for resource management in the presence of several regions of modulation efficiency.

Quality management and performance evaluation in the MAC layer of the IEEE 802.16e network were largely performed in simulation; And few analytical results have been proved in the literature. In [11], the authors analyze the performance of the random access protocol in an OFDMA-CDMA environment using contention intervals for connection engagement, as a function of the average MDT delay. In [12], the authors define a performance model based on an adaptive control of the size of each family of codes: initialization of connections (IR), periodic demand (PR) and bandwidth demand (BR), In order to improve the efficiency of competitive access.

Many previous studies assume that packets, or calls, arrive in the system following a Poisson process. This, in view of the simplification of the analytical model. Moreover, they consider that the incoming processes of any type of calls or packets are independent. Nevertheless, since in WiMAX, all mobiles share a finite number of CDMA codes, the arrivals of these calls should be dependent, as proved by [13]. Indeed, the authors develop a model of MAC access to signaling requests based on the different priority classes using the differentiation of the *backoff* parameters and the free codes for these classes. They consider the case of classification of connections based on partitioning codes between call classes with a sub-range of codes reserved for the real-time class and another under code range shared with that non-real time.

The work developed in [14], defines a QoS architecture associating a scheduler and an admission control algorithm. In a richer and more subtle way, the study [15] develops a successful and dynamic admission control algorithm in order to ensure the quality of service of each traffic class of the IEEE802.16e standard. The algorithm reserves the resources available for non-real-time traffic. These will then be rejected if the capacity of the cell is exceeded by the new request for resources. In parallel, other types of traffic will share the remaining resources. In addition, the allocation principle proposed here introduces a dynamic evolution called the degradation of resources. Indeed, the arrival of new real-time calls will result in the progressive and adaptive reduction of the remaining resources shared between non-real-time calls. Thus, the author gives the highest priority to UGS and rtPS traffic while maximizing the overall throughput by adapting the bandwidth to other traffic.

The work of [16] proposes an innovative sequencing of the allocation of resources between traffics. The principle of TRS (scheduling by timed omission) attributes the resources according to the modulation efficiency of each user. Based on the observation that users with the worst signal-to-noise ratio (SNR) generate more waste of radio resources, they will be allocated fewer communication resources and only at spaced intervals. This mechanism assumes that user mobility will enable them to take full advantage of the resources they need. This original resource allocation mechanism results in a significant gain in spectral efficiency. As a result, communications from nearby regions are quickly served, and in the context of a non-saturated network, this indirectly leads to better support for communications from more peripheral regions. This work has the particularity of taking into account the spectral efficiency of the users with respect to the radio resources allocated to them.

V. Analysis of the IEEE 802.16e System

In this section we are interested in the management of fourth generation network resources (WiMAX, known as 4G network) based on the IEEE 802.16e standard. One of the founding objectives of the WiMAX Forum is the search for interoperability: it is achieved through the channels of standardization and certification and is one of the major challenges of WiMAX. This is all the more important given that WiMAX is defined for a wide band of frequencies, from 2 to 66 GHz, in which there are existing technologies, such as Wi-Fi, which allows broadband, scopes and A wide variety of uses. This multiplicity of the frequency bands targeted, of the flows, reaches and possible uses, is besides the main pitfall that confronts the final consumer. The 4G network aims to achieve the convergence of existing networks such as Wi-Fi, UMTS, etc.

The services offered by WiMAX are classified according to the parameters defining the quality of service associated with a connection. Four classes of services are offered in the standard: Unsolicited Acceptance Service (UGS), Real Time Service (rtPS), Data Transfer Service (nrtPS) and Interactive Traffic (BE). Two main classes of service were considered during this work: real time (RT), corresponding to the classes UGS where rtPS, and non-real time or *best effort* (NRT), corresponding to the classes nrtPS and BE. Thus, we consider the case where the partitioning codes allocated to the connection requests are distributed between the call classes. We also consider in our study a single WiMAX/IEEE802.16 cell decomposed into r concentric regions and each uses a different adaptive modulation (AMC) as recommended in [4].

The objective of this paper is to model the IEEE802.16e cell in a continuous case considering the behavior of mobile users. We propose an admission control strategy based on the *Random Waypoint mobility* model (RWP). This model allows us to realistically calculate call migration rates between regions of the cell, as indicated by [17]. In this admission control mechanism, the RT calls are characterized by the same bit rate. Thus, a call of type RT receives a number of subcarriers according to its modulation efficiency and the targeted region. The system accepts RT calls until the capacity is exceeded. Thus, they could be blocked by the system. On the other hand, calls of type BE receive the same number of subcarriers. Since the BE calls tolerate the rate reduction, they will use the carriers left by the current RT calls fairly according to Processor Sharing (PS) [18]. Also, the bit rate of a BE call depends on its region (ie modulation), but also on the number of BE calls in progress. With this resource management policy for BE calls, the system will never block a call of this type.

Finally, the duration of calls RT is independent of the resources consumed, and therefore the time that will remain an RT call in the system depends solely on the behavior of the user. Conversely, BE calls remain in the system according to the consumption of the resources, and therefore the more the number of sub-carriers increases, the faster the BE call ends its service.

In addition, our CAC mechanisms seek to reduce the likelihood of loss: the likelihood that a call in progress will be rejected because of its mobility and that it changes the region. As explained above, the call consumes the bandwidth as a function of the modulation used. By migrating to a far region, a call may require additional bandwidth. This could result in a loss due to lack of available resources. To prevent this loss, our CAC mechanisms introduce some of the bandwidth reserved for mobile calls. This reservation is intended to meet the need for additional resources required for migration to areas where modulation is higher.

We consider, during our analysis and without loss of generality, adaptive modulation and coding (AMC) with only the *pathloss*. Depending on the latter, the OFDMA IEEE802.16e cell is decomposed into concentric r regions. Each region corresponds to a certain range of SNR values, and thus to an AMC, as shown in Fig. 4.

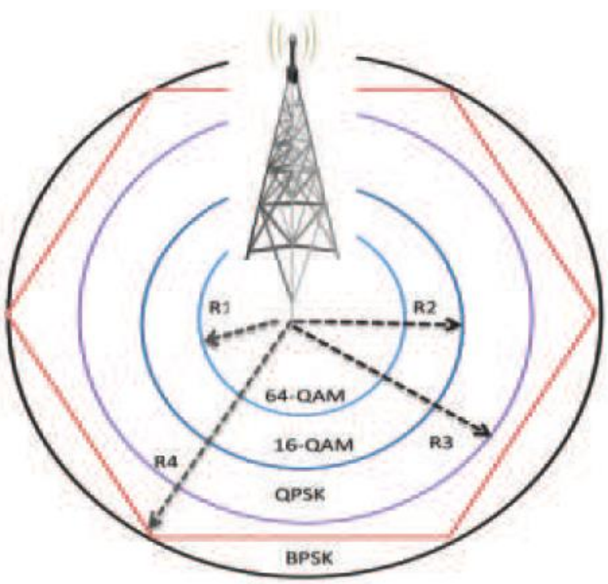

Fig. 4. The OFDMA IEEE802.16e sectored cell

We consider the following parameters:

- The OFDMA cell IEEE802.16e is decomposed into two concentric regions (r = 2) whose radii are $R1$ = 300m and $R2$ = 600m.
- The modulations of these regions are 16-QAM 3/4 ($e1$ = 3 bits / symbol) and QPSK 1/2 ($e2$ = 1 bit / symbol) [19];
- The *baud* rate is B = 2666 symbol / s;
- The block error rate $BLER_i$ = 0;
- The number of frequencies is K = 48;
- The call bit rate RT R_{RT} is 128 Kbps and that of calls BE R_{BE} is 384 Kbps [20];
- The total capacity of system L is 10 carriers;
- The average call duration RT is 120s and the average download file size corresponds to $E(Pay)$ = 5 Mbits.

Finally, we assume that the mobiles or the users move according to the RWP process in the convex disk of radius R_z = 900m. They randomly selected new speeds in each *waypoint* from a uniform velocity distribution in the interval [v_{min}, v_{max}], where v_{min} = 3km/h (low mobility) or v_{min} = 20km/h (high mobility), v_{max} = 90km/h.

Fig. 5 shows the blocking probabilities for real-time traffic in both regions based on resource reservation for *best effort* calls. This figure clearly shows the impact of L_{BE} and L_{RT}^{m} on blocking probabilities in each region. Generally, blocking probabilities are greatly increased when the minimum reserve of resources for BE calls increases. In addition, this effect becomes more important by increasing the mobility management resource reservation. From this ratio, we could compute the ranges of values for L_{BE} and L_{RT}^{m} that satisfy a maximum probability blocking threshold.

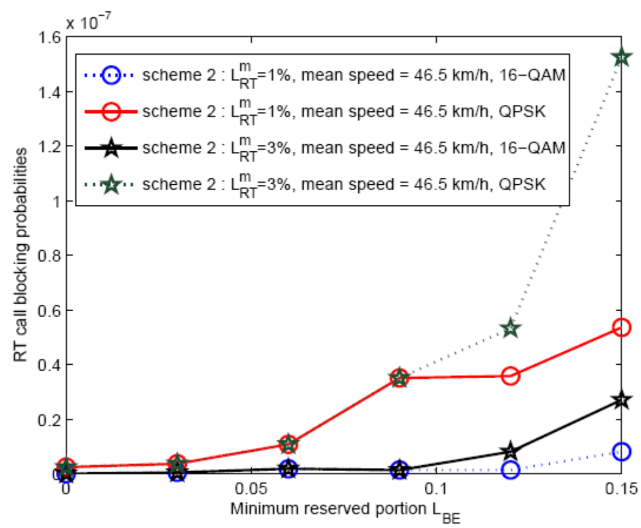

Fig. 5. Blocking probabilities for real-time traffic

Fig. 6 shows the loss probabilities for real-time traffic in the border region based on the minimum resource reservation for *best effort* calls. The figure shows how the reservation of resources L_{RT}^{m} decreases the probability of loss via the minimum threshold reserved for calls BE. In this figure, the probability of loss is reduced when the L_{BE} reservation is greater than ten percent. Thus we can determine the possible values for L_{RT}^{m} arriving at a maximum probability of loss of calls RT maximum.

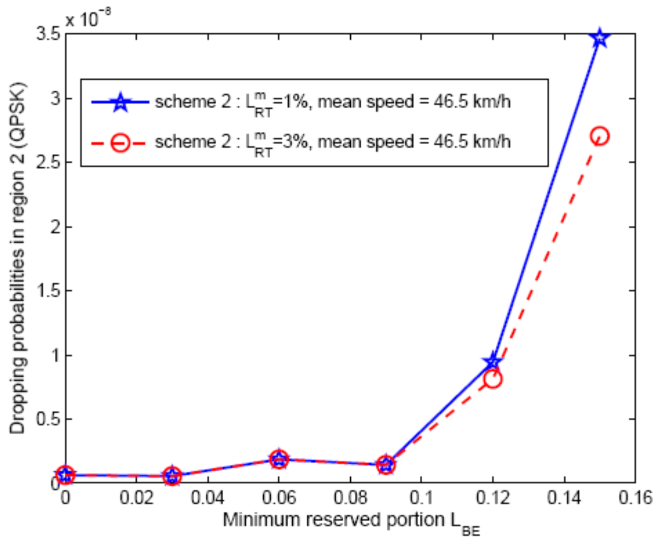

Fig. 6. RT calls loss probabilities

Finally, Fig. 7 shows the total flow rate of the cell. This figure show the impact of the different resource reservations for mobility on the increase of calls BE and the ease of the mobility of the calls. In Fig. 7 we can appreciate the important impact of the L_BE reservation. Indeed, by reserving 15% of the total capacity for BE calls, we double the average total throughput of the cell. In addition, the increase in the mobility reserve L_{RT}^{m} slightly decreases the total flow rate. This observation leads to the conclusion that a small amount of reserved sub channels for BE calls can reach a very high bit rate. In fact, by reserving some sub channels for BE calls, we also increase the probabilities of blocking and losing RT calls. Therefore, these amounts of resources released by blocked or lost calls allow BE calls to better utilize resources.

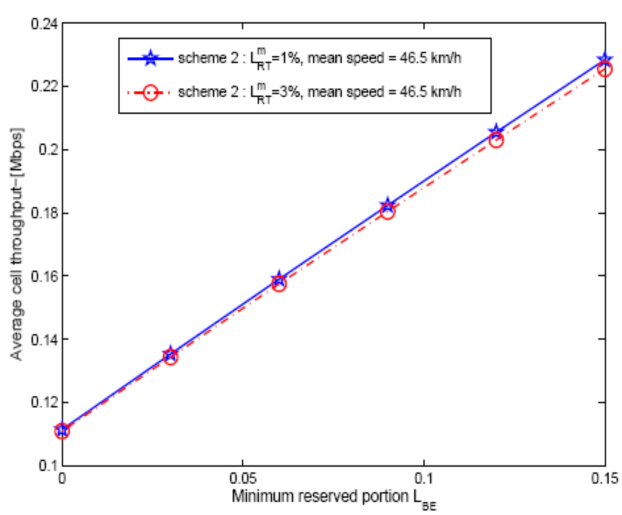

Fig. 7. Average total throughput

VI. Conclusion

In this paper, we are interested in the quality of service offered by the IEEE802.16e system. We studied the continuous case of the IEEE802.16e system; we proposed an admission control algorithm or QoS management strategy in the IEEE802.16e system. This mechanism maintains the same quality of service for real-time calls and replaces *best effort* calls with fair share of resources, while reserving minimum bandwidth for *best effort* calls to ensure minimum QoS and minimum bandwidth real-time calls in intra-cell mobility. Moreover, we have implemented a more realistic model of mobility called RWP and that is often used in ad-hoc networks. We extend the RWP model in an IEEE802.16e cell subdivided into a finite number of regions. This model allowed us to calculate call migration rates between cell regions explicitly. On the basis of this proposition, we model our system using a CMTC continuous time Markov chain to find the stationary distribution of the system. Through the numerical results we were able to see the impact of this strategy on the performance of the system.

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A Social Semantic Web based Conceptual Architecture of Disaster Trail Management System

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***Abstract*—Disasters affect human lives severely. Due to these disasters, hundreds and thousands of human beings lost their lives and gracious properties. Government agencies, non-government organization and individual volunteers act to rescue the affected people and to mitigate the disaster effects. These teams require real time information about the nature, severity, area and number of affectees. Their efforts can be supported by providing timely, effective and specific information so that the rescuers can get better idea about the available routes to reach the affectees, urgency and mass of loss. People share huge amount of data through blogs and social media that can be utilized to help rescue operations. This information can electronically be filtered, arranged and formatted in a proper manner. Thus, semantic web technologies can play a vital role in providing timeliness information. Purpose of this research is to capture explicit knowledge of the domain in form of ontologies, automatic information extraction, generation of implicit knowledge and then disseminating this information to various stakeholders. Collection of implicit and explicit knowledge will help improve decision making for disaster trail management.**

***Keywords*—Ontology; Disaster Trail Management; Information Extraction; Knowledge Management**

I. Introduction

The word ‘disaster’ comes from ancient Greek words ‘dis’ means bad and ‘aster’ means star. The astrological sense of this word bases on calamity blamed on star positions. [1]

Disasters can be categorized mainly into two types; natural and man-made. Furthermore, according to their impact, these can be subdivided into major and minor disasters. Natural major disasters include Cyclones, Tornadoes, Drought, Flood, Earthquake and Tsunami whereas Epidemic, Deforestation, Chemical Pollution, Wars and Terrorism can be considered as man-made major disasters. Similarly, Cold/Heat Waves, Thunderstorms are natural minor disasters but Road/Train Accident, Riots, Food Poisoning and Industrial mishaps can be treated as minor man-made disasters. [2, 3]

Pakistan lies on the Indo-Australian plate, which is propelling northward and edging under the Eurasian plate. This specific geographic location of Pakistan results in frequent earthquake happenings in this area [5]. Since Pakistan lies in a seismic belt therefore, it is at a risk of earthquakes of high magnitude. Mountain ranges of the northern areas, Khyber Pakhtunkhwa and Baluchistan provinces, and important cities like Islamabad, Karachi and Peshawar are located on the edges of high risk areas [6]. Pakistan is prone to disasters and has experienced a variety of major natural disasters including earthquakes and floods. These disasters cause large number of life losses, internally displaced persons (IDPs), loss of crops and agricultural lands, infra-structure and property damages. [7, 8]

Disasters always have rigorous effects on human lives [4]. Due to these disasters, hundreds and thousands of human beings lost their lives and their valued properties. Government agencies, non-government organization and individual volunteers act to rescue the affected people and to mitigate the disaster effects. These teams require real time information about the nature, severity and area of disaster and number of affectees. Their efforts can be supported by providing timely, effective and specific information so that the rescuers can get better idea about the available routes to reach the affectees, urgency and mass of loss.

Disaster management efforts affect due to multiple barriers. The most prominent factors lacking in some areas are community awareness, effective communication among the concerned departments, deployed human resources and budgeting, technology awareness and utilization and competency of management. [9]

A number of efforts have made in the field of Information and Communication Technology (ICT) to assist rescue operations by providing required information effectively and timely. The major task of ICT solutions is managing data starting from data gathering, organizing, integrating, analyzing and then generating information for decision making. Semantic Web technology can play better role in improving capability and usefulness of ICT solutions for Disaster and Trail Management using standard and mature semantic languages and tools like Web Ontology Language (OWL) [10] and General Architecture of Text Engineering (GATE) [11]. A number of ICT solutions are in local use in different countries whereas a few of them benefiting many countries. SAHANA [12] and Disaster Management Information System (DMIS) [13] are effective and the most widely used ICT solutions which have been used in various countries for natural disasters management. But these systems rely on manual data entry. In disaster management, availability of latest data facts improves the efficiency and effectiveness of rescue operations.

People share huge amount of data through blogs and social media that can be utilized (along with the manual data entry) to help rescue operations. This information can be electronically filtered, arranged and formatted in a proper manner. Thus, semantic web technologies can play a vital role in providing timeliness information. People generally share information via social media not only in English but also in their native languages. If the focus is to grasp information in English only, then a huge amount of useful information (in native language) can be missing. Urdu is the national language of Pakistan. So, majority of the population prefer to use Urdu or 'Roman Urdu' to share information on social media. Purpose of this research is to develop a system to effectively capture explicit knowledge of the domain of the disaster whether shared in English or Urdu in the form of ontologies and disseminating this information to various stakeholders.

The paper is organized in different sections, each elaborates a particular segment of discussion. Selective projects, closely related to the proposed system, are discussed with their strengths and weaknesses in section II. Last paragraph of this section briefly describes the limitations of the projects to highlight the research gap. Section III provides an overview of the proposed system whereas tools and techniques required for system development are discussed in section IV. Section V identifies the potential research challenges. Possible solutions to these challenges have also been suggested in the same section. Conclusion is given in section VI.

II. Literature Review

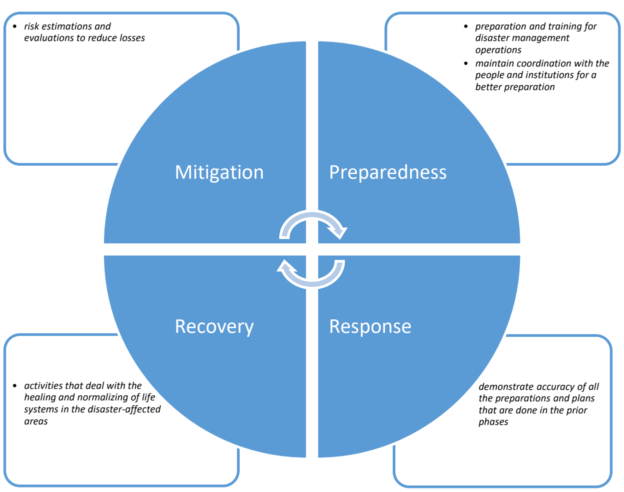

Fig. 1. The Disaster Management Cycle

Fig. 1 is self-explanatory and explains an overview of disaster management cycle with a brief introduction to phases of disaster management and activities to perform during each phase. The proposed system is related to *Recovery* Phase.

Disasters cannot be avoided but efforts can be made to minimize their effects. Disaster management is so important that although a lot of work has already been done, yet more work is required to be done to rescue the affected people. ICT is playing a constructive and vital role in this regard. Following is a brief view of ICT efforts.

A. Organizational Solution - National Level Disaster Risk Management Framework of Pakistan

Realizing the need of disaster management, Pakistan has established a National Disaster Management Commission (NDMC). NDMC, headed by the Prime Minister of Pakistan, is the national policy making body for managing disasters and executes its policies and manages Disaster Risk Management (DRM) activities through National Disaster Management Authority (NDMA). At provincial level there exist Provincial Disaster Management Commissions (PDMCs) responsible to formulate provincial level policies and plans regarding DRM. PDMC act through Provincial Disaster Management Authorities (PDMAs) which further share responsibilities at grass root level by District Disaster Management Authorities (DDMAs). Effectiveness and scope of these agencies majorly depends on their position within national government, size, allocated budget, and staff training. NDMA, is the Federal level agency which supervises all Disaster Management Activities in Pakistan. For mitigation during disaster, all stakeholders take part in rescue operations as a unit of NDMA. [7, 14]

B. Conventional Disaster Management Systems

However, efficiency and effectiveness of disaster management activities can be improved by using ICT, the most adopting and growing technology. ICT is contributing its predominant part in increasing efficiency and accuracy in almost all walks of life. It is also playing a vital role in boosting operations of all phases of disaster management cycle. Various ICT based applications and services are available for disaster management. Among these, SAHANA EDEN is the most popular disaster management system that has been deployed by over 50 nonprofit and government agencies in different countries including USA, UK, France, Italy, Japan, India, Pakistan, Sri Lanka, Indonesia, Philippines, Bangladesh, Thailand, China, Australia, Taiwan and New Zeeland.

1) SAHANA

SAHANA [12] is an open source disaster management platform that helps organizations and communities prepare for and respond to disasters. The word 'Sahana' means relief in Sinhalese, one of the national languages of Sri Lanka [12]. The software was originally developed by members of the Sri Lankan IT community in 2004 for Indian Ocean Tsunami. SAHANA is an open source software project, the development of which is contributed by a large number of volunteer programmers belonging to various countries of the world. It was successfully deployed in over 25 countries including Pakistan for 2005 earthquake and 2010 floods. Its free and open source format, excellent structure and well defined modules made it the most widely accepted and popular disaster management software.

The main modules of SAHANA EDEN include:

- Organization Registry – allows an organization to register itself in the SAHANA database and links it to other modules like Human Resources, Assets and Inventory

- Project Tracking – provides situational data to and coordination among organizations
- Human Resources – keeps track of engaged staff and volunteers
- Inventory – manages inventory and donations
- Assets – keeps track of assets and their utilization
- Shelter Management – temporary shelters, required resources and shelters population information management
- Scenarios and Events – planning effective deployments of resources
- Mapping – provides situational awareness via maps
- Messaging – group messaging facility via email, SMS, Twitter and Google Talk. Receiving short queries via interactive messaging and automatic responses [12]

Sahana Eden, which is developed in Python, can be installed on any environment like Windows or OSX, which can run Python. This project includes organization registry module to help coordinate and collaborate with organizations taking part in helping affected people. Other strengths include its multi-lingual interface and its interoperability with other applications and datasets. Sahana available translation languages include Chinese, Hindi, Spanish, English, Arabic, Portuguese, Russian, German, Tamil, Burmese, Indonesian and Sinhalese [15]. During deployment in Pakistan, some weaknesses were observed in SAHANA including lack of locations related data which is the baseline data, non-availability of Urdu translation and poor SMS infrastructure. Above all, the key weakness is that it requires manual data entry [16]. The laborious task of manual data entry is time taking and less feasible in case of an emergency.

2) Disaster Management Information System (DMIS)

DMIS [13] was launched by the "Civil Society for Research & Initiatives for Sustainable Technologies and Institutions (SRISTI)", on January 2002 in India. DMIS shares its services and data voluntarily with NGOs and especially to civil society institutions across the world. DMIS provides a platform for documenting and sharing disaster related experiences which can be utilized in developing strategies for future disaster management. It also provides coordination among individuals and disaster rescue organizations. It also provides an online database to share experiences and volunteer services but it does not provide any facility to decision makers for retrieving and processing real-time data.

C. Disaster Ontologies

The Semantic Web Community is contributing in addressing the disaster management issue by developing ontologies. Following are some notable disaster management ontologies:

In 2015, Zavarella Vanni et al. [17] developed a multilingual event extraction engine for information extraction from online print media sources. It filtered correct information via the Linked Open Data principles. They outlined a procedure which propagates the information to larger scope ontologies for Crisis Management. The base of the procedure is ontology lexicalization method for text mining from social media that does not depend on language. The team also brought a keyword based query into work to get the tweets, related to events, for language normalization but this work needs more to be done. They need some validation event data in order to measure the performance of their system.

Chen-Huei Chou et al. [18] developed an ontology structure of elements for "web-based disaster management systems (WB-DMS)" in 2011. This structure identifies web elements using the grounded-theory approach. In this, selected semi-structured data representation approaches are used to organize the resulting ontology structure. Next the ontology structure is coded into a Web-based system. This ontology structure provides a valuable guideline in creating new WB-DMS web sites. This work can be enriched on bases of opinions of domain experts and analyzing online forums and actual documents generated for crises management. Also the work can be extended to other areas like business crises management.

In 2014 Juan Li et al. [19] developed a social semantic search engine for fetching emergency related information from twitter and also proposed Emergency Information System for disaster position identification. However, the focus is on authoritative information from emergency related organizations. Tool is designed to fetch disaster related information from twitter but in future they aim to integrate other social networking sites. The authors say that trusted courses of information can be preferably ranked. Prior to storing, they emphasized on information validation by format checking.

In 2014, Z. Ashktorab et al. [20] developed a twitter-mining tool to extract meaningful and actionable information for disaster relief workers during a disastrous situation. The ontology focuses only on twitter and using a small set of labelled data to extract relevant data. In future, the authors will focus on exploration of conflicting labels and determining more accurate labels.

In 2015, F. Morstatter et al. [21] introduced social media posts analysis techniques based on location information to help first responders provide relief to disaster affectees. They discussed machine learning techniques application in location finding. This team presented an algorithm that helps find users in the region affected by a crisis. Their future work consists of finding the "event location" and location privacy.

The above-discussed efforts have their own limitations. Most of the work done so far focuses on particular aspects of disaster management domain. The ICT solutions lack in locations related data for Pakistan, which is the baseline data. Above all, the key weakness is the dependency of these solutions on laborious task of manual data entry which is not feasible during emergency situations. Moreover, the constructed ontologies do not target to integrate with existing disaster management systems. Also, the information extraction from messages shared in Urdu is completely missing. Urdu being the national language of Pakistan, is also used in sharing information on social media during and after the disaster. Ignoring the information shared in Urdu may cause missing a lot of information.

III. Proposed System

Fig. 2, describes the proposed social semantic web based disaster trail management system. By collecting nearly real time data from social media, the system adequately solves the problems discussed in the previous sections. The system will be capable to integrate with existing disaster management systems. It will enhance the working effectiveness of these DMSs by providing latest situational data related to disaster.

Focus of research is to design a disaster trail management system for Pakistan. While designing the conceptual architecture of the system, it is kept in mind that people of Pakistan also use their national language to share information on social media. The proposed model can however, easily be generalized by replacing the translator. The proposed system will only capture textual information.

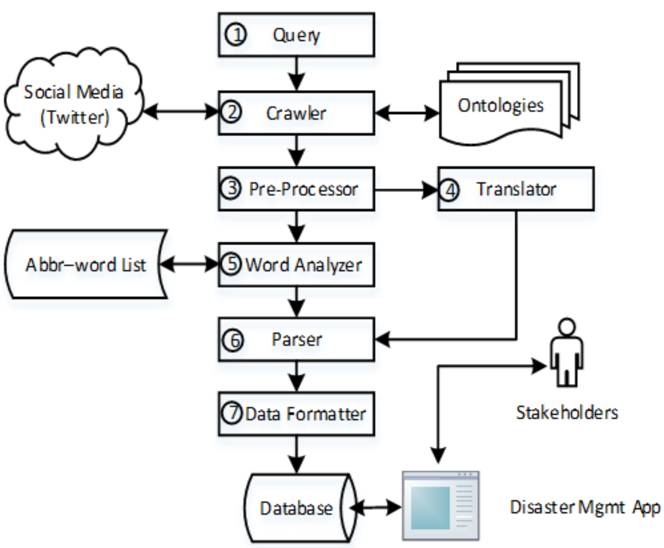

Fig. 2. Conceptual Architecture of Social Semantic Web based Disaster Trail Management System

The conceptual architecture of the proposed system has been illustrated in Fig. 2. It also clearly mentions data flow between various system components. Following is the description of the system's functionality.

Query is passed in the form of disaster related keyword(s). These keywords either can be provided by the user as command line arguments or can be stored in a text file that can be used as input file. Query is then passes to crawler.

1) The crawler performs tweets capturing from the social network, Twitter. Only text based tweets written in English or Urdu language are captured and irrelevant tweets will be ignored. Crawler makes use of semantic web ontologies for crawling the most relevant data. These filters (keyword and language) are required to use by crawler to collect only relevant set of text from a huge stream of data shared on twitter.

2) The crawled tweets are then forwarded to pre-processor. As the objective is to capture maximum information shared by Pakistani people, that's why all concerned tweets are collected whether written in English or in the national language Urdu. Information extraction is comparatively easy on text written in English language. This module identifies the tweets written in Urdu language and forwards these Urdu Tweets to Translator. The text captured in English is forwarded to Word analyzer.

3) Translator translates Urdu text into English language and forward translated text to parser.

4) Due to restriction of tweet's length, people generally use abbreviations in their tweets. Word Analyzer identifies abbreviations and replaces them with respective complete words getting from Abbr.-Word List and then passes the document to parser.

5) Parser plays an important role in separating data and metadata (if any). Information Extraction is done by this module. Key entities are identified and duplicate entities are suppressed. Ultimately, the processed data set is forwarded to data formatter for dumping it into the database.

6) Data Formatter formats and stores data in accordance with the defined database rules. These data form a knowledge base that can be utilized in decision making process and by the disaster trail management software.

IV. Tools and Techniques

The system can be subdivided into the following major sections:

- Tweets Collection
- Translation of Urdu to English
- Processing and Information Extraction
- Data storing for future use

Section 1 needs to collect textual data shared by public on social media, Twitter, which is a huge stream of data shared by people. Twitter provides streaming APIs which will be used for the data collection purpose. The objective is to collect only the relevant tweets excluding multimedia tweets. From this huge data world, to focus on relevant tweets, filters will be set for the purposes like searching keywords and setting of language only to collect tweets in English and Urdu language. Twitter has limitation of message length, that's why people use abbreviations, which increases complexity of information extraction process. For example, acdnt can be used instead of accident or abt instead of about. To make the collected messages more meaningful, it is required to identify and replace abbreviations with complete words.

The proposed model can be customized by translator. The focus is to translate tweets written into Urdu language to English. A translator like Google [22], Yandex [23], Bing [24] or SDL [25] can be embedded by using API.

Information Extraction (IE) is backbone of the system. For this purpose, Natural Language Processing (NLP) tools like GATE [11] or Stanford CoreNLP [26] can be used. GATE is provided with an IE pipeline ANNIE (A Nearly-New IE) System [11]. ANNIE relies on JAPE (Java Annotation Pattern Engine) language [11]. For Named Entity Recognition, the available ANNIE gazetteer lists will not be enough. Additional gazetteer lists will be required to develop, to make it more specific to disaster. TwitIE is a customized open-source IE of GATE ANNIE which is customized for Twitter [27].

Generally, disaster management systems have to store a huge amount of data. Instead of using traditional Relational Database Management Systems (RDBMS), NoSQL databases like MongoDB [28] are preferred due to more flexibility, performance and scalability. MongoDB is a free and open-source cross-platform document-oriented database. As the ultimate objective of data storage is to utilize this data by existing disaster management systems, so, NoSQL database will be used.

V. Challenges and Suggested Solutions

All the major sections of the proposed system have their own issues and research challenges. First of all, relevant data collection from data floating on public data stream is a challenge. Shared data may be textual or multimedia. Each and every data cannot be collected and analyzed. So, the crawler should be intelligent enough to collect only relevant text data. For this purpose, the crawler should have been provided with reasonable filters.

The next challenge to cope with is the use of self-generated acronyms or short forms. They hinder the way of understanding the gist of the message. People do this to save their time and space for the message as some social media like twitter has limit for message length. People use a lot of unregistered language words to keep their message short and to the limits. There is no universal standard format to write the words in short forms. Some short form words are commonly used but not all. People define their own abbreviations to short. This makes their message short and complete but quite unintelligible for many readers. For example, people may use “f9” instead of writing “fine” just to save two letters space. Some efforts have been made to document most frequently used short forms, which can be used to prepare abbr.-word list (consisting abbreviations and corresponding complete word).

The system aims to collect the tweets not only in English but also written in Urdu, the national language of Pakistan. So, in the translation phase, it is required to embed a translator like Google [22], Yandex [23], Bing [24] or SDL [25].

The IE phase of the system is quite complicated and is the backbone of the system. Entities and their relationships are required to be identified. As the target is to collect disaster related information, so, the general purpose tools are needed to enhance their functionality above the recognition of general entities. In this section, Information will be extracted from the collected data. NLP tools like GATE or Stanford CoreNLP will play its role in identifying entities and their relationships. The general purpose NLP tools will provide general entities which are not able to solve the purpose. For specialized disaster domain related entities, it requires to introduce another layer of exactitude, to be used by the tools for specific and targeted information extraction.

The final issue is to store extracted information in such a form that can easily be integrated with the existing disaster management systems. For this purpose, a schema-less or NoSQL open source database can be a good choice. MongoDB can be preferred for its scalability, performance and high availability [28].

VI. Conclusion

The proposed social semantic web based conceptual architecture of disaster trail management system has been elaborated with all its necessary components, their interaction and data flow. While considering the potential challenges and research issues, their possible solutions along with the tools that can be used in materializing the proposed system has also been suggested. The authors would develop the disaster trail management based on the purposed architecture and present as their future work.

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Clustering Students' Arabic Tweets using Different Schemes

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***Abstract*—In this paper, Twitter has been chosen as a platform for clustering the topics that have been mentioned by King Abdulaziz University students to understand students' behaviours and answer their inquiries. The aim of the study is to propose a model for clustering analysis of Saudi Arabian (standard and Arabian Gulf dialect) tweets to segment topics included in the students' posts. A combination of the natural language processing (NLP) and the machine learning (ML) method to build models is used to cluster tweets according to their text similarity. K-mean algorithm is utilised with different vector representation schemes such as TF-IDF (term frequency-inverse document frequency) and BTO (binary-term occurrence). Distinct preprocessing is explored to obtain the N-grams term of tokens. The cluster distance performance task is applied to determine the average between the centroid clusters. Moreover, human evaluation clustering is performed by looking at the data source to make sure that the clusters are making sense to an educational domain. At this moment, each cluster has been identified, and students' accounts on Twitter have been known by their facilities or their educational system, such as e-learning. The results show that the best vector's representation was using BTO, and it will be useful to apply it to cluster students' text instead of the TF-IDF scheme.**

***Keywords*—Twitter; Arabic tweets; Saudi Arabia; King Abdulaziz University; data mining; data preparation**

I. Introduction

Today, students use university social media accounts on a daily basis to follow university events, to exchange thoughts, and to express their views and activities [1, 2]. In addition, some students consider social media such as Twitter as the first option for sending their inquiry and complaint. This is especially relevant for online distance education students, who depend mostly on the web. Therefore, it comes as no surprise that universities have started to study students' behaviours on social media and analyse their opinions for the purpose of improving university-provided services, teaching processes, and learning experiences [3, 4].

For Twitter accounts that have extraordinarily large numbers of followers (such as the Deanship of e-Learning and Distance Education at King Abdulaziz University), answering individual tweets is time consuming.

Therefore, the aim of this study is to group similar tweets into groups such that tweets within the same group bear similarity with each other, while tweets in different groups are dissimilar with each other. This will help the university understand students' behaviours, find out the most common problems, and contact students within the same group and answer their inquiry faster.

Data mining (DM) methods have been utilised to investigate the field of educational data mining, such as association rule mining, sequence pattern, visualisation, and clustering [5-7]. Unlike most studies, the authors believe that social media has a lot of 'informative information' mentioned by students in their Twitter accounts. Moreover, these pieces of information or inquiries are sent to the university's account. For this reason, this study will concentrate on text mining and text similarity to group students' accounts that contain similar tweets.

DM techniques were utilised to make recommendations directly to students with respect to their personalised activities [8]. The most popular methods are association rule [9], sequential pattern mining [9], and clustering [10]. For this study, the clustering method was chosen, as clustering organises similar objects into groups [11]. Clustering is utilised in different areas, such as web mining [12], document grouping [13], and bioinformatics [14]. The basic clustering technique depends on the following steps: data representation model, similarity attribute measure, clustering technique, and finally, validation [15].

The rest of this paper is organised as follows: In section 2, related work is presented. Section 3 shows the methodology used and the process of clustering analysis of Arabic tweets. Section 4 presents the experiment's results and evaluations. The final section is composed of conclusions, remarks, and future works.

II. Related Work

Perera et al. proposed an affective technique to categorise both teams and similar individual members. In their approach to mining and extracting of a sequence of frequent events in learning data, their method was a sequential pattern mining. Their conclusions indicate the consequence of leadership and group interaction and give a hopeful suggestion about whether events are taking place [16].

Tang and McCalla applied a clustering method based on large generalised sequences to examine a group of students, depending on their similar characteristics with web-based learning environments [17]. Chen et al. utilised a K-means clustering algorithm to aggregate students who showed identical behaviour in an e-learning environment [18].

Moreover, they identified the formative element in assessment rules based on web-based learning. In addition, teachers could conduct specific assessments per the learning portfolio of particular students in their learning environment. Vukícevíc et al. addressed their conception of research to utilise the clustering approach for class retrieval from microarray data [19]. They reported that there is no recommendation for the selection of the right parameters and distance measure, which can improve the clustering model.

Jovanovic et al built models that can help to identify students that require extra attention in their courses [20]. Their modules involved two important data mining tasks: first, a classification model to predict if students will perform well in different courses based on web utilization; second, a clustering model that groups students with similar cognitive styles but different levels of prosperity. They concluded that analysis of student behaviours on the educational system has true potential and is a worthy investment.

Perera et al stated that group work is encouraged by online implements; their goal was to empower departments and their facilitators to see applicable parts of a group's operation and give input as to whether these are more likely to be related to positive or negative outcomes [16]. They gathered their information from understudies who were working in groups and using an online tool in a software development project and utilized clustering and sequential pattern mining approaches: clustering was connected to discover comparative groups of similar teams and similar individual members, and sequential pattern mining was acclimated to concentrate sequences of continuous occasions. Their outcomes uncovered significant patterns characterizing the work of stronger and weaker students.

Nilsson and Liu collected and analysed web data and log files [21]. In their system, they utilized Canopy Generation with k-mean to devise a method for grouping college training materials in view of their text content features, integrating it into a spring web application. They represented their data vectors using TF-IDF schemes. Their developed framework is exceptionally adaptable and likely able to coordinate custom channels and supersede grouping calculations as required. They found that there is no basic method for assessing how well a clustering algorithms performs as a rule.

III. Methodology

Figure 1 outlines the grouping procedure for Arabic tweets. As one of the best-known social networks, Twitter has been chosen for this review as a subject for clustering. Different feature selection schemes are used, such as TF-IDF (term frequency-inverse document frequency) and BTO (binary-term occurrence). TF-IDF describes how important a word is for a document [22] [23] [24]. It consists of two parts: term frequency (TF) and invert document frequency (IDF). In addition, BTO is defined as the binary value. In other words, a word or term gets 1 if present in a document, 0 otherwise.

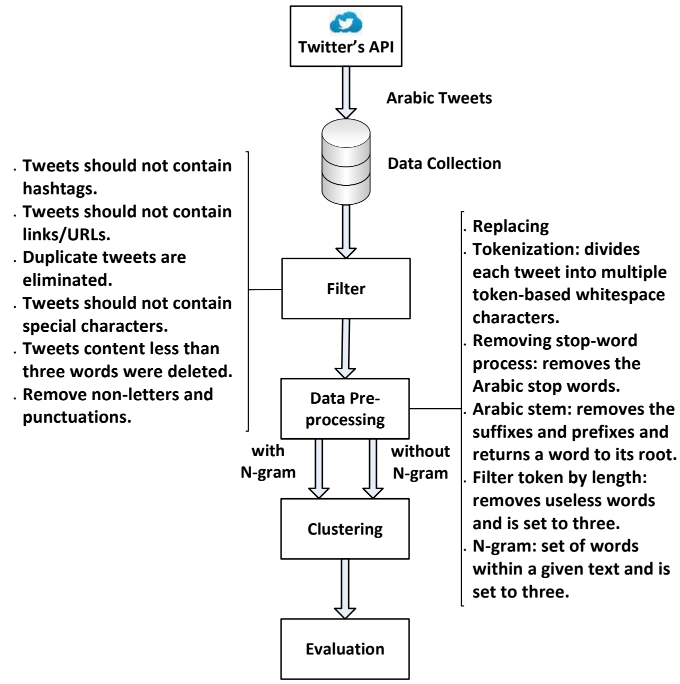

Fig. 1. The process of clustering analysis in Arabic tweets

A. Data Collection

To collect the corpus of data with Arabic tweets and save the relevant tweets and discard the irrelevant ones, a small desktop application (Twitter Data Grabber) is developed using C# with Twitter's official developer API. The tweets' source data were obtained from the Deanship of e-Learning and Distance Education at King Abdulaziz University in Saudi Arabia [25]. The tweets were collected in 50 days. The dataset included 1,121 tweets. Preliminary data were collected and contained many attributes, such as tweet ID, tweet original, tweet filtered, tweet time, and tweet user). This study has used only tweet filtered, data-type text. Only the tweet user was used to determine which cluster a tweet belongs to.

B. Data Preprocessing

Data preparation consists of different techniques that are concerned with the analysis of raw data to yield quality data, mainly including data collection, data integration, data transformation, data cleaning, data reduction, and data discretisation [26]. Data preparation is more time-consuming than data mining and equally, if not more challenging, than data mining. For instance, Arabic is a Semitic language with composite morphology; Arabic words are classified as particles, nouns, or verbs; Arabic is written from right to left; Arabic sentences do not begin with a capital letter as in many other languages such as English; and the 28 Arabic characters differ in shape depending on position in a word or sentence [15, 27-29].

The process begins with our system of filtering the original tweets and saving them in the tweet filtered field, with all the collected tweets saved in the main dataset. Afterward, these tweets are filtered to decide which ones will move to the next stage. The filtering process is performed on specific criteria. For example, duplicate tweets are eliminated. Any tweet containing fewer than three words was deleted. Tweets could not contain hashtags, special characters, nonletters, punctuations, or links/URLs.

There are five steps for preprocessing documents using RapidMiner. The first is to replace English terms with Arabic equivalent terms; all hamza forms such as ئ, ؤ, ء are removed because of diacritics and replaced with initial أ, آ, إ, ى and with alif. ا. The second is the tokenisation step, in which each tweet is divided into multiple token-based whitespace characters. The third is removing the Arabic stop words. In the fourth step, the suffixes and prefixes are removes, and words are returned to their root in the Arabic stem. The fifth step is the filtering of token by length, which removes useless words and is set to three. Finally, the N-gram set of words within a given text is set to two.

Then the "process documents from the data" operator generate a word vector from the dataset after preprocessing and represent the text data as a matrix to show the frequent occurrence of each term. K-means is applied with weighting schemes such as TF-IDF and BTO. The evaluation is conducted using clustering distance methods.

C. Clustering methods

Clustering techniques are applied when there is no class to be predicted. Clustering is a type of unsupervised learning, which is used when you have unlabelled data. The classical clustering technique is called K-means. The following steps describe how k-means works [30]:

1) The user determines in advance how many clusters are needed by the set-up *k* parameter.

2) Cluster centres are randomly initialised using K points.

3) Clusters are assigned to their closest centre according to the Euclidean distance metric.

4) Centroids are moved by recalculating the positions of the centroid of the instances in each cluster.

5) Steps 3 and 4 are reiterated until the centroids no longer move.

IV. Experiment

This experiment examines Arabic text clustering in e-learning as an educational pattern with K-means. To quantify the homogeneous attribute among the dataset, distance metrics plays a very paramount role. Identifying the manner in which datasets are interrelated, how distinct data are dissimilar or identical with each other, and which quantifications are utilised for comparison is obligatory. For this purpose, the distance metrics function is calculated based on which data are clustered. This study was evaluated for effectiveness within a cluster distance. It is a task that takes this centroid cluster model and clustered set as input and estimates the leverage of the model based on the cluster centroids [31, 32].

V. Finding and Discussion

The experiments started by setting up k with 3 and then running the process. Then, the dataset includes 1,121 tweet clusters. Using TF-IDF, Table 1 shows that the average within centroid distance is –0.943.

TABLE. I. Performance within Cluster Distance using TF-IDF

Cluster	**Total number of records**	**Centroid distance between clusters**
0	804	–6.435
1	139	–0.899
2	178	–0.851
Avg. within centroid distance: –0.943		

The dataset tweets cluster distance using TF-IDF with N-gram = 2. Table 2 shows that the average within centroid distance is –0.972.

TABLE. II. Performance within Cluster Distance using TF-IDF with N-Gram = 2

Cluster	**Total number of records**	**Centroid distance between clusters**
0	823	–0.983
1	200	–0.967
2	98	0.891
Avg. within centroid distance: –0.972		

The dataset tweets cluster distance using binary-term occurrences. Table 3 shows that the average within centroid distance is –6.435.

TABLE. III. Performance within Cluster Distance using Binary-Term Occurrences

Cluster	**Total number of records**	**Centroid distance between clusters**
0	812	–5.868
1	245	–7.865
2	64	–8.157
Avg. within centroid distance: –6.435		

The dataset tweets cluster distance using binary-term occurrences with N-gram equal to 2. Table 4 shows that the average within centroid distance is –12.819.

TABLE. IV. Clustering Distance using Binary-Term Occurrences with N-Gram Equal to 2

Cluster	**Total number of records**	**Centroid distance between clusters**
0	876	–11.756
1	219	–16.278
2	26	–19.507
Avg. within centroid distance: –12.819		

Table 5 shows the difference between the average within centroid distances for the schemas TF-IDF and BTO without N-gram equal to –5.492. In addition, it shows the difference between the average within centroid distances for the schemas TF-IDF and BTO with N-gram equal to –11.847.

TABLE. V. AVERAGE WITHIN CENTROID DISTANCE

	Without N-gram	Within N-gram
TF-IDF	–0.943	–0.972
BTO	–6.435	–12.819
Total Avg. within centroid distance	–5.492	–11.847

In conclusion, the best clustering obtained were the smaller distances within centroids. The reason for multiplying by –1 is to calculate the average distance within centroids. Theoretically, the smaller the distances are, the better the clusters are. Performance within the cluster distance operator maximises the capacity of the k-means algorithm. On the other hand, if it is not multiplied by –1, the distance evaluation calculates with a higher average distance within centroids. So clear representation of our vectors using BTO will be useful to determine similarity with students' text than the TF-IDF scheme. In addition, using the N-gram feature provides the best and most reliable way to group tweets in this study.

Table 6 shows the subtraction between the recorders or the tweets that have been grouped or clustered by comparing and carefully reading only the disagreement tweets.

TABLE. VI. CLUSTERING DIFFERENTIATION WITHIN TWEETS

Cluster	BTO	TF-IDF	Different
0	876	823	53
1	219	200	19
2	26	98	72

Figure 2 shows that there were variance subjects or inquiries involved in the data; for example, cluster zero has three inquiries: exams, payment methods, and university study plan. Cluster 1 has only one subject, almost all of which is the Blackboard system and its problems and inquiries. In cluster 2, students talk about the next year's studies or their summer semesters. However, it was difficult even for the team to make a difference about the missed clustering that comes across those methods.

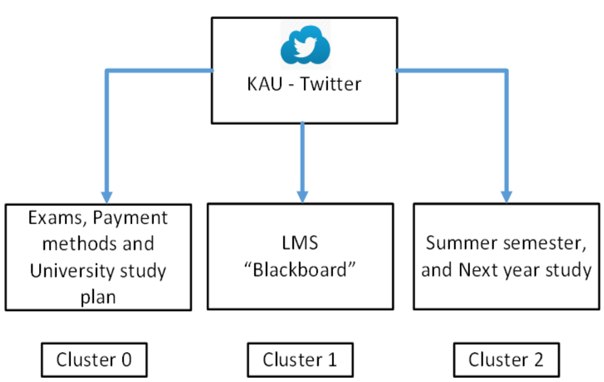

Fig. 2. Grouping tweets into three main subjects

Figure 3 shows the average within centroid distance between TF-IDF and BTO without the N-gram feature.

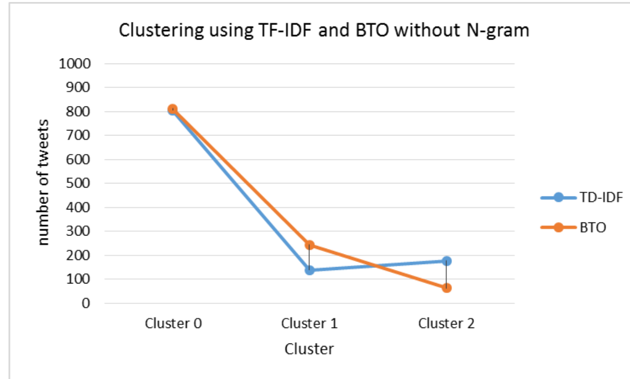

Fig. 3. Cluster Distance using TF-IDF and BTO without N-gram

Figure 4 shows the average within centroid distance between TF-IDF and BTO with the N-gram feature.

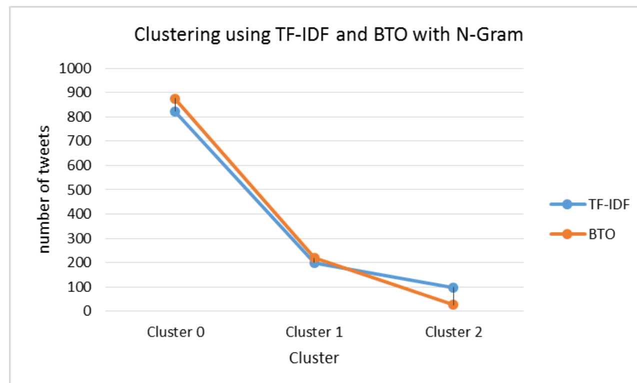

Fig. 4. Cluster distance using TF-IDF and BTO with N-gram

Finally, the university team observed our data scrupulously when the N-gram feature, which was engaged in both experiments because there was clear improvement within the average centroid distance.

VI. CONCLUSION AND FUTURE WORKS

In this paper, the design and implementation of Arabic text clustering over social media was presented to King Abdulaziz University students. The authors believe that this study demonstrates that text preprocessing is a consequential mission to prove that different generating vectors will affect the clustering of the targeted groups. The results of the two experiments lead us to conclude that the best clustering work were the smaller distances within centroids. It was achieved with BTO using the N-gram feature. On the other hand, humans interfered by looking carefully into our data when the N-gram feature was involved in both experiments. It was difficult to make a judgment of which schemes are better in representing this study corps. Nevertheless, the results of the two studies led us to conclude that Twitter can be used in education to provide such services as answering a group of students' inquiries.

For future research, we intend to integrate students' Twitter accounts through which they posted their tweets on the

Deanship of e-Learning and Distance Education account at King Abdulaziz University in the Tweeter platform to collect their data in the learning management system (Blackboard) to see the correlation between the data on social media and their real stations and grads.

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Human Visual System-based Unequal Error Protection for Robust Video Coding

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***Abstract*—To increase the overall visual quality of the video services without increasing data rate, a human visual system-based video coding, founded on a hierarchy of the video stream in different levels of importance, is developed. Determining these importance levels takes in count three classification criteria: the position of current image in the group of images (image level), the importance of the motion vectors of macroblocks in the current image (macroblock level) and belonging or not of a pixel in a spatial region of interest (pixel level). At the end of this classification process, an interpolation between the results of the three-level selection allows to establish an index of importance for each macroblock of the image to be encoded. This index determines the type of channel coding to be applied to the corresponding macroblock. Tests have shown that the technique presented in this paper achieves better results in PSNR and SSIM (structural similarity) than an equal error protection technique.**

Keywords—video coding; unequal error protection; human visual system (HVS); Regions of Interest ROI; Significant Motion Vectors SVM; Classification; index of importance

I. Introduction

Many subjective studies and experiences in the fields of human vision and electronic imaging revealed that the human visual system (HVS) tends to focus on a few favorite areas in images or scenes data. Usually, a loss occurred in the region of the image drawing the viewer's attention, causes a bigger discomfort than if it occurs outside of this area. Moreover, this discomfort can be amplified by the temporal spread of damage related to loss in several images. This phenomenon of propagation is accentuated because of the intensive use of intra and inters images in hybrid video encoders. In general, areas or regions of the image that attracts the attention of the HVS are called regions of interest (ROI), while the rest of the Image is called the background.

Many factors influencing visual attention have been identified, and are grouped into two categories. The first category includes all spatial information that stimulates visual attention (color, orientation, intensity, size, etc ...). The second category concerns the temporal information (motion).

A video sequence contains these two types of information. Since the final quality is judged by humans, it is useful to define the levels of importance of the information, according to their influence on the visual quality as perceived by the final user. The use of coding based on regions of interest in combination with radio resource management algorithms RRM (Radio Resource Management) can improve the global system capacity. However, because of the high efficiency of the compression, the resulting data is very sensitive to the effects of transmission errors. To remedy this problem, the encoding based on the regions of interest was combined with unequal error protection approaches.

This paper is organized as follows. Section 2 discusses related work using visual attention in video coding. Section 3 describes the proposed robust video encoder based on the perceptual unequal error protection. Sections 4, 5, 6 describe three classification levels: Image, Macroblocks and pixel, and section 7 explains the determination of the index of importance IG and correcting codes allocation. Synthesis results are discussed in Section 8, and conclusions are given in Section 9.

II. Visual Attention in Video Coding

A. The concept of regions of interest applied in image / video coding

The concept of regions of interest ROI has been treated by several studies in the fields of human vision and electronic imaging. These studies revealed that the human visual system (HVS) tends to concentrate on certain preferred areas when viewing an image [1]. They also revealed that certain factors may influence visual attention. These factors are: the contrasts, the shape of objects, object size, color, position. The proposed scheme in [2] exploits the hierarchical nature of the coding based on the regions of interest of the JPEG2000 standard. Two levels of protection against errors are applied. Strong protection is assigned to packets of the ROI using an extended Golay code (24,12), while a low protection is applied to the other packages using an extended Hamming code (8,4). Author in [3] proposes perceptual unequal error protection methods. These encoding techniques, employing Flexible Macroblock Ordering (FMO) for H.264 / AVC, are based on the judgment of the spatiotemporal spread of damage. [4] Presents a novel arbitrary shape ROI coding for scalable wavelet video codec. The motion information of the ROIs is estimated by macroblock padding and polygon matching. In [5], authors propose a novel rate control scheme for ROI coding. They set the area covering people are interested in as the ROI to preserve better quality than the background. A coefficient ω is set to evaluate the significance of ROI, and then it’s used to calculate the mean absolute distortion (MAD) of the ROI and the background. Finally, the quantization parameter (QP) can be decided by the quadratic model.

B. Significant Motion Vectors

The temporal aspect is crucial in determining visual attention. In a visual search context, the movement was clearly identified as a visual attractor. The contrast in movement is a key factor that attracts human visual attention. Therefore, a moving area degraded by errors draws attention immediately. Thus was born the concept of significant motion vectors (SMV). This term refers to the decisive motion vectors for a good reconstruction of the transmitted image. If these vectors are lost, the quality of the decoded picture deteriorates considerably. So it's wise to overprotect these vectors comparative to motion vectors judged insignificant.

In [6]; the authors propose a technical error resistance based on the determination and protection of so-called significant macroblock. This schema attributes for each macroblock of the current image a degree of importance (SD Significant degree), calculated from three factors: the prediction mode of the macroblock, the difference between the predicted motion vector and the estimated ones, and residual error between the original image and the reference image. The result of the error concealment technique is also taken into account in determining the degrees of importance. Another way to determine the significant macroblock is presented in [7]. The distortions caused by the compensation motion vectors are used for evaluating the effects of error propagation. Macroblocks with most of these effects are encoded Intra, limiting the propagation of errors. In [8], significant motion vectors are selected and protected according to the value of the image PSNR decoded using the motion vectors and the concealment technique. A model of rate distortion optimization is proposed for determining the rate allocated to significant motion vectors. Authors in [9] propose an enhanced error protection scheme using flexible macroblock ordering in H.264/AVC. The algorithm uses a two-phase system. In the first phase, the importance of every macroblock is calculated based on its influence on the current frame and future frames. In the second phase, the macroblocks with the highest impact factor are grouped together in a separate slice group using the flexible macroblock ordering feature of H.264/AVC.

III. Robust Video Encoder based on the Perceptual Unequal Error Protection

The influence of packet loss on the image quality of a video sequence depends on several factors including the spatial position of the loss in the image, the amount of movement between images, and the image position in the group of pictures (GOP). A protection technique does not take into account these factors, can be costly in terms of bit rate. So, to increase the global visual quality of service video without increasing bit rate, an unequal error protection technique based on the prioritization of the video stream in different levels of importance, are developed. This technique consists of two main steps (Fig. 1):

1) The extraction of some image characteristics enabling the development of cards. These cards allow a classification of macroblocks according following selection criteria:

- Image Level: The position of the image to be encoded in the group of images.
- Macroblock level: The importance of the motion vector of a macroblock in the image to be encoded.
- Pixel level: belonging or not of a pixel in a spatial region of interest.

2) Interpolate between the results of the three-level selection allows assigning an index of importance IG to each macroblock of the image to be encoded. This important index determines the type of channel coding to be applied to the corresponding macroblock.

IV. Image Classification Level

In a video encoder, each video sequence is distributed in Group of pictures GOP. Each GOP begins with an Intra Image I followed by a number of predicted images P. the impact of an error transmission occurred in an image, on the rest of the images differs depending on the position of this image in GOP. Indeed, the authors in [10] have shown that the propagation of errors due to predicted images, depend on the position of those images within the sequence encoded: If the predicted image P is just after an intra-image I, then its influence on the rest of the sequence will be greater than if it is just before or near an image I. therefore, one can obtain a gain on the quality of the video by increasing the protection of first predicted images P.

Since the redundancy introduced by this approach should not exceed one introduced by a conventional equal protection technique, the latest predicted images P in each sequence will be sacrificed in terms of protection.

So it's important to determine the best compromise between the number of the protected images and one of the least protected images, a compromise that minimizes the global average distortion evaluated by MSE or PSNR.

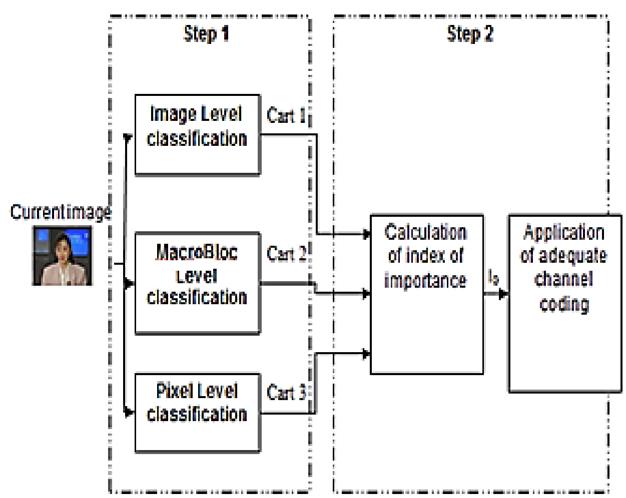

Fig. 1. Unequal Error Protection based on a hierarchy of the video stream in different levels of importance

MSE is calculated from the decoded sequence S_d (transmitted through an imperfect channel), the original sequence S_0, the image size N * M and the length T of the sequence [10].

The global MSE Is:

$$MSE_g = \frac{1}{T\,M\,N} \sum_{t=0}^{T-1} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \left[S_o(i,j,t) - S_d(i,j,t) \right]^2 . \qquad (1)$$

Tree categories of image are considered (Fig. 2): R1 class of high protected images, R2 class of medium protected images and R3 class of least protected images. Determine t0 (= 0), t1, t2 and t3 (= T): limits of each class, is to minimize the global distortion of the sequence.

Let C1, C2 and C3 correcting codes assigned to classes R1, R2 and R3 respectively.

The relationship between the encoding efficiency and the parameters t0, t1, t2 and t3 is formulated as follows [10]:

$$\sum_{r=1}^{3} C_r (t_r - t_{r-1}) - C_m T = 0 \qquad (2)$$

t1 is the solution of the following equation:

$$(C_2 - C_3)(P_1 - P_2) Ln\left[1 + \gamma (T - t_1)\right] - (C_1 - C_2)(P_2 - P_3) Ln\left[1 + \gamma \frac{C_1 - C_2}{C_2 - C_3}\right] = 0 \qquad (3)$$

P1, P2 and P3 are the error probabilities of the classes R1 R2 and R3 respectively.

t2 is calculated by:

$$t_2 = T - \frac{C_1 - C_2}{C_2 - C_3} \qquad (4)$$

Since the 1/3 turbo codes are used in UMTS systems, we opted to use the same codes in the proposed scheme, Such as:

- If $I_G = 1$, the macroblock will be coded by a C1 = 1/3 code;
- If $I_G = 2$, the macroblock will be coded by a C2 = 2/5 code ;
- If $I_G = 3$, the macroblock will be coded by a code C3 = 1/2.

So, taking into account these codes, values of t are: $t_1 = 5$ and $t_2 = 25$. This means that the 5 first images of GOP belong to the class R1, the following twenty images belong to the R2 class and images that remain belong to R3.

V. Macroblock Classification Level, based on Significant Motion Vectors

Given the major impact of the loss of significant motion vectors, the degradation of the visual quality of reconstructed images; we chose to take into account the importance of the motion vectors in the development of an unequal error protection scheme. In the following, two methods to identify significant motion vectors are presented [11].

A. *First approach: classification based on the global distortion*

SMVs are extracted in function of the measure of the distortion. We propose to express the visual importance of a macroblock in terms of distortion that would be caused by the loss of this macroblock. Such distortion may be calculated by comparing the video sequence decoded using the correct data with the video sequence decoded using the replacement data generated by the concealment technique in the decoder. If transmission errors are not quite hidden, the distortion will be high and therefore the corresponding motion vectors corrupt macroblock are considered important.

Temporal concealment technique of corrupted macroblocks is integrated in the encoder. Error is injected into the encoded stream; lost macroblocks are replaced by those corresponding to the previous image. The importance of each macroblock in an image is therefore estimated by calculating a distortion measure between this macroblock and the one produced by the error concealment from the previous image. This value is compared to a threshold. If it is below the threshold, the motion vector is considered insignificant. Otherwise, it is classified significant.

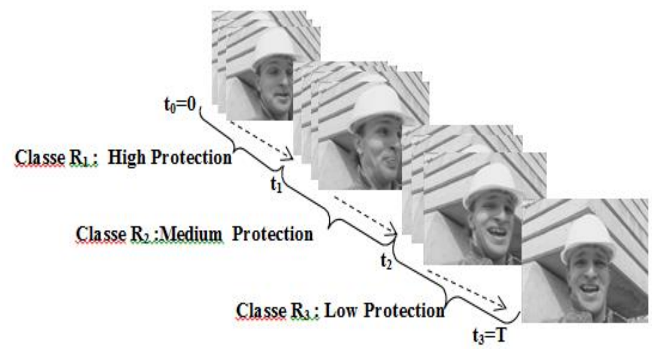

Fig. 2. P images Classification according to their positions relative to I image

Let D(i), the distortion of the i^{th} macroblock (MBi) decoded without transmission error, and Dc(i) distortion of the i^{th} macroblock corrupted by errors, and decoded using the concealment technique. The distortion is calculated by MSE.

Let Y(i) the difference between D(i) and Dc(i), Y_s is the comparison threshold.

$$Y(i) = | D(i) - Dc(i) |. \qquad (5)$$

- If Y (i) $< Y_s$, this means that the error concealment is able to predict correctly MB_i. The MV associated at MB_i is classified not significant.
- By cons, if Y (i) $\geq Y_s$, the corrupted or lost macroblock cannot be substituted. In this case, the motion vector associated at this Macroblock is defined as important.

The selection of a comparator threshold is crucial insofar as this threshold will determine the number of significant motion vectors in an image. Now if this number increases the redundancy introduced by the channel coding also increases. Therefore, two criteria must be taken into account in the choice of Y_s: the computational complexity and compression efficiency translated by the number of macroblocks judged significant. In order to find a compromise between the two criteria, Y_s is chosen as the overall average distortion Y_m of the current image. It represents the mean values of Y (i) of all the macroblocks of the image. This value is easy to calculate and does not require complex operations or intensive computation time and memory.

Fig. 3 shows the result of a macroblock classification in the 2nd image of Foreman sequence, according to the value of the distortion associated with each macroblock.

This approach has two major disadvantages: the complexity of the encoder diagram and not taking the subjective quality of images into account. Indeed, the use of MSE as distortion measure does not allow classifying motion vectors according to the impact of the injected errors on the visual quality of the image. Appeal to subjective quality measures for calculating distortions, will certainly remedy this disadvantage, but will greatly increase the encoder complexity, especially as this complexity is already increased by the need to integrate a decoder within encoder to assess the performance of the error concealment technique in the case of a corrupted stream and determine thus significant motion vectors. This added complexity of the scheme affected the performance of this approach and makes it unsuitable in the case of mobile wireless transmission and real-time applications. In the following, another approach to classify the motion vectors are proposed, which are not based on the distortion but on the value of the motion vector himself.

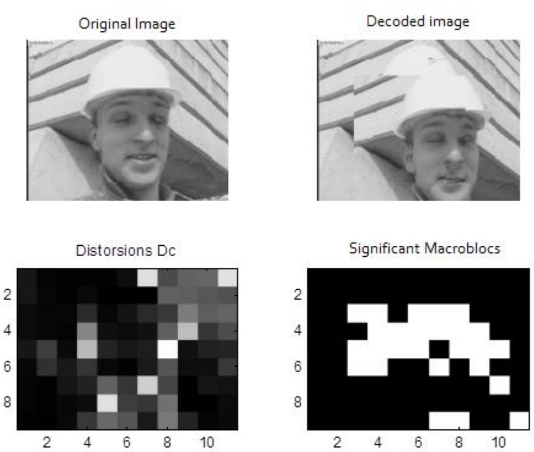

Fig. 3. Classification of macroblocks of the 2nd image of Foreman sequence, according to the value of the distortion associated with each macroblock

B. *Second approach: classification based on the amplitude of motion vectors*

The idea is to make a "coarse" classification of the motion vectors. This idea is based on the fact that at the decoder level, the simplest concealment technique is replacing a lost macroblock; by the corresponding one in the previous image, considering the motion vector of the macroblock as zero (VM = 0). Therefore, the zero motion vectors do not need a large protection since, in the decoder, they can be correctly compensated.

Thus, a motion vector is defined as:

- Non-significant if its magnitude is zero (no movement);
- Significant in the opposite case (presence of motion).

This classification will cause, certainly, a slight reduction in compression efficiency; however, it will be compensated by the use of two other classification blocks. In addition, this approach allows us to take advantage of the resources offered by the encoder in the classification algorithm. Thus, the results of motion estimation block will be used directly in the development of the map of significant motion vectors. Fig. 4 shows the classification of the macroblocks of the image number 2 of the Foreman sequence, depending on the value of the motion vectors associated with each macroblock.

VI. PIXELS LEVEL CLASSIFICATION

This classification is made according to or not belonging of a pixel to a region of interest. In an encoding scheme based on ROI, the identification of these regions is crucial. Indeed, the results of ROI automatic identification algorithms should be consistent with the results of identification done by a human observer. For this, human perception and visual attention (AV) should be taken into account when developing algorithms to identify regions of interest.

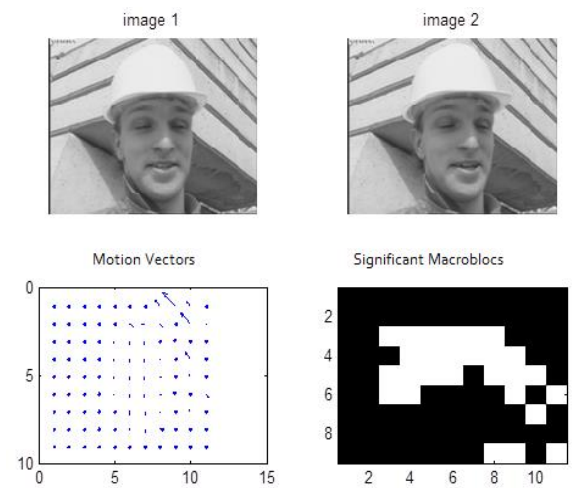

Fig. 4. Classification of macroblocks of the Image No. 2 of the sequence Foreman, depending on the value of the motion vectors associated with each macroblock

In this work we have chosen to apply the identification algorithm of ROI based on visual attention model proposed by [12]. Its functional principle is as follows: first, primitive visual characteristics (intensity, color and orientation) are extracted from the image to form maps of characteristics (Fig. 5 (a)). Then, the cards are standardized by filtering using a difference of two-dimensional Gaussian filter. In each map, the most salient areas are selected and finally the maps are combined by a weighted average to obtain the saliency map of the image (Fig. 5 (b)).From this map, a belonging card of pixels to a ROI was developed (Fig. 5 (c)).

In part two of this scheme, we have to make an interpolation between the card delivered by the Macroblocks classification process and that delivered by the pixel classification process. Now, these two cards do not have the same dimensions (9X11 for the first and for the second 144X176). To remedy this inconvenience, another card representing the membership or not of a macroblock to a region of interest was created (Fig. 6 (d)). A macroblock is considered belonging to a region of interest, if at least half of its pixels belong to a region of interest.

VII. Determination of the Index of Importance I_G and Correcting Codes Allocation

As it been explained above, proposed unequal error protection scheme is in two phases: classification process and allocation of different correcting codes to Macroblocks. This allocation is done according to an index of importance calculated from the results of the first phase.

Once the classification process is completed, a *Multi-criteria evaluation (MCE)* is conducted to estimate the global index of importance of each macroblock of the image to be encoded. The value of this index will determine the type of correcting code applied to each macroblock. This evaluation consists of applying to the result of the classification process, a *Boolean overlay* with intersecting operators (AND*)* and union operators (OR*)*, that act as constraints.

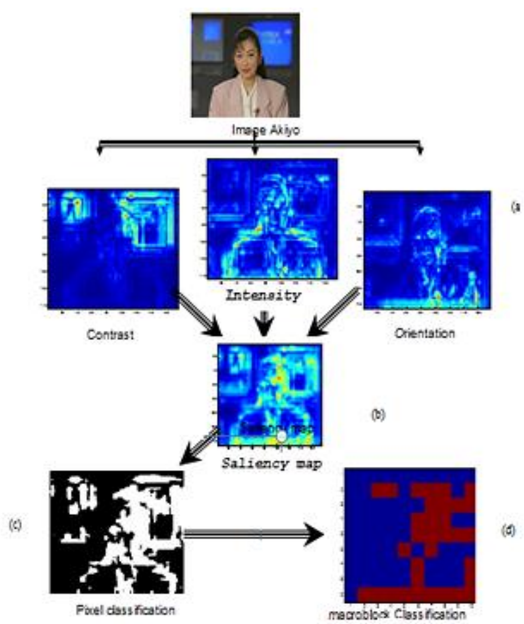

Fig. 5. Identification of regions of interest in image 2 of Akiyo sequence (a) maps of the primitive visual characteristics; (b): saliency map (c), pixel classification map; (d) macroblocks classification map

The classification stage presented in the previous section, delivers three index cards for each image:

Index card, relative to the image classification. It is noted I_R, such as:

$$I_R = 1 \text{ if } P \in R1;\ I_R = 2 \text{ if } P \in R2 \text{ et } I_R = 3 \text{ if } P \in R3;$$

Index card, relative to the macroblocks classification. It is noted I_{MB}, such as: $I_{MB} = 1$ if the macroblock is significant, otherwise $I_{MB} = 0$;

Index card, relative to the macroblocks classification. It is noted I_{pixel}, such as: $I_{pixel} = 1$ if the macroblock is in ROI, otherwise $I = 0_{pixel}$.

The global index of importance I_G of a macroblock is calculated according to the diagram in Fig. 6. In images of the R1 class, the criteria I_{MB} and I_{pixels} are combined with a logical OR (union), which means that a macroblock is considered important, if only one criterion equals 1. While in the images of the R2 class, the criteria are combined with a logical AND (the intersection operator) requires a macroblock respond positively to the two criteria for it to be selected as important. This selection process is done in the worries of keeping good value rate / quality.

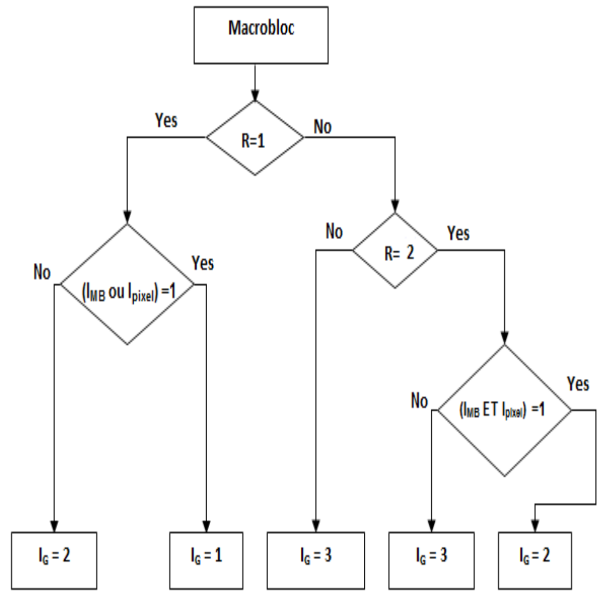

Fig. 6. Determination of Index of importance I_G

Using a different correcting code for each P image requires the implementation of three coding blocks in the encoder, and such in the decoder, which increases the complexity of the global configuration. To reduce this complexity, we use only one type of correcting code, with different rate. Convolutional codes are a highly efficient and flexible class error correction codes. These are the most used in fixed and mobile telecommunications systems code.

Since the 1/3 turbo codes are used in UMTS systems, we opted to use the same codes in this scheme, Such as:

- If $I_G = 1$, the macroblock will be coded by a code C1 = 1/3 ;
- If $I_G = 2$, the macroblock will be coded by a code C2 = 2/5 ;
- If $I_G = 3$, the macroblock will be coded by a code C3 = 1/2.

It has been explained in section 4 that the values of t_1 and t_2 depend on C1, C2 and C3. So, taking into account the chosen yield values obtained $t_1 = 5$ and $t_2 = 25$. This means that 5 first images belong to R1 class, the following twenty belong to R2 and images that remain belong to R3.

VIII. Tests and Results

In the simulation two video sequences of 30 images was used: Foreman and Akiyo (QCIF size and 176 x 144 pixels). The GOP size is 30: an Image I is inserted periodically every thirty images. The transmitted signal is subjected to Rayleigh noise. This proposed system is compared to a conventional Equal Error Protection technique (EEP) using a correcting code of 2/5 rate. Convolution encoder Rates applied to the high, medium and low protection, are respectively 1/3, 2/5 and 1/2.

To better correlate the proposed technical performance with the real quality as perceived by humans, it is necessary to use measures that integrate the characteristics of the human visual system in their algorithms. PSNR and SSIM measures (structural similarity) between the reconstructed video and the original video are used to measure the quality of the decoded video.

A. The distribution of Macroblocks according to their importance

The distribution of Macroblocks according to their importance in GOP is presented in Fig.7 Foreman sequence. Since the first image is encoded Intra (no motion vectors), 1 is assigned to all elements of the card 2, which implies that all I_G in this image are set to 1. Certainly, this image will be overprotected (all macroblocks are important) by the channel code C1. Nevertheless, this overprotection is acceptable given the importance of I image in the prediction of following P-type images.

B. Visual quality of images

The performance of our proposed scheme, in terms of quality, compared to the equal error protection (EEP) scheme is shown in Fig 8. It can be seen that this unequal error protection shows better results than equal error protection. Indeed, in terms of PSNR, this method allows an improvement that can reach up to 3dB.

In Fig. 9 and Fig. 10 are presented the images from the decoded Foreman sequence and Akiyo sequence. To illustrate the robustness of this technique, errors are injected into the ROI of three P Images belonging to three different classes (R1, R2 or R3). The resulting images demonstrate the efficiency of this approach even in extreme cases. Indeed, the impact of the errors is barely visible on the images coded by this technology, while images encoded by EEP are considerably degraded by the effect block. The visual quality drops rapidly in the last images because of errors propagation.

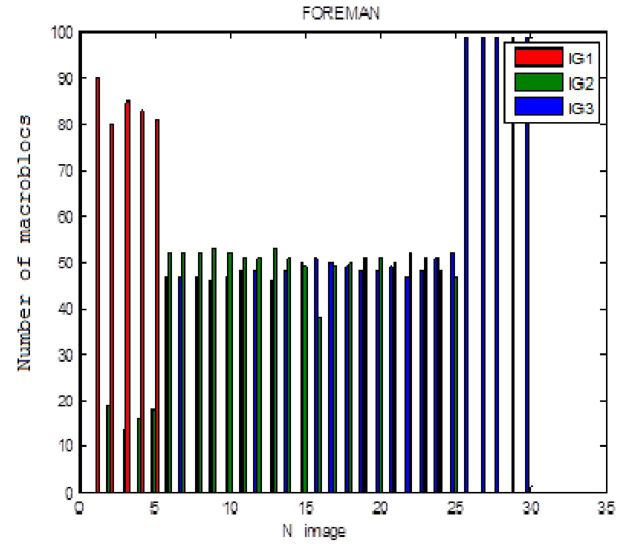

Fig. 7. The number of Macroblocks according to their importance in the 30 images of the sequence Foreman

The results of table 1, in terms of SSIM (structural similarity) show that this technique also overcomes the equal protection in tests of the subjective quality of the reconstructed images.

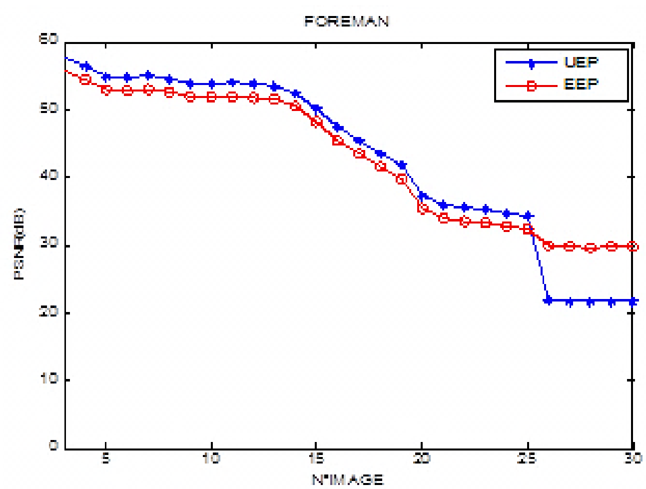

Fig. 8. Comparison between this unequal error protection and equal error protection of the Foreman sequence

Fig. 9. Images taken from Foreman sequence (left), images encoded by this unequal error protection UEP (middle), and image encoded by equal error protection EEP (right)

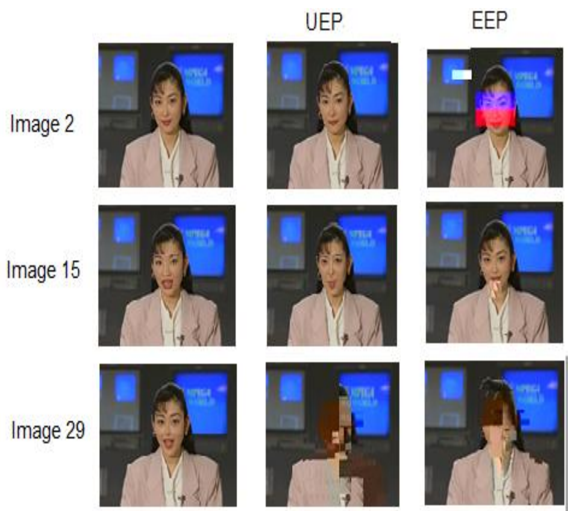

Fig. 10. Images taken from Akiyo sequence (left), images encoded by this unequal error protection UEP (middle), and image encoded by equal error protection EEP (right)

TABLE. I. SSIM RESULTS FOR FOREMAN SEQUENCE AND AKIYO SEQUENCE

	Foreman sequence			*Akiyo sequence*		
	Image 2	***image1 5***	***Image 29***	***Image 2***	***Image 15***	***Image 29***
UEP	0990	0983	0609	0992	0966	0730
EEP	0.991	0971	0353	0993	09497	0683

The proposed scheme provides robustness against transmission errors. However, this performance must be obtained without increasing bit rate. For comparing the bit rate generated by this unequal error protection and of equal error protection, the number of bits used to encode each image of GOP was calculated. Fig. 11 shows that, apart from the images of the R1 class, this approach uses fewer bits to protect images than the traditional approach.

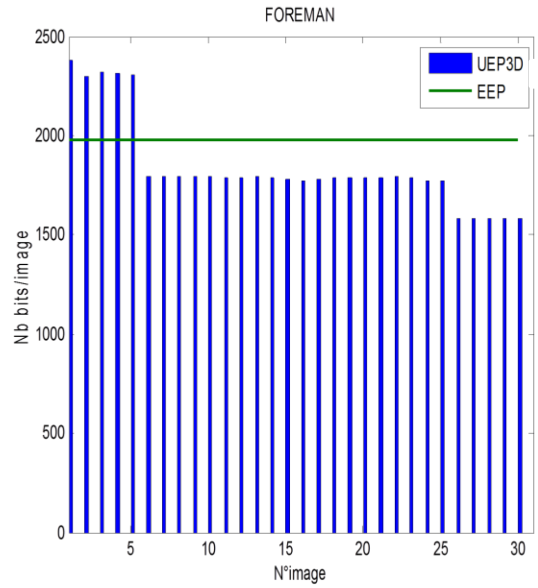

Fig. 11. Comparison in terms number of bits / image between this unequal error protection and equal error protection

IX. CONCLUSIONS

A new technique of error resilience based on a perceptual unequal error protection of the video stream is proposed in this paper. The video image is prioritized according to three criteria: the position of the image in the GOP, amplitude of motion vectors and spatial saliency.

Tests have shown that the proposed technique of video coding achieves better results in PSNR and SSIM (structural similarity) than an equal error protection. The selection of various parameters such as the selection criteria, the selection algorithms and channel coding; was made such that the diagram shows satisfactory performance without increasing bit rate.

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Proposing a Keyword Extraction Scheme based on Standard Deviation, Frequency and Conceptual Relation of the Words

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***Abstract*—At each text there are a few keywords which provide important information about the content of that text. Since this limited set of words (keywords) is supposed to describe the total concept of a text (e.g. article, book), the correct choosing of keywords for a text plays an important role in the right representing of that text. Despite several efforts in this field, none of the so far published methods is accurate enough to elicit representative words for retrieving a vast variety of different texts. In this study, an unsupervised scheme is proposed which is independent on domain, language, structure and length of a text. The proposed method uses the words' frequency in conjunction with standard deviation of occurred location of words in text along with considering the conceptual relation of words. In the next stage, a secondary score is given to those selected keywords by the statistical criterion of TFISF in order to improve the basis method of TFIDF. Moreover, the proposed hybrid method does not remove the stopwords since they might be a part of bigram keywords while the similar approaches remove all stopwords at their first stage. Experimental results on the known SEMEVAL dataset imply the superiority of the proposed method in comparison with state-of-the-art schemes in terms of F-score and accuracy. Therefore, the introduced hybrid method can be considered as an alternative scheme for accurate keyword extraction.**

Keywords—Keyword extraction; key-phrase extraction; TFISF; standard deviation; frequency

I. Introduction

Since a tremendous of texts in the form of book, scientific paper, news, technical reports are daily added to the internet, researchers in big databases develop automatic methods for analyzing the texts and finding semantic relations between them. To search a desired topic among a huge number of texts, brute force search does not work and to diminish the size of each text into some representative words, the idea of keyword extraction is emerged [1]. Keywords are one or a short consequence of limited words that represent a text [2,3]. In some research fields like natural language processing (NLP), there is a serious need to investigate a huge number of texts. Therefore, by providing a set of keywords as indicators of each text, this investigation can be remarkably eased, especially when a text is searched according to its keywords [4].

In addition, there are some text processing applications that their methods contain a similar trend to the keyword extraction techniques. These applications include: automatic text summarization [5,6], information retrieval [7], text classification [8], fast and accurate searching of texts in web [9] and automatic indexing [10,3]. Keyword extraction methods are the basis schemes for all of these applications and the right choosing of essential keywords is the main purpose of this research. Reading keywords of a text can help the query to choose or reject of that text. In fact, keyword checking can be an effective way to find a relative text where the searched keywords are enough similar to the keywords of the corresponding text. Therefore keyword extraction can help the query in learning how to arrange correct keywords in the search engines to find his favorite document quickly.

Keyword extraction is usually performed in two stages. At the first stage, the text is preprocessed using heuristic rules and some words are selected as the keyword candidates. One of the most applicable heuristic rules is removing the stopwords since these words are repeatedly scattered throughout the text and the conventional keyword extraction methods select them as the best candidates while they carry no I nformation about the text's concept. Some methods use a list of stopwords and remove every similar stopword in the text. In some other methods, those words with high frequencies throughout the text are removed.

In the second stage, the methods are divided into two categories including supervised and unsupervised schemes. In both categories a dataset with labels (keywords) is required in order to assess the results. One of the problems in supervised approaches is requiring a training phase while in unsupervised

*The corresponding author

schemes the train is carried out through the stages of algorithms and there is no need to a separate train phase. In addition, supervised methods have usually more computational complexity rather than the unsupervised ones. One of the basic methods employed in both categories is the statistical methods which benefits from the simplicity and low computational complexity. One of the famous statistical methods is TFIDF (Term Frequency-Inverse Document Frequency) which provides suitable results in different applications [11]. Nevertheless, TDIDF suffers from high dependency to the length and the size of the corpus; consequently, researchers made a lot of attempts to overcome its drawback by combining it with other basic methods [12].

II. Related Work

In this regard, Witten et al. [13] developed a supervised method by combining TFIDF [14] with the first occurrence location factor in the text and called this method as KEA and applied it to 75 journal papers. In this algorithm, root location is adopted as the preprocessing method and in the learning phase, Naïve Bayes classifier is employed and finally the recall measure is utilized for the assessment. The accuracy of this method is assessed based on Human Judi and is highly dependent to the size of the train set. Nevertheless, this method could be assessed by a more robust measure. This method is also employed for text abstraction, searching through the web and classification of different texts is utilized.

Hulth [15] suggested a supervised method for the keyword extraction just from the abstract [16] parts of scientific papers using INSPEC dataset. He combined the statistical measure with the linguistic knowledge in order to remove the dependency of the frequent words to both the length of document and number of documents. Nevertheless, it still suffers from the dependency to the structure of the text. Their performance in terms of F-measure provides 33.9, while its main deficiency is to estimate the correct label for the dataset in the training phase. To compensate this defect, it is possible to use the knowledge of finding the relevance among the words and assign label to them accordingly. They removed the stopwords according to their high frequency. They also incorporate the concept of each sentence containing a candidate keyword for giving a score to each keyword. This is done by a graph based method for giving a score to the candidate keywords according to the type of the graph and the semantic role of that keyword in the text. Finally the keywords were sorted according to their scores. They could get a considerable improvement in terms of F-measure by incorporating the sentence information for the keyword extraction. Nevertheless, this scheme highly biased the keyword to the importance of the sentence and if they used TFIDF, their results could be more robust to the sentences.

In another attempt, Zahedi et al. [17] for improving the better accessibility to the web content using keywords, focused on the search engines for ranking the keywords. They used the retrieved information results as the training data and for improving their supervised method, genetic algorithm is deployed to optimize the features. The preprocessing of the text contained two steps where in the first stage, the unification is done and then the stopwords were eliminated. The key point in this algorithm is to determine a threshold such that 60% of predefined keywords by the authors of that text considered as the candidate keywords. In this scheme TFIDF is used and assessed by F-score (40.82) on Farsi websites. Their results outperformed the other compared methods on their dataset, though their method suffered from the problem of supervised approaches and also imposes lots of computational burden.

Sharon et al. [18] applied a different method in construction of a semantic graph for each text in an unsupervised manner. They used word net for determining the conceptual links using the GEPHI tool for graph demonstration. Each node takes a score according to the sorted rank of keywords using human judgment. They applied their method to two different datasets and demonstrated keywords are those having a high conceptual value despite TFIDF that considers keywords as high frequency words in a text. Unlike TFIDF, this approach does not need a lot of texts.

Lu et al. adopted an unsupervised scheme for keyword extraction that uses literature references within the framework of word co-occurrence and topic distribution. They applied their method to ACM digital library and assessed their method by F-score resulted in 0.276. It is has been demonstrated that using references could improve the performance of each method compared to the situation that the references is not incorporated.

Das et al. [12] developed an unsupervised method based on collocation and fuzzy set theory for keyword extraction to handle the ambiguity of high occurrence rate of words in a text [19]. This method does not need any corpus and can be applied on a single document. Moreover, this method could solve the dependency of TFIDF to the size of documents. This method is able to elicit both keywords and key-phrases. They applied their method to the electronic documents which contains scientific articles on different issues which are accessible by different sources like Wikipedia. For the exactness of the elicited keywords, the precision is determined up to 95% accuracy. This high precision rate can be originated from applying a filtering in the preprocessing stage.

Siddiqi et al. [20] utilized an unsupervised scheme for keyword extraction which I independent to the length of corpus, its domain and type of language. Their method helped TFIDF to consider both the frequency of words and spatial distribution of the words. In this method, for each word a spatial sequence is generated which demonstrate the places of that word in a document. By this distribution, stopwords can be detected since they are regularly distributed throughout the text while key words do not have a specified spatial pattern. Each word is given a weight according to its spatial distribution and this weighting is determined such that the stopwords are automatically takes very low value. After eliciting the keywords according to the mentioned weight mechanism the precision is determined. They applied this method to an Indian book and achieved 0.8 precision. Since this method uses a statistical criterion, it needs a big document to be able to correctly find the keywords.

Yang et al. [21] suggested an unsupervised graph based scheme for keyword extraction. They pay attention to each sentence during keyword extraction. In their method, the importance of each word within a sentence is measured and these words are ranked according to their importance in an iterative manner throughout a document. The ranking of keywords is determined according to their ranking of their corresponding nodes in the graph of that document. One advantage of this method is its applicability on just one document which overcomes to the TDIDF drawback and decreases its dependency to the size of corpus. They have applied their scheme to the WEB TEXT 13702 dataset and compared their result with the text ranking algorithm and demonstrated that they have got a better F-score (25.2%) in comparison with text ranking method.

In this study, we propose a new method based on multi-factorial features, which can quickly be extracted from each single document. In fact, the proposed method is an extension of the method introduced by Siddiqi et al. [20] by being added a language model for generating better results. We have applied the proposed method to the SEMVAL dataset and compared our method to the base method.

The rest of this paper is organized as follows. Section 2 is devoted to introduction of the proposed method along with the base method [20]. Section 3 presents the experimental results. Finally, section 4 concludes the paper and gives an outline to clarify the horizon of this study in the future.

III. Methods and Materials

In this section, the method proposed by Siddiqi et al. [20] and the scheme proposed here are presented. Afterward, the employed datasets in this study are introduced and their features are explained. In accordance with the limitation of supervised methods, most of the conventional algorithms in this field are unsupervised whose goal is the independency to the type of language, topic, length and structure of the document while preserving the accuracy. Eliciting of the correct representative keywords remarkably help a search engine to find its required document in big data bases at a glance.

One of the research approaches which provide logical results, published by Siddiqi et al. [20]. The used the concept of standard deviation over a difference sequence for each word. Their method was dependent to the length of data since statistical criterion for limited numbers of occurrences cannot provide an acceptable index. This method is able to significantly differentiate keywords and stopwords, as shown in Fig. 1 (a) and (b), respectively.

In order to compare and demonstrate the spatial occurrences of a real keyword and stopword, two diagrams in the form of barcode are shown in Figure 1. The horizontal axis in each diagram presents the spatial length of the document, while the vertical axis shows the occurrence of that word. As we see in this figure, the occurrence place of a keyword is much irregular than that of a stopword. This difference rises from this fact that each sentence needs one of more stopwords and therefore its spatial distribution is uniform while a single keyword which carries a part of main concept of a document cannot be appeared in all sentences since there are some other keywords and each part of text is concentrated on a certain concept. Consequently, standard deviation of this barcode graph can be a good indicator to distinguish a stopword from a keyword.

In the Siddiqi's method [20], keywords and key-phrases are extracted in two phases by two algorithms, each of which has similar steps. The candidate keywords are chosen at the first step, then the chosen keywords are assessed and the correct ones are determined. Both the keyword extraction algorithm (SDFKWE) and the modified version of SDFKPE (MSDFKPE) are proposed by Siddiqi et al. [20] use only the standard deviation criterion for extracting the keywords. The results are then used for extracting the key-phrases in the second algorithm. In this study, we have attempted to improve their method by adding additional factors. In the following sections, the proposed method and its steps are illustrated.

A. *Keyword extraction phase*

The first step is to preprocess the input text by eliminating the irrelevant words. In this regard, the sentences are separated according to the separating signs, i.e., punctuations. Then, all of the grammatical signs within each sentence are removed and the text is tokenized for separating single words. The whole text is then stored in the form of sentences captured in arrays. After that, all unique words along with their synonyms whose frequency is lower than a threshold are removed. The most profit of the proposed scheme is that it does not need to remove stopwords at this stage. The second step is carried out for diagnosing the precision of the elicited keywords by calculating two scores for obtaining the Final-Score.

Fig. 1. Comparison of the spatial distribution of a) A keyword, b) A stopword throughout a document [20]

Score1:

In the second phase, for each word, two different scores are determined and the final decision is made according to these two scores. The first score is related to the occurrence sequence of each word and its synonyms [22] and the words with the same root and then standard deviation of spatial distribution of each word is determined. To do this, if a word with its synonyms and the same root are placed in the $X_1, X_2, \ldots, X_N$ locations, the differential sequence of occurrence locations as the standard deviation of spatial filter will be determined as equation 1.

$$S_W = \{ (X_2 - X_1), (X_3 - X_2), (X_4 - X_3), \ldots (X_N - X_{N-1}) \} \quad (1)$$

The mean of these locations for each word is denoted as μ and is determined as equation 2.

$$\mu = \frac{(X_2 - X_1) + (X_3 - X_2) + \cdots + (X_N - X_{N-1})}{N} = \frac{(X_N - X_1)}{N} \quad (2)$$

After that, by the equation 3 we can determine the standard deviation of difference sequence for each word.

$$\sigma = \sqrt{\frac{\sum((X_{i+1} - X_i) - \mu)^2}{N}} \quad (3)$$

The above formula is adopted from the method proposed by Siddiqi et al. [16]. In order to diminish the dependency of the standard deviation to the repeated number of a word, this squared deviation is divided by the number of repetition of that word. Then the difference deviation values of all words are sorted in a descending order. The top ranked words are selected as the primary candidate set of keywords. In order to finalize the keywords, the second score, here called Score2, needs to be calculated.

SCORE2:

Consider a text about the computer; it is obvious that in such a text the keyword *computer* is repeatedly occurred throughout the text. Hence, this word is not likely to be removed in the former processing stage. In addition, this word takes a high value in Score1. As this general word at all texts about the computer would have the same status; it would be considered as a general word and cannot be a good keyword. For this reason, in addition to the criterion of the word frequency, the number of sentences containing that keyword over the whole number of sentences should also be considered so as to avoid choosing very general words. In fact, a real keyword should be occurred in specific part of a text, not to be appeared in all sentences. General words act like stopwords since they are occurred in all sentences and must be removed. In order to incorporate the sentences containing the candidate keywords, in this work, we have used the TFISF (Term Frequency-Inverse Sentence Frequency) statistical criterion. TFISF is somehow similar to TFIDF in order to normalize the frequency of each word based on the number of corresponding sentences. The TFISF criterion is determined as follows:

Consider the text D with the array of N sentences denoted as D = {S_1, S_2, ..., S_N} where each S_i includes a set of words in the form of $w_{1i}, w_{2i}, ..., w_{ni}$. TFISF is composed of two main elements, i.e., TF and ISF. TF_{ti} is roughly defined as the number of time that the keyword t has occurred in the i^{th} sentence. ISF for a typical keyword t is defined as equation 4.

$$\mathrm{ISF_t} = \log(\frac{\mathrm{N}}{\mathrm{N_t}}) \quad (4)$$

Where N is the whole number of sentences in text D and Nt stands for the number of sentences in text D that contain the word t. Finally, the TFISF for the word t in the ith sentence is obtained from the equation 5.

$$\mathrm{ISF} \times \mathrm{TF} = \mathrm{TFISF} \quad (5)$$

To determine score2 using the concept of TFISF over the retrieved keywords up to the rank of 120 with score1 is performed and the final keyword is determined by forming the equation 6.

$$\text{Final-Score}(W_i) = \text{Alpha} \times \text{score1}(W_i) + (1-\text{Alpha}) \times \text{score2}(W_i) \quad (6)$$

Regarding the achieved value of a word in the score1 and score2 observed that there was a difference in the range of these two scores; consequently, before combining these two scores each of them is normalized in the interval of [0,1]. Next in order to make these two scores comparable the value of ALPHA within the range of [1, … , 0.1, 0.05, 0] is considered to regularize these two score and the summation of this regularization will determine the final score. It is obvious that this regularization parameters should be determined to the cross validation phase.

In order to provide an efficient algorithm for extracting the keyword, we proposed Improved-Standard Deviation Based Keyword Extraction algorithm (Improved-SDFKWE) in which in addition to considering the statistical factors like frequency and standard deviation, in the SDFKWE algorithm, introduced by Siddiqi et al. [20], considering the semantic links between the sentences overall the text.

1) Proposed method: improved –SDFKWE algorithm

In this study, an improvement is performed on the efficient algorithm of SDFKWE and equipped with the following factors:

- Generating the unique word list as candidate keyword and arrays of synonym and the same root words for each word separately.
- Determine the frequency of each word with onsidering the frequency of that word and its synonyms and words which have the same root.
- Eliminating the word with the frequency bellow than the threshold.
- Constructing a different sequence of occurrence of the each word in consecutive sentences with considering the location of that word and the corresponding the synonyms words and the words which have the same root.
- Determining the score1 with finding the standard deviation of the sequence SW and normalizing of that with the mean of this sequence and determining score2 with calculating the TFISF for each word by considering its synonyms and those which have the same root and finally determining the Final-Score of each word in the text.
- Now the lists of keywords are ranked according to the Final-Score in an descending order and selecting those which have a higher rank according to a threshold.

B. Key-phrase Extraction Phase

In this algorithm for extracting key-phrase containing two words, denoted as bigram, is considered and the phrases which exceed two words are eliminated. Key-Phrase extraction is performing in two similar steps in which the routines for the functional each word is determined as followed.

In the first step the input text was preprocessed to generate the candidate bigrams in the text. We should first determine these bigrams according to the discriminative sign at each sentence for each unique bigram. At each sentence like Q which contains N words in the form of $W_1\ W_2\ W_3\ W_4 \dots W_N$ unique bigrams in the form of $W_1\ W_2$,$W_2\ W_3$,$W_3\ W_4$,….. , $W_{N-1}\ W_N$ are considered and finally an array of consecutive sentences of bigrams are stores afterward the number of occurrence times of each bigram in the text determined and those bigrams which their number of repetition exceed than a threshold are considered and those which are lower than this threshold are eliminated.

The second step is diagnosing the precision of elicited bigrams by calculating two different scores for creating the Final-Score.

The first step to calculate the Final-Score is to determine the score1 of its constructing bigrams elements (Score1: word#1, Score1: word#2) and the next step is to determine the score2 of the bigram's TFISF.

SCORE1:

This score is determined by the summation of score1 of each component in a bigram phrase in the keyword extraction phase as shown in equation 7.

$$\mathrm{SCORE1}(W_i\ W_{i+1}) = \mathrm{SCORE1}(W_i) + \mathrm{SCORE1}(W_{i+1}) \quad (7)$$

Where $\mathrm{SCORE1}(W_i)$ is calculated from equation 3.

Then the candidate bigrams according to the score1 are listed in a descending order.

SCORE2:

This score for those statistical samples up to the rank of 120^{th} achieved from the sorting of bigrams resolving score1 is determined. To do this, the TFISF criterion is employed here by this difference that TFISF determination instead of a single word, employ a bigram there for TFISF. In this phase, the number of occurrence time of bigrams in a sentence is determined and compared to the occurrence times of that bigram in all over sentences of the text.

The Final-Score is the summation of score1 and score2 as shown in equation 8, in regularization manner for the bigram in this phase and this score is sorted in a descending order as similar to the base algorithm and finally the top ranks bigrams are selected as the key-phrase candidate.

$$\text{Final-Score}(W_i\ W_{i+1}) = \text{Alpha}\times\text{score1}(W_iW_{i+1}) + (1\text{-Alpha})\times\text{score2}(W_iW_{i+1}) \quad (8)$$

In order to provide an efficient algorithm for extracting the Key-Phrase, we proposed Improved-Modified Standard Deviation Based Key-Phrase Extraction algorithm (Improved-MSDFKPE) in which in addition to considering the statistical factors like frequency and standard deviation, in the MSDFKPE algorithm, introduced by Siddiqi et al. [20], considering the semantic links between the sentences overall the text.

1) Proposed method: Improved –MSDFKPE algorithm

To ease the understanding of the proposed method, it has been clarified in terms of pseudo-code.

- Generating the list of unique bigrams as the key-phrase candidates.
- Determining the frequency of each unique bigrams and eliminating the other bigrams which their occurrence is lower than the predefined threshold.
- Determining score1 for each bigram is determined by the summation of score1 and score2 of that bigrams using the statistical criterion of TFISF and finally the score is descending in a regularized manner.
- Ranking of candidate bigrams according to the Final – Score and choosing the bigrams as the key-phrases.

The execution time of this algorithm with a certain value of Alpha is approximately suitable; therefore, it should be considered similar to the improved-MSDFKPE algorithm that for achieving the best precision, this regularization parameter should be found in an iterative manner.

C. Datasets and Tools

In this section, empirical results of applying the proposed method along with SDFKWE method on two different datasets are presented. In order to find the synonyms and common-root words of each keyword, the Wordnet software is used. Wordnet is written by JAVA at MIT University[1].

As we mentioned before, SEMEVAL and the book titled "on the origin of species" were used as the datasets to evaluate the methods. The mentioned book contains 14 chapters and 222 pages[2].

SEMEVAL is one of the known standard datasets for assessing the keyword extraction and phrase extraction methods[3]. This dataset contains 284 documents in four fields to cover several topics in which by providing train and test sets, in addition to the unsupervised methods, it is possible to apply them to the supervised methods. The labels of this dataset for evaluating each of the supervised and supervised schemes are introduced in three categories. This information contain the labels (keywords) that the authors selected for their documents, the labels that the readers assign to each document and labels which are the combination of labels are assigned by the authors and readers for each document.

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IV. Experimental Results

In the preprocessing stage, for executing over each of the above mentioned datasets, the words of each sentence are separated and all the capital letters are converted to lower case letters. The advantage of the proposed scheme is that in its first stage, the stopwords are not eliminated since a part of a bigram keyword can be a stopword [12]. For instance the keyword of "Sun" along with a stopword "the" can make a bigram keyword of "The Sun". Therefore, preserving the stopwords in the first stage of the algorithm is one of the key points while the other conventional methods try to remove all stopwords at the first stage.

In order to preparing the first dataset (the book), we did not apply our method to each chapter separately while we concatenate all chapters and produce a long document. In contrast, the SEMEVAL data set, our proposed method and SDFKWE were separately applied to each document separately.

A. Experiment on Basic Dataset

1) Results Provided by Improved - SDFKWE algorithm

Siddiqi et al. [20] applied their method to this dataset and used precision criterion for evaluating their method. They elicited keywords and compared them by the indexed words of that book, as the real labels. For comparing the proposed method to the introduced rivals, the proposed method is applied to this book and their extracted keywords are compared to those labels which are selected by Siddiqi et al. [20]. The comparison results of the proposed method to SDFKWE are illustrated in terms of precision, Score-1 and the final regularized Score in Table 1.

TABLE. I. Results of the Improved-SDFKWE over Different Number of Top Ranked Words in Terms of Precision Evaluation Measure

method	Top-10	Top-20	Top-30	Top-40
Improved - SDFKWE: Score1	0.2400	0.4000	0.4857	0.5250
Improved - SDFKWE: Final-Score	1	1	0.9667	0.9500
SDFKWE	0.7000	0.6500	0.6000	0.6000
Improvement rate	0.30	0.35	0.37	0.35

As it can be seen in Table 1, precision of the final regularized Score of the proposed method in comparison with the Score-1 gets better and by comparing to SDFKWE, our results are enhanced up to 30%. Keywords in a text are not necessarily those which are highly repeated in all its sentences. As we mentioned before, to find the real occurrence rate of a word, its synonyms and its common-root words are selected. Therefore, is a word is repeated with a low rate, it cannot be considered as a keyword. The threshold for considering a word as a key word is empirically set to 10. The highest accuracy for the Improved-SDFKWE in Table 1, with considering Alpha=0.55, is achieved. In addition, the threshold for the base algorithm, proposed by Siddiqi et al. [16] was set to 10.

2) Results Provided by Improved- MSDFKPE

In this phase, according to the improvement method proposed by Siddiqi et al. [20], the correctness of the bigrams as keywords is assessed. The results of their method and the proposed method in this datasets are brought in Table 2.

TABLE. II. Results Of Different Improved -MSDFKPE over Different Number of Top Ranked Words in Terms of Determines Precision Evaluation Measure

method	Top-10	Top-20	Top-30	Top-40
Improved- MSDFKPE:SCORE1	0.40	0.30	0.26	0.27
Improved - MSDFKPE: Final-Score	0.60	0.55	0.43	0.40
MSDFKPE	0.30	0.30	0.23	0.17
Improvement rate	0.30	0.25	0.20	0.23

As we can see in Table 2, the accuracy of the proposed scheme in terms of final score is improved compared to Score-1. Moreover, our scheme compared to the SDFKWE, at each iteration of retrieved keywords is improved about 20 to 30%. The threshold for eliminating the words with low occurrence rate was set to 5 by Siddiqi et al. [20]. The parameters of our scheme for this comparison were set to 4.88 as the threshold and 0.46 for the regularization parameter of Alpha. The run time of the proposed improved SDFKWE was higher than that of the Improved- MSDFKPE. This difference is raised from calculating the Score-1.

B. Experiment on SEMEVAL Dataset

In order to compare the performance of the proposed algorithm to the conventional schemes, in the keyword extraction phrase, the SEMEVAL dataset is adopted. As far as the most documents in this dataset are with their correct corresponding keywords and key phrases, to customize this dataset for our application, just the single keywords and bigrams were selected and the precision of our method compared to the other ones are made according to single and bigram keywords and the longer key words were all eliminated.

Since the labels of this dataset are brought in the form of root using the porter stemmer, all of the achieved unique words in the preprocessing stage (phase 1), using this rooting algorithm are represented in form of root. Next, the proposed algorithm on each document of the SEMEVAL dataset is executed separately and finally to determine the precision of the algorithm all over the documents, for the top ranked words exceed than micro average, the precision and recall are determined and finally F-Score for the top ranked keywords are determined as follows:

$$F = \frac{2PR}{P+R} = \frac{2}{\frac{1}{R}+\frac{1}{P}} \quad \textbf{(8)}$$

Where P and R denote for precision and recall, respectively. It is necessary to note that in the evaluation of keywords extraction performance is carried out in the form of exact match and as far as in the comparison Table 2, the results of algorithm are brought for 5, 10 and 15 top ranked keywords, the performance of proposed algorithm is determined accordingly. The performance of conventional supervised and unsupervised algorithms with respect to the base lines of SEMEVAL, are brought in Table 3 [23].

TABLE. III. PERFORMANCE OF SUBMITTED SYSTEM OVER THE COMBINED ASSIGNED KEYWORDS RANKED BY F-SCORE [23]

System	Rank	TOP-5			TOP-10			TOP-15		
		P	**R**	**F**	**P**	**R**	**F**	**P**	**R**	**F**
HUMB	1	39.0	13.3	19.8	32.0	21.8	26.0	27.2	27.8	27.5
WINGNUS	2	40.2	13.7	20.5	30.5	20.8	24.7	24.9	25.5	25.2
KP-Miner	3	36.0	12.3	18.3	28.6	19.5	23.2	24.9	25.5	25.2
SZTERGAK	4	34.2	11.7	17.4	28.5	19.4	23.1	24.8	25.4	25.1
ICL	5	34.4	11.7	17.5	29.2	19.9	23.7	24.6	25.2	24.9
SEERLAB	6	39.0	13.3	19.8	29.7	20.3	24.1	24.1	24.6	24.3
KX-FBK	7	34.2	11.7	17.4	27.0	18.4	21.9	23.6	24.2	23.9
DERIUNLP	8	27.4	9.4	13.9	23.0	15.7	18.7	22.0	22.5	22.3
Maui	9	35.0	11.9	17.8	25.2	17.2	20.4	20.3	20.8	20.6
DFKI	10	29.2	10.0	14.9	23.3	15.9	18.9	20.3	20.7	20.5
BUAP	11	13.6	4.6	6.9	17.6	12.0	14.3	19.0	19.4	19.2
SJTULTLAB	12	30.2	10.3	15.4	22.7	15.5	18.4	18.4	18.8	18.6
UNICE	13	27.4	9.4	13.9	22.4	15.3	18.2	18.3	18.8	18.5
UNPMC	14	18.0	6.1	9.2	19.0	13.0	15.4	18.1	18.6	18.3
JU-CSE	15	28.4	9.7	14.5	21.5	14.7	17.4	17.8	18.2	18.0
Likey	16	29.2	10.0	14.9	21.1	14.4	17.1	16.3	16.7	16.5
UvT	17	24.8	8.5	12.6	18.6	12.7	15.1	14.6	14.9	14.8
POLYU	18	15.6	5.3	7.9	14.6	10.0	11.8	13.9	14.2	14.0
UKP	19	9.4	3.2	4.8	5.9	4.0	4.8	5.3	5.4	5.3

As we in Table 3, the first and second rank methods are supervised while the third rank belongs to the KP-Miner which is an unsupervised. By a short look through this list, we can see that the performances of unsupervised algorithms are approximately similar to the supervised ones in the first 15 top ranked methods. The achieved F-Scores are not impressive since one of the weaknesses of the conventional keywords extraction is its subjectivity. Therefore, reaching to the F-Score 100% in this field is infeasible. On the other hand, in this task, the maximum number of extracted keywords is 15. It should be mentioned that if we set the number of keywords more than 15, the F-Score might be improved but for comparing to the other methods, we had to set the same number to them [23].

According to Table 3, among the unsupervised approaches, KP-Miner [24] provided the best rank; therefore, we have compared our method to KP-Miner on the SEMEVAL dataset and bring the comparative results in Table 4. The threshold of the top ranked keywords is set to 10 to provide the best result. To show the effectiveness of the parameters like the number of top ranked keywords, regularization parameter (Alpha), the proposed algorithm is executed by different values and in those parts that our method outperformed KP-Miner is bolded in Table 4.

The main goal of this research is presenting a method for the evaluation of the amount of relativity of keywords to a text. Regarding the subjectivity of this area, whatever the elicited keywords get near to opinion of reader-assigned, it can be claim that this method could provide higher accuracy. In contrast, whatever the extracted keywords are nearer to the authors' suggested keywords rather to the readers' assigned keywords, it shows the lack of enough accuracy in extracting the keywords. As it is demonstrated in Table 4, the accuracy of the proposed method is better than that of KP-Miner for the 5 top ranked keywords. In retrieving the keywords more than 5, although our method outperforms KP-Miner in terms of recall, its precision could not compete to that of KP-Miner. This is therefore the low number of bigrams in the SEMEVAL labels leading to diminish the F-Score.

TABLE. IV. PERFORMANCE OF KP-MINER & IMPROVED -MSDFKPE ALGORITHM ON P, R AND F INDEXES, GIVEN AS PERCENTAGES

Rank		TOP-5			TOP-10			TOP-15		
Assigned key-phrases	**Method**	**P**	**R**	**F**	**P**	**R**	**F**	**P**	**R**	**F**
Author	**KP-MINER**	19.0	24.6	21.4	13.4	34.6	19.3	10.7	41.6	17.1
	Improved-MSDFKPE	13.26	**27.85**	17.96	9.78	**41.09**	15.80	7.53	**47.48**	13.00
Reader	**KP-MINER**	28.2	11.7	16.5	22.0	18.3	20.0	19.3	24.1	21.5
	Improved-MSDFKPE	22.39	16.37	**18.91**	16.84	**24.64**	20.01	12.89	**28.29**	17.72

V. CONCLUSION AND FUTURE WORK

Keyword extraction for a text is very necessary since most of the search engines find the related documents according to the maximum matching between the searched items and keywords of each text. For this purpose, developing a method for providing high rate of true keywords is of interest. In this paper, a multi aspect algorithm was introduced which considers several factors. The proposed scheme uses the standard deviation of difference sequence of the occurred place for each word, in addition to preserving the synonyms and common-stem words of each keyword candidate while it does not eliminate the stopwords. This unsupervised scheme was executed on two datasets and could outperform state-of-the-art methods for detecting the 5 top ranked keywords. The accuracy of the algorithm is assessed by both reader-assigned and author-assigned approaches and the matching of the elicited keywords to the reader-assigned labels imply on the higher performance of the proposed scheme compared to the rivals.

As a future work, for applying the proposed method to a book with several chapters, using TFISF and TFIDF in keyword extraction may improve the accuracy of elicited keywords for each chapter. In addition, considering the semantic relation of unique words with the title of each chapter and considering it as an additional score could be enhance the results.

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Output Feedback Controller Synthesis for Discrete-Time Nonlinear Systems

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***Abstract*—This paper presents a computational approach for solving optimal control problem for a class of nonlinear discrete-time systems. We focus on problem in which a pre-specified N local subsystems are given to describe the studied systems. For such problem, we derive an output feedback controller and a cost function such that the resulting closed-loop system is asymptotically stable and the closed loop cost function is minimized. The main results are demonstrated numerically through the implementation of the proposed algorithm for solving the optimal control problem of a mechanical system.**

***Keywords*—nonlinear systems; discrete-time systems; optimal control; output feedback control**

I. Introduction

The optimal control of discrete-time nonlinear systems remains an important open control problem in control engineering and continue to attract significant attention of control research [1-4]. For the static output feedback, the reader is referred to [5-9]. It is well known that the optimal control of linear systems with respect to a quadratic cost function can be achieved by solving the Riccati equation [10].

However, when studying the nonlinear discrete-time systems we often need to solve either nonlinear partial difference or differential Hamilton-Jacobi-Bellman equation [11,12], which is generally a difficult task. Despite recent advances [13-17], some of the developed techniques have limited applicability because of the strong conditions imposed on the system. Other implemented solutions are often partial and of significant complexity because of the need to find an accurate model of the system. In practice, an accurate complete model of the studied system isn't usually available. The full model information cannot be available at the time of design or it might change or the system can have different operating conditions. For all the previous reasons and even for the reason of simplifying the tuning and the maintenance of the system we need to rely on local model control based on local modeling. Motivating by what discussed above we will investigate the best closed loop performance that is achievable by an output feedback controller based on multi-model approach [18-20].

The rest of the paper is organized as follows: Section 2 provides the description of the studied systems and problem statements. The proposed strategy of the optimal output feedback control of the discrete time nonlinear studied systems is presented in section 3. Main results are derived and summarized by an efficient algorithm. Then, the validity of the proposed approach is illustrated by simulation results in Section 4. Concluding remarks are given in Section 5.

II. Problem Statements

Let's consider in this study a class of nonlinear and uncertain discrete-time systems described as:

$$(S)\begin{cases} x(k+1) = f\left(x(k), u(k), \theta(k)\right) \\ y(k) = h\left(x(k), \theta(k)\right) \\ \theta(k) \in ID \end{cases} \quad (1)$$

where $x(k) \in \Re^n$ is the state vector, $u(k) \in \Re^m$ is the input vector and $y(k) \in \Re^p$ is the output vector. The functions $f(.)$ and $h(.)$ depend on a vector of parameters $\theta(k)$ which is considered unknown, but evolving in a convex domain ID.

In the literature, various approaches [15,16] like identification, linearization or convex polytopic transformation can be used to determine the multi-model description of a complex system.

In this paper, we assume that the nonlinear mathematical model of the studied system is known. By linearization around its several operating points $(u_{i0}, x_{i0}), _{i\,=\,1\ldots N}$, different and simpler local models are obtained. So the complex studied system described initially by a nonlinear mathematical model (1) can be then described by a library of N local linear model characterized by the following state space equations:

$$(M_i)\begin{cases} x_i(k+1) = A_i x_i(k) + B_i u_i(k) \\ y_i(k) = C_i x_i(k) \\ i = 1, \ldots, N \end{cases} \quad (2)$$

where N *is* the number of local models, $x_i(k) \in \Re^n$, $y_i(k) \in \Re^p$ and $u_i(k)$ are respectively the state vector, the output vector and the control input vector of the *i-th* submodel noted M_i.

The state space matrices A_i, B_i, C_i are constant of appropriate dimensions to be determined.

$$A_i = \frac{\partial f}{\partial x}\bigg|_{(u_{i0}, x_{i0})}, \quad B_i = \frac{\partial f}{\partial u}\bigg|_{(u_{i0}, x_{i0})}, \quad C_i = \frac{\partial h}{\partial x}\bigg|_{(u_{i0}, x_{i0})} \tag{3}$$

and let's note:

$$\begin{cases} x_i(k) = x(k) - x_{i0} \\ u_i(k) = u(k) - u_{i0} \\ i = 1, \ldots, N \end{cases} \tag{4}$$

Each model of the library, involving N sub-models, contributes to the process description with a degree of trust measured by a validity coefficient. The validity appears to be of great importance if realizing their influence on the performances of the global control law.

Indeed, the use of the validity coefficients is a convenient mean to experiment with sub-collection of systems and is also useful to put more emphasis on the performances of some particular instances of parameter values. In the literature several methods were proposed for the estimation of these validities. In this paper the approach proposed in [19] is considered for validities computing. Because the implementation of linear controllers is straightforward and cost effective, the multi-model approach was also proposed in the following section as a solution for the control and analysis of the nonlinear studied discrete systems.

III. Optimal Output Feedback Control for Discrete-Time Nonlinear Systems

In this section, our objective is to design an output feedback controller for the studied system and a cost function such that the resulting closed-loop system is asymptotically stable and the closed loop cost function is minimized.

Assume for each isolated subsystem M_i, a local controller is designed.

$$u_i(k) = -F_i y_i(k) \tag{5}$$

where $F_i \in \Re^{m\times p}$ is the control gain matrix to be determined by minimizing the proposed quadratic function:

$$J_i = \sum_{k=0}^{\infty}\left(x_i^T(k)Q_i x_i(k) + u_i^T(k)R_i u_i(k)\right) \tag{6}$$

where $Q_i = Q_i^T \geq 0 \in \Re^{n\times n}$ and R_i are the state and input weighting matrices.

Applying controller (5) to the system (2) results in the closed-loop system:

$$x_i(k+1) = (A_i - B_i F_i C_i)x_i(k) \tag{7}$$

The performance index associated with the studied system (1) is then the following quadratic function

$$\begin{aligned} J &= \sum_{i=1}^{N}\mu_i J_i \\ &= \sum_{i=1}^{N}\mu_i \sum_{k=0}^{\infty} x_i^T(k)(Q_i + C_i^T F_i^T R_i F_i C_i)x_i(k) \end{aligned} \tag{8}$$

where μ_i, $i = 1,\ldots,N$ are the validity coefficients of the proposed multi-model description.

Using the solution of the recurrent equation (7), one can write:

$$x_i(k) = (A_i - B_i F_i C_i)^K x_i(0) \tag{9}$$

and substituting (9) in (8), the global performance index (8) can be rewritten:

$$J = \sum_{i=1}^{N}\mu_i \sum_{k=0}^{\infty} x_i^T(0) * \left[\left((A_i - B_i F_i C_i)^K\right)^T \left(Q_i + C_i^T F_i^T R_i F_i C_i\right)(A_i - B_i F_i C_i)^K\right] x_i(0)$$

and presented in a simplified expression:

$$J = \sum_{i=0}^{N}\mu_i x_{i0}^T P_i x_{i0} \tag{10}$$

where

$$P_i = \sum_{k=0}^{\infty}\left[\left((A_i - B_i F_i C_i)^K\right)^T \left(Q_i + C_i^T F_i^T R_i F_i C_i\right)(A_i - B_i F_i C_i)^K\right] \tag{11}$$

are symmetric positive definite matrices, solutions of the following Lyapunov equations:

$$\begin{aligned} &\left(A_i - B_i F_i C_i\right)^T P_i \left(A_i - B_i F_i C_i\right) - P_i + \\ &Q_i + C_i^T F_i^T R_i F_i C_i = 0\,; \quad i = 1,\ldots,N \end{aligned} \tag{12}$$

The dependency of the optimal solution on the initial condition can be removed when considering the average value function $E(.)$ such that:

$$E\left(x_{i0}^T P_i x_{i0}\right) = I_n \tag{13}$$

Based on equation (13), the corresponding closed-loop cost function will be written as follows:

$$\bar{J} = \sum_{i=1}^{N}\mu_i trace\left\{P_i\right\} \tag{14}$$

A. Main Results

In order to derive the necessary conditions of optimal gain matrices of the feedback control, the optimization problem formulated by (11) is reduced to the minimization of the following Lagrangian:

$$\zeta(F_i, P_i, S_i) = \sum_{i=1}^{N} \mu_i \, trace\{P_i\} + \sum_{i=1}^{N} \mu_i \, trace\left\{\Gamma_i^T \left[\left((A_i - B_i F_i C_i)^T P_i (A_i - B_i F_i C_i) - P_i + Q_i + C_i^T F_i^T R_i F_i C_i\right)\right]\right\} \quad (15)$$

where $\Gamma_i \in \Re^{n\times n}, \Gamma_i = \Gamma_i^T \geq 0, i = 1,\ldots,N$ selected to be symmetric positive definite matrices are Lagrange multipliers.

By using the gradient matrix operations [20,21], the necessary conditions for F_i , P_i and Γ_i , to be optimal are given by

$$\begin{cases} \dfrac{\partial\zeta(F_i,P_i,\Gamma_i)}{\partial F_i} = -2\sum_{i=1}^{N} \mu_i \left[B_i^T P_i A_i \Gamma_i C_i^T - B_i^T P_i B_i F_i C_i \Gamma_i C_i^T - R_i F_i C_i \Gamma_i C_i^T \right] = 0 \\ \dfrac{\partial\zeta(F_i,P_i,\Gamma_i)}{\partial P_i} = \sum_{i=1}^{N} \mu_i \left[(A_i - B_i F_i C_i)\Gamma_i (A_i - B_i F_i C_i)^T - \Gamma_i + I_n \right] = 0 \\ \dfrac{\partial\zeta(F_i,P_i,\Gamma_i)}{\partial \Gamma_i} = \sum_{i=1}^{N} \mu_i \left[(A_i - B_i F_i C_i)^T P_i (A_i - B_i F_i C_i) - P_i + Q_i + C_i^T F_i^T R_i F C_i \right] = 0 \\ \qquad i = 1,\ldots,N \end{cases} \quad (16)$$

Solving the first equation in (16), one obtains the optimal control gain matrix F_i of the local model M_i :

$$F_i = \left(B_i^T P_i B_i + R_i\right)^{-1} \left(B_i^T P_i A_i \Gamma_i C_i^T\right)\left(C_i \Gamma_i C_i^T\right)^{-1} \quad (17)$$

and from the two others equations we can determine the matrices Γ_i and all the matrices P_i solutions of the Lyapunov equations (12). Indeed, based on (16), Γ_i and P_i are also the solutions of the following equations:

$$\begin{cases} G_2(F_i, \Gamma_i) = 0 \\ G_3(F_i, P_i) = 0 \end{cases}$$

$$G_2(F_i, \Gamma_i) = (A_i - B_i F_i C_i)\Gamma_i (A_i - B_i F_i C_i)^T - \Gamma_i + I_n \quad (18)$$

$$G_3(F_i, P_i) = (A_i - B_i F_i C_i)^T P_i (A_i - B_i F_i C_i) - P_i \; Q_i + C_i^T F_i^T R_i F_i C_i \quad (19)$$

To solve instantly the three equations (17), (18) and (19), and to calculate all the introduced matrices F_i, P_i and Γ_i , we propose an iterative algorithm which can be summarized in the following way:

Algorithm (A)

Step1 : Initialize $n = 1$

Select $Q_i \geq 0, R_i > 0$ and an initial matrix F_{i0} as initial starting value such that $A_i - B_i F_{i0} C_i$ is a stable for each local model.

Step 2 : n[th] iteration

- calculate F_{in} (17)
- solve $G_2(F_{in}, P_{in}) = 0$ and calculate Γ_{in} .
- solve $G_3(F_{in}, P_{in}) = 0$; and get the matrix P_{in} .
- calculate

$$F_{i(n+1)} = \left(B_i^T P_{in} B_i + R_i\right)^{-1} \left(B_i^T P_{in} A_i \Gamma_{in} C_i^T\right) \times \left(C_i \Gamma_{in} C_i^T\right)^{-1}$$

Step 3 : incrementation

repeat step 2 until verifying $\left\| P_{in} - P_{i(n-1)} \right\| \leq \varepsilon$

End

ε is a prescribed small number used to check the convergence of the algorithm.

B. The Optimal Controller Design

Given the predetermined matrices F_i, the system (1) can be controlled in an optimal manner by the following control policy $u(k)$, which guarantees the minimization of the infinite horizon cost function (8).

$$u(k) = -\sum_{j=1}^{N} \mu_j F_j \; y(k) \quad (20)$$

then the closed-loop system (1) admits the realization:

$$\begin{cases} x(k+1) = f\left(x(k), u(k), \theta(k)\right) \\ y(k) = h\left(x(k), u(k)\right) \\ u(k) = -Fy(k) \end{cases}$$

where

$$F = \sum_{i=1}^{N} \mu_i F_i \;, \; F \in \Re^{p\times m} \quad (21)$$

C. Stability Analysis

In order to prove the asymptotic stability of the controlled system, let's consider $V(x_i(k))$ the Lyapunov function defined by the following quadratic form:

$$V(x_i(k)) = x_i^T(k)P_i x_i(k) \tag{22}$$

where $P_i \in \Re^{n\times n}$ are the symmetric positive definite matrices solution of the equation (12) and (16).

The stability of the controlled system (7) is ensured if the difference of Lyapunov function (22) along the trajectory of (7) is negative definite.

One has

$$\begin{aligned}\Delta V(k) &= V\left(x_i(k+1)\right) - V\left(x_i(k)\right)\\ &= x_i^T(k+1)P_i x_i(k+1) - x_i^T(k)P_i x_i(k)\\ &= x_i^T(k)\left[(A_i - B_iF_iC_i)^T P_i(A_i - B_iF_iC_i) - P_i\right]x_i(k)\end{aligned} \tag{23}$$

Using the third equation of system (16), (19) becomes:

$$\Delta V(k) = -x_i^T(k)\left[Q + C_i^T F_i^T R_i F_i C_i\right]x_i(k) \tag{24}$$

According to the properties of matrices Q_i and R_i, the matrix $Q_i + C_i^T F_i^T R F_i C$ is symmetric positive definite. The variation of the quadratic Lyapunov function, expressed by (24), is then negative defined and the controlled system is then asymptotically stable.

IV. Application to a Mechanical System

In order to demonstrate the effectiveness and merits of the proposed optimal output feedback controller over the existing results, the following mechanical system described by a spring damper mass M is considered:

$$M\ddot{x}(t) + c_1\dot{x}(t) + c_2 x(t) = \left(1 + c_3\dot{x}^3(t)\right)u(t) \tag{25}$$

where:

- $M = 1Kg$ is the mass of the system,
- $c_1 = 1$, $c_2 = 1.155$ and $c_3 = 0.13$ are constants,
- $u(t)$ is the exerted force for the spring,
- $\dot{x}^3(t)$ is the nonlinear term.

and rewritten in the following state space equations:

$$\begin{cases}\begin{bmatrix}\dot{x}_1(t)\\ \dot{x}_2(t)\end{bmatrix} = \begin{bmatrix}-\frac{c_1}{M} & -\frac{c_2}{M}\\ 1 & 0\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix} + \begin{bmatrix}\frac{1}{M}\left(1 + c_3 x_1^3(t)\right)\\ 0\end{bmatrix}u(t)\\ \begin{bmatrix}y_1(t)\\ y_2(t)\end{bmatrix} = \begin{bmatrix}x_1(t)\\ 2x_1(t) + x_2(t)\end{bmatrix}\end{cases} \tag{26}$$

where $x_1(t)$ is the velocity of the mass and $x_2(t)$ the position of the same mass.

By using an appropriate discretization method and a suitable sampling period $T = 0.05s$, it comes the discrete-time state space equations:

$$\begin{cases}\begin{bmatrix}x_1(k+1)\\ x_2(k+1)\end{bmatrix} = \begin{bmatrix}1 - T\frac{c_1}{M} & -T\frac{c_2}{M}\\ T & 1\end{bmatrix}\begin{bmatrix}x_1(k)\\ x_2(k)\end{bmatrix}\\ \qquad + \begin{bmatrix}\frac{T}{M}\left(1 + c_3 x_1^3(k)\right)\\ 0\end{bmatrix}u(k)\\ \begin{bmatrix}y_1(k)\\ y_2(k)\end{bmatrix} = \begin{bmatrix}1 & 0\\ 2 & 1\end{bmatrix}\begin{bmatrix}x_1(k)\\ x_2(k)\end{bmatrix}\end{cases}$$

we pointed out that the nonlinearity of the system is considered as uncertainty and the term of linearities depend on $x_1(k)$ which is assumed to vary in the range $[-1.5 \quad 1.5]$.

According to section 3, and based on the multimodel approach the nonlinear dynamical system (26) can be described by:

$$\begin{cases}x(k+1) = \sum_{i=1}^{2}\mu_i\left(x_1(k)\right)\left(A_i x(k) + B_i u(k)\right)\\ y(k) = \sum_{i=1}^{2}\mu_i\left(x_1(k)\right)C_i x(k)\end{cases} \tag{27}$$

where

$$x(k) = \begin{bmatrix}x_1(k)\\ x_2(k)\end{bmatrix} \text{ and } A_1 = A_2 = \begin{bmatrix}0.9 & -0.1155\\ 0.1 & 1\end{bmatrix},$$

$$B_1 = \begin{bmatrix}0.1439\\ 0\end{bmatrix}, B_2 = \begin{bmatrix}0.0561\\ 0\end{bmatrix}, C_1 = C_2 = \begin{bmatrix}1 & 0\\ 2 & 1\end{bmatrix}.$$

The validity coefficients of this system are expressed as follows:

$$\mu_1(x_1(k)) = 0.5 + \frac{x_1^3(k)}{6.75}$$

$$\mu_2(x_1(k)) = 1 - \mu_1(x_1(k))$$

Using the proposed iterative algorithm the following results are derived:

- The quadratic criterion:

$$J_1 = 0.7727,\ J_2 = 0.9708$$

- The symmetric positive definite matrices:

$$P_1 = \begin{bmatrix} 0.1412 & 0.1148 \\ 0.1148 & 0.6315 \end{bmatrix},\ P_2 = \begin{bmatrix} 0.2735 & 0.1806 \\ 0.1806 & 0.6973 \end{bmatrix}$$

- The symmetric positive definite matrices of Lagrange multipliers:

$$\Gamma_1 = \begin{bmatrix} 5.9552 & -5.2978 \\ -5.2978 & 7.0525 \end{bmatrix},\ \Gamma_2 = \begin{bmatrix} 6.9638 & -5.3482 \\ -5.3482 & 9.8512 \end{bmatrix}$$

and all the gain matrices of the proposed optimal control are calculated:

$$F_1 = \begin{bmatrix} -1.0621 & 1.7891 \end{bmatrix},\ F_2 = \begin{bmatrix} -0.3236 & 1.4268 \end{bmatrix}$$

To show the effectiveness of the proposed optimal output feedback control we have carried out some simulations shown from figure 1 to 2. It appears from figure1 a satisfactory stabilization of the state variables of the controlled discrete-time studied system. The figure 2 illustrates the evolution of the proposed optimal output feedback control law. Indeed, its high performances shows the aptitude of the proposed **Algorithm (A)** to be implemented and to give interesting results for the output feedback control of a large class of nonlinear discrete-time systems.

V. Conclusion

An iterative algorithm is proposed to derive all the gain matrices of the designed optimal feedback control. The nonlinear discrete-time studied system is first represented by a multi local linear models. Then, an output feedback controller based on the multimodel control approach and minimizing a quadratic criterion is derived assuring the asymptotic stability of the controlled system. The gradient resolution of the Lagrangian functions and the iterative algorithm allowed the calculus of all the gain matrices. An illustrative example of a mechanical system is considered and the simulation results show the effectiveness of the proposed control strategy.

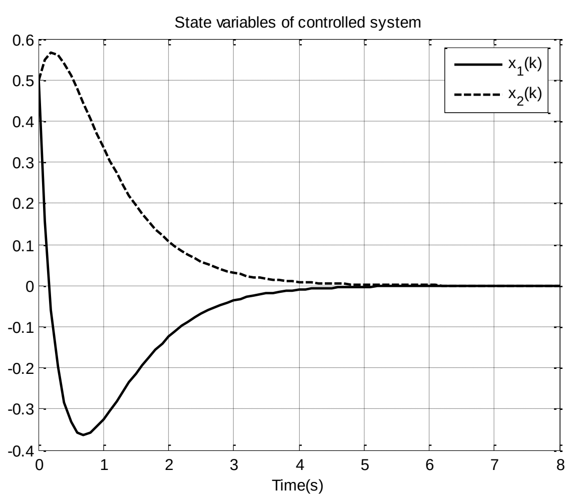

Fig. 1. State trajectories subject to the proposed control

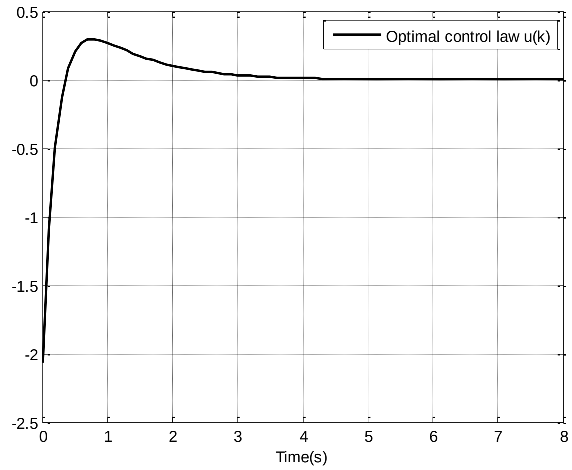

Fig. 2. The proposed optimal control law

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Interactive Mobile Health Monitoring System

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***Abstract*—Health monitoring system is an active application in pervasive and ubiquitous computing. It is an application of mobile computing technology for enhancing communication among health care workers, physicians and patients with a view to provide better health care system. Recent elevation in sensors, wireless communication and low-power integrated circuits has empowered the design of pocket size, light weight, low-cost, and interactive bio-sensor nodes. These nodes are seamlessly integrated for mobile health monitoring using wireless body area network which can sense, process and communicate one or more vital parameters.**

The proposed system, through mobile device can provide patient health parameters (such as temperature, heart rate and ECG) to medical server, care taker and to medical practitioner based on the biomedical and environmental data collected by deployed sensors. In this system, multiple physiological parameters are incorporated for monitoring as against one or two parameters in legacy system. In this paper hardware, software and implementation of system is discussed whereas the focus is on authentication, power consumption, accuracy in transmission of health parameters to medical server.

***Keywords*—Biomedical sensors; Wireless body area network; mobile device and microcontroller**

I. Introduction

The citizens aged 65 will almost double by 2030 and as they age, [24] various ailments in that age group prevail. Patients in this age group generally prefer to be at home rather than getting admitted to the hospital. If affordable healthcare services are provided for patients who prefer to stay at home and still being monitored due to an ailment through which they are undergoing, this will not only be beneficial to the patients but to the country as well, as it will decrease the load on health care systems. There are number of reasons for their decision, such as need for security, privacy and accessibility. So, it is the time to overcome the bodily limitations of hospitals and instead of bringing patients to the hospital extending patient monitoring facilities at home will benefit. The solution to this is the “Mobile Health Monitoring System”.

The fundamental driving component for the mobile health monitoring system is “Pervasive Computing” [24] also known as pervasive health care. The Embedded systems and handhelds devices avail information access to anyone, anytime and anywhere. Number of citizens are participating in design, development and evaluating mobile technologies for customized health care. People are usually advised to visit their doctors periodically for repetitive medical check-ups for common health issues such as diabetes, irregular heartbeat, high blood pressure and obesity. A solution is proposed to provide a smarter and more personalized service to save time, cost and aspire personal health care.

The proposed Interactive Mobile Health Monitoring System indicates promise in terms of Telemedicine and Tele-home-care. It uses biometric sensors to monitor patient’s health status in real time. The proposed system incorporates sensors for temperature detection, heart rate and ECG along with Wearable Body Area Network which sense and collect data from patients, mines the data and sends real time physiological data to Medical server, medical practitioner and also delivers comments to patients’ mobile device for corrective action.

The framework of the paper is as follows: a short description of previous work in section 2, architecture of the system in section 3, Design and implementation of the proposed system in section 4, Characteristics of the system in section 5, Impact on society in section 6, System testing and Evaluation in section 7, Result in section 8, Conclusion and Future Scope in section 9.

II. Previous Work

In 2007 [7] describes Open issues, challenges, requirements, network infrastructures for the number of pervasive health care applications. A dedicated research program [18] to design, develop and evaluate pervasive computer technologies to help citizens to participate in taking care of their personal health and also health professionals to treat patients in modern and smart way.

P. Szakacs-Simon, S.A. Moraru and L. Perniu [3] presents health monitoring system to detect and monitor abnormal heart rate and blood oxygen level to avoid emergency situations and keep updating patient about corrective measure. Whereas the proposed Interactive Mobile Health Monitoring System along with heart rate monitors temperature and an ECG signal also.

Dennis Joe Harmah, Kathirvelu D [4] Developed PC and Tablet based miniaturized ECG monitoring system for preliminary detection of heart disease. The system is implemented using programmable single chip microcontroller to indicate the heart condition by analysing bio signals. Health professionals are prompted with alerts if any cardiac abnormality is observed. Whereas the proposed system can transmit the same ECG signal to Medical Server as well as on Doctor’s mobile along with real time heart rate and temperature of patient.

Dheerendra S. Gangwar [5] describes an exemplar model for keeping track of fitness and cardiovascular activity using various IEEE standards such as Body Area Network (IEEE 802.15.6), Cardiovascular Activity and Fitness Monitor (IEEE 11073-10441) and ZigBee (IEEE 802.15.4) which he tries to justify that this will lead to development of cost effective devices. Whereas the proposed implemented model shows that an ECG is transmitted wirelessly, precisely and cost effectively to Medical Server and to Doctor's Mobile.

III. Architecture of System

An Interactive Mobile Health Monitoring System is proposed to gather patient's physiological data (temperature, ECG, oxygen saturation and heart beats) through biosensors. The data is sensed by the sensor network and collected data is transmitted to a patient's cell phone, PDA or to PC which in turn is transmitted to Medical Server.

A. General Block Diagram of proposed system:

The proposed Block diagram mainly comprises of three main blocks:

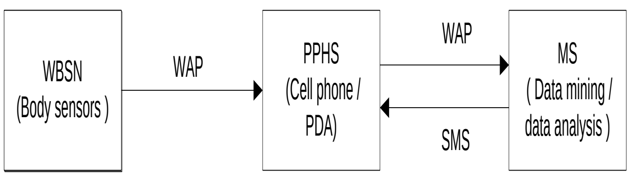

Fig. 1. Block Diagram of proposed system

1) WBSN (Wearable Body Sensor Network): It is a network of wearable biosensors on the patient's body. In the proposed system, the temperature sensor used is LM 35, heart rate sensor, CO2 sensor and ECG sensors AD624 which senses temperature, heart rate, environmental CO2 and ECG from patient's body, then these signals are processed by microcontroller ARM7 which acts as a central controller of WBSN and through Bluetooth send the processed data to PPHS (Patient's Personal Home Server).

2) PPHS (Patient's Personal Home Server): PPHS is nothing but an android mobile device employed to gather data from WBSN such as real time temperature, heart rate, and environmental CO2 and ECG data and then forward this data to the Medical Server (MS) using GPRS. PPHS can decide whether to forward this information to MS or not. Thus, PPHS initiates the service request which will be responded by MS.

3) MS (Medical Server): It accepts real time temperature, heart rate, and environmental CO2 and ECG data from PPHS. At periodic intervals or uninterruptedly doctor can investigate parameters and ECG signals. In addition, MS provide the log files to compare and verify the irregularities in the patient's health status at different time intervals, which in turn helps doctor to update patient with instant messages. But if some patient is at high jeopardy, it can notify the ambulatory service and arrange the medical assistance.

The heart of this proposal is the Medical Server (MS). The Proposed interactive mobile health monitoring system will monitor the temperature, oxygen saturation, heart beats and ECG. Why these parameters need to be monitored is described in detail with possible situations below:

Patient's vital parameters such as temperature, heart rate, etc. are continuously monitored in an intensive care unit. Generally, patients get well and return home from the hospital but even after discharge, they require attention to avoid return of disease or other contagious diseases which can be fatal. So, in many cases, patients are strongly recommended to be under observation and rest for some time. In these cases, an interactive mobile health monitoring system is very useful.

Patient's medical history can be observed by the doctor date wise, event wise etc. using the network of sensors and the Medical server.

PPHS can transmit all vital parameters continuously including ECG. Suppose a patient has returned home after cardiac surgery and is suffering from cardiac arrhythmia which leads to irregular variations in the heart signal that may occur once or twice a day. So, in this situation if PPHS is continuously transmitting the ECG data so variations in ECG signal is instantly noticed and alerts will be issued.

Hardware and software requirement:

The major components of hardware and software [25] are sensors, 32-bit ARM7 TDMI-S, LPC 2148 flash memory, android based handset, 802.15.1 Bluetooth, Eclipse, KEIL and VB.

IV. Design and Implementation of Proposed System

The proposed Interactive Mobile Health Monitoring System uses small wearable sensors such as temperature sensor, heart rate sensor, CO_2 sensor and ECG sensor for sensing critical physiological parameters. These signals are sensed by sensors and processed by ARM7. The processed data is transmitted to PPHS using Bluetooth and then to Medical Server via GPRS where parameter analysis and diagnosis are done by health professional. Further during analysis if some deviations are encountered, doctor can direct instant messages or advice as corrective measures to the patient.

The schematic representation of proposed system is as shown in figure.

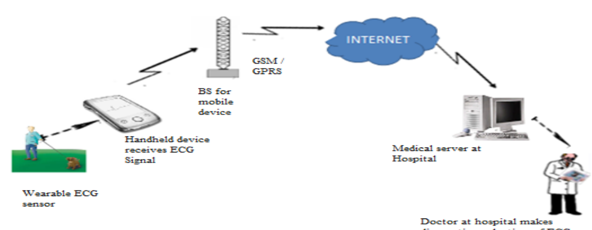

Fig. 2. Schematic representation of the proposed system

The patient's data is communicated to doctors or to hospital using the proposed system in following steps

Step1. Biological parameters are sensed and collected by sensors.

Step2. Collected data is processed by ARM7 controller.

Step3. Through Bluetooth processed data is communicated to Medical Server using GPRS through PPHS.

Step4. Medical Server analyse the collected data and provide feedback to the patient on his/her cell phone, PDA or PC regarding abnormalities of physical parameters.

B. Sensors used in the proposed system:

1) Temperature sensor:
LM35 a precision centigrade temperature sensor, is used to record the patient's body temperature. Output is directly proportional to Celsius temperature. It is a three terminal IC having input, output and ground pin. Its output voltage is linearly proportional to Celsius. The output of this sensor is connected to the P0.28 of ARM7.

2) Heart beat sensor:
It is observed that cardiac arrest is responsible for increasing number of deaths in the world; therefore, the heartbeat needs to be monitored constantly for the patients with cardiac ailment's history. As per WHO (World Health Organization) standard 60 to 135 is the normal heart beat range whereas heart beats above 145 or below 55 may be fatal. The heart beat is continuously sensed by sensor and if the heartbeat deviates from its standard range, it will take the intended action determined by the system to inform the doctors and to obtain the expert's advice in the prevailing circumstances.

Heart beat sensor LM358 IC and its basic principle and working:

The sensor with light detector and LED which needs to be super bright as the emitted light must pass through the finger and to be detected at another end. The principle used here is the opacity of finger changes as the blood flow in finger veins which in turn indicates variations in heart beats. These variations are detected in terms of electrical pulse, amplified to the required signal level. The output of heart beat sensor is connected to P 0.2 of ARM7 processor.

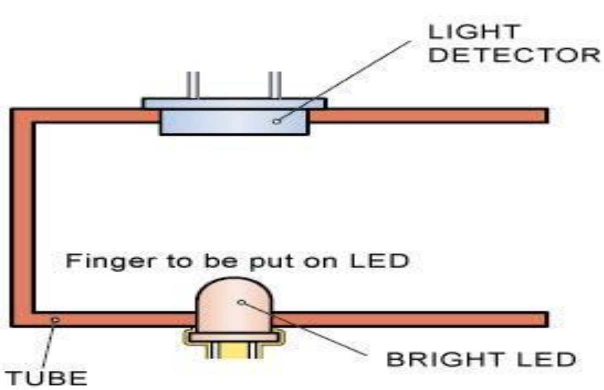

Fig. 3. Heart beat sensor

3) ECG (Electrocardiograph) sensor:
An ECG records the heart's rhythm and activity on a moving strip of paper or a line on a screen. In the medical tests the ECG deviation of actual verses normal patterns reflects heart condition.

ECG sensor:

For ECG sensor [25], a precision instrumentation amplifier an IC AD624 is used. It is high precision, low noise amplifier which is predominantly considered for use with low level transducer. Thus, it is ideally suitable for high resolution data acquisition system.

ECG sensor circuit:

ECG is the electrical potential [25] generated by heart appears throughout the body and on its surface. The potential difference is predetermined by placing electrodes on surface of body and measuring the voltage between them and then applied to the instrumentation amplifier as these voltages are very low level signals. After amplification, the output of the instrumentation amplifier is applied to the low pass filter. The output of the filter is connected to P0.29 of ARM7.

ECG measurement:

It uses 3 leads for ECG measurements. The most commonly used electrode placement scheme is

(a) Lead I: Right arm Left arm, (b) Lead II: Right arm left leg, (c) Lead III: Left arm Left leg

From ECG measurement, various features of the heart's depolarization can be calculated. Thus, ECG waveforms are referred to get pulse rate, QRS detection, P-wave and T-wave. Abnormalities in the wave pattern, helps health professional for diagnosis of cardiac problems.

V. Characteristics of System

1) Simple: The system architecture of Interactive Mobile Health Monitoring System is simple as only the biosensors need to be worn by the patient.

2) Cost: The proposed system is cost effective. WBSN requires some low-cost sensors and communication from WBSN to PPHS is also very cheap due to the use of low cost Bluetooth hardware.MS will incur some cost as it serves large number of patients. But still it is cost effective as numbers of patients are served by a single MS.

3) Security: Security is the main concern in our proposed system and without which the system is incomplete. It is provided by public key cryptography. As the patients' data is confidential and important, as well as large amount of data need to be transmitted at four different points in a system (such as WBSN, PPHS, MS and on doctor's mobile). So to protect the patient's data from security vulnerabilities the data is transmitted in encrypted form.

4) Flexible communication: The proposed system uses flexible communication protocol such as Bluetooth, internet, EDGE or GPRS. WBSN can communicate with PPHS (patient's mobile) using Bluetooth which in turn communicate with MS through internet/GPRS/EDGE. So, as the system is supported by number of alternative ways of communication and this makes communication simple and flexible.

5) Capability to deliver the status of patient and predict spread of disease:

The proposed system delivers the status of patient and helps in predicting the spread of contagious disease in a particular locality.

VI. IMPACT ON SOCIETY

Mobile health monitoring is not a new concept for developed countries. But, in developed countries Medical Servers are only for data storage whereas our system provides alerts and real time feedback to patients and doctors. For this development, all the existing central storage server can be replaced easily by our MS i.e. their central Medical Server's data needs to be migrated to our MS. Thus, the proposed system can aid physician and specialists for better treatment of patients as the whole medical data and treatment history is stored in MS. The system helps patient by providing continuous health monitoring facility anytime and anywhere**.**

VII. SYSTEM TESTING AND EVALUATION

The system evaluation is carried out through cognitive walkthrough and evaluation of measured data by comparing mean and standard deviation of proposed system against standard device.

A cognitive walkthrough strategy [28] which includes a group of evaluators to inspect a user interface through a set of tasks and assess its understand-ability and ease of learning. To evaluate our system, we have followed this strategy

1) Who is the user of the system? The patient of different age, literate, illiterate both males and females.

What health parameters and how they need to be analyse? They are analysed by verifying their transmission, data integrity and precision.

2) What is the correct action sequence for using this system at Medical Server side? First the process is explained to observer (doctor, nurse or care taker) and as the system's speciality is that patient's intervention is not required while he/she is under observation using the system. So a questionnaire is given to patient regarding usability and ease of handling the device with different ratings such as 5 has the highest value and 0 has lowest value.

A. Screenshots of Implementation

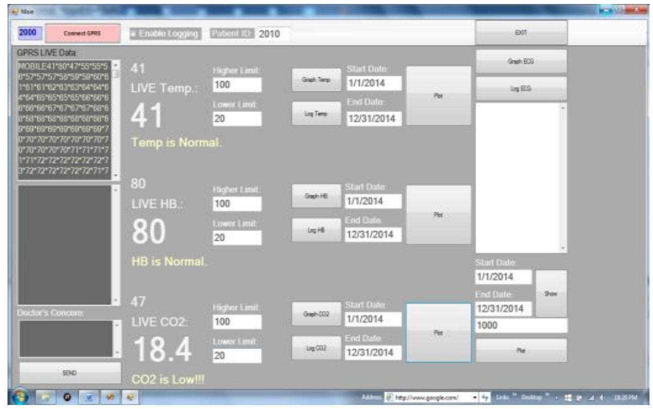

Fig. 4. GUI of Medical Server

Fig. 4 is main GUI of system at medical server side where care taker, medical practitioner can have observed the patient's real time data continuously.

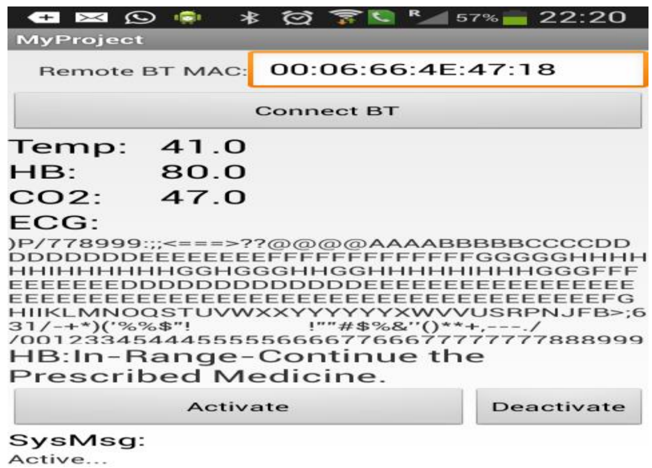

Fig. 5. Display at PPHS Patient Personal Home Server

Fig. 5 is display on patient's mobile phone where he can get the alerts or advice from medical practitioner.

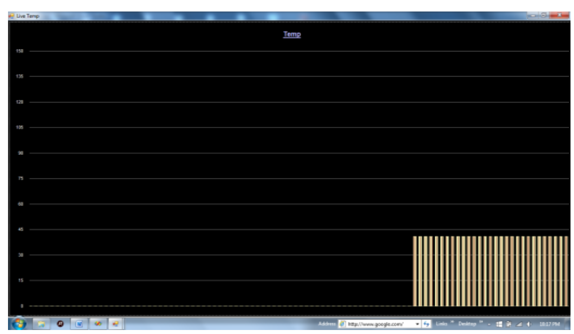

Fig. 6. Temperature Graph at MS

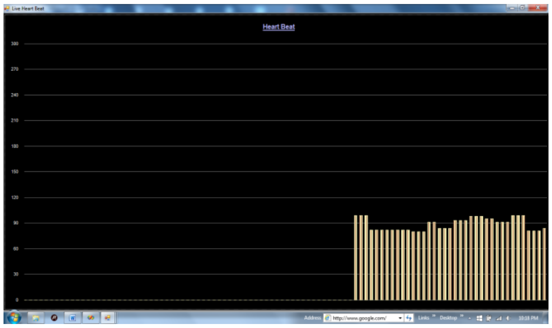

Fig. 7. Heart Beat Graph at MS

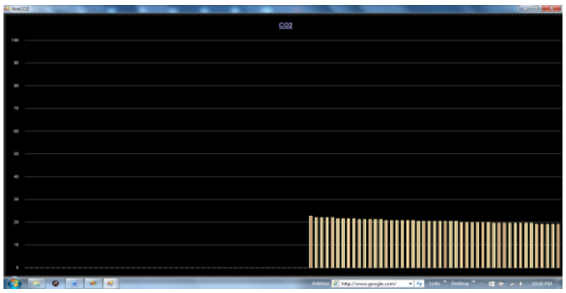

Fig. 8. CO2 Graph at Medical Server

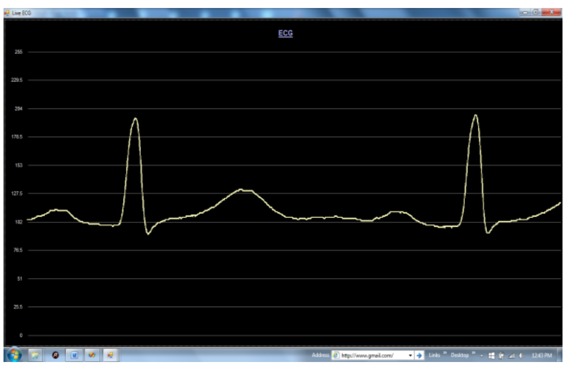

Fig. 9. ECG at Medical Server

Fig. 6, Fig. 7 and Fig. 8 is a graph of temperature, heart rate and carbon dioxide on X-axis with respect to time on Y-axis which is obtained on Medical Server side.

Fig. 10. ECG graph on Doctor's mobile

Fig. 10 is display on doctor's mobile which displays patient's parameters in critical range and real time ECG signal.

B. System Evaluation

System is evaluated by calculating the mean, variance, standard deviation and correlation for theoretical and practical values obtained by using standard device and our proposed system for various parameters such as temperature, heart rate and ECG pattern at various points such as Medical Server, PPHS and on Doctor's Mobile. Thus, precision and accuracy of system is examined by using following equations

$$\mu = \frac{\sum_{i=1}^{N} Xi}{N} = \frac{\sum X}{N} \qquad (1)$$

$$\sigma^2 = \frac{\sum(X-\mu)^2}{N} \qquad (2)$$

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2} \qquad (3)$$

$$r_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}} \qquad (4)$$

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \sum_{i=1}^{n}(x_i-\bar{x})^2}} \qquad (5)$$

Where in equation (1), (2),(3),(4) &(5) μ is mean , $\sigma^2$is variance, s is the standard deviation and r_{xy} is a correlation

TABLE. I. STATISTICAL INFORMATION OF TEMPERATURE OF PATIENT USING STANDARD DEVICE AND THE PROPOSED DEVICE

Sr No	Patient Id	Patient Name	Temperature	
			TH	*PR*
1	2001	A	39.1	39.5
2	2002	B	40.5	41
3	2003	C	36.5	37
4	2004	D	37.5	38
5	2005	E	37.5	38
6	2006	F	37.5	38

TH: Theoretical Value measured by the standard device.

PR: Practical Value measured by the proposed system.

Table 1 shows the statistical information of temperature of patient recorded using the standard device and the system.

TABLE. II. AGGREGATED STATISTICAL INFORMATION OF TEMPERATURE OF PATIENT

Values		Min	Max	Range	Mean	Variance	SD	Correlation
Temp	TH	36.5	40.5	4	38.10	2.08	1.44	1.0043
	PR	37.0	41.0	4	38.58	2.04	1.43	

Table 2 shows the aggregated information of temperature of patient with range, mean and SD. The theoretical SD is 1.44 and practical is 1.43 with a difference of 0.01 and correlation is 1.0043 which is desirable as per precision point of view.

TABLE. III. STATISTICAL INFORMATION OF HEART RATE OF PATIENT USING THE STANDARD DEVICE AND OUR PROPOSED DEVICE AT PPHS AND MS

Sr No	Patient ID	Patient Name	Heart Rate		
			TH	*PRMS*	*PRPPHS*
1	2001	A	85	86	99
2	2002	B	78	80	80
3	2003	C	80	82	90
4	2004	D	91	93	99
5	2005	E	84	83	84
6	2006	F	80	82	93
Total			498	506	545
Average			83	84.33	90.83

TH: Theoretical Value measured by the standard device. PR MS: Practical Value measured by the proposed system at MS. PR PPHS: Practical Value measured by the proposed system at PPHS.

Table 3 shows the statistical information of Heart rate of patient using the standard device and the proposed system which shows the data collected at PPHS and MS.

TABLE. IV. AGGREGATED STATISTICAL DATA OF HEART BEAT USING THE STANDARD DEVICE AND THE PROPOSED SYSTEM AT MEDICAL SERVER

Values		Min	Max	Range	Mean	Variance	SD	Correlation
Heart rate	TH	78	91	13	83.00	22.40	4.733	0.967
	PR	80	93	13	84.33	21.86	4.676	

Table 4 gives aggregated statistical data of heart beat in terms of range, mean, variance, standard deviation and correlation, wherein theoretical heart beat is measured by using standard device and practical is by the proposed system. Thus Table 5 gives the SD difference of 0.054 and correlation in theoretical and practical readings of heart beat is 0.967 which is desirable.

TABLE. V. AGGREGATED STATISTICAL DATA OF HEART BEAT MEASURED AT MEDICAL SERVER AND AT PPHS

Values		Min	Max	Range	Mean	Variance	SD	Correlation
Heart rate	MS	80	93	13	84.33	21.8600	4.68	0.7548
	PPHS	80	99	19	90.83	60.5665	7.78	

Table 5 gives aggregated statistical data of heart beat on Medical Server and at PPHS, as the data is sensed by the sensors and through PPHS it is transmitted to MS and displayed there. So to check the data integrity at different point's precision is calculated in terms of range, mean variance, SD and correlation. Thus Table 5 shows the difference of 3.106 in SD and correlation is 0.7548 which is deviated from ideal value. This may be attributed to delay in transmission and data latency from PPHS to MS.

Advantages:

1) It is low power android based Health Monitoring system which monitors multiple parameters such as temperature, heart rate, CO2 and ECG.

2) This system can be applied to monitor the cardiovascular disease through wireless communication as the information provided is reliable and hence also can be used in critical condition to raise alarms and for initiating early first aid.

3) As the results are viewed on smart phone, all the parameters can be examined anytime-anywhere, this will improve the quality of medical treatment.

4) The alarm in the system will prompt the doctor about irregularities in patient's health status.

The advantages compact size, low power, user friendly, cost effective and being android based can revolutionize the patient health care.

VIII. RESULTS

The proposed system communicates the real time physiological parameters such as temperature, heart rate and ECG signals of the patient to medical practitioner either on PC or/and on his handheld device. If the temperature, heart rate goes either below or above the threshold, an alarm and a pop up message will be sent to patient to take corrective measures and if the doctor is also mobile these real-time parameters which are in critical range along with real time ECG signal will be sent on the doctor's handset. So, from each segment / interval of ECG waveform the medical professional can discover the different diseases like hyperkalaemia, ventricular tachycardia arrest, fibrillation, ischemia etc. Changes and various patterns that occur in ECG signal i.e. in PQRS waveforms are ST elevation, ST depression, T positivity, T negativity, tall peaked QT and long QT indicates various diseases. Thus, the system helps the medical practitioner in diagnosis of various heart diseases. Thus, system results are verified by comparing standard deviation and correlation between the values measured by the standard device and our proposed system. For temperature SD difference is 0.014 and correlation is 1.003 whereas for the heart rate SD difference is 0.054 and correlation is 0.967 which shows that the degree of agreement between them is highly desirable.

Thus, the proposed system effectively and precisely transmits patient's physiological parameters to Medical Server, on doctor's mobile and on the patient's mobile for taking corrective measures in order to avoid health risks.

IX. CONCLUSION AND FUTURE SCOPE

Interactive Mobile Health Monitoring System indicates promise in terms of applications in Tele-home-care and Telemedicine. Patients' health status can be monitored in real time by doctors using various biometric sensors even when the patient is residing at home. Also, hospitalized patients can peacefully leave the hospital as they are monitored by health professionals even if they are outside the hospital.

Thus, the proposed system helps individuals as well as the whole society. It can help the patient by nursing his or her health and send alerts to take required actions against any upcoming health alarming conditions. The system can be used securely to diagnosis and monitor life threatening diseases such as cardiac arrest, dengue and asthma by measuring various physiological parameters such as temperature, heart rate and ECG.

Future Modifications:

Based on current developments, now only feedback can be provided to patient and patient needs to take action. Biosensors itself can't take necessary actions. With advancements in biosensors, a system can be think where the patients need not do any actions at all. The bio-sensors itself can take necessary actions e.g. a patient needed glucose does not need to take it manually rather the bio-sensors can push glucose to the patient's body depending on the feedback from MS.

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Wireless Sensor Network Energy Efficiency with Fuzzy Improved Heuristic A-Star Method

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***Abstract*—Energy is a major factor in designing wireless sensor networks (WSNs). In order to extend the network lifetime, researchers should consider energy consumption in routing protocols of WSNs. Routing will serve to facilitate a number of sensors on the technology of WSNs to identify the optimal path and manage energy consumption saving at the time of transmitting data. Current Wireless Sensor Networks efficiency system uses node selection as the main parameter without applying path finding routing. It will not complete the optimization of energy. This research was designed to address the problem of energy optimization by using fuzzy-improved heuristic A-Star. A new algorithm named improved heuristic A-Star was developed from previous A-Star algorithm. The result of fuzzy-improved heuristic A-Star indicated node sensor to sink destination saved 0.3698 joule energy dissipation which resulted in longer lifetime.**

***Keywords*—Improved Heuristic A-Star; Fuzzy Logic; Wireless Sensor Network**

I. Introduction

A sensor node has limited memory, energy, and resources thus requiring hierarchical settings using clustering so as to lead energy efficiency. Clustering forms an organization of groups called clusters, where each cluster is determined by a node functioning as a head called a cluster head[1]. This cluster head collects data from sensor nodes and sends information to the base station, thus it can be said that the cluster head serves as a bridge between the sensor nodes and the base station and sometimes between cluster heads for the multihop case. Cluster heads are in charge of protecting sensor nodes, adding or removing sensor nodes, scheduling time between sensor nodes, and undertaking data aggregation and message management between nodes and the base station[2].

In this research[3], the approach of fuzzy logic is employed for choosing cluster head Wireless Sensor Networks. It was suggested to improve the lifetime of the network by two times compared to using LEACH and SEP with multi-hop transmission and to modify the technique of choosing cluster head which could extend the lifetime of Wireless Sensor Networks. Based on that research, the present research attempts to compare Fuzzy Sugeno and Fuzzy Mamdani in terms of efficiency in extending the lifetime of Wireless Sensor Networks.

LEACH is a cluster based on classic routing protocol with balanced energy consumption for Wireless Sensor Networks. However, cluster head selection is not based on energy. PEGASIS forms related structure by connecting the node in the farthest edge from the Sink to the node which is closer to the base station. Based on the research, this research attempted to optimize PEGASIS and LEACH as well as fuzzy which only provide the result of sensor node selection. Yet, the algorithm consumes more energy because the farthest node is selected to be the cluster head[6]. The farthest node would be optimized in this research by using A-Star algorithm. However, A-Star had a weakness which is the inaccuracy of heuristic value because it used assumption value.

The process of A-Star algorithm considers the formula

$$f(n) = h(n) + g(n) \tag{1}$$

In which the algorithm employs assumption value h(n) as the heuristic value from the sensor node to sink[12]. This research attempted to develop A-Star algorithm from heuristic value assisted by fuzzy algorithm to fill in the weight value of sensor node which had been calculated by fuzzy.

The rest of this paper is organized as follows. Section 2 describes the research framework of Fuzzy approach and Improved Heuristic A-Star. Section 3 presents the related studies on improving network lifetime. Section 4 introduces and discusses the proposed methodology. Section 5 describes result the simulation. Section 6 concludes this paper.

II. Research Framework

Clustering is a critical network management operations that are used to reduce network energy consumption and increasing the lifetime of wireless sensor network[4], so it has an important role in wireless sensor network. Previous research [5]-[11] mostly discussed residual energy and distance of neighboring nodes. For an optimum efficiency of energy, not only it needs the result for reference but also the result of evaluation after the cluster head has been selected. In research[6], the result of PEGASIS, LEACH, and Fuzzy Cluster Head Selection consume too much energy because the farthest node is selected as the cluster head. A solution framework which is needed to achieve the optimized value is presented in Fig 1.

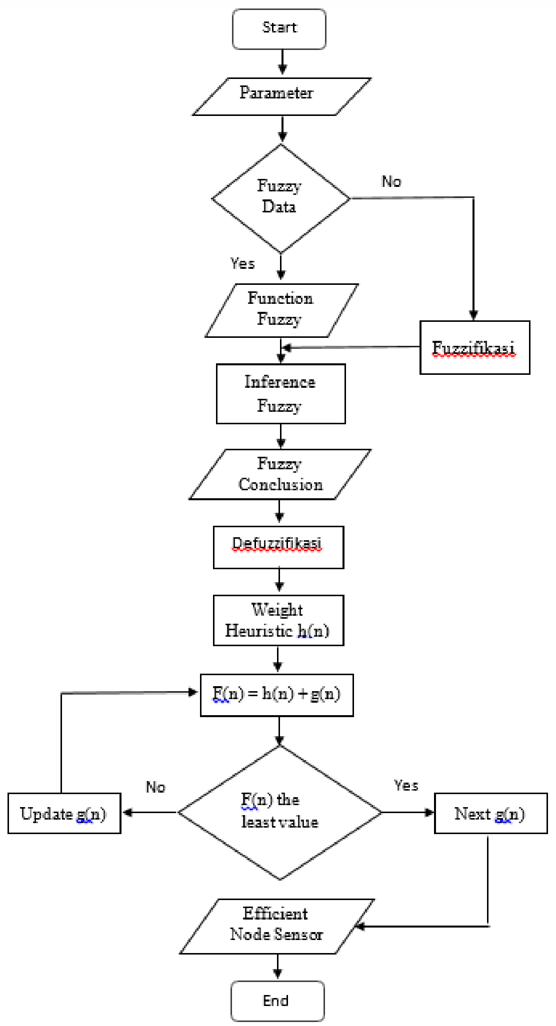

Fig. 1. Solution Framework

III. Related Studies

Gupta et al.[5] in their research using an approach of fuzzy logic to cluster head selection based on three parameters, namely the energy level of each node energy, node concentration and node centrality. In their research, the parameter node centrality played a vital role where the base station selected every single node to be selected as the cluster head by calculating the square of the distance from each node. The lower the centrality value, the lower the amount of energy required by the node to be a cluster head is.

Kim et al.[6] in their research introduced the Cluster Head Election mechanism using Fuzzy Logic (CHEF) to achieve energy efficiency, where a cluster head is selected using two parameters, namely the energy level of each node (energy) and the total distance between each node in the cluster (local distance). The benefits of using CHEF is minimizing the overhead resulting from a centralized process for selection of a cluster head is undertaken locally.

Natajaran and Selvaraj.[6] stated that reselection of cluster head may consume time and energy. Rate parameter of recurrent Communication of Sensor Node (RCSN) is added to solve the problem. RCSN is defined as the number of times a node communicates with its cluster head. In order to emphasize the effect of RCSN to Cluster Head Selection Probability (CHSP), the algorithm of cluster head selection is based on proposed fuzzy. By using RSCN, this algorithm is able to predict energy consumption of node which provides better way for CHSP compared to previous research. This research employs 5 parameters namely Residual Power of Sensor Nodes (RPSN), Degree of Neighbouring Nodes (DNN), Distance between Node and Base Station (DNBS) and Sensor Node Movement (SNM).

Mishra et, al.[7] cluster head selection in wireless sensor network uses fuzzy logic which can solve the problem in CHEF and other cluster head selection protocols. The proposed scheme could help to extend the lifetime of wireless sensor network by selecting the best node for cluster head in order to extend the lifetime of wireless sensor network. This research used residual distance parameter in self-organizing scheme because cluster head has data aggregation responsibility, data processing, data routing, etc. Local distance is the total distance between node A and its surrounding node. Base station distance is the distance from cluster head to base station and concentration is the direct relationship between cluster head and node member.

Singh et al.[8] unique strategy for cluster head selection in WSN by taking two important parameters namely energy from node and centrality node using fuzzy. This approach had succeeded in significantly extending lifetime compared to LEACH base station approach. According to simulation, this fuzzy scheme extend the lifetime of the network around 70% compared to LEACH probability approach.

Mhemed et al.[9] introduced a new approach for forming cluster in Wireless Sensor Networks by using Fuzzy Logic to extend the lifetime of the network. The performance is compared with LEACH protocol using FND metric and Paired T-Test in MINITAB. It was found that protocol extended the lifetime from 12% to 19%. The extension is related with the fact that the protocol used three parameters in the process of forming the cluster while LEACH only used one parameter. The parameters were energy level, distance to base station, and distance to cluster head.

Ando et, al.[10] conclude that cluster head selection becomes difficult when there are many parameters involved in the decision of selecting cluster head. It was suggested to use algorithm of power reduction for wireless sensor based on fuzzy logic and the number of node with simulation system to group algorithm in sensor network. This research used three parameters i.e. Remaining Battery Power of Sensor, Degree of Number of Neighbor Nodes, Distance from Cluster Centroid.

Bidaki and Tabbakh.[11] conclude that fuzzy clustering method changes the selection of cluster head probability in LEACH protocol. The fuzzy system which was used in the inferential machine is fuzzy mamdani which is a simple rule base method. This scheme creates symmetrical cluster and reduce the node of total cluster head distance. It can reduce energy consumption of the sensor and extend the lifetime of Wireless Sensor Networks better than LEACH protocol. The parameters used are neighbour node and remaining energy. The reasons why those parameters are used are:

- Some nodes which have less neighbour nodes can be selected as the cluster head and the network can be utilized as benefits of data aggregation.
- Each node can independently select itself as cluster head; cluster head can be positioned close to each other.
- Random selection of cluster head does not create symmetrical cluster and it can increase total distance of node cluster head communication. Increasing distance means more energy consumption to transfer data to cluster head which results in shorter lifetime of the network.

Alshawi et, al.[13] concluded that nodes operate by utilizing efficiency of limited energy in battery. The main characteristic of this network is its lifetime that related to the selection of route. Unbalanced energy consumption is an inseparable problem in Wireless Sensor Networks, and proposing new algorithm by using combination of two fuzzy approaches and algorithm A-Star. This new method was able to select optimum routing from source node by supporting the highest residual energy, minimum hop and lowest traffic. The performance of the proposed method is evaluated and compared with other two methods under the same criteria in two different fields of topography. The result of the simulation indicated that the effectiveness of the new method was related to the random extension of the lifetime of the wireless sensor network with node.

Septiana et al.[12] concluded that the process of finding the optimum route in Wireless Sensor Networks routing technique using algorithm A-Star is much dependent on heuristic function. Evaluation function will be more effective if the function has more than one heuristic function. It is because evaluation function conducts more detailed calculation to obtain route cost value by using heuristic A-Star and addition of heuristic value with faster computation time.

Based on research [5]-[13], it could be concluded that majority of the used parameters were energy and distance. However, there is a different research among those research which uses RCSN parameter which is the number of times a node communicates with cluster head. It functions to emphasize the effect of RCSN on Cluster Head Selection Probability algorithm CHSP selection of cluster head based on fuzzy logic. RCSN is claimed to be able to predict better node energy consumption for Cluster Head Selection Probability compared to other parameters. Therefore, in this research the used parameters were RSCN which is the number of times a node communicates with its cluster head, Residual Power of Sensor Nodes (RSPN) which is used in self-organizing scheme because cluster head consumes a lot of energy from sensor node since it has responsibility of data aggregation, data processing, and routing data, Local distance which is the number of distance between node A and node in its surrounding, Base Station Distance which is the distance from cluster head to base station and Remaining Battery Power of Sensor (RPS) which is used to monitor battery left in the sensor. After cluster head is selected, it is optimized by A-Star algorithm. In research [12], the value of h(n) uses estimation, but in in the present research it is in form of real value based on consideration of a number of parameters.

IV. Methodology

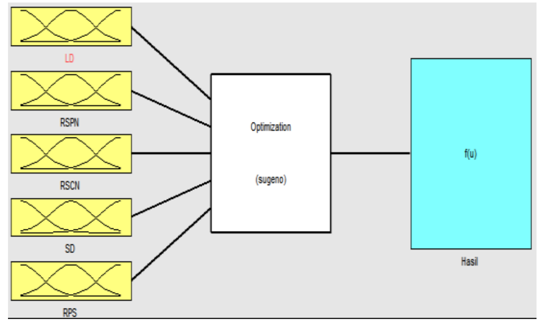

Fig. 2. Variables of the Research

In the present research, fuzzy was used to figure out the heuristic value of h(n) so the value accuration of A-Star was no longer an estimation but a certain value from the used parameters in this research. The variables of the research are

A. *Local Distance:* the total distance between each node in the cluster.

B. *RSPN:* Residual Power of Sensor Nodes

C. *RPS:* Remaining Battery Power of Sensor

D. *Station Distance:* Distance to Base Station

E. *RCSN:* Rate of recurrent Communication of Sensor Node

A. Membership Function of Local Distance

The compilation of fuzzy of Local Distance membership is presented in Fig 3.

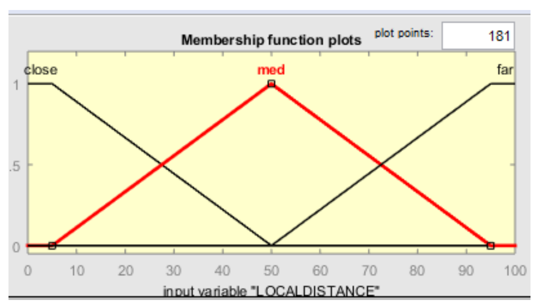

Fig. 3. Local Distance Parameter

$$\mu \text{ LD (close)} = \begin{cases} 0 \; ; \; C \le 5 \\ \left(\frac{C-5}{50-5}\right); \; 5 \le C \le 50 \\ 1 \; ; \; C \ge 50 \end{cases} \tag{2}$$

$$\mu \text{ LD (med)} = \begin{cases} 0 \; ; \; \mathrm{M} \le 50 \\ \left(\frac{\mathrm{M}-50}{95-50}\right); \; 50 \le \mathrm{M} \le 95 \\ 1 \; ; \; \mathrm{M} \ge 95 \end{cases} \tag{3}$$

$$\mu \text{ LD (far)} = \begin{cases} 0 \; ; \; \mathrm{F} \le 95 \\ \left(\frac{\mathrm{F}-95}{100-95}\right); \; 95 \le \mathrm{F} \le 100 \\ 1 \; ; \; \mathrm{F} \ge 100 \end{cases} \tag{4}$$

B. Membership Function of RSPN

The following Fig 4 presents RSPN parameter

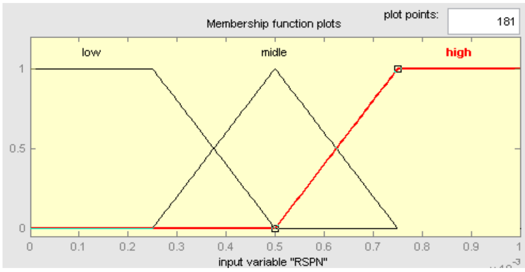

Fig. 4. RSPN Parameter

$$\mu\ \text{Low} = \begin{cases} 0\ ;\ L \le 0 \text{ or } L \ge 0{,}5 \\ \left(\frac{L}{0{,}25}\right);\ 0 \le L \le 0{,}25 \\ \left(\frac{0{,}25 - L}{0{,}5-0{,}25}\right);\ 0{,}25 \le L \le 0{,}5 \end{cases} \quad (5)$$

$$\mu\ \text{Midle} = \begin{cases} 0\ ;\ M \le 0{,}25 \text{ or } M \ge 0{,}75 \\ \left(\frac{M - 0{,}25}{0{,}5-0{,}25}\right);\ 0{,}25 \le M \le 0{,}5 \\ \left(\frac{0{,}5 - M}{0{,}75-0{,}5}\right);\ 0{,}5 \le M \le 0{,}75 \end{cases} \quad (6)$$

$$\mu\ \text{High} = \begin{cases} 0\ ;\ H \le 0{,}5 \text{ or } H \ge 1 \\ \left(\frac{H - 0{,}5}{0{,}75-0{,}5}\right);\ 0{,}5 \le H \le 0{,}75 \\ \left(\frac{0{,}75 - M}{1-0{,}75}\right);\ 0{,}75 \le H \le 1 \end{cases} \quad (7)$$

C. *Membership function of RPS*

The compilation of fuzzy of RPS membership is presented in Fig 5.

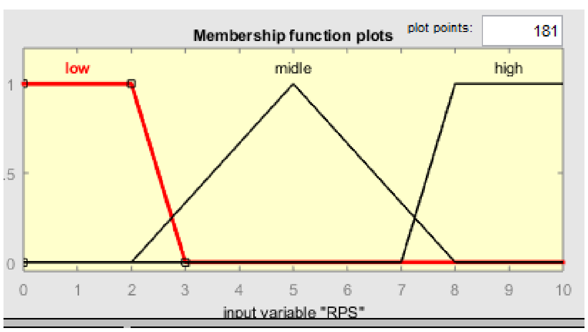

Fig. 5. RPS Speed Parameter

$$\mu\ \text{RPS (Low)} = \begin{cases} 0\ ;\ L \le 2 \\ \left(\frac{L-2}{3-2}\right);\ 2 \le L \le 3 \\ 1;\ L \ge 3 \end{cases} \quad (8)$$

$$\mu\ \text{RPS (Midle)} = \begin{cases} 0\ ;\ M \le 5 \\ \left(\frac{S-5}{8-5}\right);\ 5 \le M \le 8 \\ 1\ ;\ S \ge 8 \end{cases} \quad (9)$$

$$\mu\ \text{RPS (High)} = \begin{cases} 0\ ;\ H \le 8 \\ \left(\frac{H-8}{10-8}\right);\ 8 \le H \le 10 \\ 1\ ;\ C \ge 10 \end{cases} \quad (10)$$

D. *Membership Function ofStation Distance*

The compilation of fuzzy of Station Distance membership is presented in Fig 6.

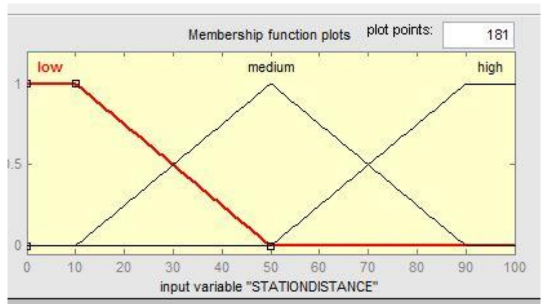

Fig. 6. Station Distance Parameter

$$\mu\ \text{SD (Low)} = \begin{cases} 0\ ;\ L \le 10 \\ \left(\frac{L-10}{50-10}\right);\ 10 \le L \le 50 \\ 1\ ;L \ge 50 \end{cases} \quad (11)$$

$$\mu\ \text{SD (Medium)} = \begin{cases} 0\ ;\ M \le 50 \\ \left(\frac{M-50}{90-50}\right);\ 50 \le M \le 90 \\ 1\ ;M \ge 90 \end{cases} \quad (12)$$

$$\mu\ \text{SD (High)} = \begin{cases} 0\ ;\ H \le 90 \\ \left(\frac{H-90}{100-90}\right);\ 90 \le H \le 100 \\ 1\ ;H \ge 100 \end{cases} \quad (13)$$

E. *Membership Function of RCSN*

The compilation of fuzzy of RCSN is presented in Fig 7.

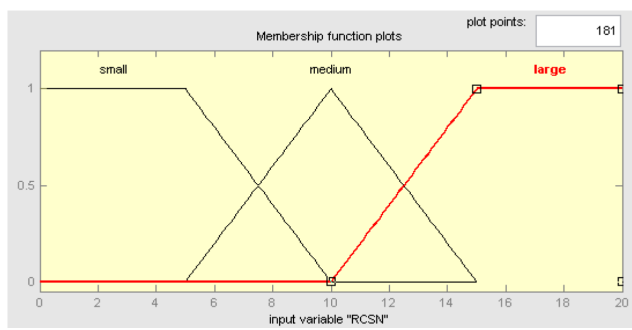

Fig. 7. Parameter RCSN

$$\mu\ \text{RSCN(Small)} = \begin{cases} 0\ ;\ S \le 0 \text{ or } S \ge 10 \\ \left(\frac{S}{5}\right);\ 0 \le S \le 5 \\ \left(\frac{5-S}{10-5}\right);5 \le S \le 10 \end{cases} \quad (14)$$

$$\mu\ \text{RSCN(Medium)} = \begin{cases} 0\ ;\ M \le 5 \text{ or } M \ge 15 \\ \left(\frac{S-5}{10-5}\right);\ 5 \le M \le 10 \\ \left(\frac{10-S}{15-10}\right);10 \le M \le 15 \end{cases} \quad (15)$$

$$\mu \text{ RSCN (Large)} = \begin{cases} 0 \;;\; L \leq 10 \text{ or } L \geq 20 \\ \left(\frac{L-10}{15-10}\right);\; 10 \leq L \leq 15 \\ \left(\frac{15-L}{20-15}\right);\; 15 \leq L \leq 20 \end{cases} \quad (16)$$

After all parameters have membership function, a rule is made to evaluate the values of all parameters. It is called *rule evaluation*[7]. Since there are five parameters and each parameter has three membership attributtes, the rule evaluations are 3^5 which means there are 243 rules.

The next step is making fuzzy final output by using sugeno fuzzy. Output from final output is constant or linear equation

$$\text{IF } (x_1 \text{ is } y_1) \text{ AND} \ldots \text{AND } x_n \text{is } y_n \text{THEN}_Z \quad (17)$$

The result of final pocess is obtained by using the following equation

$$\text{If } (A\ x_1 \text{ is } y_1) \text{ AND } (B\ x_1 \text{ is } y_1) \text{ AND } (C\ x_1 \text{ is } y_1) \text{ AND} (D\ x_1 \text{ is } y_1) \text{ AND } (E\ x_1 \text{ is } y_1) \ldots\ldots \text{AND } (A\ x_n \text{ is } y_n) \text{AND } (B\ x_n \text{ is } y_n) \text{ AND } (C\ x_n \text{ is } y_n) \text{ AND } (D\ x_n \text{ is } y_n) \text{AND } (E\ x_n \text{ is } y_n) \text{ then } Z=O \quad (18)$$

TABLE. I. FUZZY RULE BASE

Rules	RSPN	Lokal distance	Station distance	RPS	RCSN	Output
1	low	close	high	low	small	low
2	low	close	high	low	medium	vlow
3	low	close	high	low	large	vlow
.						
20	low	close	low	low	medium	low
28	low	medium	high	low	small	vlow
.						
57	low	far	high	low	large	low
61	low	far	high	high	small	low
63	low	far	high	high	large	rlow
.						
82	midle	close	high	low	small	medium
.						
109	midle	medium	high	low	small	rhigh
127	midle	medium	low	low	small	mlow
136	midle	far	high	low	small	rhigh
.						
190	high	medium	high	low	small	rlow
217	high	far	high	low	small	vhigh
218	high	far	high	low	medium	rhigh
219	high	far	high	low	large	medium
223	high	far	high	high	small	rhigh
224	high	far	high	high	medium	mhigh
225	high	far	high	high	large	vhigh
226	high	far	medium	low	small	vhigh
227	high	far	medium	low	medium	rhigh
228	high	far	medium	low	large	high
232	high	far	medium	high	small	medium
233	high	far	medium	high	medium	medium
234	high	far	medium	high	large	medium
238	high	far	low	medium	small	rhigh
239	high	far	low	medium	medium	high
240	high	far	low	medium	high	medium
241	high	far	low	high	small	rhigh
242	high	far	low	high	medium	medium
243	high	far	low	high	large	medium

The next step is determine the value of range fuzzy output or fuzzy output chart. Chart of fuzzy output is presented in Fig 8.

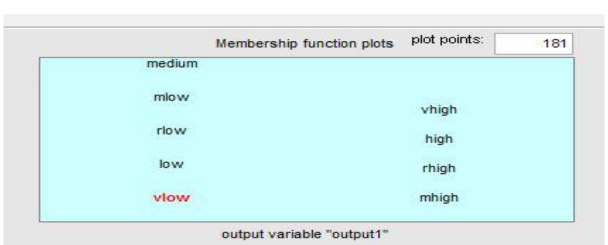

Fig. 8. Range Fuzzy Output

From the Fig 8, the range fuzzy has been determined. The next step is defuzzyfication by using weight average. By using weighted average, each result value of inference to fuzzy rule (W) is multiplied by the value of fuzzy output chart (Z), then the result is summed. The sum is the divided by the sum of final output. Weight average generates real numbers which become the weight of each route Cluster Head Section Wireless Sensor Networks

$$\text{Final Output} = \frac{\sum_{i=1}^{N} w_i z_i}{w_i} \quad (19)$$

The steps of fuzzy process are complete. The results of fuzzy weight represent each Selected Cluster. If the selected cluster is A and the sink is F, then "H" represent fuzzy weight to A-B (Hab) and the weight will be considered by A-Star algorithm for efficiency optimization process of Wireless Sensor Networks path. The development of A-Star algorithm is as follows

$$f\ (n) = g\ (n1) + g\ (n2) - h\ (\text{weight fuzzy}) \quad (20)$$

$$f\ t\ (n) = gt\ (n1) + gt\ (n2) - ht\ (\text{weight fuzzy}) \quad (21)$$

f evaluation function is the sum of cost calculation result, where:

- The value of g (n) is the cost paid while moving from source node to neighbor node.
- The value of h (weight fuzzy) is the cost f weight fuzzy needed to move from mediator node to target node.
- F (t) is the total of the cost of g and neighbour heuristic fuzzy if there is branch node which functions to compare the weight of f to n.

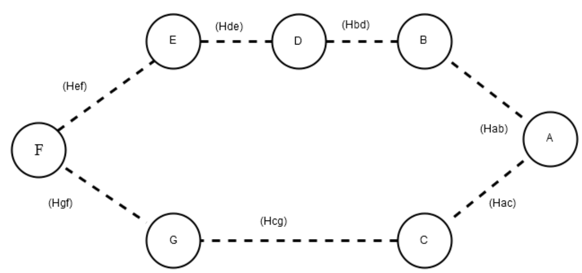

Fig. 9. Cluster Selection Weight with Fuzzy logic

The next step is calculating the formula of enegy disipation[13],

$$EnT\ (k) = Eelec \bullet k + Eamp \bullet k.d^2 \quad (22)$$

Transmission and accepting cost is marked by expression Ent (k) = Eelec • k + Eamp • $k.d^2$ dan En R (k) = Eelec • k, where k is the number of byte per package, d is the distance from sender node to receiver node, Eelec and Eamp per byte energy dissipation in transmission or accepting circuit and energy needed per byte per square meter as booster to achieve each (SNR) ratio.

V. Results and Discussions

Each node has fuzzy output as weight consideration for cluster head which is presented in Table 2

TABLE. II. Testing Sample

Node Sensor	RSPN	LD	SD	RPS	RSCN	Fuzzy Output
A	0.00024	12.4	18.9	1.95	2.77	0.13
B	0.00042	40.8	2.5	5.5	15.5	0.28
C	0.00083	94	87.5	9.54	15.5	0.97
D	0.00012	30.9	28.9	0.67	2.06	0.20
E	0.00046	45.7	48.9	4.93	14.8	0.68
F	0.00046	91.1	7.5	0.53	18.8	0.69
G	0.00090	24.5	91.1	9.75	19.1	0.86

In Fig 10, candidates of cluster head weight are considered by Heuristic A-Star in order to find the optimum point. Node A-B-D-E-F and A-C-G-F are the probabilities of cluster head selection to be continued to the sink. It uses simulation data where Limit of transmission distance (meters) 30 m, Initial energy of node 0.5 J, Eelec 50 nJ/bit, Eamp 100 pJ/bit/m2, Packet data size 2 bit, Number of transmission packets 2 × 104. The test results are presented in Table 3.

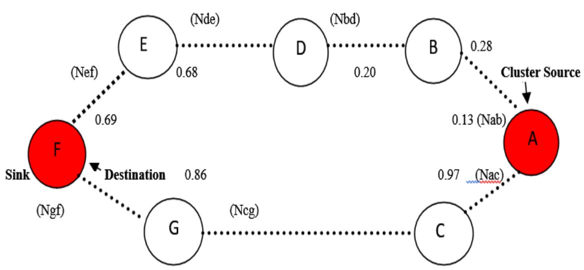

Fig. 10. The Result of Node Sensor Weight

TABLE. III. Test ResultNN NVC V

Node Sensor	Heuristic	F (n)	F (t)	Energy (Joule)
A-B-D (3 Node)	0.69	0.08	1.83	0.0035
A-C-G (3 Node)	0.97			0.2968
A-B-D-E (4 Node)	0.69	0.27	1.83	0.0050
A-C-G-F (4 Node)	0.97			0.3928
A-B-D-E-F (5 Node)	0.69	-	-	0.0230

VI. Conclusion and Suggestion

From this research, it can be concluded that:

- Algorithm hybrid fuzzy-Improved Heuristic A-Star was able to give optimum point which substitutes PEGASIS and LEACH which only considered the selection of cluster head
- Fuzzy with Improved Heuristic A-Star succeed in selecting node sensor which is efficient in energy
- In the experiment, node sensor A-B-D-E consumed energy dissipation 0.0050 joules compared to A-C-G-F 0.3928. Improved Heuristic A-Star algorithm was able to release node based on the most efficient energy dissipation which is A-B-D-E-F 0.0230 joule by saving 0.3698 joule.
- The next research is expected to develop that method by doing experiment in some different topologies for seeing optimum routing result.

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Utilization of Finite Elements Programs and Matlab Simulink in the Study of a Special Electrical Motor

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***Abstract*—This paper presents the study of a single-phase synchronous motor with permanent magnets (PM) using some computer programs. This motor type is used especially in household applications, and it has a low power. It is known that PM synchronous motors have a great advantage consisting in the lack of rotor losses. For this motor the starting problem has been solved performing a variable air gap under polar shoes, what determine the occurrence of the starting torque due to the fact that the axis of the rotor field created by PM in the rest position differs from the axis of the stator. First the parameters of the motor have been determined by tests and finite elements (FE) simulations, without knowing the properties of the PM. At the beginning magnetostatic FE simulations have been performed and then in magnetodynamic regime. The obtained results in the two regimes are closed. Secondly, with the determined parameters, a Matlab Simulink model has been realized (this being the final goal), and the dynamic regime of the motor has been studied. The results regarding the motor speed in starting process, the current variation, are also presented and discussed.**

Keywords—parameters; synchronous motor; single-phase; permanent magnet; finite elements programs; Matlab/Simulink

NOMENCLATURE

V - Nominal voltage

I - Total stator winding current

I_{Fe} - Current corresponding to the iron losses

I_L - Magnetizing and load current

L - Inductance of the stator winding

R_{Cu} - Resistance of the stator winding

R_{Fe} - Resistance corresponding to the iron losses

v_e - Voltage induced by the rotor PM

g_1 - Large air gap

g_2 - Small air gap

θ_0 - Rest position of the rotor

θ - Instant rotor position (angle between the rotor and stator axes)

N - Number of turns of one stator coil

ω - Angular frequency

Ω - Rotor speed

V_m - Maximum value of the induced voltage

ϕ_{rp} - Peak flux of the rotor PM

J – Total moment of inertia of the rotor

T_{rp} – Peak reluctance torque;

T_l – Load torque

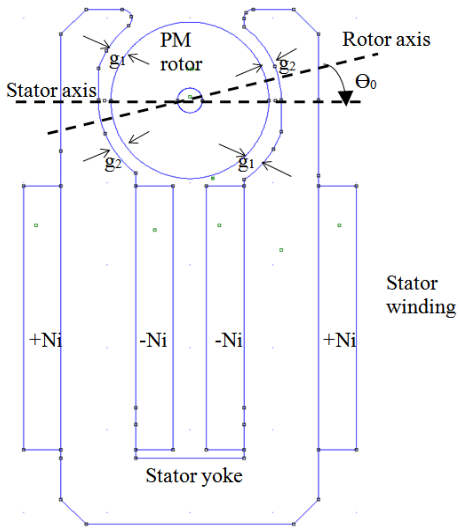
I. INTRODUCTION

Increasing the performance of electrical equipment is a global priority, knowing that electrical power consumption is the most important cost over the lifetime of such equipment.

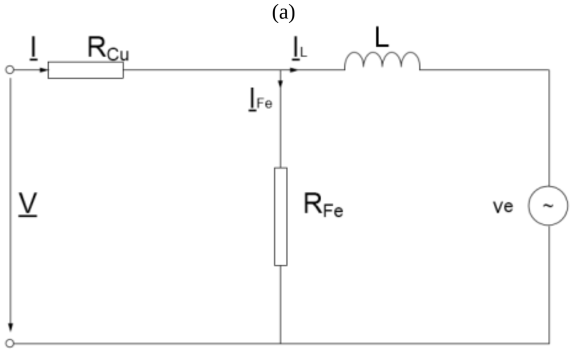
On the other hand, in terms of electric motors, the new standards have already imposed minimum efficiency increase. There are possible a few ways to increase the efficiency of electrical motors and it will be mentioned some of them: the use of new materials, reducing the electrical and magnetic loads or the utilization of new constructive solutions (new types of motors).

In household appliances industry, for low power drives, that do not require speed control, are used some motors with special construction. These motors must be cheap and to provide a high efficiency. Induction motors are cheap, robust but unfortunately they have a low efficiency compared with other electrical motors. The brushless direct current motors (BLDC), switched reluctance motors (SRM) or the synchronous motors, particularly PM motors, are an alternative. BLDC and SRM require more complex control equipment and for this reason they are not used for these drives. As regarding synchronous motors, these must be single-phase type in order to be fed directly from the single-phase distribution network. For low power drives, synchronous motors with PM are preferred. But like the other synchronous motors, these do not have starting torque. In order to obtain starting torque different design solutions are used: the realization of pole shoes with some notches or achieving a tapered air gap, the utilization of the rotor with some additional permanent magnets (parking magnets) [1], [2], [4], [9]; all these constructive solutions in order to impose to the rotor a preset rest position, so the PM magnetic field axis to be unaligned with the axis of stator winding.

This paper will refer to such motor, with tapered air gap, U-shaped magnetic circuit and PM rotor, and it completes the study presented in [5]. Fig.1a shows the cross section of the motor and Fig. 1b presents the electrical equivalent circuit.



(a)



(b)

Fig. 1. Cross section of the motor; (b) Electrical equivalent circuit.[5]

For the rotor, PM with radial or parallel magnetization can be used. In the studied case the PM have parallel magnetization. The main data of PM are field coercivity, H_c and magnetic permeability, μ.

Based on electrical equivalent circuit, the motor equations can be written [1]-[3],

$$V = iR_{Cu} + i_{Fe}R_{Fe} \tag{1}$$

$$i_{Fe}R_{Fe} = L\frac{di_L}{dt} - v_e \tag{2}$$

$$i_L + i_{Fe} = i \tag{3}$$

The voltage induced by PM can be written in terms of the peak flux of the rotor and the rotor speed [1],

$$v_e = 2\omega N\phi_{rp}sin(\theta - \theta_0) \tag{4}$$

And, the motion equation is,

$$J\frac{d\Omega}{dt} = 2Ni\phi_{rp}sin\theta - T_{rp}sin[2(\theta - \theta_0)] - T_l. \tag{5}$$

In the previous equations it was assumed that the reluctance torque and the flux created by PM have a sinusoidal variation depending on the rotor position (θ). This assumption is not far from reality as will be seen in what follows.

II. Study of the Motor

A. *Determination of the motor parameters*

The final objective of this study is to achieve the Matlab /Simulink model of the motor. In order to perform this, the main parameters of the motor must be determined. The most important electrical parameters are stator winding resistance and inductance [6]-[8], and they were measured using a RLC meter. The resistance of the stator winding was 170 Ω. When the stator inductance is measured, the rotor must be at 90^0 to the axis of the stator, so that the PM linked flux to be minimum. The rotor has to be blocked in this position during the measurements because the rotor is in unstable equilibrium. The stator winding inductance was 1.355 H. Because the rotor is blocked, the voltage induced by PM is zero and by measuring the power, current and voltage, the resistance corresponding to the iron losses can be determined. The obtained value was 11000 Ω.

Another very important parameter of this motor is the rest position, which can be easily obtained by FE simulations. But the problem is that the PM parameters, needed in simulations, are not known exactly, only the PM type as being Ferrite and the geometrical dimensions. In order to obtain the PM properties, the real peak flux of the PM has been determined from the voltage induced in stator winding, Fig. 2. This voltage has been recorded with an oscilloscope and the dedicated software while the main motor was driven by another same type motor.

The relation between peak flux and peak voltage derives from relation (4),

$$\phi_{rp} = \frac{V_m}{2N\omega} \tag{6}$$

As the number of turns is known, the peak flux was determined, and then, more simulations have been performed with the free software FEMM (Finite Element Method Magnetics) in order to establish the suitable field coercivity.

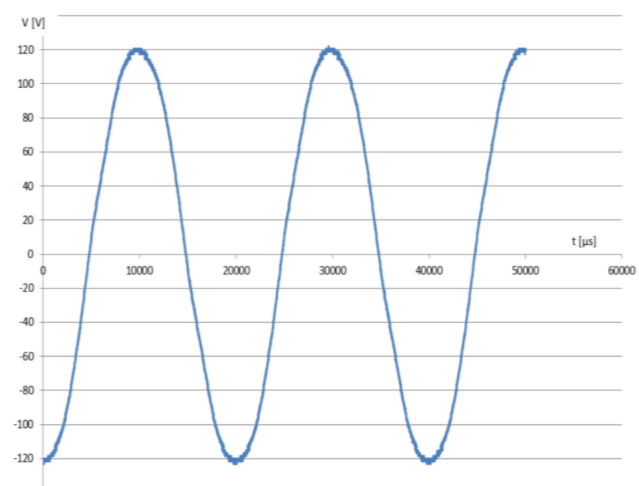


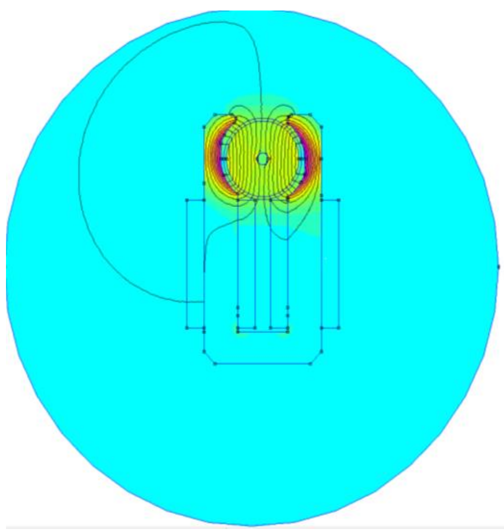
Fig. 2. Registered voltage induced in stator winding.[5]

The value of the coercivity and permeability for which the peak linkage flux is the same as the real determined value, have been considered as reference values (H_{cr}, μ_r). For the magnetic circuit of the stator the considered material was US Steel Type 2-S 0.024-inch thickness.

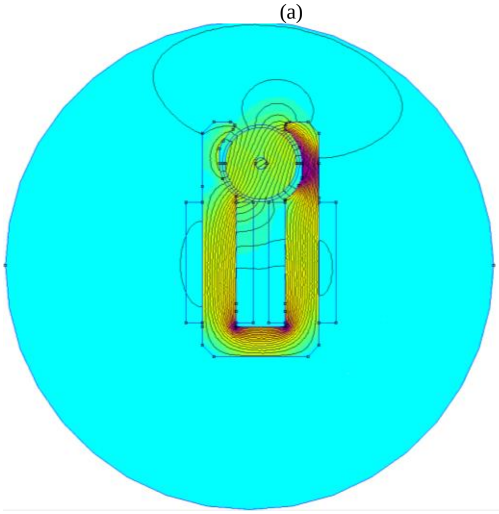
The inductance of the stator winding has been determined by performing two magnetostatic FE simulations with the rotor placed at 90^0: first without current, Fig. 3a and the second simulation with rated current in the stator winding, Fig. 3b[5].

From the total magnetic flux (produced by PM and stator winding current) obtained from the last simulation, the flux produced only by PM (first simulation) has been subtracted and the resulted flux beeing reported to the current, the stator winding inductance has been obtained. This value was 1.38 H.

The rest position of the motor is another important parameter that must be identified by simulations. In this position the reluctance torque of the motor is zero, and the PM flux is maximum. In FEMM, the torque *M* was obtained by Maxwell Stress Tensor Method[1].



(a)



(b)

Fig. 3. FEMM simulations, flux lines and flux density map: (a) without current; (b) with rated current

The dependence of the torque by the rotor position has been obtained by performing simulations for different positions of the rotor, θ having values between 90^0 (considering positive values toward the small air gap) to -90^0.

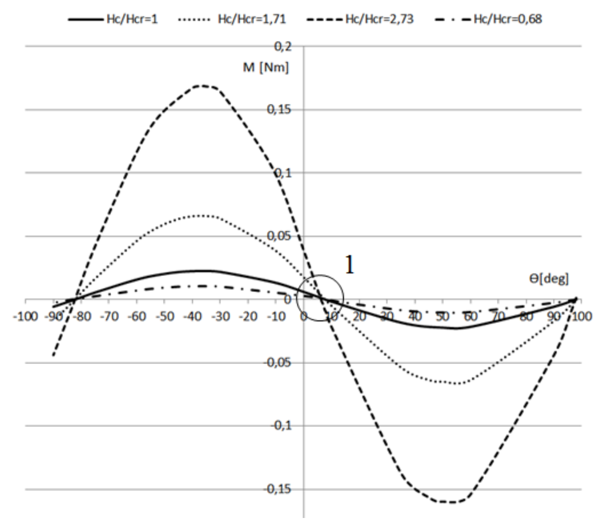
The effect of the PM properties on the reluctance torque and also on the rest position of the motor has been studied by performing simulations for different values of H_c and μ.

Fig. 4 shows the variation of the torque in terms of the rotor position for different values of the PM coercivity, the permeability beeing kept constant.

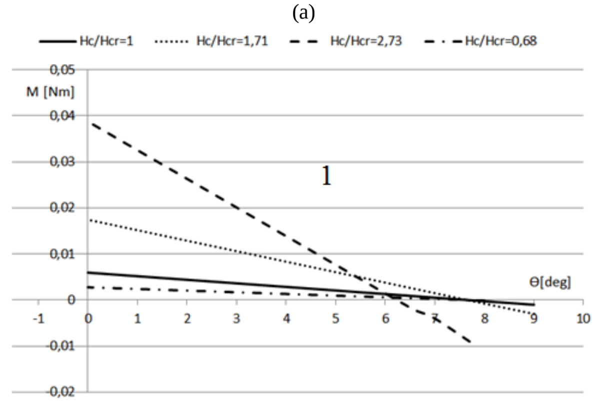
Fig. 5 shows the same curves, but in this case the PM coercivity is kept constant and the magnetic permeability has different values.

In both figures, continuous line has been used for the curve corresponding to the actual rotor.

From Fig. 4 and 5 it can be noticed that the motor has four positions where the reluctance torque is zero, but only two correspond to a rest position (near to 0^0 and 180^0), the rotor being in a stable equilibrium. In the other two (near to $+/-90^0$) the rotor is in an instable equilibrium.



(a)



(b)

Fig. 4. Reluctance torque for different coercivities: (a) normal view; (b) enlarged view in zone 1.[5]

[1] Finite Element Method Magnetics.
Available online: http://www.femm.info/wiki/HomePage.

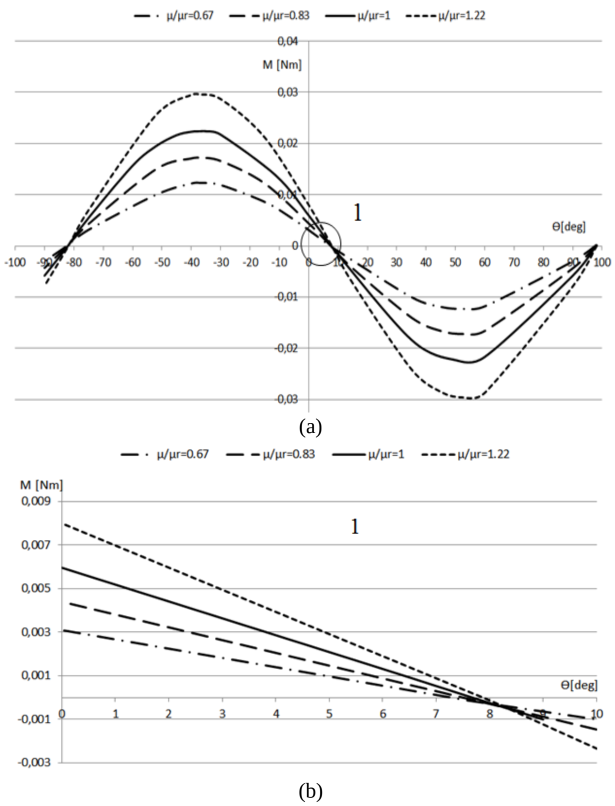


Fig. 5. Reluctance torque for different μ: (a) normal view; (b) enlarged view in zone 1.[5]

As it can be seen from Fig. 4, for different coercivities of the PM, different rest positions have been obtained. The rest position varies between 6.2^0 (for the lowest H_c) and 8^0 (when H_c is the largest). In case of the actual rotor this angle is 7.68^0, a value in accord to the literature [10], [11]. The magnetic permeability (the chosen values being specific to these magnets) has only insignificant influence on the rest position.

The resultant torque in relation with the reluctance torque for two values of the stator current is showed in Fig. 6.

The rest position has been determined also by magnetodynamic FE simulations. Two transient simulations have been made; the rotor has been set at 20^0 and 10^0 to the stator axis, toward the large air-gap. The rotor is left free and it moves towards the rest position and oscillates around it.

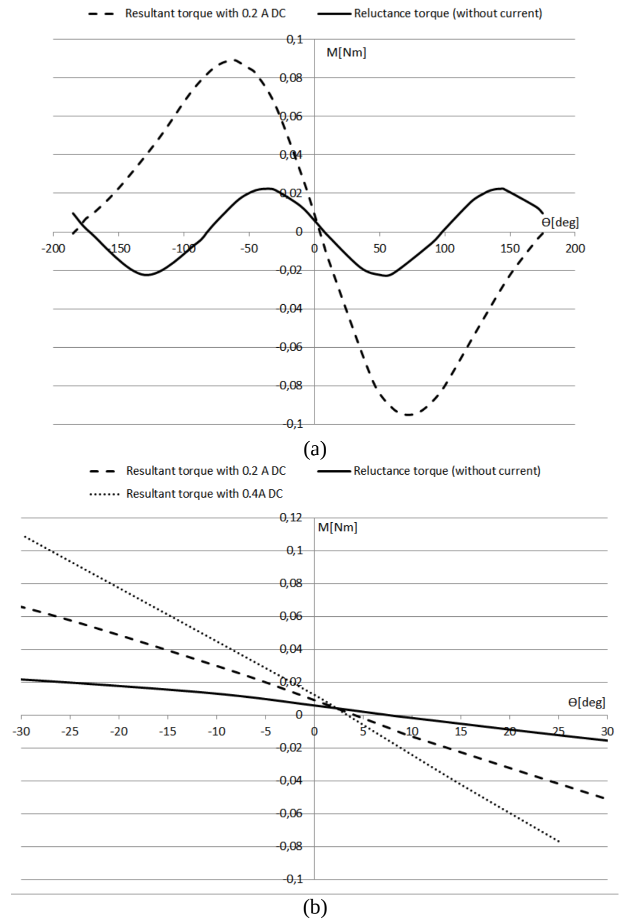


Fig. 6. Resultant and reluctance torque for: (a) 0.2 A; (b) 0.2 and 0.4 A.[5]

To reduce the simulation time, a friction couple, opposite to movement was imposed. As is shown in Fig. 7, the rotor tends towards a position of equilibrium around 7.5 degrees from the stator axis (7.5+20 and 7.5+10 respectively). Another magnetodynamic simulation has been made in order to obtain the rotor speed during starting regime. The stator winding was fed from a voltage source by industrial frequency what should determine a rotor speed of 3000 rev/min or 18000 degrees/second. Fig. 8 shows the speed variation in the first milliseconds at starting.

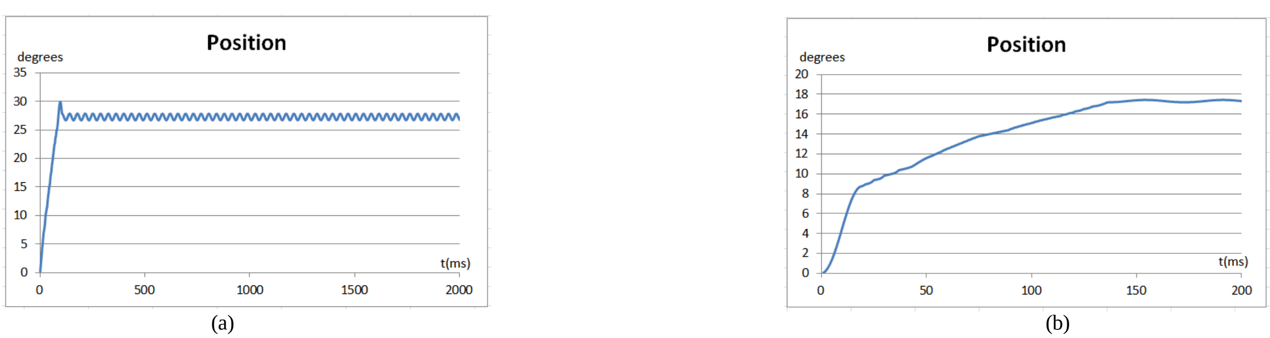


Fig. 7. The rest position determination by transient FE simulation starting from: (a) -20^0; (b) -10^0

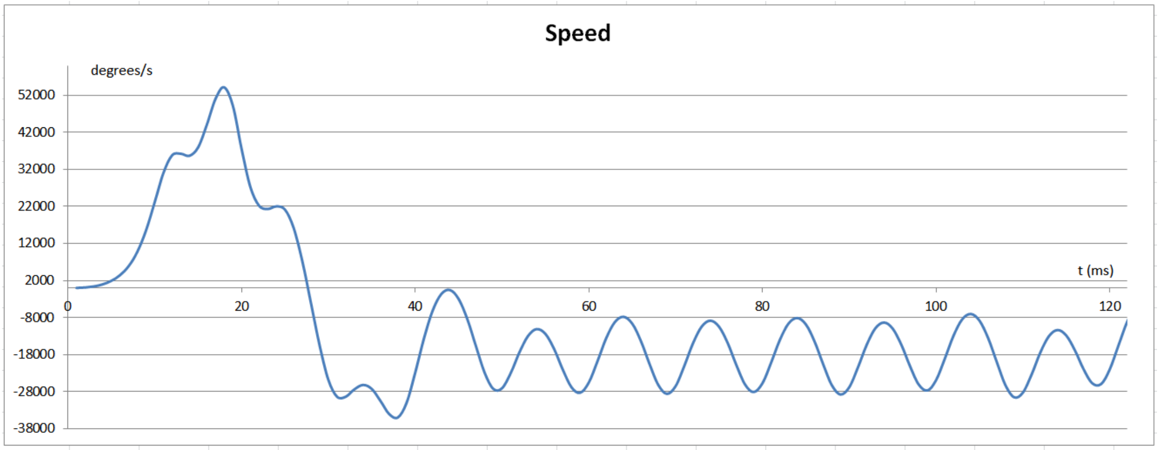


Fig. 8. Rotor speed at starting

It can be observed that the rotor moves first in opposite direction (it is considered positive direction to the left, Fig. 1) and then it reverses in the right direction, and the speed oscillates around the synchronous speed. These oscillations are quite large; one explanation could be the lack of a resistant torque.

The induced voltage was also determined by magnetodynamic FE simulation. For the rotor, synchronous speed was imposed, and the voltage induced by rotor PM was obtained and it is shown in Fig. 9. How the inductance depends on the winding current, the rotor being blocked at 90 degrees, is shown in Fig. 10. In order to obtain this, a transient simulation without motion was carried out, the stator winding being fed by a voltage source.

B. Motor modeling in Simulink

With the motor parameters determined, the model can be implemented in Matlab/Simulink. Based on motor equations, a model in Matlab/Simulink has been created, it being presented in Fig. 11.

A voltage source has been used for generation of the sinusoidal signal, and at this time the stator inductance was considered constant. The other blocks are common for Simulink. For visualization of different parameters, many oscilloscopes have been used. The simulations have been performed for five seconds, the zero moment being at starting. In the following some of the obtained results are presented.

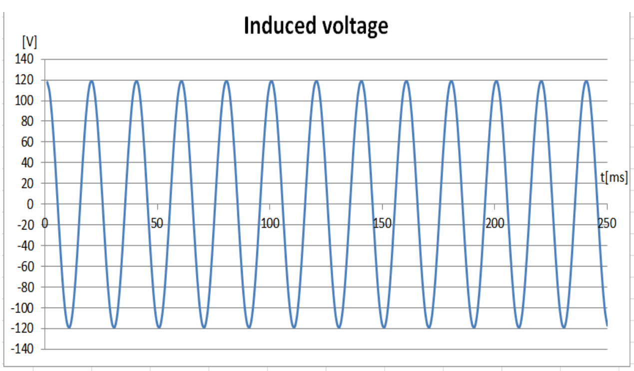


Fig. 9. Voltage induced by PM in magnetodynamic FE simulation

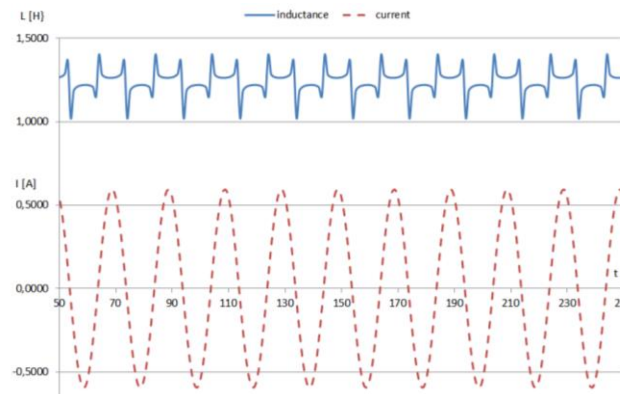


Fig. 10. Inductance dependence on the winding current

The rotor speed reaches an average speed equal with synchronous speed, Fig. 12, but there are also large oscillations. It is specified that the resistant torque imposed to the rotor was again insignificant.

The voltage induced by rotor PM is shown in Fig. 13.

The stator winding current, obtained in the following three situations: recorded, FE magnetodynamic simulation and by Simulink is shown in Fig. 14.

The recorded current and the current obtained by Simulink are in steady state operation while the current obtained by FE simulation is represented from starting to steady state.

III. Discussion

This paper presents how the parameters of the studied motor have been identified, without knowing the properties of PM, only the geometrical dimensions were known. These properties have been determined based on the induced voltage in stator winding, recorded in no load regime. The stator winding inductance and stator winding resistance have been obtained by measurements and tests and also by FE simulations.

Another parameters as the rest position, the reluctance and resultant torque, and also the PM properties on the mentioned parameters have been studied by magnetostatic simulations.

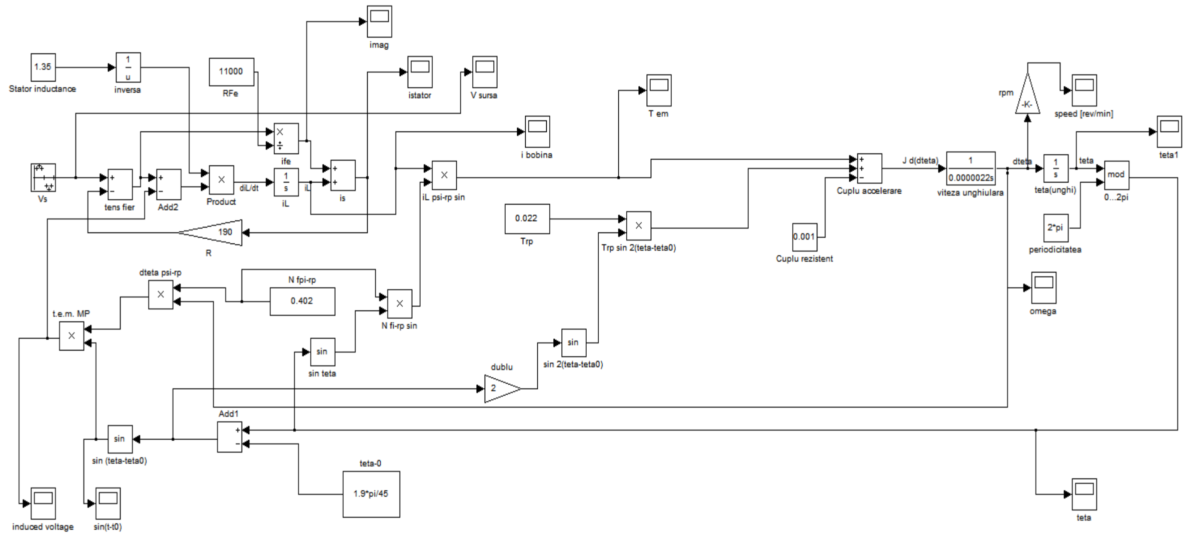
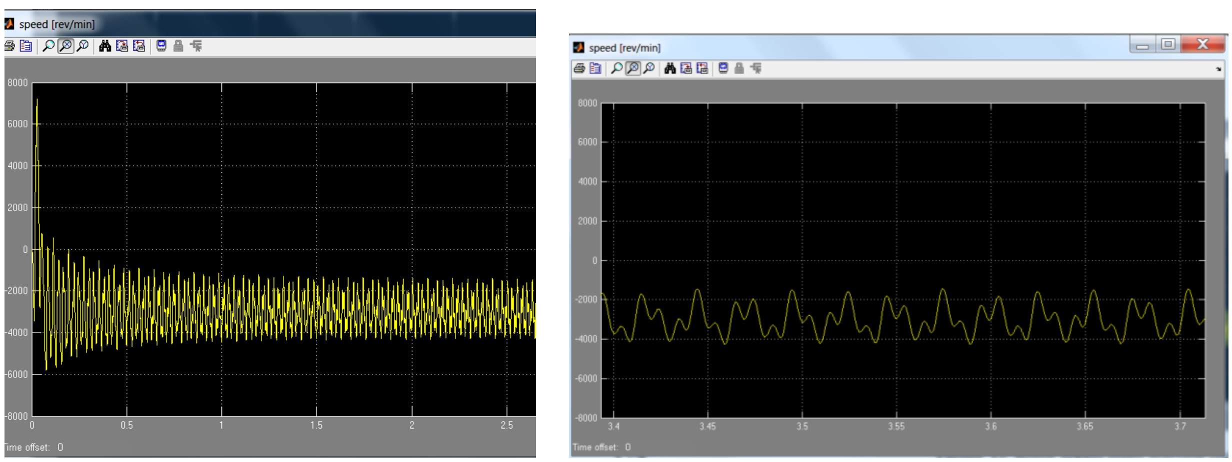


Fig. 11. Model of the motor in Simulink



(a) (b)

Fig. 12. Rotor speed [rev/min]: (a) from starting to steady state; (b) in steady state operation

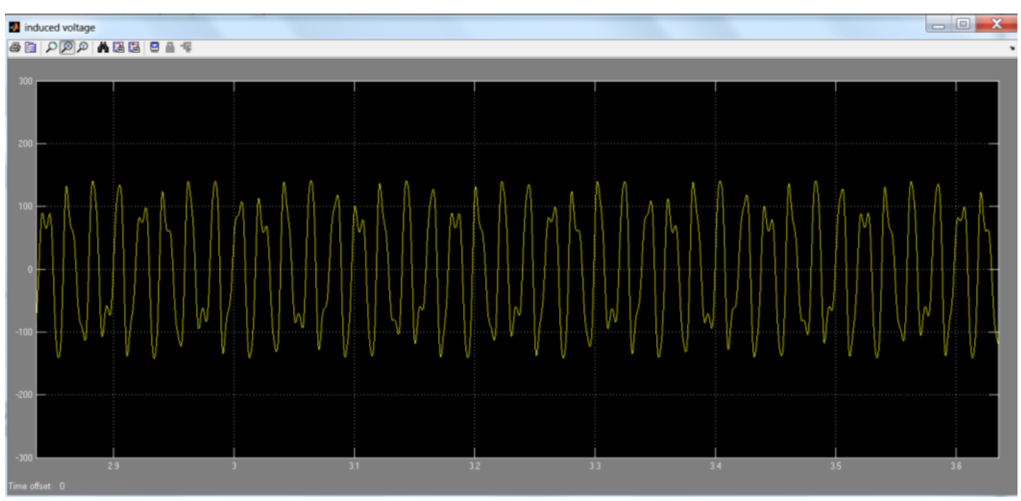


Fig. 13. Induced voltage [V] in steady state operation

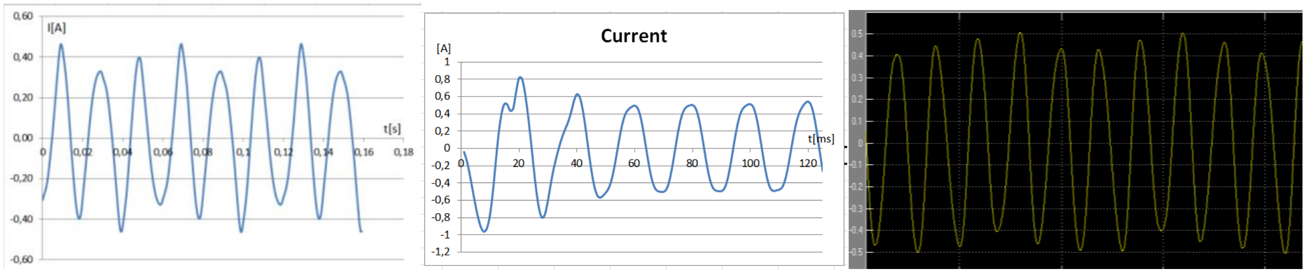


Fig. 14. Stator winding current (Amper vs. seconds): (a) recorded; (b) FE simulation; (c) Simulink

The rest position of the rotor has also been calculated by magnetodynamic simulations. In the same manner were determined the induced voltage, rotor speed and winding current.

The main purpose of this paper was to achieve in Matlab/Simulink a motor model, model that can be integrated into a system control, and replicate as accurately the actual behavior of the motor.

The FE modeling is the one that can faithfully reproduce the behavior of the motor if all designing data are known, but these programs require important hardware/time resources. And finally, the model of the motor must be integrated into a more complex system which will be carried out in Matlab, for this reason the Simulink model needs to be very accurate.

In this regard a Matlab/Simulink model of this motor was carried out. In model was used the parameters determined by tests or simulations. Some of the results obtained with Simulink were presented.

A few conclusions concerning the presented results must be done. The no load rotor speed is not constant, but the motor runs with an average speed equal to synchronous speed (3000 rev/min). This was emphasized both by FE simulations and Simulink. The measurements determined only the average speed. Although the oscillations of the rotor speed were not evidenced experimentally (measurements performed did not allow this) they are logical. While synchronous torque of the motor maintains the movement, keeping the sense, the reluctance torque periodically changes its sense; a quarter of the rotation strengthens the synchronous torque and another quarter weakens it. When synchronous torque is strengthened, the rotor accelerates and increases its speed; when synchronous torque is weakened, the rotor speed decreases. Thus, during a rotation that takes 20 ms, the rotor speed rises and falls twice; this is seen in the speed chart, Fig. 12b.

The induced voltage has the same rms value, but with Simulink its form differs from the one recorded or determined by FE simulation.

The stator current variation, in no load operation, obtained by simulations, is slightly different from the one recorded.

The greater or smaller differences between results are caused by the necessary simplifications to realize the models and the impossibility of accurate reproduction of the conditions from the measurements time.

In order to improve the Simulink model, transient measurements will be required to record at the same time, the instant values of the voltage, current, speed and torque. Only in these conditions simulation results can be compared fairly with measurements.

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A Rich Feature-based Kernel Approach for Drug-Drug Interaction Extraction

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***Abstract*—Discovering drug-drug interactions (DDIs) is a crucial issue for both patient safety and health care cost control. Developing text mining techniques for identifying DDIs has attracted a great deal of attention in the last few years. Unfortunately, state-of-the-art results didn't exceed the threshold of 0.7 F1 score, which calls for more efforts. In this work, we propose a new feature-based kernel method to extract and classify DDIs. Our approach consists of two steps: identifying DDIs and assigning one of four different DDI types to the predicted drug pairs. We demonstrate that by using new groups of features non-linear kernels can achieve the best performance. When evaluated on the DDIExtraction 2013 challenge corpus, our system achieved an F1-score of 71.79%, as compared to 69.75% and 68.4% reported by the top two state-of-the-art systems.**

Keywords—Drug–drug interaction; Feature-based approach; Nonlinear kernel; Biomedical informatics; Natural Language Processing

I. INTRODUCTION

"A drug-drug interaction is a modification of the effect of a drug when administered with another drug" [1]. Unexpected side effects of DDIs are generally dangerous and can lead to deaths. Understanding these DDIs and their side effects is of great importance, leading to reduced healthcare costs and reduced number of drug-safety incidents. New DDIs are always reported in new scientific publications and technical reports, but extracting those DDIs by hand is expensive and time consuming. Therefore, automatic DDI extraction, which detects DDIs in unstructured text and classifies them into predefined categories, has become an urgent need in medical text mining.

DDI extraction has attracted a special attention in the last few years. With the organization of DDIExtraction challenges in 2011 and 2013 [2,3] and the creation of the DDIExtraction 2013 challenge corpus [4] several approaches to manage this task have been proposed. Zheng et al [5] used context vectors with a graph kernel to build the second best system. There system achieved an F1-score of 68.4%. Convolutional Neural Networks (CNN) have been used by [6] to build the top performing system. Word embeddings and position embeddings are used to represent DDI instances. This system gets 69.75% in F1-score and outperforms the graph kernel system by 1.35%. Feature-based linear kernel has been used by [7] to build a simple system that uses few types of features. The results was encouraging and the system achieved 67% F1-score. We think that the DDI extracting task can't be solved only by a linear kernel because of the high complexity of the task. Non-linear Feature-based kernel can be more powerful to perform this task especially if combined with intelligently chosen features.

With the goal to build an intelligent and powerful system, we develop a DDI extraction system based on a non-linear SVM classifier. Interacting drugs are identified first, and then classified into specific DDI types. We define five types of features to represent the complexity of data: "word features" with position information, "one-drug features" to represent features related to each drug, "pair features" to represent features related to the drug pair, "main-verb features" to represent features related to the main verb of the sentence, and finally the negation features. This system separates candidate drug pairs into five groups based on their syntactic structures then features are optimized for each group.

When evaluated on the standard corpus [4], our system achieved an overall F1-score of 71.79%, which outperforms the current best system by 2%. We believe that the strength of our method comes from combining intelligent features with non-linear kernel. In addition, the cascade strategy [8], used to perform the classification, contributes to the higher performance.

In this section, we describe our method for extracting drug–drug interactions from biomedical texts. Fig 1 illustrates the general architecture of our system. Candidate drug pairs are separated into five groups based on their syntactic structures. For each group a binary classifier is trained to extract interacting drug pairs. Extracted drug pairs are then grouped before being classified into predefined relation categories by a DDI type classifier.

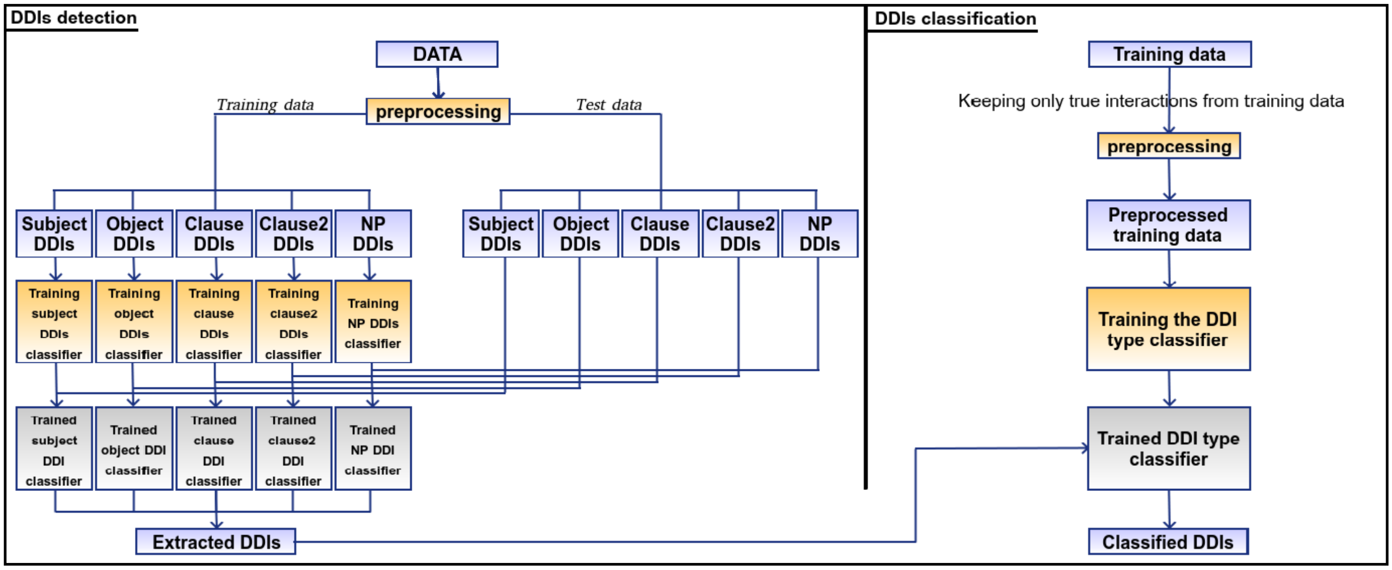

Fig. 1. The general architecture of our system

II. Methods

A. DDIs Extraction

1) Text preprocessing

Several preprocessing steps are completed on both training and test data. To ensure generalization of the input sentences, drugs are blinded in the following way: the two drugs of interest are replaced by "ARG" while all the other drugs are replaced by "DRUGi" where i is the drug index. Sentences that have no trigger word or contain only one drug are filtered out. We use the same list of trigger words created by [8]. After drug blinding, we use LingPipe NLP toolkit [9] to tokenize and tag sentences with POS tags, OpenNLP shallow parser [10] is then used to produce chunks. Dependency graphs and constituent parse trees are also generated for all sentences using Stanford parser [11, 12].

2) Candidate drug pairs partitioning

In a previous study, [13] demonstrated that partitioning candidate DDI pairs based on their syntactic properties then using specific group of features for each partition improves the performance of the DDI extraction system. Following this strategy, we classify candidate pairs into different groups based on their positions into the sentence. Every sentence will be divided into clauses. Each clause consists of a subject phrase, a verb chunk and an object phrase as shown in Fig 2.

Candidate DDI pairs will be classified into one of the following groups based on their syntactic containers:

Subject: If the candidate DDI pair belongs to the same subject phrase.

Object: If the candidate DDI pair belongs to the same object phrase.

Clause: If the candidate DDI pair belongs to the same clause.

Clause_2: If the candidate DDI pair is separated by two verb-chunks.

NP: If the sentence contains only one phrase.

We filtered out all candidate DDI pairs that are separated by more than two verb-chunks. We build a classifier for each group. Different combination of features are used for each classifier.

3) Features

In this section we describe all features used by our DDI extraction system. Table I shows the optimal combination of features used by all classifiers built for the 5 groups. For each classifier, the selection of features is based on a 10-fold cross-validation over training data. Fig 4 shows an example of features generated for a DDI pair.

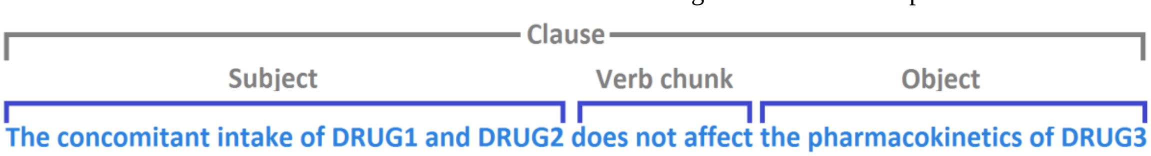

Fig. 2. Example of a sentence containing one clause

a) Word-features

In previous studies [14, 15, 16, 7] individual words and sequences of words in a sentence have been used successfully in extracting relational knowledge like protein–protein interactions or drug-drug interactions. Hence, in our system, we use unigrams and bigrams of lemmatized tokens as features. Many studies [14] [7] have shown the importance of appending position information to word features. In our system the position information can takes 3 values:

BF (before): If the concerned word is before the investigated drug pair.

BE (between): If the concerned word is between the investigated drug pair.

AF (after): If the concerned word is after the investigated drug pair.

We use four form of windows to select words for the generation of word-features:

W1: All words of the sentence containing the candidate pair are selected.

W2: All words of the clause containing the candidate pair are selected.

W3: Words between the beginning of the clause containing the candidate pair and the end of the sentence are selected.

W4: words between the beginning of the chunk containing the first drug and the end of the chunk containing the second drug are selected.

For each classifier the best window is selected using a 10 fold cross validation, results are shown in Table I.

b) One-drug features

Are designed to capture relations between each drug of the candidate DDI pair and the phrase to which it belongs. One-drug features comprises three groups of features:

Surrounding words: Words before and after each drug are added as features.

Surrounding triggers: Trigger words that belong to the same phrase of the concerned drug are added as features. We append position information (before or after) and all prepositions between the trigger words and the concerned drug. If no trigger word exist in the phrase containing the drug, then “no_rel_word” is add as feature.

Succeeding drugs: Relations between the concerned drug and the succeeding drugs in the same phrase are added as features. Punctuation, coordination and prepositions are also captured by this group of features. If no drug exist then the "no_other_drug" is added as feature.

c) Pair features

Pair features consist of three groups of features:

Same_chunk features: Detect if the two investigated drugs are within the same chunk.

Between_drugs features: Detect trigger words, connectors (because, since, until ….), prepositions and negations between the two investigated drugs.

Trigger_DRUG_Position features: Like Bui et al [13] we determine the relative position of each trigger word within the phrase by checking the following cases:

- Trigger [prep] DRUG1 [prep] DRUG2
- DRUG1 [prep] trigger [prep] DRUG2
- DRUG1 [prep] DRUG2 [prep] trigger

Where DRUG1 and DRUG2 are drugs of the candidate DDI pair and “prep” are prepositions connecting chunks that contain the trigger word and the drug.

Depending on the obtained case, features are generated to represent:

The position of the trigger relative to the candidate pair (before, between, after).

Prepositions that connect the trigger with the candidate pair.

Prepositions that connect chunks between drugs of the candidate pair.

d) Main-verb features

Are designed to indicate how DRUG1 in the subject phrase and DRUG2 in the object phrase are related. To perform this task unigrams, bigrams, negations and trigger-words are extracted from the verb chunk to be used as features. Connectors before the verb chunk and adverb phrase after the verb chunk are also used as features.

e) Negative-sentence feature

In some cases, the sentence deny the existence of a relation between two drugs, and it is important to detect those cases to avoid any miss-classification. For example, adding “Negative-sentence” as feature to the sentence in Fig 2 can be very helpful to avoid the classification of DRUG1 and DRUG2 as interacting drug pair.

To perform this task we generate first the dependency graph of the sentence by the Stanford parser [11, 12]. This graph uses nodes to represent words and edges to describe governor-dependent relations between them. One of the important governor-dependent relations is the negative dependency relation which describe the relation between a negation word and the word it modifies.

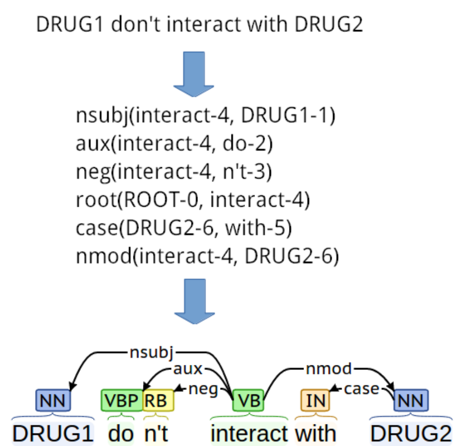

Fig. 3. An example of a dependency graph

For example in the sentence on Fig. 3 the Stanford parser will generate a negative dependency relation between “not” and “interact” [neg(interact-4, not-3)] where “not” is the governor and “interact” is the dependent word.

To exploit the negative dependency relation we have developed a list of trigger words. If the dependent word of any negative dependency relation belongs to this list, the “NEGATIVE_SENTENCE” feature will be added to the vector of features. For example, “NEGATIVE_SENTENCE” feature will be generated for the sentence on Fig 3 because its list of dependences contains a negative dependency and the dependent word ("interact") belongs to the trigger words list.

4) Machine learning

For DDI detection, we use LIBSVM, the popular SVM library [17], with a default radial basis function (RBF) kernel. For each candidate pair, individual features generated are normalized and added to a single vector as proposed by [18].

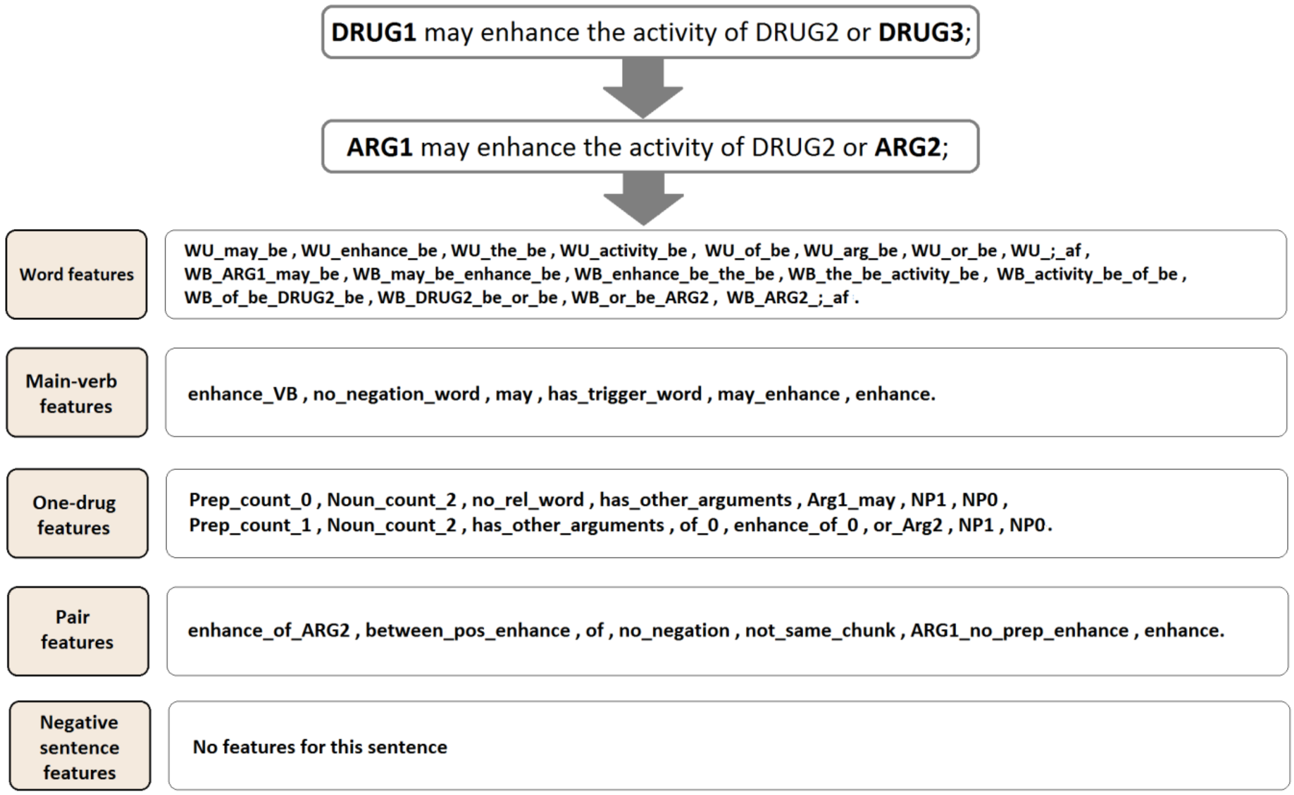

Fig. 4. An example of of feature extraction

TABLE I. THE OPTIMAL COMBINATION OF FEATURES FOR EACH GROUP BASED ON 10-FOLD CROSS-VALIDATION RESULTS OVER TRAINING DATA.

Features			Subject	Object	Clause	Clause2	NP
Word features	***Unigrams***	W1		X	X		X
		W2				X	
		W3	X				
	Bigrams	W1				---	X
		W3	X		X		
		W4		X			
One-drug features	***Surrounding triggers***		X		X	X	
	Succeeding drugs		X		X	X	
	Surrounding words		X	X	X	X	X
Pair features	***Same_Chunk***		X	X	X	X	X
	Between_Drugs		X	X	X	X	X
	Trigger_DRUG_Position		X	X	X		X
Main-verb features			X	X	X	X	X
Negative-sentence features			X	X	X	X	

B. DDIs Classification

The objective of the classification task is to assign one of four DDI types (Mechanism, Effect, Advice and Int) to interacting pairs extracted in the detection step. Kim et al (2015) [7] have shown that the one against one strategy gives better performance in DDIs classification comparing to the one against all strategy. Raihani et al (2016) [8] have built a new DDIs classifier that exploits the lexical field particularity of each DDI type. When compared to a one-against-one strategy classifier, the new classifier gets better results. Thus we will use the same classification system developed by [8].

III. Results and Discussion

A. Dataset

To evaluate our system we use the corpus from the DDIExtraction 2013 challenge [3,4]. This corpus includes 905 manually annotated documents from MEDLINE abstracts and DrugBank database, which are split into 714 and 191 documents for training and test sets, respectively. The corpus provides examples by sentences, for each sentence all drug pairs are annotated.

Four types of DDI relationships is used to annotate interacting drug pairs in the set: Mechanism, Effect, Advice, and Int. Mechanism is used if the interaction is described by the pharmacokinetic mechanism. Effect is used when the effect of the interaction is described. Advice is used if an advice or recommendation concerning the DDI is given. Int is used when the sentence doesn't provide any information about the type of the DDI.

Table II shows statistics of training data and test data before and after preprocessing. The removed negative pairs constitute 18.5% of the negative set while the removed positive pairs constitute only 2.3% of the positive set. This portion is negligible compared to the advantage of not showing 18.5% of negative pairs to SVM classifiers.

B. Performance Comparison

Compared with state-of-the-art systems, including the best existing system our feature-based kernel system shows much better performance. It outperforms the current best system [6] by 2%, mainly due to much higher recall.

Table III compares our system with top three performing systems based on F1 scores. Our system achieves 71.79% F1-score for detection and classification performance ("CLA"), whereas [6], [5] and [7] produced 69.75%, 68.4% and 67% F1-score respectively. For DDIs detection performance ('DEC') the current best system [5] achieved 81.8% F1-score while our system gets better results by achieving 82,4% F1-score.

Shengyu Liu et al [6] define a range criteria for filtering out some negative instances, then they use Convolutional Neural Networks with word embeddings and position embeddings, which capture the semantic information of words and relative distances between words and the two drugs of interest, to perform the detection and the classification tasks. Zheng et al [5] apply context vectors to a graph kernel to detect and classify DDIs from biomedical texts. There method focuses on the effective use of types of contexts and relations among words with different distances. In addition, they use the one-against-all strategy to perform the classification task. Kim et al [7] use linear kernel with a simple binary SVM classifier for identifying DDIs and use the one-against-one strategy for assigning DDI types to the extracted pairs. They use the one-against-one strategy to handle the bad effect of unbalanced classes.

On the other side, our method exploits new groups of features and uses a binary SVM classifier with RBF kernel to identify DDIs. In addition we use a system of 4 binary SVM classifiers, work in cascade, to perform the classification task. Previous study [8] has shown that this method gives the best performance in DDIs classification.

In Table III, our system performs best for advice, mechanism and effect types. In contrast, the same system does not perform well for Int. Int type is defined as DDIs which cannot be assigned to other types. We think that the general description of Int or the small number of training and test sets (188 and 96 instances for training and test data respectively) may be the cause of the poor results for this type.

Table IV shows the separate performance of our system on DrugBank and MEDLINE test documents. The DDI detection and classification performance on the DrugBank set shows 74.7% F1, while the performance on the MEDLINE set is substantially lower (44,5% F1). This difference is consistent with the results reported by state-of-the-art systems [5, 6, 7] and the results from the DDIExtraction 2013 challenge [4].

One reason may be the small number of training examples provided for MEDLINE. MEDLINE training set is significantly smaller than DrugBank training set and constitute only 7% of the overall training data. Another reason can be the scientific language used in MEDLINE abstracts, which use long and complex sentences to describe relations. In contrast, sentences used in DrugBank are usually short and concise.

TABLE II. Statistics of Training and Test Data Before and After Preprocessing and Filtering.:

	Original set		Preprocessed set	
	Positive	**Negative**	**Positive**	**Negative**
training	4020	23772	3922	19194
test	979	4737	960	4016
all	4999	28509	4882	23210

TABLE III. Performance Comparison between Our System and the Top-Ranking Systems on the DDI2013 Test Data. 'CLA' Refers to Detection and Classification Performance. 'DEC' Refers to Detection Performance. the Performance is Measured based on F1 Scores.

Method	CLA	DEC	Mechanism	Effect	Advice	Int
Our method	**71.79**	**82.46**	**74.26**	69.81	**78.68**	**51.74**
Shengyu Liu et al [6]	69.75	-	70.24	69.33	77.75	46.38
Zheng et al [5]	68.4	81.8	66.9	**71.3**	71.4	51.6
Kim et al [7]	67	77.5	69.3	66.2	72.5	48.3

C. Feature Analysis

Using lexical features without position information as a baseline, position information, one-drug features, main-verb features, pair features, and n*egative-sentence features* are added respectively to the system and evaluated one the test dataset. Table V shows the contribution of each group of features.

Adding the position information to the word-features improves the F1 performance by 4.5%. This significant improvement is understandable because relative position help the system to understand if an individual word is used in describing an interaction between two drugs or not. These results confirms the conclusion of [7] about the importance of attaching position information to the words.

One-drug features, main-verb features, pair features, and negative-sentence features contribute on performance by increasing F1-score by 0.56%, 0.44%, 0.58% and 0.44% respectively. One-drug features, pair features and negative-sentence features help get higher recall while main-verb features help to improve the precision. While one-drug features cover neighbouring words, pair features and main-verb features seem to help with the overall picture of a relation between two drugs into the sentence. It is remarkable that using words with position information alone achieves such high performance for detecting DDIs. Integrating position information into word features helps differentiate the context of interacting pairs from that of non-interacting ones in sentences that involve multiple drug mentions.

TABLE IV. COMPARISON BETWEEN PERFORMANCE RECORDED ON DRUGBANK AND MEDLINE TEST SETS. 'CLA' REFERS TO DETECTION AND CLASSIFICATION PERFORMANCE. 'DEC' REFERS TO DETECTION PERFORMANCE. THE PERFORMANCE IS MEASURED BASED ON F1 SCORES.

Dataset	CLA	DEC	Mechanism	Effect	Advice	Int
DrugBank	**74.73**	**84.88**	**77.78**	**73.44**	**79.33**	**55.07**
MEDLINE	44.57	58.7	40	46.15	61.54	22.22

TABLE V. IMPROVEMENT OF DDIS DETECTION AND CLASSIFICATION PERFORMANCE WHEN ADDING FEATURES ONE BY ONE TO THE BASELINE SYSTEM. 'IMPROVEMENT' COLUMN SHOWS THE F1-SCORE DIFFERENCE BETWEEN EACH ROW AND ITS PREVIOUS ROW. THE LAST ROW SHOWS THE TOTAL IMPROVEMENT.

Features	Precision	Recall	F1	Improvement
Baseline (w/o pos)	0.6491	0.6557	0.6524	-
Baseline	0.7358	0.6629	0.6974	+4.50%
+ One-drug features	0.7108	0.6956	0.7031	+0.56%
+ Main-verb features	0.7482	0.6710	0.7075	+0.44%
+ Pair feature	0.7439	0.6853	0.7134	+0.58%
+ *negative sentence* features	0.7360	0.7007	0.7179	+0.44%
All features	0.7360	0.7007	0.7179	+6.55%

IV. CONCLUSION

We present a two-step classification approach to extract DDIs from biomedical literature. Interacting drug pairs are first identified by a single SVM classifier then the cascade strategy [8] is used to assigning DDI types to drug pairs. The main factors of our approach are the partition of the datasets and the combination of novel feature sets. Based on many syntactic properties, the original dataset is partitioned into 5 subsets to obtain more consistent sub datasets, then feature sets are optimized for each sub dataset. When evaluated on the DDIExtraction 2013 challenge corpus, our system achieved an overall F1-score of 71.79%, which outperforms the current state-of-the-art system by 2%. As future work, we plan to complete this system by a named entity recognition module. The system is initially built to extract DDIs, but it can effortlessly be adapted to other relation extraction tasks such as gene-disease relations and protein-protein interactions.

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OTSA: Optimized Time Synchronization Approach for Delay-based Energy Efficient Routing in WSN

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***Abstract*—Time Synchronization is one of the problems and still ignored problem in area of wireless sensor network (WSN). After reviewing the existing literatures, it is found that there are few studies that combinely address the problem of energy conservation, clustering, routing along with minimizing the errors due to time synchronization in sensor network. Therefore, this manuscript presents a delay-based routing which considers the propagation delay to formulate a mechanism for delay compensation in large scale wireless sensor network. The prime goal of this technique is to jointly address energy problems, time synchronization, and routing in wireless sensor network. The outcome of the proposed study was found to posse's minimized communication overhead, minimized synchronization errors, lower energy consumption, and reduced processing time when compared with the existing standards of time synchronization techniques.**

Keywords—Wireless Sensor Network; Routing; Time Synchronization; Optimization; Hardware Clock

I. Introduction

Wireless sensor network is increasing finding its utility in unmanned monitoring system over hazardous geographical locations [1]. Normally sensors are positioned in those area where is inaccessible for humans. Various applications of sensors network includes habitat monitoring, healthcare monitoring system, industrial monitoring system etc. In all the application, time is one of the important factors to guarantee the communication success. Two decades ago, the applications of the sensor network were more focused on just delivering the remote data. However, with the changing times, the information has become more time bound in terms of delivery. Another change in modern sensor network is the data quality in sensor network, which is only possible when an effective time stamp is given. Hence, time plays an extremely critical role in providing data quality as well as Quality-of-Service. However, there is one impediment in this regards, which is called as time synchronization [2] [3]. It is essentially use to map as well as synchronize all the hardware clocks residing in the sensors. Time synchronization plays an important role in wireless sensor. The hardware clock in the senor node has an inbuilt oscillator that is responsible for generating pulse. The problems start shooting when the sensor present in the environment start exhibiting different local time with higher difference in their values. In such cases, the two sensors sense the same event at same time but time stamps it with different value. Such problem gives rise to all sort of data quality issues that poses a potential threat to both communication performance as well as security [4][5]. The problem of time synchronization is often studied with respect to some standard terms e.g. clock offset, clock drift, and clock synchronization. Clock offset can be stated as just the different of local clocks with respect to its local time. Clock drift can be stated as frequency difference of the logical clocks. The originations of the time difference occur when sensors are turned on very frequently at arbitrary intervals.

In order to study time synchronization, various research work have been already carried out in the last decade. In such research work, various performance parameters selected by the researchers are accuracy, precision, energy consumption, fault tolerance, and memory utilization. However, there are various constraints which the prior research work have been highlighting pertaining to the time synchronization viz. i) different forms of precision needs, ii) scalability to large scale computing, iii) minimal mobility, iv) non-regularization of higher value of throughput or delivery ratio, v) insignificant transmission delay among the adjacent sensors. An effective algorithm for time synchronization should permit the sensor to be in synchronized state around the clock. The prime idea is also restore maximum amount of energy consumption which finally leads to maximum level of energy drainage. There is various applications where time synchronization plays a critical role in delivering quality services e.g. healthcare. A minor form of error in received message will cost the life of patient. Hence, still the research community is emphasizing on this issues as sensors are increasingly used in healthcare sector. Hardware availability has improved keeping back the appropriate software / protocol availability.

Therefore, the present manuscript presents a novel optimized algorithm for time synchronization with equal emphasis on energy efficiency as well as delay-based routing in large scale WSN. The outcome of this paper is an energy efficient routing protocol that reduces synchronization error in WSN with benchmarked outcomes to prove its effectiveness. Section II discusses about the prior research work carried out in the area of time synchronization followed by discussion of problem identification in Section III. Proposed system is discussed in Section IV followed by research methodology adopted for the designing it in Section V. Algorithm implementation is discussed in Section VI followed by discussion of comparative analysis result accomplished from the study in Section VII. Finally, Section VIII makes some concluding remarks.

II. Related Work

This section discusses about the existing studies being carried out in the problem area of time synchronization pertaining to wireless sensor network. In prior study [6] have discussed about various techniques adopted and introduced in past for reducing the synchronization error in sensor network.

Xiong et al. [7] have developed a technique that assists in performing localization in sensor network. The presented technique has implemented standard Gaussian noise model for estimating the time difference from the detection with the targeted object and the sensors. Although, the author have not directly used time synchronization concept, but the technique is meant for eliminating the difference of time among the communicating nodes in case of localization application in sensors. Xing et al. [8] have developed a novel synchronization technique using linear approach. Linear predictive-based frameworks have been introduced by the author where the prediction estimation is carried out using statistical parameters. Using synchronization model of master and slave, the proposed system minimizes the synchronization errors. Ting et al. [9] have developed a state-spaced framework in order to establish a persistent relationship among the communicating nodes using control strategies. The study has even used an iterative Kalman filter. Kim and Yoo [10] have presented a scheme of time synchronization in sensor network considering the challenges of reducing errors occurring undersea bed. The controlling strategy of synchronization is developed by using mobility factor and node usage. Kalman filter is still found to be used in this mechanism for minimizing the localization errors. The outcome of the study is analyzed with respect to position in particular direction with respect to elapsed time, error in skew value, localization error, etc.

Jin et al. [11] have used voltage factor in minimizing errors causing due to time synchronization. The technique initially identifies the extent of skewness in clock and performs updating operating on local clocks only based on extent of residual voltage. The technique that fine tunes the resynchronization arbitrarily depending on the rate of errors occurring in controlling and balancing the synchronization errors. Dengchang et al. [12] have applied the logic of maximum consensus in order to compensate clock drift as well as mean consensus for compensating offset of clock. The author had presented the work in the form of mathematical modelling and graph theory to find reduced synchronization error as an outcome. Wang et al. [13] have presented a mechanism that can perform synchronization of time along with supportability of multi-hop communication in sensor network. The author have perform rectification of time synchronization problems on two hops for minimizing an adverse effect of overhead and furnishing seamless synchronization to all nodes in dynamic networks. Ardakani et al. [14] have presented a unique algorithm that can perform on-demand time synchronization in sensor network. It is a kind of reactive protocol that performs minimization of time synchronization errors along with exponential minimization of network overheads.

A standard study towards computing time synchronization is carried out in sensor network considering the distributed fashion by Stankovic et al. [15]. The authors have presented a stochastic based technique in order to compensate the evaluated clock drift and offsets. The uniqueness of the study is that it attempts to minimize synchronization errors in presence of noise using mathematical modelling approach. Youn [16] have also studied about the clock synchronization problems in sensor network. Some of the interesting findings include usage of MAC layer for performing time stamping. The authors have also advocated about the usage of the linear approach for truncating the failures of the local clocks in sensor network thereby allowing the system to perform effective time synchronization. Kerkez [17] have presented another unique study that emphasizes on the adaptive fashion of synchronizing the sensor nodes. The authors have used channel hopping scenario with enhancing the MAC layers. Applicability of this technique is found to be highly suitable for mobile agents in sensor network for minimizing errors. A similar form of study is carried out by Wang et al. [18] who have also used MAC layer time stamping mechanism using real-time sensors. The authors have used the technique over TinyOS where the outcomes were evaluated with respect to precision value in presence / absence of compensation techniques. Ikram et al. [19] have presented an idea where time synchronization is carried out in sensor network using radio resources where the study particularly focuses on reducing the errors occurring due to probabilistic sources. The study uses hardware-based approach to justify the claims of minimizing time synchronization. Gautam and Sharma [20] have presented a study that emphasizes on comparative analyses of various techniques used for time synchronization in sensor network.

Lenzen et al. [21] have presented a standard model of time synchronization called as PulseSync that is designed to rectifying the errors in large scale sensor network. Implemented in hardware platform in TinyOS, it is found to offer better accuracy with respect to existing flooding based approaches. Security was also incorporated with respect to synchronization issues by Sanchez et al. [22]. The study uses a predictive-based technique with exchange of synchronization beacons in body area network. Another standard model was presented by Tang et al. [23] that uses multiple channel MAC protocol for performing time synchronization in sensor network with emphasis on energy efficiency. The experiment was carried out over real-time Mica Z sensors with respect to packet delivery ratio, latency, and duty cycle. Albu et al. [24] have presented a study that jointly enhances the clock synchronization and energy efficiency in sensor networks. The study was performed in network simulator to accomplish the better accuracy.

Hence, it can be seen that there are various studies being carried out toward time synchronization in wireless sensor network, which essentially contributes to formulate novel idea for future enhancement. The next section discusses about the inherent limitations in the existing literatures, which will be addressed in present manuscript as proposed study.

III. Problem Identification

This section discusses about the problems that are found to be likely unaddressed in existing techniques. The proposed study find that there are various techniques in past where

Kalman filtering is deployed for ensuring better accuracy in time synchronization in sensor network. Fundamentally, Kalman filter is best suited for any state which is continuously changing. However, how this change will be required to be updated to all the nodes in a large scale sparsely populated sensors is still an unsolved question. Researchers have not found any substantial evidence that usage of Kalman filter can also affect simultaneous updates of continually changing values of local clock nor it assists in energy preservation owing to its iterative process of monitoring the changes in clock drifts.

One of the most essential parts of the time synchronization is its capability to discretize time between two nodes located at two different distances. In majority of the conventional studies, the synchronization is carried out by the reference node that is responsible for estimating the drift value as well as offset value of the reference clock as well as local clock. Unfortunately, in order to maintain the accuracy of the clock, it is essential that propagation delay should be considered. This phenomenon causes although better precision, but it overlooks various non-communicating nodes in the sensor network. If the delay calculation is carried out for transferring the values of the local clock readings from one to another node that it would be able to perform compensation of the transmission delay. Unfortunately, the existing studies are more inclined towards compensation of drift and offset and less focus on compensating the propagation delay. It is also possible that there could be serious synchronization errors owing to the delay of message transmission from the neighbour nodes if they are located very far away from the reference node. A missing gap in this assumption is clusterhead and its charecteristics.

Another research gap found in this context is enhancing the network lifetime. In order to combinely address time synchronization problems and energy efficiency, it is required that retransmission interval as well as ratio of synchronized messages with respect to cumulative message be considered as a part of delay calculations with network updates. However, all these are independent problems which still were not addressed with one single algorithm in past or recent studies in sensor network. It has not come across any potential research work towards time synchronization that has focused on data aggregation problems, clustering problems, and time synchronization problems jointly. Considering of transmission delay posses various complexities in design principle of time synchronization in wireless sensor network. It is still an unsolved problem to consider delay factor in optimization of time synchronization technique in sensor network.

Hence, the problem statement of the proposed study could be stated as "*It is a computationally challenging task to develop a novel optimized algorithm that can consider delay factor in data aggregation to ensure energy efficient time synchronization in sensor network.*" The next section discusses about the proposed study that targets to eliminate the explored problems pertaining to time synchronization.

IV. Proposed System

The prime aim of the proposed study is to formulate a novel optimization technique that can combinely address the problem of i) time synchronization, ii) enhancement of network lifetime, and iii) data aggregation for large scale wireless sensor network. It is Optimized Time Synchronization Algorithm or OTSA, where the optimization is a terms that is more associated with delay-based routing to enhance network lifetime and significantly reduce errors occurring in time synchronization. This work is a continuation of the prior techniques [25][26][27][28][29] for the similar reason. The schematic architecture of the proposed system is showcased in Fig.1.

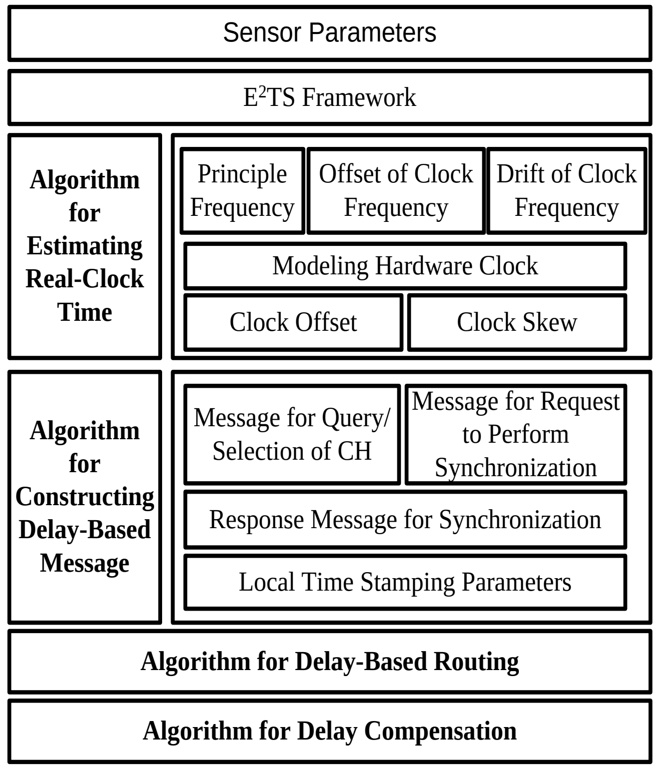

Fig. 1. Schematic Architecture of OTSA

The contribution of the proposed OTSA is as follows:

- To develop a novel delay-based routing that considers transmission delay and formulates the estimation procedure of drift, skew, and offset.
- To develop a completely new type of control message that can extract information pertaining to time synchronization between clusterhead and member nodes.
- To develop a robust technique that can explore the network dynamics and can allow the node to formulate strategy for delay compensation along with enhancement of network lifetime.
- To perform a comparative analysis of the proposed system with the existing approaches of the time synchronization on multiple performance parameters.

The next section of the study will discuss about the research methodology being adopted for developing the proposed study.

V. Research Methodology

The proposed study considers analytical research methodology to be incorporated in the clock model. While developing the proposed system that all the broadcasting beacons to be time stamped only at the MAC layer. However, bring their a new mechanism of considering the local time stamping mechanism, which the conventional studies on time synchronization are not found to posses. The local time stamping mechanism considers multiple states of the sensor to forward request or to receive the response. Such abundant time parameters (T_{for}, T_{rec}, T_{res}, T_{CH_res}) are considered for delay considerations. It's developed their proposed OTSA over prior E^2TS [29] framework itself considering the enhancement of the network lifetime.

The proposed system initiates by modelling the hardware clock considering the computation of skew as well as drift value over network dynamics. In order to emphasize on the delay-based routing, it is formulated 3 different forms of message viz. query message, request message, and response message. In order to specifically infer the meaning of the control message, it uses positive and negative values in the messages. The control message for OTSA will consists of i) type of beacon, which is a message pertaining to query or selection of clusterhead, ii) source node ID, iii) destination node ID, iv) intermediate node ID, v) clusterhead identity, vi) timestamp at message forwarding process, v) timestamp at message receiving process, vi) timestamp at response forwarding process, vii) time at which the CH forwards the response. One novelty of OTSA design is its independence from graph theory as it has its more applicability on multiple forms of network topology. Any node in the network who wants to communicate will be require to broadcast the above mentioned control message. The other node (it can be destination or intermediate node) than responds according sharing the transmission delay information which will be required to be compensated at the end of the processing.

The delay based-routing works as follows – whenever a sensor has received a control message, it checks if the received control message is query type or selection of clusterhead type. In case, if the received message is of query type, than it forwards the response with clusterhead identity or else it check for of the identity of the clusterhead is register in their routing table or not. In case of unidentified identity of clusterhead, the new identity is added in the routing table as a process of updating or else, it check if the residual energy of the cluster head is more or less to perform this communication. However, if the inbound control message is a request message, it checks for identity of the node to clusterhead or member node. Even the system finds that inbound control message is neither a query / selection, nor request message, than it checks if the inbound message is response message. In case of positive identification of response message, the node estimates transmission delay and add the local time stamping data with the message to be prepared for response message. In case of presence of an intermediate hops, the algorithm forwards the response to the prior sender. In a nutshell, the prime task in this stage is to ensure that proper identification of the control message being made that ends with calculations of transmission delay and local time stamping parameters to be incorporated as a measure of delay compensation strategy. In the entire process, the proposed system implements a first order radio model just to calculate energy, but in order to enhance the network lifetime, the OTSA technique ensures that that messages to be sent by run-time verification of the delay. This phenomenon will result in instant message propagation resulting in better Quality-of-Services. This process also results in minimizing the probability of retransmission that significant restores the transmission energy.

The proposed OTSA technique also ensures proper selection of clusterhead, which is extremely different from any existing techniques of selection. It is to be noted that every node to start the minimization process of synchronization request depending on the skew. Interesting, the proposed system also ensures that an algorithm provides better information of the global time, which is required for updating the clock drifts. Hence, delay estimation significantly assists in overcoming the major deviations in the time synchronization. In order to save energy, threshold-based energy has been used, so that when the clusterhead reaches the threshold value of energy, it is simply treated as member nodes. In such cases algorithm makes prior selection of clusterhead based on delay-oriented routing in large scale wireless sensor network. Table 1 highlights the notations being used in the proposed study.

TABLE I. NOTATION USED

New	Meaning
$\lambda_t(t)$	Frequency of clock
t	Principle time
λ_o	Principle frequency
$\Delta\lambda$	Offset of clock frequency
δ_λ	Drift of clock frequency
$\varepsilon_\lambda(t)$	Random error of clock
$h_i(t)$	Hardware clock
O_i	Clock Offset
S_i	Clock Skew
m_1	Message for Query/Selection of CH
m_2	Message for Request to Perform Synchronization
m_3	Response Message for Synchronization
lt	Local time stamping parameters
d	Delay
E_{res}	Residual energy
Th	Cut-off residual energy
T_{for}	timestamp at message forwarding process
T_{rec}	timestamp at message receiving process
T_{res}	timestamp at response forwarding process
T_{CH_res}	Time at which the CH forwards the Response

VI. Algorithm Implementation

This section discusses about the algorithm that has been implemented for developing the proposed study. The design of the proposed system is carried out considering 4 different algorithms for the purpose of rectifying errors in synchronization and performs delay-based routing with enhancement of network lifetime in large scale wireless sensor network.

1) Algorithm for estimating real-clock time

Although the proposed study is carried out using simulation approach, but still attempt to perform estimation of real clock time, which is basically the hardware clock time. The algorithm takes input of λ_o(principle frequency), $\Delta\lambda$ (offset of clock frequency), and δ_λ(drift of clock frequency). A temporary variable x is used in order to get the added value of $\Delta\lambda$ (offset of clock frequency), and δ_λ(drift of clock frequency), which is the prime deviation in clock value from the global values of other sensors present in the simulation area (line-2). The novelty of this algorithm is it considers modelling of hardware clock considering both drift and offset. Another novelty of this algorithm is consideration of the error. As owing to various forms of hardware-related issues, there could be possibility of slight errors in the clock values. This may be also due to related interfering operations in same sensors. Hence, It consider the error $\varepsilon_\lambda(t)$ to be a random type and add it with the adopted frequency of a clock. Therefore, line-4 is valid only for the cases of local clocks that don't have much dependency on any significant issues related to hardware. Line-5 shows the test-observation time considered for the hardware clock $h_i(t)$ with the new variable *y* representing ratio of offset of clock frequency to principle frequency. Finally, considering zero value of error, It normalize to look like line-6 consisting of clock offset (O_i) and clock skew (S_i). It is to be noted that value of clock skew parameter S_i lies between (1-*r*) and (1+*r*), where *r* is optimal rate of drift of hardware clock.

Algorithm for framing clock component

Input: λ_o, $\Delta\lambda$, δ_λ

Output: hardware clock time

Start

1. init λ_o, $\Delta\lambda$, δ_λ
2. $x = \Delta\lambda + \delta_\lambda$
3. Estimate oscillation frequency

   $\lambda_t(t) = \lambda_o + x$
4. Add random error

   $\lambda_t(t) = \lambda_t(t) + \varepsilon_\lambda(t)$
5. Evaluate test-observation time

   $h_i(t) = h_i(0) + (1+y).t$
6. Perform normalization

   $h_i(t) = O_i + S_i .t$

End

2) Algorithm for Constructing Delay-based message

The proposed system performs minimization of the synchronization error by interchanging the control message among the sensors with incorporated information of delay. Normally, the sensors uses control message for performing for perform either route discovery or for using it as acknowledgement for certain message delivery process. In the process of construction of control message, cluster head (CH) plays a big contributory role. The algorithm can process any one form of input at a time i.e. m_1(message for selection of CH), m_2(message for request to perform synchronization), and m_3(response message for synchronization) as shown in line-1. It is defining that control message should take up positive sign if the message of type m_1 is of *query* type or else it takes negative sign of the same message m_1 represents selection of cluster head (line-2). The algorithm than considers all the communicating nodes (line-3), where the node sends request message m_2 to the cluster head (line-4), which upon receiving forwards the response message m_3 to node *i*. Finally, where the response is received by the node i, both node i and cluster head interchanges more information about the local time parameter *lt*. The local time parameter is a set of local time that records timestamp at message forwarding process, message receiving process, response forwarding process, and time at which the cluster head forwards the response.

Algorithm for Constructing Delay-based Control Message

Input: m_1(message for selection of CH), m_2(message for request to perform synchronization), m_3(response message for synchronization), *lt* (local time stamping parameters)

Output: constructing and disseminating control message

Start

1. init m_1, m_2, m_3, *lt*
2. define msg[query]$\rightarrow$-m_1 || msg[select]$\rightarrow$+m_1
3. for i=1:n
4. $\quad i \rightarrow m_2(req(d_i)) \rightarrow CH$
5. $\quad CH \rightarrow m_3(res(d_i)) \rightarrow i$
6. $\quad \overleftrightarrow{CH \Leftarrow lt \Rightarrow node}$
7. End

End

3) Algorithm for Delay-based Routing

The prior two algorithm can easily formulate a message and incorporate in enhancing time synchronization in sensor network considering delay-factor. However, this algorithm is responsible for constructing routes from node to cluster head that finally leads to base station. This algorithm will use a probability theory and network dynamics to estimate delay and then perform compensation of the computed delay while performing routing as well as minimization of synchronization errors. In order to advocate routing in sensor network, we understand that selection of cluster head has been always an essential part of data dissemination process of any wireless sensor network. However, the novelty of an approach is that consider cluster head to perform parallel task apart from data aggregation in the sensor network. In design, cluster head is also responsible for performing flooding operation for its timestamp values in the same simulation area. In proposed system, a node performs broadcasting of the beacons essentially to explore the identity-related information of the cluster head.

The first step of this algorithm basically works in this manner: A sensor broadcast the test beacons and computes the preliminary end-to-end delay after receiving the acknowledgement (or response). Till the computation of preliminary delay, the node doesn't send any other forms of message or data packets. After that the node concatenates the message with identity of the clusterhead. Its compute the delay factor by estimating time spend by both cluster head (to disseminate query message) and member node (to forward query message to its clusterhead itself) (Line-1-5). However, in case of maximum delay, there is a potential probability that the sensor queried for the clusterhead will not receive any response (Line-7). In such case of maximum delay, the sensor performs re-broadcasting of the beacons (m_1). Although the objective of this node is to develop a delay-aware route from a sensor to a cluster head but also will put a condition here for selection of energy-efficient clusterhead. Therefore, only the clusterhead whose residual energy E_{res} is found to be more than certain cut-off level will be considered to perform routing with the enquired sensor. However, when the response is received from the clusterhead, the sensor checks for the identity of clusterhead.

Algorithm for Delay Based Routing

Input: m (message, m_1, m_2, m_3), CH_{ID} (clusterhead ID)

Output: Delay-based routes

Start

1. i→m_1(-1 concat CH_{ID}) //broadcast
2. if (i(m_3)=0)
3. i→m_1 //re-broadcast
4. i←m_3(CH(E_{res}>Th)
5. save CH_{ID}
6. End
7. For (max(d))
8. if (CH_{ID} ~ -ve)
9. m_1=query msg
10. else
11. m_1=selection of CH
12. routeConstruct(CH→broadcast(CH_{ID}))
13. Remove dup(m)
14. End

End

However, if the sensor finds presence of any non-positive values in the inbound delay-aware message, it is considered to be a query message. In such case, if the CH_{ID} is already with the sensor that it directly constructs a route between them. But in case the inbound delay-aware beacon consists of a positive values, than the beacon is considered to be announcement message, which will be again required to be transmitted in the network. In this case of the sensor doesn't have pre-defined information of CH_{ID} (from prior routing table) than it just add it to its tree list and then performs broadcasting of message. The final step will be to construct routes and check for duplicated message in order to remove it. This task is carried out by receiver.

4) Algorithm for Delay Compensation

The proposed system considers a unavoidable network parameter called as delay in order to correctly perform time synchronization in large scale wireless sensor network. One of the interesting points to be noted in this regard is that it is perform computation of the amount of delay, than perform routing. While performing routing, the algorithm also considers compensating an adverse effect of drift of clock as well as offset of clock. This algorithm is a complementary algorithm in proposed routing mechanism. In this process, the sensor will need to scrutinize the inbound message type. In case of positive acknowledge of receiving message, the sensor mark the receiving time as T_{rec}. However, if the other node is not a member node but a clusterhead than its forwards a response beacon that consist of local time stamping parameters *lt*. The part of the algorithm is the computation of two new variables of difference in time stamps i.e. α and β.

Algorithm for Delay Compensation

Input: T_{rec} (receiving time), T_{for}(timestamp at message forwarding process), T_{res}(response forwarding process),
Output: Delay compensation

Start

1. i←m_3
2. Estm T_{rec}
3. If responseGenerator=CH
4. forward lt to CH
5. End
6. estimate delay

$$\Delta = \frac{\alpha - \beta}{2}$$

7. Optimized delay,

T_{CH_res}= T_{CH_res} + Δ

8. Delay compensation

T_{delay_compen}= T_{CH_res}+(T_{res}-T_{loc})

9. Apply Algorithm for Delay-based routing

End

Basically, it compute the variable α as an absolute difference of timestamp at message receiving process (T_{rec}) and timestamp at message forwarding process (T_{for}). Whereas, the other variable β can be computed as mean difference of local time and timestamp for response forwarding process (T_{res}). After the estimation of the network delay Δ due to time synchronization in line-6, the process attempts to add (T_{CH_res}) time at which the cluster head forwards the response (line-7). This adds further optimization part that can be used for minimizing the delay. Finally, perform exact amount of delay (Line-8), which has to be compensated in the entire process of routing continued by prior delay-based algorithm for routing (line-9).

VII. Result Discussion

This section discusses about the outcomes accomplished from the proposed study. The algorithms discussed in the prior section are implemented on Matlab on simple 32 bit windows environment. The simulation parameters considered for the proposed study is highlighted in Table 2.

TABLE II. ADOPTED SIMULATION PARAMETERS

Parameter	Value
Network area(Simulation) area	1000 x 1200 m^2
Nodes	50-500
Clock speed	$3x10^3$ Hz
Simulation Iterations	1000
Path loss exponent	0.5
MAC Type	802.11
Traffic Model	CBR
Channel capacity	300 kbps
Channel sensing time	0.2 sec
Control packet size	32 bits
Data packet size	2000 bytes
Antenna Model	Omni-directional
Transmission range	10m
Transmission Energy consumption	0.5 J
Receiving Energy consumption	0.25J
Ideal mode Energy consumption	0.035 J
Sleep mode Power consumption	0.02J
Initial battery Energy of each node	10J

In order to perform comparative analysis, choose to compare proposed OTSA with prior technique of time synchronization viz. TFTS [25] and E^2TS [29]. The rationale behind this selection for comparative analysis is discussed as below:

1) Reason for selecting TFTS [25]: We have modelled TFTS [25] for the reason that it is one of the techniques that provides three different types of algorithm in order to meet three different circumstances of time synchronization in sensor network. Designed using probabilistic technique, TFTS [25] uses graph theory to provide hypothetical time synchronicity, empirical time synchronicity, and optimized time synchronicity. A closer look into the outcome of TFTS [25] will show that it is scalable and have exhibited good performance in form of error minimization of time synchronicity. However, TFTS [25] couldn't answer how much energy efficient it is or how much capable it is to control the communication overhead. It is quite understood that maximum of the routing protocols in sensor network works on retransmission scheme with increase of rounds. This phenomenon will lead to formation of duplicated message during data aggregation which will definitely increase the communication overhead. Hence, it choose TFTS [25] to understand its effectiveness with rest of the protocols with new performance parameters.

2) Reason for selecting E^2TS [29]: have designed E2TS [29] in order to overcome the energy gaps in the prior TFTS [29]. Using standard radio-energy model, we develop a simple modelling of clock along with framing up the control message. The prime focus was laid on the minimizing i) time synchronization errors and ii) energy consumption in sensor network. The mathematical modelling involved in E^2TS [29] uses clock drift, offset, and skew for designing the modelling of hardware clock. It also considers formulation of a control message with source node ID, message ID, and intermediate hop ID, destination node ID, and time factor. The outcome of the E^2TS [29] was also compared with the standard techniques of time synchronization to find it more energy efficient with less errors. However, this model has more scope of improvement if the modelling is carried out by considering the delay factor. As stated in algorithm implementation section, consideration of transmission delay has a significant effect on both clock drift and skew. The analysis of the situation becomes more challenging if the sensor nodes works on multihop communication base leading impediment to accuracy rate. Hence, E2TS may claim better energy efficiency, but strongly felt that its capability to minimize synchronization error could be more enhanced. Therefore, it can be said that proposed study of OTSA is an enhanced work of E^2TS [29].

3) Reason for selecting PulseSync [21]: This protocol was found to offer a better scalability specifically designed for distributed and large scale wireless sensor network. PulseSync is the latest protocol to overcome the accuracy problems in other flooding based approaches in time synchronization in sensor network. The technique uses sleep scheduling for energy conservation. An adverse effect of propagation time was found to be reduced by MAC layer based time stamping. The author also uses regression and flooding technique. However, it was found that skew value was kept very small initially in this work inspite of computing the original value. Unfortunately, PulseSync is not fault tolerant with its scalability property till questionable. Moreover, PulseSynce was only tested for minimized errors in time synchronization and it doesn't really prove its extent to communication overhead or computational complexity.

Therefore, it implement all the above stated techniques of time synchronization using common simulation parameters stated in Table 1 with respect to proposed OTSA which performs three different task of i) delay-based routing ii) enhancing network lifetime, and ii) optimizing time synchronous in large scale sensor network. Table 3 shows the numerical outcome accomplished after implementing the proposed OTSA along with other existing techniques for comparative performance analysis with respect to overhead, synchronous error, energy, and processing time.

TABLE III. NUMERICAL OUTCOMES OF COMPARATIVE ANALYSIS

		Existing System			
	No. of Nodes	**PulseSync [21]**	**TFTS [25]**	**E^2TS [29]**	**OTSA**
Communication Overhead (bits)	50	20.21	14.26	12.35	12.34
	100	25.38	17.28	14.28	14.26
	150	27.41	21.76	19.76	18.77
	200	30.01	28.76	25.26	18.97
	250	31.56	30.98	26.78	19.36
	300	34.76	32.87	27.86	21.01
	350	50.38	42.09	29.31	22.53
	400	52.38	43.21	29.84	22.54
	450	53.98	43.35	29.98	22.56
	500	60.01	43.31	30.07	22.57
		Existing System			
	Iterations	**PulseSync [21]**	**TFTS [25]**	**E^2TS [29]**	**OTSA**
Synchronization Errors (ms)	100	0.752	0.535	0.419	0.534
	200	0.751	0.527	0.417	0.534
	300	0.746	0.519	0.408	0.512
	400	0.703	0.479	0.374	0.415
	500	0.693	0.489	0.369	0.409
	600	0.638	0.497	0.355	0.351
	700	0.617	0.462	0.345	0.317
	800	0.599	0.428	0.329	0.302
	900	0.555	0.362	0.318	0.203
	1000	0.528	0.361	0.303	0.106
		Existing System			
	Data (bytes)	**PulseSync [21]**	**TFTS [25]**	**E^2TS [29]**	**OTSA**
Total Energy Consumption (J)	1500	3.34	4.87	3.76	2.54
	2000	3.45	4.89	3.87	3.32
	2500	4.63	4.98	3.99	3.65
	3000	4.79	5.28	4.25	3.74
	3500	5.37	5.36	4.37	3.89
	4000	5.39	5.55	4.55	3.98
	4500	6.02	5.89	4.78	4.01
	5000	6.77	6.32	5.29	4.1
	5500	7.28	7.56	5.36	4.28
	6500	8.99	7.59	5.59	4.29
		Existing System			
	Data (bytes)	**PulseSync [21]**	**TFTS [25]**	**E^2TS [29]**	**OTSA**
Processing Time (s)	1500	310	389	372	250
	2000	363	392	375	251
	2500	376	399	379	257
	3000	389	417	389	269
	3500	394	439	393	278
	4000	410	463	410	287
	4500	499	478	428	288
	5000	519	482	455	292
	5500	535	495	458	295
	6500	555	501	471	299

The above Table 2 shows the numerical outcomes for 4 different performance parameters e.g. communication overhead measured in bits, time synchronization errors measured in milliseconds, cumulative energy being consumed measured in Joule, and algorithm processing time measured in seconds. The numerical outcome obviously shows that proposed OTSA has outperformed the existing system. More discussion on the performance parameters are as follows:

1) Analysis of Communication Overhead

As the proposed system performs time synchronization based on delay-based routing, hence it bears a strong relationship with communication overhead. With more number of sensors adding, overhead could be anticipated to be more. The graphical outcome shown in Fig.2 exhibits that PulseSync [21] posses significant communication overhead which is due to incapability of supporting network dynamics and multihop communications in sensor network. TFTS [25] is found lower communication overhead owing to its supportability of multihop network. However, TFTS [25] can likely show the hypothetical outcomes in case of dynamic traffic, which is overcome using E^2TS [29]. E^2TS [29] significantly considers authenticating the messages for time synchronous and thereby controls the overhead to a very large extent. OTSA further enhances this using optimization technique where transmission delay was emphasized in conjunction with routing approach supporting multihop network with network dynamics.

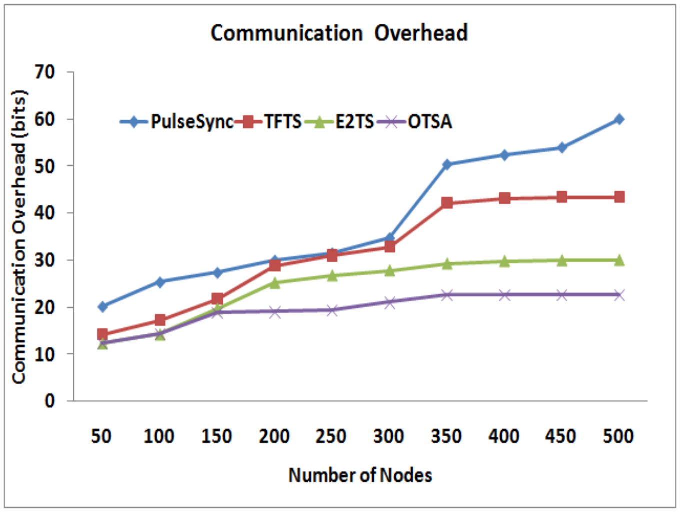

Fig. 2. Analysis of Communication Overhead

2) Analysis of Synchronization Errors

Fig.3 showcases the synchronization errors with increasing iterations (100-1000). The outcome clearly shows that OTSA has significant improvement with respect to existing protocols. PulseSync [21] has somewhat pattern of better descend in its curve, but owing to significant overhead its further scope for minimizing errors cannot be further optimized. TFTS [25] and E^2TS [29] was found with better error minimization capabilities owing to its design flexibility, message formulations of exchanging the synchronous time. Similarly, proposed system of OTSA has further enhancement by incorporating multiple mechanism of evaluating local time stamping procedures. An error minimization process was completely based on the three different forms of control message for time synchronization during clustering and data aggregation stage that results in effective computation of actual and run-time delay causing the network to respond faster. Hence OTSA exhibits less error in time synchronization compared to existing approaches.

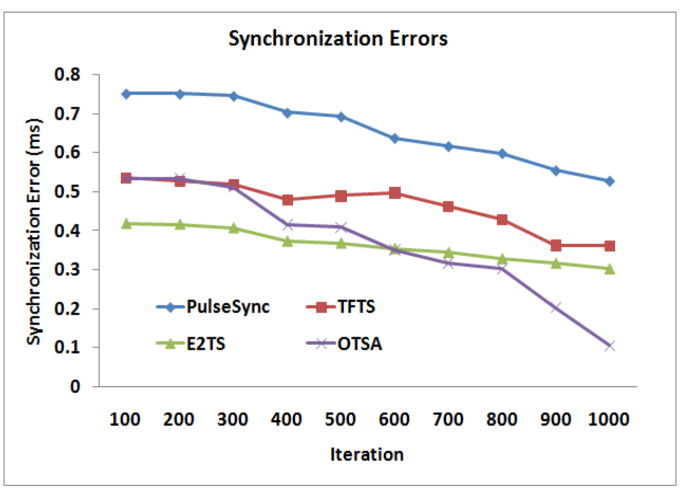

Fig. 3. Analysis of Synchronization Error

3) Analysis of Network Lifetime

Establishing a better balance between communication (with less time synchronous error) and energy consumption is one of the challenging tasks which is addressed in OTSA using delay-based routing approach. Using a simple first order radio model, OTSA only uses transmittance energy after the estimation of the synchronous error is computed which is carried out in the route discover process itself. Hence, transmittance time is almost unchanged and is not affected even in increasing number of the inbound data to be aggregated in OTSA. Hence, OTSA provides better network lifetime. However, PulseSync [21] performs extra processing almost in all the steps of data aggregation just to ensure drift minimization, which drains more energy. The prior TFTS [25] and E^2TS [29] scheme also has better supportability of energy efficiency as compared to PulseSync [21]. However, OTSA has significant reduction f skew resulting is lesser probability of retransmission event, which significant maximum extent of energy consumption in OTSA. Therefore, it exhibits linearity in its controlling strategies for energy consumption.

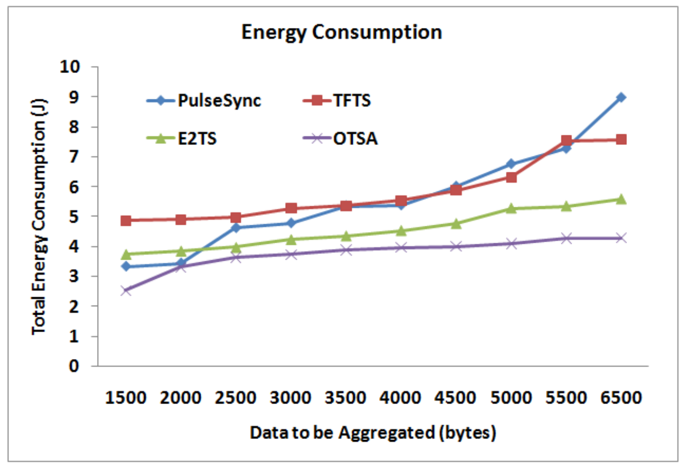

Fig. 4. Analysis of Energy Consumption

4) Analysis of Processing Time

Algorithm processing time plays an essential performance parameter to justify its effectiveness as sensors have lesser computational capability with availability of resources. It is quite natural that processing time will always have increasing trends with increasing number of the data packets to be processed during data aggregation. The processing time of PulseSync [21] was found to be almost linearly increasing which also states why PulseSync consumes more energy. Similarly, prior TFTS [25] and E^2TS [29] has been witnessed with faster convergence time owing to usage of graph to be working on multihop networks. OTSA provides further improvement by considering delay factor, which is non-iterative in nature causing the algorithm to converse faster. Hence, algorithm processing time is quite lower in proposed OTSA as compared to existing approaches.

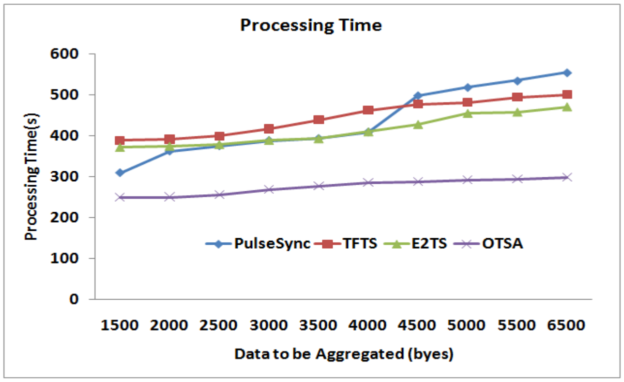

Fig. 5. Analysis of Processing Time

VIII. CONCLUSION

The proposed system has presented a novel technique those combinely addresses the problems of clustering, selection of clusterhead, routing, time synchronization. This study is the first attempt to address all the above stated problems in one technique. It use first order radio model and developed a technique which allows a node to live longer. It uses a threshold-based technique which ensures whenever a clusterhead reaches the cut-off values of threshold energy level; it converts itself to member node, which is quite different than existing techniques of clustering. Also, develop a technique that allows the sensor to share the time stamp information of the local clock in the broadcasting stage itself. Using this technique, the sensors (be it member node or clusterhead) are in better position to formulate a routing protocol by estimating delay. This design principle has a significant benefit that allows the sensor to rectify the errors in synchronization and then perform forwarding of the data. The best part of the technique is its capability to forward the data packet with extremely less probability of the packet drop that could lead to retransmission. The outcomes of the study is found to provide superior outcomes with respect to communication overhead, synchronization errors, extent of energy consumption, and algorithm processing time.

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Formal Specification of a Truck Geo-Location Big-Data Application

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***Abstract*—In the last few year's social networks, e-commerce, mobile commerce, and sensor networks have resulted into an exponential increase in data size. This data comes in all formats i.e. structured, un-structured and semi-structured. To efficiently extract useful information from these huge data sources is important. This information can play a central role in making future decisions and strategies. A truck geo-location big-data application integrated with formal model is proposed. The truck geo-location data is un-structured and it is accessed and manipulated by Hadoop query engine. Labelled transition system based formal model of the application is proposed to ensure safety and liveness properties of correctness.**

Keywords—Big-data; Formal methods; Correctness properties; Safety; Liveness; Internet-of-Things (IoT); MapReduce; Hadoop Distributed File System (HDFS); Finite State Processes (FSP); Labelled Transition System (LTS)

I. INTRODUCTION

During the last few years, with the increasing use of sensor networks and social networks, the data size has increased very rapidly. This huge amount of data is not easy to maintain and modify, and is of no use if not treated in an organized way. Conventional techniques are not sufficient for getting useful information from these huge amounts of data. Big-data sources are social networks, e-commerce, mobile commerce, and sensor networks. Relational database is a structured way of representing data. Big-data can be structured, un-structured, or semi-structured; and data-type cannot be easily defined. Therefore, managing and processing un-structured data is different than structured data. Big-data cannot be processed and managed by using traditional algorithms and techniques. It is huge in size and is generated at a much faster rate than traditional data. In order to efficiently process big-data, appropriate processing capabilities, proper hardware, with efficient algorithms are required. For processing, analyzing, and transferring big-data large space and high bandwidth is required. Data science deals with the huge amount of data i.e. data retrieval, data processing and data manipulation.

The first and the most challenging task is to ensure correctness of the methodology used for the extraction and manipulation of big-data i.e. verification of the process of data extraction and analysis. The step of verification is important and it affects the whole process of data analysis. The verification of data extraction methods and techniques can be made more reliable by introducing formal methods and techniques. Formal methods and techniques can be applied for accessing, searching, and storing big-data. Statistical analysis can be performed on big sets of data to extract useful information for future decision making, and proposing future roadmaps and strategies.

Why Big-Data?

With the advent of social media, e-commerce, and Internet of Things, use of sensor devices have increased and the data size are huge. The data generated can be dig up and proper meaning can be extracted for making future planning. Big-data extraction and analysis make a business follow pro-active approach. A pro-active business analyzes the current and past situation of business and also compare the changes made by other businesses and prepare the new business policy to be launched. Big-data analysis helps a business to make better future strategies, policies, and decisions. Each big-data set contains huge amounts of data and correct methods are required for the extraction and analysis of these big-data sets.

Why Formal methods?

Formal methods are based on mathematical logics, proofs and formulas. These methods give precise and accurate answers. Use of formal methods on each step of data analysis minimize significantly the probability of errors.

II. MOTIVATION

Data is the most important part of any organization. There are huge sets of sensor data, data size are huge and data growth is fast. Big-data has a tremendous scope, and by performing statistical analysis of huge quantities of data; future forecasts can be made; better strategies can be proposed; and businesses can be improved.

The use of formal methods for specification and verification of the process of data extraction is very recent. Now big-data is an important aspect of data science, and formal verification has its own importance. There is a need to propose correct methods for the analysis and design of big-data based applications. In this paper, formal specification and verification for big-data based truck-geolocation application is proposed.

III. PROBLEM STATEMENT

Formal modeling and verification of a system that generates, extracts, and analyzes massive sets of data. This work addresses the following research questions:

***RQ-1**: Why correctness is important in the process of big-data storage, retrieval, and analysis?*

***RQ-2**: How the process of big-data storage, retrieval, and analysis can be formally verified?*

***RQ-3**: How the process of big-data storage, retrieval, and analysis can be made correct?*

A truck geo-location system is formally modelled in the form of a labelled transition system and verified. Queries are applied to massive sets of data and extracted data is analyzed. For this purpose Apache Hadoop is used. Apache Hadoop is an open source framework for the processing of big-data in a distributed environment. Hadoop has two main and distinct features. These features are Hadoop Distributed File System (HDFS) and MapReduce. HDFS is a distributed file system which provides scalable and reliable storage medium. It stores huge amount of data and is reliable. It can easily deal up to 200 PB of data and can easily be scalable up to 4500 severs. MapReduce consists of two further functions of Map and Reduce. Statistical analysis of big-data based truck geo-location system is proposed, then formal specification and verification of the methodology is proposed.

IV. State of the Art

A. Formal methods

Formal methods have a mathematical foundation. The fundamental use of formal methods is in ensuring correctness. They provide a concise and precise representation and proofing of a software model. Formal methods and techniques use algorithms, logics, predication, proofs, propositional calculus and first-order predicate calculus.

A formal language is an alphabet of symbols and a set of grammar rules used to construct well-formed formulas from the alphabet [18]. A broad view of formal methods includes all applications of (primarily) discrete to software engineering problems. Formal application involves modeling and analysis where the models and analysis procedures are derived from or defined by an underlying mathematical precise foundation [19]. Abstract State Machines, B-method, Event-B and Colored Petri Nets are some examples of formal languages. Colored Petri-net is a mathematical and graphical modeling technique widely used for specification and verification purpose [20].

Formal verification focuses on safety and liveness properties of correctness. Both of these two properties are critical to assure correctness. They complete each other (i.e. safety or liveness alone is not sufficient to ensure system correctness). Liveness property relates with the execution and working of a model and is concerned with a program eventually reaching a good state. Safety property assures that nothing bad will happen in the model. Safety is concerned with a program not reaching a bad state [21]. Labelled Transition System (LTS) [21] is a finite state machine which specifies and verifies the functional behavior. It models a system in the form of states and transitions. It consists of all the states which a component can reach and all the possible transitions that it may perform. It mechanically checks that a system is satisfying all the mentioned properties.

B. Big-data

Big-data is huge in size that use special processing algorithms and methods that are capable of processing peta-bytes of data within finite time. Big-data has to be analyzed for making future strategies and decisions. Analyzing the data in minimum time is important. Data is the most important component in computer science. Data science is the field which came in to existence after the peta and zeta-bytes of data. Data science is rebranding of computer science and applied statistical skills [1].

Data size is increasing day by day due to Internet-of-Things (IoT), social media, and e-commerce. IoT enables the physical objects to connect wirelessly and communicate with one another using sensors. These devices share million bytes of data within few seconds. This communication generates huge amounts of data continuously. IoT are a major source of big-data, communicating massive amounts of streamed information from billions of Internet-Connected Objects (ICO's) [2]. With the use of IoT, the number of challenges have also increased. These challenges range from capturing and storing data; processing and analyzing the captured data and managing communication in such a way that those users can seamlessly search, find and utilize their data [3].

Big-data analyzed the data to find and extract out the useful information. The patterns and trends of data have to be studied for analyzing and gaining knowledge. The whole designed process of finding patterns in big sets of data is data mining. In data mining the exact groups and patterns of data are searched and extracted [4]. According to NIST [5] in big-data the data volume, acquisition speed, data representation limits the capacity of using traditional relational methods to conduct effective analysis or data which may be effectively processed with important horizontal zoom technologies.

Big-data requires new technologies and architecture for its processing and analysis purpose, and it cannot be processed and managed using traditional relational database models [6]. In a big-data based system the data generation speed is more than its storing and capturing speed [7], therefore data size is huge in every dimension, and normal algorithms are not suitable for data processing. Big-data is a comprehensive term for all the huge and complex sets of data which are not able to store, process and curate under traditional means [8]. Essence of big-data is not only massive data processing, but also optimization of real world knowledge which is extracted from such a huge data [9]. [10] Define big-data as 3 V's model. The 3 V's are its *volume*, *velocity* and its *variety*. [11] Define big-data as 4 V's and these are *volume*, *variety*, *velocity* and *value*. *Complexity* can also be added to these 4 V's. Complexity means that storing and capturing of big-data is not easy. The fast speed and huge size make big-data complex to process.

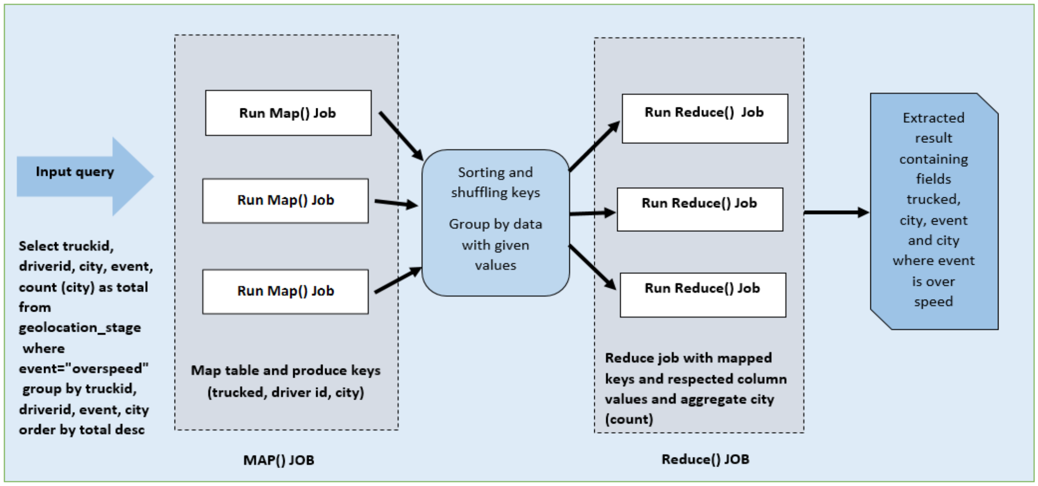


Fig. 1. Parallel model for Data Extraction and Formal Verification

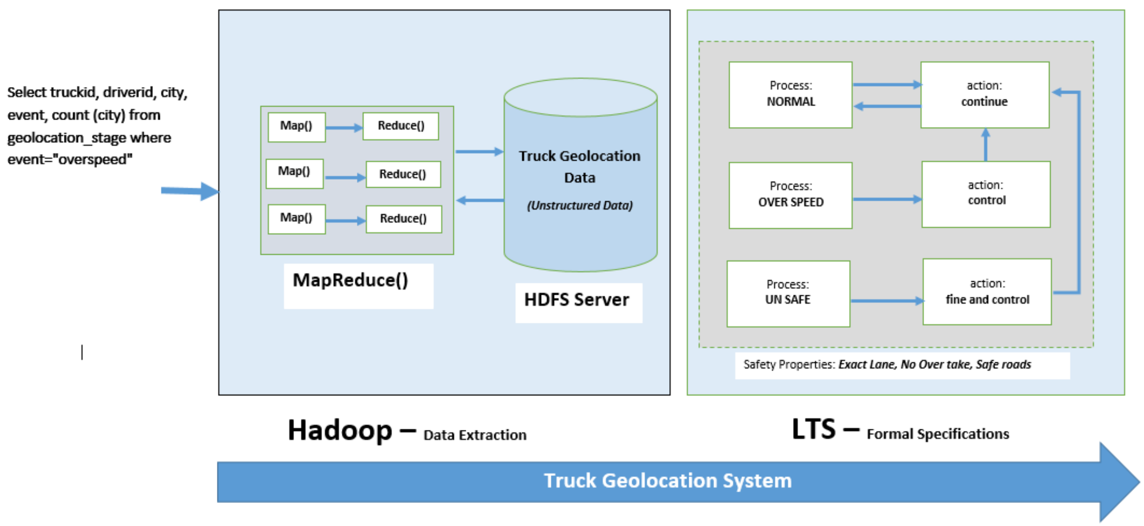


Fig. 2. Data mapping and reduction

Big-data describe the voluminous amount of structured, un-structured (i.e. data from social media, sensors, research, online shopping, scientific application and surveillance) and semi-structured (i.e. xml) [12]. Big-data defines a set of data that actually grows exponentially, that is too raw and too unstructured and difficult to process by the conventional methods [13]. Big-data not only handles and utilizes large amounts of data but also utilizes various types of data including unstructured data and attributes [14]. Major challenges in big-data environment is its security and privacy. The process of analyzing data by applying theorems, procedures, and algorithms for finding patterns and to extract accurate required knowledge is known as data analytics. Analyzing data is more challenging than data organizing, managing, storing, and processing [15]. The scalability of the data analytics process i.e. whether data analytics process scales as data sets increases is a major issue [16]. Data has no meaning and possess very low value by itself. Many organizations are collecting different types of data of very high volume, at a very high velocity. This collected big-data is analyzed using big-data analytics. As a result, organizations can get deeper knowledge about their business and customers' behavior, eventually making better forecasting and decisions [17].

MapReduce plays a vital role in the processing and analysis of big-data. Its features of fault-tolerance, scalability, and simplicity make it useful for processing big-data by using its two main functions of map() and reduce(). The explosive growth of big-data processing imposes a heavy burden on computation, storage, and communication.

V. Big-Data Based Truck Geo-Location System

A. Proposed Approach

The main purpose of data extraction is to give data a proper meaning. Some of the techniques which are followed to analyze big-data are Association Rule Learning, Data Mining, and Cluster Analytics. All of these techniques are adopted with the aim to analyze data to get the desired results.

Model checking is applied to get *correctness*, *preciseness*, and *accuracy*. They can be applied to any extent to any step in the data analysis process. A model has been proposed in which formal specification for the truck geo-location system is proposed. A user generates a query and graph for the extracted results. Finite State Processes based Labelled Transition System verifies the processes of data extraction and check all possible paths.

B. *Requirement Elicitation and Data Extraction*

The main purpose of modeling a verified system is to eliminate the errors and chances of failure at very initial level. This system is proposed to enhance the use of formalism in every step of big-data analysis. A query without verification leads to false extraction of data or may disturb the whole process of data analytics from the start of procedure. The goal of big-data analytics is to provide the useful and required information from the huge sets of data. This information helps to make statistical analysis which leads to future strategies and decisions. The formally verified big-data analytics provide the true means of data extraction and decisions based on the extracted results.

Hadoop divides the input stream into smaller independent chunks which are processed in a concurrent manner. The MapReduce paradigm sorts the output of the mapped data. Hadoop works with a number of components. These components work together to facilitate the whole procedure. Major components of Hadoop are HDFS (Hadoop Distributed File System), MapReduce, Ambari, Yarn, and Hive. HDFS provides access to application data and it's very useful for the applications that contain huge data sets. It is like a distributed file system and it provides an environment of shared resources that can be accessed simultaneously. It provides a fault-tolerant system, and it is particularly designed to be deployed on low cost hardware. It has a common Master-Slave architecture. It has a single, master name-node which not only manages the whole file system but also controls the access to file system by different clients. It also manages its slave-nodes which are known as data-nodes. Data-nodes are responsible for managing data storage related to the system. Data-nodes also perform various tasks including creation, deletion and replication of data blocks as instructed by the name-node. Second major component of Hadoop is MapReduce. MapReduce is responsible for parallel processing of huge data sets. It works in a reliable and fault-tolerant manner. MapReduce framework divides a huge set of data into independent chunks. These chunks are then processed by map tasks. After processing the framework sorts the output. This sorted output becomes the input for the Reduce task. Reduce task perform the summarizing operations on the data.

C. *Formal modelling*

The proposed model focuses on the use of formal specifications with Hadoop. A query which is deployed on Hadoop system is modelled in LTS. The possible states and transitions of data extraction process is modelled. All the conditions mentioned in query can be represented as processes and actions of FSP which generates LTS. These processes are constituted by series of actions that define behavior. Once the query is modeled, the next step is to execute it using the Hadoop framework. Hortonworks is one of the implementation of Hadoop. The query is deployed on Hadoop using Hortonworks. This query generates the required set of results from the bulk of data.

Big-data analysis is important as it helps in future predictions, future policies and business decisions. Future policies for the trucks travelling in different cities of a state can be proposed.

The data sets basically contain two large log files. First log file named geolocation contains all the data related to the location with the related truck. It contains 10 fields including *truck id*, *driver id*, *event*, *latitude*, *longitude*, *city*, *state*, *velocity*, *event_ind* and *idling_ind*. It contains huge amount of data sets of related trucks and area. The other log file named trucks contains all the data sets related to the trucks that are travelling in these areas. It contains more than 90 fields containing truck id, driver id, model and the gas consumption by every truck from January 2009 to June 2013. Both of log files are actually linked with truck id and driver id. Each driver has its own truck which can travel in any area. Event field in geolocation actually represent the speed limit of truck. It has five instances normal, over speed, unsafe following distance, unsafe tail distance and lane departure. This information can help to figure out the truck that are doing over speed, and can also make an analysis about the trucks and the respective truck drivers. Analysis can also be done by taking the longitude and latitude to trace the exact location which is travelled most of the times. This analysis helps to find which road is frequently used and it also helps to make new policies while planning and making new road in a specific area.

```
SELECT truckid, driverid, city, event, count (city) as total
  from geolocation_stage
    where event = "overspeed"
      group by truckid, driverid, event, city
        order by total desc;
```

The event field in log file geolocation mentioned different events occurred during driving. This includes five instances. A query can be applied to find out which truck is doing over-speed maximum time and at which location. This information can further be used to take an action against the drivers who are doing in an unsafe manner. Future security measures can be applied on the generated data.

This query fetches the truck id, diver id, city, event and total city count where drivers did over speed. The data is arranged in the descending order and grouped by truck id, driver id, event and city.

The actual process of Map and Reduce can also be monitored and displayed in the Hortonworks. This shows how the data is fetched using MapReduce() function. The log files contain thousands of rows and huge amount of data. From this data the required precise information is extracted.

Query Process Results (Status: SUCCEEDED)

Logs Results

Filter columns...

truckid	driverid	city	event	total
A51	A51	Modesto	overspeed	2
A24	A24	Napa	overspeed	2
A60	A60	Apple Valley	overspeed	2
A7	A7	Santa Rosa	overspeed	2
A97	A97	Lodi	overspeed	2
A10	A10	Apple Valley	overspeed	1
A11	A11	Willits	overspeed	1
A12	A12	San Pablo	overspeed	1
A13	A13	Lodi	overspeed	1
A13	A13	Willits	overspeed	1
A14	A14	San Quentin	overspeed	1
A14	A14	Willits	overspeed	1
A16	A16	San Pablo	overspeed	1
A17	A17	Arbuckle	overspeed	1
A17	A17	Roseville	overspeed	1
A18	A18	San Quentin	overspeed	1

Cities visited maximum times

The query extracts the total number of times a city is visited. It shows the city with maximum visits at the top. It shows which truck visited which specific city with total number of visits. This information facilitates the development of new roads infrastructure. Cities with the maximum truck visits can be shortlisted, therefore useful information like if more roads are needed to that specific city can be found out.

```
SELECT truckid, city, count(city) as cities
   from geolocation_stage
      group by truckid, city
         order by cities desc;
```

The query fetches the truck id, city and count (i.e. total number of visits) of a particular city by a specific truck. The result is arranged in descending order with respect to count and also the data is grouped by truck id and the city so that each row will depict which truck visited which city and how many times.

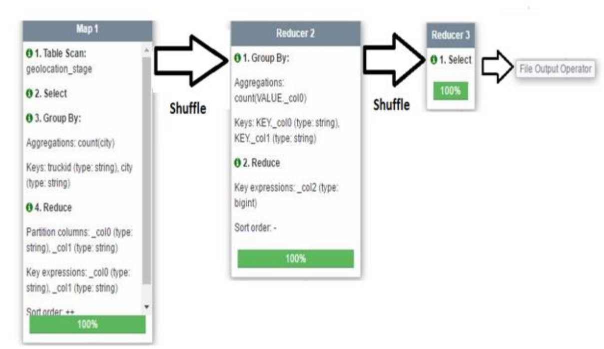
Query Process Results (Status: SUCCEEDED)

Logs Results

Filter columns...

truckid	city	cities
A85	Santa Rosa	27
A84	Santa Rosa	26
A92	Santa Rosa	22
A65	Santa Rosa	21
A38	Santa Rosa	21
A3	Santa Rosa	20
A57	Santa Rosa	20
A49	Santa Rosa	20
A58	Santa Rosa	19
A11	Santa Rosa	19
A80	Santa Rosa	19
A12	Santa Rosa	19
A81	Santa Rosa	19

The MapReduce operation performed in the query is also visualized in a map or tree structure to show the actual operations performed on the query. It displays each step of Map() and Reduce() operations performed on the data.



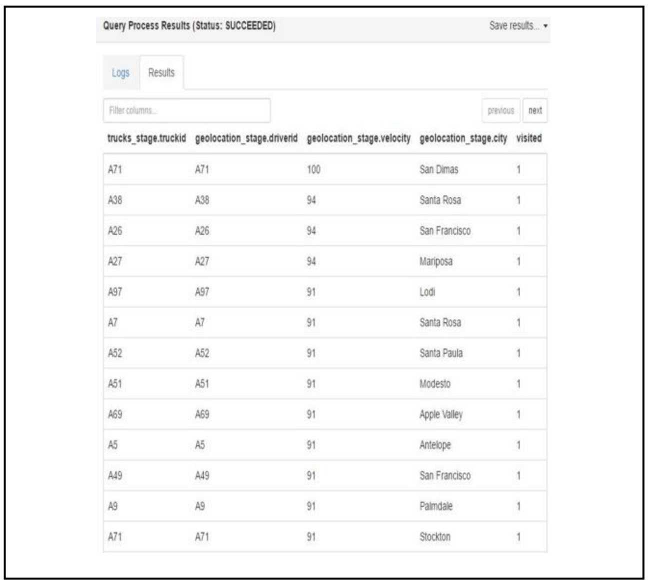
Graph can also be made to analyze quickly from the extracted data that can give a complete understanding of data. In the graph, it can be seen clearly which truck is visiting which city for how many times.

Truck moving with the highest speed

```sql
SELECT trucks_stage.truckid, geolocation_stage.driverid,
 geolocation_stage.velocity, geolocation_stage.city,
  count (geolocation_stage.city) as NoOfVisits
   from trucks_stage, geolocation_stage
     where trucks_stage.truckid = geolocation_stage.driverid
     group by trucks_stage.truckid, geolocation_stage.driverid,
       geolocation_stage.velocity, geolocation_stage.city
         order by geolocation_stage.velocity desc;
```

This query identifies the truck that is moving with highest speed. It shows the respective drivers. It helps to make complete analysis about the truck drivers by showing their trucks, velocity and the cities they visited

The query joins geolocation data and truck data by using ‘when’ condition with truck id. As truck id is making a link between the two. After joining the two tables, the query fetches the mentioned fields (truck id, driver id, velocity and city). This result leads to a complete analysis about truck drivers, their velocity and cities where they travelled. This result of query is basically focusing on the information of truck drivers.



Query Process Results (Status: SUCCEEDED) Save results...

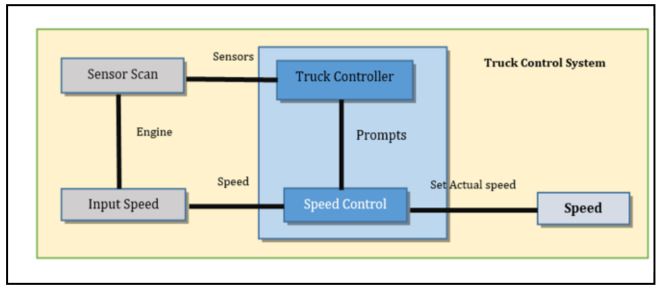
Logs Results

Filter columns... previous next

trucks_stage.truckid	geolocation_stage.driverid	geolocation_stage.velocity	geolocation_stage.city	visited
A71	A71	100	San Dimas	1
A38	A38	94	Santa Rosa	1
A26	A26	94	San Francisco	1
A27	A27	94	Mariposa	1
A97	A97	91	Lodi	1
A7	A7	91	Santa Rosa	1
A52	A52	91	Santa Paula	1
A51	A51	91	Modesto	1
A69	A69	91	Apple Valley	1
A5	A5	91	Antelope	1
A49	A49	91	San Francisco	1
A9	A9	91	Palmdale	1
A71	A71	91	Stockton	1

Labelled Transition System based verification

Verification ensures system correctness. The use of labelled transition system ensures correctness of the truck geolocation system. As these trucks are moving in different cities, a model has been proposed that checks and verifies the working of trucks and maintains the pattern on which they are moving. A model based on labelled transition system is proposed. The model is constituted of processes and actions. Well-defined requirements lead to a well-defined model. This formal model specifies the properties of liveness and safety. *Liveness property* assures that system will work and *safety property* assures that nothing bad will happen in the model. The process SAFETY assures that the truck geolocation system is working.

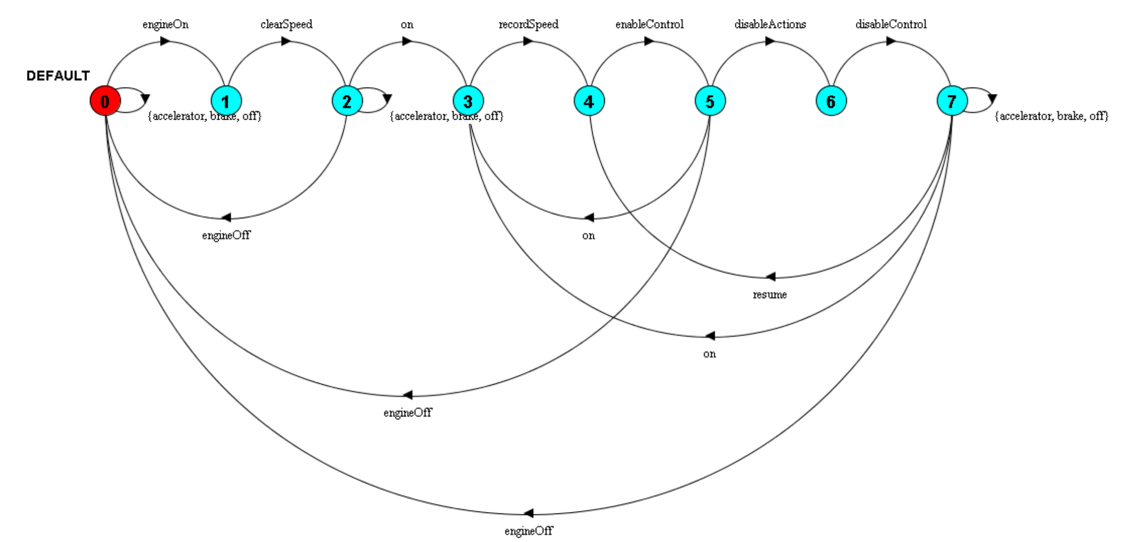


Model - Structure and actions

Model - Design, Process and Actions Truck Controls model

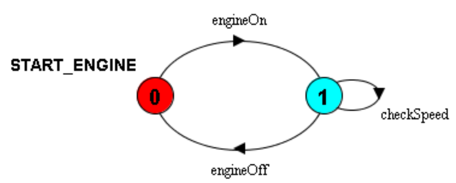
```
////  Engine Control Actions  ////
set ControlActions = {off, brake, accelerator}

TRUCK_CONTROLLER = INACTIVE,
INACTIVE = (engineOn -> clearSpeed -> ACTIVE
               | {ControlActions} -> INACTIVE),
ACTIVE = (engineOff -> INACTIVE
               | on -> recordSpeed -> enableControl -> MOVING
               | {ControlActions} -> ACTIVE),
MOVING = (engineOff -> INACTIVE
               | disableActions -> disableControl -> STANDBY
               | on -> recordSpeed -> enableControl -> MOVING),
STANDBY = (engineOff -> INACTIVE
               | resume -> enableControl -> MOVING
               | on -> recordSpeed -> enableControl -> MOVING
```

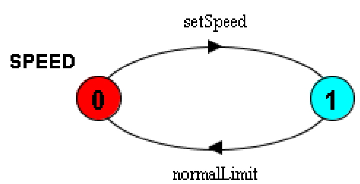
```
                | {ControlActions} -> STANDBY).
```

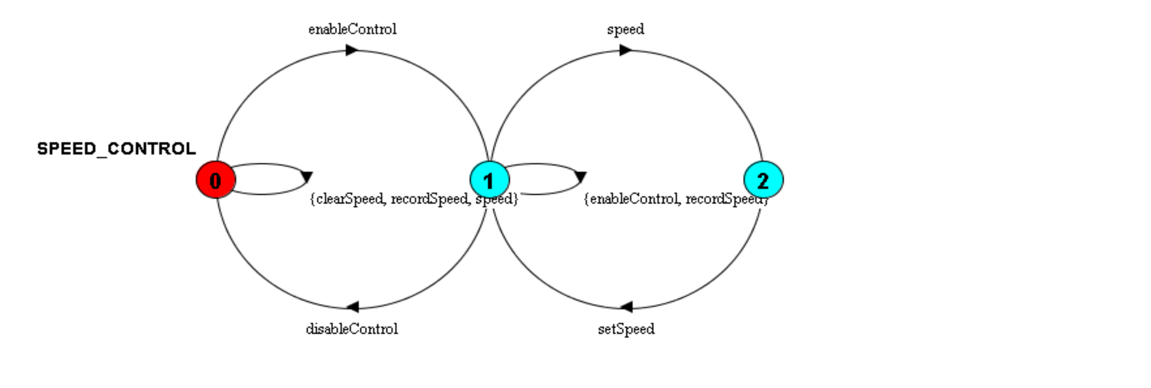


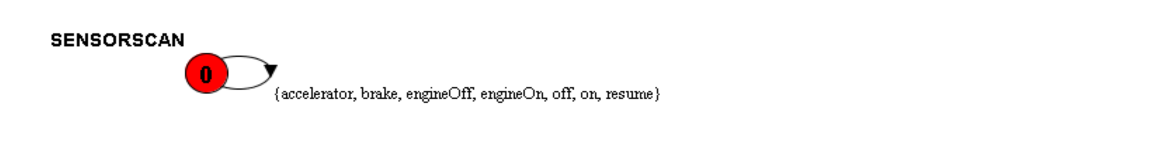
Truck Speed Sensors model

```
//// Truck Sensors ////
set Sensors = { engineOn, engineOff, on, off, resume, brake, accelerator }
//// Engine States ////
set Engine = { engineOn, engineOff }
//// Scan the Sensors ////
SENSORSCAN = ({Sensors} -> SENSORSCAN).
//// Start Truck Engine ////
START_ENGINE = (engineOn -> CHECK_SPEED),
//// Check Truck Speed ////
CHECK_SPEED = (checkSpeed -> CHECK_SPEED | engineOff -> START_ENGINE).
SPEED = (setSpeed -> normalLimit -> SPEED).
//// Truck Speed Control  ////
SPEED_CONTROL = DISABLED,
DISABLED = (  {speed, clearSpeed, recordSpeed} -> DISABLED
             | enableControl -> ENABLED ),
ENABLED = (  speed -> setSpeed -> ENABLED
           | {recordSpeed, enableControl} -> ENABLED
           | disableControl -> DISABLED).
```



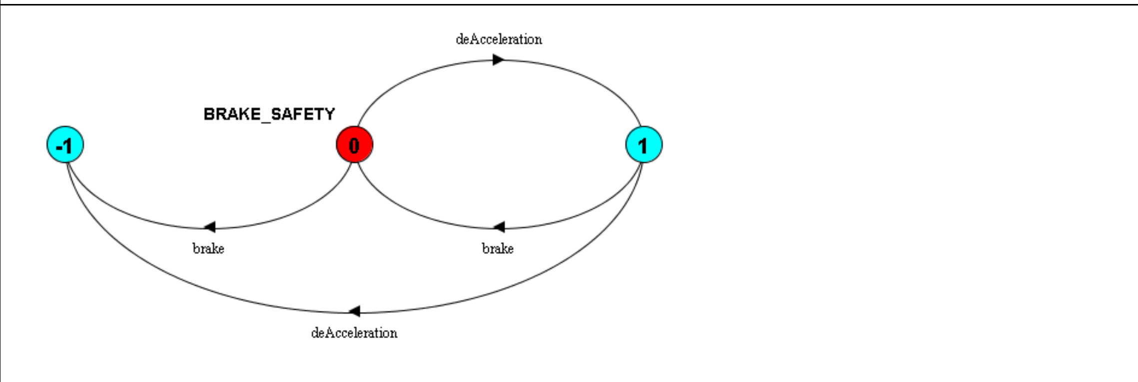


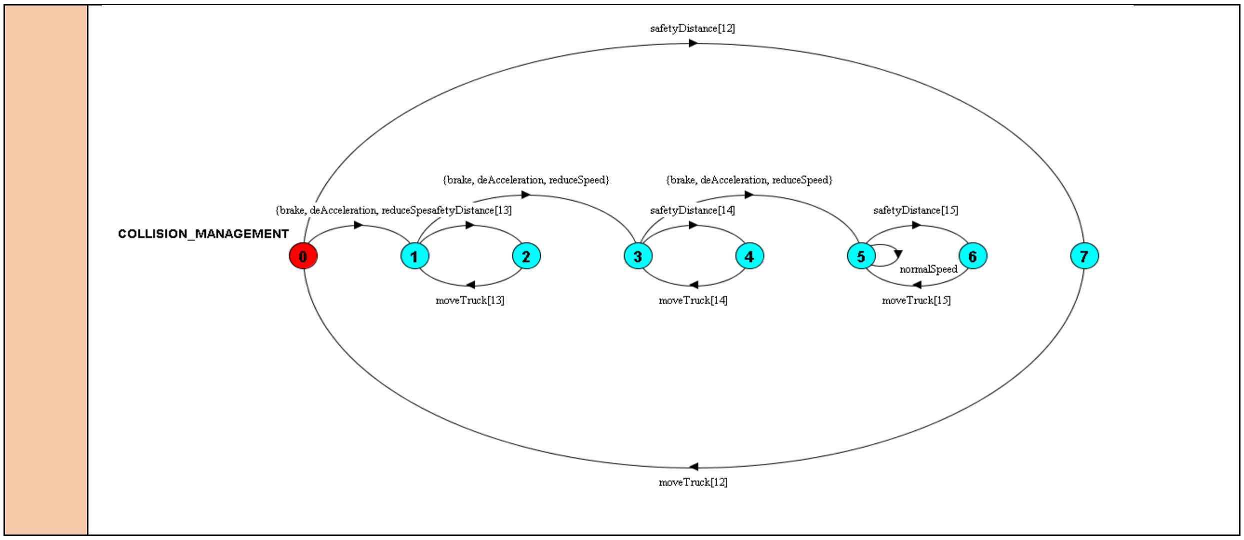




Truck Safety properties – Brake safety and Collision avoidance properties

```
property BRAKE_SAFETY = (deAcceleration -> brake -> BRAKE_SAFETY).

set DecreaseSpeed = {reduceSpeed, brake, deAcceleration}
const MinDist = 12   /// minimum safety distance
const MaxDist = 15   /// maximum safety distance
range R = MinDist..MaxDist

COLLISION_MANAGEMENT = COLLISION_AVOIDANCE[MinDist],
COLLISION_AVOIDANCE[r:R] =
      ( safetyDistance[r] -> moveTruck[r] -> COLLISION_AVOIDANCE[r]
| when(r >= MinDist && r < MaxDist) {DecreaseSpeed} -> COLLISION_AVOIDANCE[r+1]
| when(r == MinDist) {DecreaseSpeed} -> COLLISION_AVOIDANCE[r+1]
| when(r == MaxDist) normalSpeed -> COLLISION_AVOIDANCE[r]).
```





VI. Results and Discussion

State space evaluation checks all the possible paths in a system and guarantees a system with zero chances of failure. Big-data based applications generates huge and massive amounts of data that is used for making future predictions, so it is necessary to verify such applications using formal methods which will ensure the correct working of model.

Therefore, in order to have reliable data labelled transition system based model-checking technique is used.

VII. Summary and Contributions

A truck geolocation system based on big-data is considered. This system is based on large sets of data of goods transport trucks and their routes. This data includes the *truck velocity*, *cities visited*, *fuel consumption* and *the driving pattern of each truck driver*. The information is stored in two log files named *geolocation* and *trucks*. These files contain the data that are of huge size and cannot be used directly to get any information. Furthermore this system of trucks was not verified at all. Queries are applied on the data on the basis of our requirement. For making analysis and big-data Hadoop framework is used.

In order to verify the working pattern of truck system, a labeled transition system is proposed. Each possible state is checked. Analyzing and verifying the whole system by using labelled transition system based model checking generate accurate results which can be further used in analysis.

The data generated from a big-data application is in semi-structured, or non-structured form, getting useful information from this data is important. This analysis extracts information required for making future predictions.

Big-data applications are important for large business organizations to make future predictions. It's important to verify the data extraction and analysis method by using model checking. For giving the exact meaning to data, data needs to be extracted on the bases of required criteria. After extraction useful analysis could be performed on the data sets. These analysis can be used to make future reports and policies. Businesses can predict about their future policies, and make strategies regarding their future roadmaps. An important aspect of the use of big-data technique is the formal verification of the methodology used for *data extraction*, *data analysis*, and *information retrieval* from this data.

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Wi-Fi Redux: Never Trust Untrusted Networks

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***Abstract*—This study analyzes the dangers posed to computer user information and their equipment as they connect to untrusted networks, such as those found in coffee shops. Included in this study is a virtualized lab consisting of the target and attacker nodes and router to facilitate communication. Also included are a binary for reverse connection and a modified binary that was created to connect back to the attacker node and bypasses most Anti-virus software.**

Keywords—Wi-Fi; Untrusted Network; Pineapple; MITM; DNS Spoofing; Least Privilege

I. Wireless Fidelity (Wi-Fi)

A. Introduction

Wi-Fi is convenient and in general terms, often fast. Its use is also ubiquitous in today's connected world. At times a user may be unaware that a device is connected to a Wi-Fi access point instead of cellular technology such as LTE; the transition is often seamless. Convenience functions include Wi-Fi Protected Setup (WPS), device auto association and the choice to use encryption technology. This research explores how the convenience of Wi-Fi and its convenience related functions may be used in attacks which could lead to data theft, invasion of privacy or the compromising of devices.

B. Wi-Fi Use

The world is very data hungry, with the amount of data consumed and generated growing at an exceedingly increased rate. In fact, some estimates put the total monthly traffic for mobile users around 3.6 EB [1]. And, to stay connected on the go, many users flock to coffee shops or similar businesses that offer free Wi-Fi. Companies often leave the Access Point (AP) unencrypted or display the network password in clear sight or available after purchasing good or services.

Although there is a growing trend in the adoption of the WPA2 encryption method, one website, whose data is collected from volunteers who War Drive, reports roughly 6% of scanned networks still do not use any encryption method at all [2]. Furthermore, when the user utilizes these "free" untrusted networks, they may not think about the potential for misuse and how a malicious actor may be able to obtain sensitive information or possibly break into their system via malicious software (malware).

C. Wi-Fi Pineapple

One attack vector that poses a threat to consumers on untrusted public networks such as coffee shops is the well-known Man-in-The-Middle (MITM) attack. An MITM is accomplished by an attacker placing a node in between the router and the victim so that all or selective network traffic passes through the attacking node, which then puts the attacking node in complete control of said traffic. There are several ways to implement an MITM on wired and wireless networks.

For wireless networks, the "Wi-Fi Pineapple" (hereafter Pineapple) manufactured by Hak5 LLC, is a consumer device that easily facilitates and automates much of the process of deploying a Wi-Fi honeypot, thus placing the clients connected to the instrument in an MITM situation. The Pineapple works in part by exploiting 802.11 broadcasted beacon frames that are sent out at specific intervals from clients seeking to connect to remembered networks. Included, in section 4 of a beacon frame is the Service Set Identifier [3] or network name, to which the Pineapple responds affirmatively either selectively or all the time, depending on the Pineapple's configuration.

The beacon frame response from the Pineapple to the client facilitates the opportunity for association (to connect) to the spoofed AP. The association can be seamless for unencrypted remembered networks and often requiring user intervention for encrypted networks, depending on client side factors such as the operating system or user settings. Deauthentication frames, which "invalidate the authentication relationship" [4] can be sent to clients from the Pineapple in the hopes that the clients start associating with the rogue AP, not the legitimate AP (see Figure1).

In the context of most coffee shop networks, deauthentication attacks do not require user intervention due to there being no authentication, nor in most cases are the users alerted that their device has associated with a rogue AP.

II. Lab Setup

A lab intended to mimic a real-world situation might consist of three virtual machines: a victim node, attacker nodes, and a router. The router is the modern and open source pfSense firewall (see: https://pfsense.org) with the default configuration of 192.168.1/24. The victim node runs Microsoft Windows 7 with a wireless card. And, the attacker node is running the popular open source penetration testing distribution, Kali Linux (see: https://kali.org) with the Pineapple directly connected via USB, providing the Wi-Fi and MITM, on the 172.16.42/24 network. See Figure 2.

III. Attack Vectors

A. Introduction

Once an attacker decides to attack a device, system or network, he/she will need to determine, from the investigation, what type attack to execute. Not all attacks have to be on systems and networks. In fact, many attackers may find that people hacking or social engineering is a very effective avenue to gain entrance into systems and networks. The Pineapple and other attack types such as DNS Spoofing, in part, relies on uneducated users who may not notice what is occurring behind the scenes.

B. The Pineapple and Remembered Networks

As mentioned earlier about device association, the Pineapple's power relies on the fact that target devices have at least one recognized Wi-Fi network. When seeking to associate, the client will send out probes looking for any remembered networks [5]. The Pineapple uses this to exploit a client's default behavior of trying to automatically associate when an AP sends a crafted beacon response that matches the initial probe from the client.

The Pineapple includes a module as part of PineAP called Dogma that allows the attacker to specify the rate at which the Pineapple will send out beacon responses, 200-400 times normal for a standard AP [6]. Dogma's aim is to reinforce the legitimacy of the AP and aid in device association. The odds for most phones and computers to have at least one remembered and unsecured network are high. In fact, most users are likely not to know that such a list of remembered networks exist and are likely to include the Wi-Fi networks of Starbucks, Walmart, Best Buy, Airports, etc.

C. DNS Spoofing

Once device association has occurred with the Pineapple (or any rogue AP), the traffic flow pattern is from the victim to the rogue AP to the attacking node and finally to the Internet. Therefore, a wide variety of attacks is possible such as traffic analysis, information gathering, X.509 stripping, DNS spoofing, credential harvesting, etc. For this research, DNS spoofing of the regent.edu domain was utilized to redirect the victim to a web page instructing the user to download a flash player update file, which is malicious. See Figure 3. **Note:** DNS spoofing of the target domain does not affect any user not connected to the rogue AP. As of the time of writing, the legitimate resolution of the regent.edu domain is 70.175.9.91.

D. Malicious Binary Generation and Anti-virus Detection

Veil-Evasion is an open source project that can be used to generate an executable payload that may bypass some, if not all, Anti-virus software via selectable payload encryption [7]. Veil-Evasion is installable on many Linux distributions including Kali Linux which the attacking node in this research uses. As of writing the software includes 51 different payloads. An attacker can also add their custom shellcode as well. This study used the Ruby Base64 payload to generate a binary, that when executed opens a connection back to the attacking node for further exploitation. The Ruby Base64 offered the lowest detection rate [8] of the large Anti-virus vendors flagging the binary, as of writing [9].

E. Binary Delivery

Utilizing DNS Spoofing, as outlined earlier, the regent.edu domain is the target that resolves to the Pineapple, which is running a minimal web server. The web server delivers to the client a page that states the client's flash player plugin needs to be updated. See Figure 4. A convincing web page can be crafted by hand or used from other projects such as the open source Wi-Fi Phisher, which is another way of creating a rogue AP (see: https://github.com/wifiphisher/wifiphisher).

IV. Post Exploitation

A. Introduction

The post exploitation stage in an attack is where the attempt to exploit the user, technology or systems was successful. The attacker now has a foothold in the system/network and may leverage further exploits, networking mapping, monitoring, etc. One tool that is open source and readily available in the Kali Linux penetration testing distribution is Metasploit which includes meterpreter which can be used for post-exploitation.

B. Opening a Reverse Shell and Privilege Escalation

Once the binary executes, meterpreter, opens a shell, connecting to the attacking node on the port specified during binary generation. See Figure 5. The process of opening the shell starts with the stager executable, which is the binary generated earlier. The stager prompts for UAC access (if enabled) and when granted downloads a DLL from the attacking node, which contains the reverse shell payload that loads into memory [10]. Once the shell opens, the attacker has the same permission as for when the stager executed, in this case, Administrator privileges. The next step the attacker may take is to obtain system privileges which will allow just about any modification desired. See Figure 6. Running netstat on the victim node will also show the connection from the ephemeral port of 49641 to port 8080. See Figure 7.

C. Maintaining Access

Once the shell is opened; the attacker will likely want to maintain access to the system. Metasploit has a built-in function to upload a Visual Basic Script (VBS) to the victim that will open a shell every time the user logs into the computer. However, many Anti-Virus flags the VBS as malicious. Another route may be to hide the stager in a legitimate executable. If an attacker chooses this path, the first step might be to determine what programs are installed on the victim node and find a program that is likely to run on a regular basis. See Figure 8. A candidate is PuTTY, the popular SSH and Telnet client.

Veil-Evasion, discussed earlier when generating the stager executable, has a payload called Backdoor Factory that was created by Joshua Pitts. Backdoor Factory (BDF) exploits the nature of the Portable Executable (PE) format. The PE format is a data encapsulation method that "provide[s] the best way for the Windows Operating System to execute code and also to store the essential data which is needed to run a program" [11].

BDF relies in part on the concept of code caves, which is the process redirecting program execution (like a function) to separate code and then returning for normal execution [12]. So, in other words, the newly generated binary from Veil - Evasion includes the stager and original PuTTY program, the stager code will run inside of PuTTY and PuTTY will run as normal. See Figure 9. Anti-Virus detection rates are high for this method but may be allowed anyway as PuTTY is a legitimate program.

D. Implications

Once an attacker has access to a node, meterpreter offers many commands such as those used for data exfiltration and infiltration, keylogging (See Figure 10), screenshots, remote desktop access, further system exploitation, webcam recording, timestamp and log manipulation and so on. If the user allowed the stager through UAC, the shell could likely get system authority which has more access to the system than even an Administrator account and is often used for system services; otherwise the attacker may try to exploit the system further depending on the attacker's overall goal.

V. Prevention

A. Introduction

In many cases, there may be little recourse for attacks occurring in a public location. Many coffee shops, for example, only provide Wi-Fi as a service enhancement for patrons. Users may use the service at their own risk own risk and the network may be unmanaged by an administrator. However, there are some remediation tactics users can employ, including education and technical controls.

B. Least Privilege

It is not uncommon for the average user to be logged in as a local administrator, which can be a bad idea for a variety of reasons. Programs that are executed as the Administrator retain those permissions. One option is to create a second unprivileged account for everyday use. The user would still need to enter Administrator credentials when installing a program, but such a delay might give the user a chance to stop the attack from progressing as the UAC is often disabled or not fully understood.

C. Remove any Saved Networks

It is standard practice in most operating systems to maintain a list of remembered networks the device associates. It may be good hygiene to clear this list, turn off this function or leave only one SSID on the list that the user trusts, which must be an encrypted network. Unencrypted networks, as demonstrated, are easy to spoof.

D. No Unencrypted Wi-Fi

As stated earlier, there is a cost-benefit tradeoff many users are seeking when they connect to open (and free) networks. Users have an allotted amount of data on cellular plans or pay per the megabyte or gigabyte. By using free Wi-Fi, the user offsets the cost of the mobile data plan which may include tethering for laptops or other devices.

However, the potential dangers of using unsecured and untrusted networks can far outweigh the perceived benefit which is why it might be better to stay off such networks or at a minimum, build a Virtual Private Network (VPN) tunnel to ensure the confidentiality and data integrity of the session. **Note:** encrypted Wi-Fi is still susceptible to attacks such as DNS Spoofing if the proper technical controls are absent such as client isolation.

E. Turn off Wi-Fi

By turning off Wi-Fi on the device when unneeded, the user negates the effect of the auto association behavior built into modern operating systems. When Wi-Fi is in the off state, probes for remembered networks will not send and may be helpful when the device is in a public space, but the user does not need or want Wi-Fi access.

F. Check What the Device is Doing

One indication of a rogue AP to a user may be that their device associates with an AP but the physical location of the business that offers the access is far away or not in the same place as the device. For example, a device associated with the SSID of "SouthwestWi-Fi" but the device may not be in an airport or on an airplane.

However, most operating systems have their Wi-Fi settings pane in such a way that it requires the users to manually navigate to the panel to see what network the device is associated. Fortunately, programs like NetStumbler exist for Windows to quickly scan the Wi-Fi space and will display the details of every network in range and band (2.4, 5 GHz or both depending in the Network Interface Card).

VI. Conclusion

In conclusion, it was discussed the growing trend for mobile and computer users to offload some of their data use to Wi-Fi networks due partly to the fact the mobile data are often allotted a finite amount of bandwidth or charged per use. Although the trend for encrypted Wi-Fi networks is on the rise, there are still many networks to remain unencrypted. These unencrypted networks can be found in coffee shops, malls, and businesses, etc. and often offered free of charge.

However, there are several attack vectors that users may be subject to and unaware of such as rogue access points, DNS spoofing, and malware delivery. Mitigation techniques may include the installation of software on the device to do a minimal site survey for legitimate access points, turning off Wi-Fi when unneeded, clearing out the list of saved networks, creating an unprivileged account on computers, and veering away from unencrypted networks, if possible.

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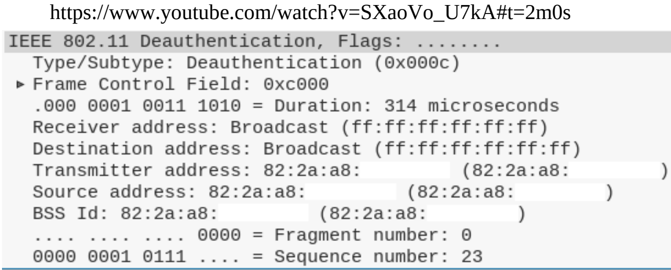

Fig. 1. Deauthentication Frames sent to Broadcast

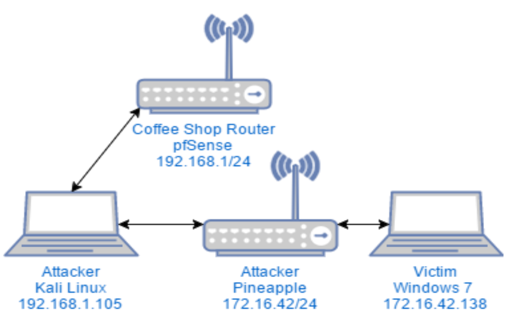

Fig. 2. Lab Network

Fig. 3. DNS Spoofing of a domain

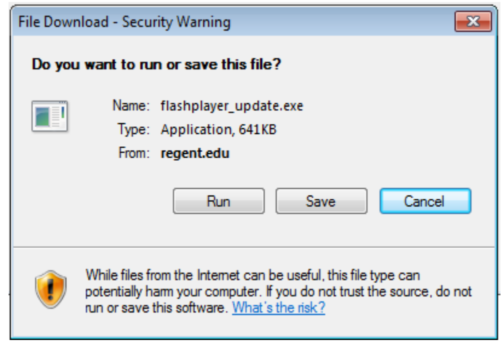

Fig. 4. Downloading the Binary in Internet Explorer

Fig. 5. The Stager binary sending the DLL and opening a session

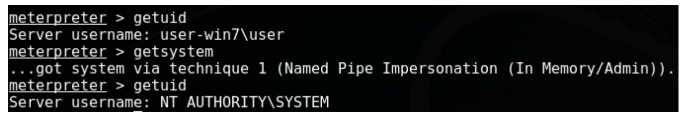

Fig. 6. Privilege escalation

Fig. 7. Showing the connection to the attacker on the victim node

Fig. 8. Enumerating installed applications in meterpreter

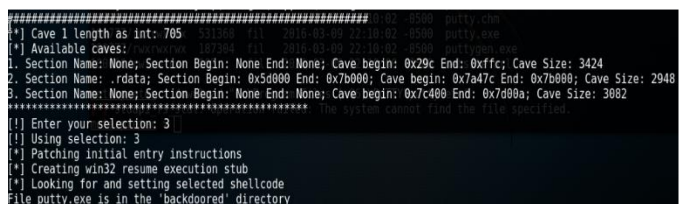

Fig. 9. Binary modification with BDF to include the meterpreter stager

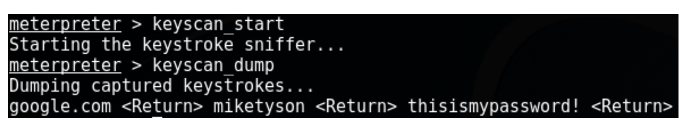

Fig. 10. Keylogging with meterpreter keyscan

Simplex Parallelization in a Fully Hybrid Hardware Platform

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***Abstract*—The simplex method has been successfully used in solving linear programming (LP) problems for many years. Parallel approaches have also extensively been studied due to the intensive computations required, especially for the solution of large LP problems. Furthermore, the rapid proliferation of multicore CPU architectures as well as the computational power provided by the massive parallelism of modern GPUs have turned CPU / GPU collaboration models increasingly into focus over the last years for better performance. In this paper, a highly scalable implementation framework of the standard full tableau simplex method is first presented, over a hybrid parallel platform which consists of multiple multicore nodes interconnected via a high-speed communication network. The proposed approach is based on the combined use of MPI and OpenMP, adopting a suitable column-based distribution scheme for the simplex tableau. The parallelization framework is then extended in such a way that it can exploit concurrently the full power of the provided resources on a multicore single-node environment with a CUDA-enabled GPU (i.e. using the CPU cores and the GPU concurrently), based on a suitable hybrid multithreading/GPU offloading scheme with OpenMP and CUDA. The corresponding experimental results show that the hybrid MPI+OpenMP based parallelization scheme leads to particularly high speed-up and efficiency values, considerably better than in other competitive approaches, and scaling well even for very large / huge linear problems. Furthermore, the performance of the hybrid multithreading/GPU offloading scheme is clearly superior to both the OpenMP-only and the GPU-only based implementations in almost all cases, which validates the worth of using both resources concurrently. The most important, when it is used in combination with MPI in a multi-node (fully hybrid) environment, it leads to substantial improvements in the speedup achieved for large and very large LP problems.**

Keywords*—*Parallel Processing; Linear Programming; Simplex Algorithm; MPI; OpenMP; CUDA

I. Introduction

Linear programming is the most important and well studied optimization problem. The simplex method, which can be found in many textbooks, has been successfully used for solving linear programming problems for many years. Parallel approaches have also extensively been studied due to the very intensive computations required and the substantial need for faster implementations that make effective use of modern computer architectures.

Most research (with regard to sequential simplex method) has been focused on the revised simplex method since it takes advantage of the sparsity that is inherent in most linear programming applications. The revised method is also advantageous for problems with a high aspect ratio; that is, for problems with many more columns than rows. However, there have not been seen many parallel/distributed implementations of the revised method that scale well [1]. On the other hand, the standard method is more efficient for dense linear problems and it can be easily converted to a distributed/parallel version with satisfactory speedup values and good scalability [1-4]. A detailed overview is given in Section II. Also, lately, some alternative very promising efforts have been made, based on the block angular structure (or decomposition) of the initially transformed problems [5-6], and they have led to very good results for large scale problems over distributed memory multicore environments.

Furthermore, with regard to parallelism, until recently, the relevant models, languages, and libraries for shared-memory and distributed-memory architectures have evolved separately, with MPI [7] becoming the dominant approach for the distributed-memory (message-passing) model, and OpenMP [8] emerging as the dominant high-level approach for shared memory with threads. Recently, the hybrid model has begun to attract more attention, for at least two reasons. The first is that it is relatively easy to pick a language/library instantiation of the hybrid model (OpenMP, MPI, MPI 3.0 Shared Memory etc.). The second reason is that scalable parallel computers now appear to encourage this model. The fastest machines now virtually all consist of multi-core nodes connected by a high speed network. The idea of using OpenMP threads to exploit the multiple cores per node (with one multithreaded process per node) while using MPI to communicate among the nodes is the most known. The last 3-4 years however, another strong alternative has evolved; the MPI 3.0 Shared Memory support mechanism, which improves significantly the previous existed Remote Memory Access utilities of MPI, towards the direction of optimized operation inside a multicore node. As analyzed in [9-11] both the above referred hybrid models (MPI+OpenMP, MPI+MPI 3.0 Shared Memory) have their pros and cons, and it's not straightforward that they outperform pure MPI implementations in all cases. Among all the alternatives the MPI+OpenMP hybrid approach is still regarded as the most efficient one, however the MPI+MPI 3.0 Shared Memory approach is highly competitive.

Moreover, nowadays the computational power provided by the massive parallelism of modern graphics processing units (GPUs), has brought increasingly into focus several kinds of

GPU-accelerated solutions. Although in simplex parallelization there have not been noticed as many relevant attempts as one would expect and no parallel GPU-based implementation of the simplex algorithm has yet offered significantly better performance relative to an efficient sequential simplex solver (at least not in all types of problems), quite significant progress has been achieved at least for dense LP problems [12]. There also exist various approaches in the field of parallel scientific computing that adopt extended CPU/GPU collaboration [13-17]. However, the efficient CPU/GPU collaboration through the combined use of relevant programming models (such as OpenMP and CUDA) still remains a major research challenge. Also, to the best of our knowledge there is no relevant approach in the literature adopting extended CPU/GPU collaboration for parallelizing the simplex method.

In this work we focus on the parallelization of the standard full tableau simplex method and we firstly present and evaluate a relevant highly scalable implementation (on the basis of a carefully designed column-based distribution scheme) for the most efficient of the hybrid parallelization alternatives referred above (MPI+OpenMP) assuming there are not GPU-accelerators in our hybrid hardware platform. We then demostrate the high efficiency and scalability of the proposed hybrid MPI+OpenMP parallelization scheme, over a suitable subset of the well known and widely used NETLIB test LP problems. The corresponding experiments have been perfromed over a hybrid, newly developed, parallel platform which consists of up to 8 quad-core processors (making a total of 32 cores) connected via Gigabit ethernet interface. In all cases the hybrid MPI+OpenMP based parallelization scheme leads to considerably high speedup and efficiency values and performs better than other alternatives [18]. Note also that it has been shown (over the less powerful platform of [18]) to perform quite better than the relevant, higly competitive, approach presented in the work of [4].

Secondly, we extend the proposed hybrid parallelization scheme (MPI+OpenMP) over multicore platforms with CUDA-enabled GPUs, and we present a highly efficient framework which can exploit the full power of both the provided multiple CPU-cores and the GPU, concurrently. In the above context, we've designed and implemented a hybrid multithreading/GPU offloading scheme (based on the combined use of OpenMP and CUDA) that efficiently adopts full CPU/GPU collaboration, as well as two complementary schemes for comparison purposes, i.e. a (multithreading) OpenMP-based only scheme, and a GPU-based only (CUDA). The corresponding experimental results show that the performance of our GPU-based only implementation is comparable to other relevant approaches in the literature [18], and superior to our OpenMP-based only implementation (leading to speedup values up to 14.06 for a GTX 760 GPU and up to 23.22 for a GTX TitanX GPU - compared to the sequential implementation). Moreover, the performance of our hybrid multithreading/GPU offloading scheme is clearly superior to the GPU-based only implementation in almost all cases (leading to an additional speedup of up to 1.28 for the GTX 760 GPU and up to 1.23 for the GTX TitanX GPU), which validates the worth of using both resources concurrently. The most important, when the proposed CPU/GPU collaboration scheme is used in combination with MPI in a multi-node (fully hybrid) environment, it leads to substantial performance gains that rise up to 15,9%.

A very early version of this work (in a much less powerful platform, without adopting full CPU/GPU collaboration, and without addressing the fully hybrid platform integration) has been presented in [18,20]. The rest of the paper is organized as follows. In Section II the related work is summarized. In Section III the necessary background is stated with regard to simplex method. In Section IV the detailed description of our basic hybrid parallelization scheme (using MPI and OpenMP) is given. In Section V the relevant extension with CPU/GPU collaboration is presented. In Section VI the experimental results of our basic schemes (MPI+OpenMP and OpenMP+ CUDA) are given, whereas in Section VII we present the performane gains of our fully hybrid parallel approach (MPI+OpenMP+CUDA). Section VIII concludes the paper.

II. Related Work

Earlier work on simplex parallelization focused mainly on tightly coupled or shared memory hardware structures as well as on clusters and networks of workstations. Hall & McKinnon [21] and Shu & Wu [22] worked on the parallel revised method over powerful shared memory and hypercube platforms respectively. Thomadakis & Liu [23] worked on the standard method utilizing the MP-1 and MP-2 MasPar. Eckstein et al. [24] showed in the context of the parallel connection machine CM-2 that the iteration time for parallel revised method tended to be higher than for parallel full tableau method even when the revised method is implemented very carefully. Stunkel [25] found a way to parallelize both the revised and standard methods so that both obtained a similar advantage in the context of the parallel Intel iPSC hypercube. Two other valuable attempts are presented in [26-27] following the primal-dual simplex method and the sparse simplex method, and they've led to satisfactory results for large scale problems. Till recently, no other valuable attempts have been made to parallelize the classical revised simplex method, thus making the one presented by Huangfu and Hall [28-29] a distinguished one. The authors in [28-29] have designed and implemented a very efficient parallelization scheme of the dual revised method with use of the suboptimization technique, and they have obtained speedup values comparable to those of the best commercial simplex solvers. A relevant survey which covers adequately all the recent advances in simplex parallelization can be found in [12].

As already mentioned, the standard method can be easily and effectively extended to a coarse-grained, distributed algorithm [4]. It should also be noted that although dense problems (which suit better the standard method) are uncommon in general, they do occur frequently in some important applications within linear programming [24]. Furthermore, existing distributed memory implementations of the standard simplex method naturally vary in the way that the simplex tableau is distributed among the processors [1,30]. Either a column distribution scheme or a row distribution scheme may be applied, depending on several parameters (relative number of rows and columns, total size of the problem, target hardware environment details etc.). The most recent works following the column distribution scheme (mostly used for practical problems) were by Yarmish et al. [4] as well as (an older one) by Qin et al [3]. On the other hand, the work of Badr et al. [2] referred above followed the row distribution scheme and presented a quite efficient implementa-tion for loosely coupled processors. A comprehensive study and comparison of the above distribution schemes as well as corresponding implementations achieving particularly high speedup values are given in the recent works of Mamalis et al. [18,30]. As shown in [30], the column distribution scheme is the most efficient one for the most types of LP problems.

A number of valuable simplex parallelization attempts have also been seen in the literature with use of GPU accelerators. Spampinato et al [31] have proposed a parallel implementation of the revised simplex method based on NVIDIA CUBLAS and LAPACK libraries, with a maximum speedup of 2.5, using a GTX 280 GPU vs. the sequential implementation on CPU with Intel Core2 Quad 2.83 GHz for randomly generated LP problems of size 2000x2000. In [32] another implementation of the revised simplex method on GPU was proposed, which permits one to speed up solution with a maximum factor of 18 in single precision on a GeForce 9600 GT GPU card as compared with GLPK solver run on Intel Core 2 Duo 3GHz CPU. Lalami et al. [19] have presented a GPU mainly based parallel implementation via CUDA of the standard simplex algorithm for dense LP problems. Experiments carried out on an Intel Xeon 3GHz and a GTX 260 GPU have shown substantial speedup of 12.5 in double precision, for randomly generated LP problems of size up to 8000x8000. The authors have also extended their work on a multi-GPU implementation [33] and their computational results showed a maximum speedup of 24.5, using two Tesla C2050 boards. Meyer et al. [34] proposed a mono- and a multi-GPU implementation of the tableau simplex algorithm, and they compared its performance to the serial Clp solver, using a Tesla S1070 board with T10 GPUs. Their implementation outperformed Clp solver on large sparse LP problems. Finally, Ploskas and Samaras [35] proposed two efficient GPU-based implementations of the revised simplex and a primal–dual exterior point simplex algorithm, using Matlab. The experimental results showed great speedups for the exterior point algorithm and quite worse for the revised simplex method. Other valuable attempts can also be found in [36-38] achieving very satisfactory speedups with C1060, S1070 and GTX 670 boards.

Considering also the general field of parallel scientific computing, several attempts have been made adopting extended CPU/GPU collaboration. Harmony [15] is an integrated programming model which allows the coding and executing of programs for CPU/GPU systems. It also includes an automated distribution of the computational load on the CPU and the GPU, and achieves very good performance mainly in audio-processing systems. In [14,16-17] more recent, relevant approaches are presented in the field of linear algebra and systems. In [17] an additional speedup of up to 1.25 is achieved (compared to the GPU-only implementation) for the parallel execution of the conjugate gradient method, whereas in [14,16] the CPU/GPU collaboration schemes in the field of linear algebra achieved a speedup ranging from 1.15 up to 1.35 for different sizes and types of problems. The works of [14,17] have the major advantage of supporting dynamic distribution of the workload between CPU and GPU. Finally in [39] the authors present a novel generic framework that transparently orchestrates collaborative execution of a single data-parallel kernel across multiple asymmetric CPUs and GPUs. To our knowledge there is no relevant approach in the literature adopting extended CPU/GPU collaboration (i.e. not only for the reduction operations as in [19] or semi-hybrid as in [20]) for parallelizing the simplex method.

III. The Simplex Method

In linear programming problems [34], the goal is to minimize (or maximize) a linear function of real variables over a region defined by linear constraints. In standard form, it can be expressed as shown in Table I (full tableau representation), where A is an mxn matrix, x is an n-dimensional design variable vector, c is the PRICE vector, b is the right-hand side vector of the constraints (m-dimensional), and T denotes transposition. We assume that the set of basis vector (columns of A) is linearly independent. The simplex algorithm consists of two steps; first, a way of finding out whether a current basic feasible solution is an optimal solution, and second, a procedure of obtaining an adjacent basic feasible solution with the same or better value for the objective function. We focus here on the standard full tableau format of the simplex method, which is more efficient for full dense linear problems and it can be easily converted to a distributed version for cluster platforms or hybrid environments.

TABLE I. Simplex Full Tableau Representation

	x_1	x_2	...	x_n	x_{n+1}	...	x_{n+m}	z	
	$-c_1$	$-c_2$	...	$-c_n$	0	...	0	1	0
x_{n+1}	a_{11}	a_{12}	...	a_{1n}	1	...	0	0	b_1
x_{n+2}	a_{21}	a_{22}	...	a_{2n}	0	...	0	0	b_2
...	...	...	...	...	...	...	...	...	...
x_{n+m}	a_{m1}	a_{m2}	...	a_{mn}	0	...	1	0	b_m

Based on the full tableau representation, the basic steps of the standard simplex method can be summarized (without loss of generality) as follows:

Initialization Step: Start with a feasible basic solution and construct the corresponding tableau.

Step 1: Choice of entering variable: find the winning column (the one having the larger negative coefficient of the objective function – entering variable).

Step 2: Choice of leaving variable: find the winning row (apply the min ratio test to the elements of the winning column and choose the row number with the min ratio – leaving variable).

Step 3: Pivoting (this step involves the most calculations): construct the next simplex tableau by performing pivoting in the previous tableau rows based on the new pivot row found in the previous step.

Iterate/Finalization Step: Repeat the above steps until the best solution is found or the problem gets unbounded.

IV. Basic Parallelizaton

In the following paragraphs we present in details the algorithmic approach we followed in our basic hybrid parallel implementation. Our approach is based on the most popular and widely used column-based distribution scheme [4] (as opposed to the other relevant alternative of row-based distribution). This is a relatively straightforward parallelization scheme within the standard simplex method which involves dividing up the columns of the simplex table among all the processors and it is (both theoretically and experimentally) regarded as the most effective one in the general case.

Following this scheme all the computation parts except step 2 of the basic (sequential) algorithm are fully parallelized. Additionally, this form of parallelization looks as the most natural choice since in most practical problems the number of columns is larger than the number of rows. It has also been proved to be the most efficient one (as shown in the literature [4,30]). The basic steps of the algorithm are given below:

Initialization Step**:** The simplex table is shared among the processors by columns. Also, the right-hand constraints vector is broadcasted to all processors.

Step 1: Each processor searches in its local part and chooses the locally best candidate column – the one with the larger negative coefficient in the objective function part (local contribution for the global determination of the entering variable).

Step 2: The local results are gathered in parallel and the winning processor (the one with the larger negative coefficient among all) is found and globally known. At the end of this step each processor will know which processor is the winner and has the global column choice.

Step 3: The processor with the winning column (entering variable) computes the leaving variable (winning row) using the minimum ratio test over all the winning column's elements.

Step 4: The same (winning) processor then broadcasts the winning column as well as the winning row's id to all processors.

Step 5: Each processor performs (in parallel) on its own part (columns) of the simplex tableau all the calculations required for the global rows pivoting, based on the pivot data received during step 4.

Iterate/Finalization Step**:** The above steps are repeated until the best solution is found or the problem gets unbounded.

Based on the above step by step decomposition we've designed and implemented our basic hybrid parallelization scheme, assuming a hybrid parallel platform which consists of multiple multicore nodes interconnected via a high-speed communication network. MPI was used for the communication among the network connected nodes, whereas OpenMP was used for the communication among the multiple cores in each node. More concretely, the available constructs, functions and special mechanisms of both the above parallelization frameworks were suitably used as follows:

- Appropriately built OpenMP *parallel for* constructs were used for the efficient thread-based parallelization of the loops implied by steps 1, 3 and 5.
- Especially with regard to the parallelization of steps 1 (in cooperation with step 2) and 3, in order to optimize the parallel implementation of the corresponding procedures (which both involve a reduction operation), we used the *min/max reduction operators* of OpenMP API.
- Also, with regard to the parallelization of step 5, in order to achieve even distribution of computations to the working threads (given that the computational costs of the main loop iterations cannot be regarded a-priori equivalent) we used *collapse-based nested parallelism in combination with dynamic scheduling policy*.
- Beyond the OpenMP-based parallelization inside each node, the well-known MPI *collective communication functions (MPI_Scatter, MPI_Bcast, MPI_Reduce etc.)* were also used for the communication between the network connected nodes as in pure MPI implementation.

V. CPU / GPU Collaboration

Furthermore, considering within each multicore node the case of existence of a CUDA-enabled GPU, we've extended our basic parallel approach in such a way that it can exploit concurrently the full power of the provided resources (i.e. using the CPU cores and the GPU concurrently), and thus lead to even better performance. The relevant extension is based on a suitable hybrid multi-threading/GPU offloading scheme, implemented with the combined use of OpenMP and CUDA. In the following paragraphs we briefly present the extended algorithm separately (as an autonomous hybrid approach operating on a single-node multicore environment with a CUDA-enabled GPU), for better understanding. Apparently, it can fit in a straightforward manner to our fully hybrid approach described in the previous section, in the case of multi-node environments (see also section VII). Specifically, we first suppose (upper-level parallel approach) that a global column-based distribution scheme is followed with regard to the distribution of the full simplex tableau among the provided resources (CPU-cores and GPU).

Next, with regard to the required CPU/GPU collaboration we apply a suitable extension of the GPU-oriented parallel approach presented in [19][1], by assigning a portion (a number of columns) of the full simplex tableau to be processed by the GPU and leaving the remaining portion to be processed by the CPU. However, with respect to the internal processing within the GPU-cores, the distribution scheme of the corresponding tableau portion is turned to a block-oriented one, which fits better to the internal architecture and the processing capabilities of an NVIDIA GPU [19].

Based on the above considerations, and assuming that we have a single node with n CPU-cores and one CUDA-enabled

[1] The work of [19] is mostly a GPU-only approach, with the CPU being used only for the reduction operations.

GPU, we've implemented a hybrid CPU+GPU implementation (OpenMP+CUDA) as follows:

Setup: A process with t (n ≥ t ≥ 2) threads is scheduled, with one of them mainly used for GPU handling (offloading / kernel launching) and the remaining t-1 threads kept for CPU assigned computations.

Initialization Step: A portion θ of the simplex tableau is offloaded to the GPU. The remaining portion (1-θ) remains for shared-memory computations among the t-1 CPU threads. The right-hand constraints vector is both offloaded to the GPU and kept in the CPU shared memory too.

Step 1: The t-1 CPU threads and the GPU compute (in parallel) the maximum negative coefficient over their own protion of the first line of the simplex tableau, yielding to two local maximum index values, say k1 and k2 respectively. The GPU local maximum k2 is transferred to the CPU memory, it is then compared to k1, and the global maximum index of the winning column is determined (entering variable).

Step 2: If the entering variable belongs to the portion θ of the GPU-assigned simplex tableau, the index k is transferred to the GPU memory. The ratio computation is applied to all the elements of the winning column in the GPU. The minimum ratio is also computed in parallel by the GPU cores and the index r of the winning row is determined (leaving variable). The index r of the winning row as well as the elements of the winning column are transferred to the CPU memory.

Step 3: If the entering variable belongs to the portion 1-θ of the CPU-assigned simplex tableau, the t CPU threads apply in parallel the ratio computation to all the elements of the winning column in the CPU memory. Consequently, they also compute in parallel the minimum ratio, and the index r of the winning row is determined (leaving variable). The index r of the winning row as well as the elements of the winning column are transferred to the GPU memory.

Step 4: The t-1 CPU threads and the GPU perform (in parallel) on their own portion of the simplex tableau all the calculations required for the global rows pivoting, based on the pivot data received during the previous step.

***Iterate/Finalization Step*:** The above steps are repeated until the best solution is found or the problem gets unbounded. A suitable synchronization is required in this step between CPU and GPU per iteration.

The tasks implied by steps 1 and 2 of the sequential algorithm (determining the entering and the leaving variables) require finding a max/min within a set of values. In our hybrid approach, part of the corresponding operations are being performed in the GPU, using appropriate reduction techniques. Our experiments showed (as opposed to [19] and [20]) that the performance obtained by sharing these reduction steps in both the CPU and GPU, was at least equivalent (and in any case note worse) to the alternative followed there (of performing the reduction operations totally in the CPU). The relatively large size of the tested problems, the double precision operations, and the limitations of the NVIDIA architecture itself, lead to limited efficiency when the GPU participates in the reduction computations. However, in the more recent NVIDIA GPUs the efficiency of these computations has been improved, thus allowing their proper use in corresponding tasks.

VI. Experimental Results

Our basic parallelization scheme presented in section IV has been implemented with the use of MPI 3.0 message passing library and OpenMP 4.0/4.5 API, and it has been extensively tested (in terms of speed-up and efficiency measures) over a powerful hybrid parallel environment (distributed memory, multi-core nodes)[2]. The speed-up for p processors (Sp) is computed as the time required for the execution in one processor divided by the time required for the execution in p processors, whereas the efficiency for p processors (Ep) is computed as the speed-up achieved in p processors divided by p. The efficiency measure actually represents the fraction of the maximum theoretical speed-up that has been achieved. The corresponding results are presented and discussed in the next paragraph, whereas in the rest of the section we give the results of the extensions presented in section V. Our test environment for this set of experiments consists of up to 8 Intel Core 3.0GHz quad-core processors (making a total of 32 cores) with 4GB RAM each, connected via gigabit ethernet (1Gbps) network interface. The relevant computing components were mainly available and accessed through the Okeanos Cyclades cloud computing services [40] and local infrastructure in T.E.I. of Athens and Democritus University of Thrace.

A. *Performance of the MPI+OpenMP hybrid scheme*

In order to examine and validate the high efficiency and scalability of our basic hybrid MPI+OpenMP parallelization scheme, we've run on our platform a suitable subset of the well known and widely used NETLIB test linear problems of varying (large and very large) sizes that reflect close to the real word practical cases. The corresponding measurements, over all the non-trivial power-of-two numbers of processors/cores (from 4 up to 32), are presented in Table II.

As it can be seen in Table II the achieved speed-up and efficiency values of the hybrid MPI+OpenMP approach are particularly high in all cases, even for large number of cores and very large NETLIB problems. One can also easily observe that the efficiency values decrease with the increase of the number of processors. However, this decrease is quite slow, and the efficiency values remain high even for 16 and 32 processors/cores (no less than 81% and 70% respectively), in all cases. Moreover, particularly high efficiency values (almost linear speedup) are achieved for all the high aspect ratio NETLIB problems (e.g. see the values for problems FIT2P, 80BAU3B and QAP15 where the efficiency even for 16 and 32 processors/cores is over 90% and 85% respectively). This happens because in the case of 16 or 32 processors/cores (4 and 8 nodes respectively), although the required communications progressively increase, as it is shown in [30]: the higher the aspect ratio of the linear problem the better the performance of the column distribution scheme we follow here, with regard to the total communication overhead.

[2] Much more powerful than the one used in [18].

TABLE II. SCALABILITY OF MPI+OPENMP FOR VERY LARGE PROBLEMS

Linear Problems	Speed-up & Efficiency / MPI+OpenMP							
	2x2=4 cores		2x4=8 cores		4x4=16 cores		8x4=32 cores	
	Sp	Ep	Sp	Ep	Sp	Ep	Sp	Ep
FIT2P (3000x13525)	3.94	98.50%	7.80	97.50%	15.25	95.30%	29.50	92.20%
80BAU3B (2263x9799)	3.91	97.80%	7.72	96.50%	14.93	93.30%	28.64	89.50%
QAP15 (6330x22275)	3.89	97.30%	7.62	95.30%	14.48	90.50%	27.10	85.20%
MAROS-R7 (3136x9408)	3.87	96.80%	7.54	94.30%	14.13	88.30%	26.27	82.10%
QAP12 (3192x8856)	3.86	96.50%	7.50	93.80%	13.97	87.30%	25.70	80.30%
DFL001 (6071x12230)	3.85	96.30%	7.50	93.80%	14.05	87.80%	25.95	81.10%
GREENBEA (2392x5405)	3.84	96.00%	7.40	92.50%	13.58	84.90%	24.38	76.20%
STOCFOR3 (16675x15695)	3.79	94.80%	7.23	90.40%	12.96	81.00%	22.50	70.30%

Note also that the proposed hybrid scheme has been shown [18] to perform better than the alternative of MPI+MPI3.0 Shared Memory approach, as well as than the coresponding implementation of [4] which is one of the most competing relevant approaches in the literature. Furthermore, consider that the implementation of [4] has also been compared to MINOS, a well-known implementation of the revised simplex method, and it has been shown to be highly competitive, even for very low density problems.

B. *Performance of the CPU/GPU collaboration scheme*

The complementary single-node hybrid parallellization scheme presented in section V (that assumes the existence of a CUDA-enabled GPU as well) has also been implemented with the use of OpenMP 4.5 API and CUDA 7.0 Toolkit, and it has been extensively tested over a real hybrid hardware platform (much more powerful than the one in [20]). More concretely, for this set of experiments we've used an Intel Dual Quad Core 3.0GHz Xeon system (8 cores in total), as well as one GTX 760 and one GTX TitanX NVIDIA GPUs, which are of different technologies (Kepler and Maxwell respectively). These desktop-level GPUs have relatively low double precision (DP) performance (the GTX 760 gives ~95 GFLOPS with 1152 cores, whereas the GTX TitanX gives ~192 GFLOPS with 3072 cores), however as it can be seen they can lead to quite significant improvements. This emphasizes the capability of using GPUs for scientific computing on desktop environments too. Note also that we've chosen to use the above referred 8-core Xeon system instead of one of the quad-core machines used in our first set of experiments in order to have more available cores in a single machine, and conclude to more representative, conveincing and sufficiently reliable results. However, it should be noticed that the per core performance of the two different test platforms is approximately the same.

1) *Performance of the GPU offloading only scheme*

First, we briefly present our initial experiments, in which our CPU-only and GPU-only schemes are compared to each other for varying number of CPU-cores. The performance gains achieved by our GPU-only approach are shown in Tables III,IV as well as in Fig. 1. Later on we present the additional performance gains achieved by our CPU/GPU collaboration (OpenMP+CUDA) scheme over the GPU-only approach, thus demonstaring the really high level of improvements that can be offered by the use of a combined CPU/GPU computing approach in hybrid (multi-node, multi-core) environments that involve CUDA-enabled GPUs too. The measurements presented in Tables III and IV have been taken over a dense randomly generated LP problem of size equal to 10000x10000 and similar properties as in [19,33].

The specific problem size is the larger one in our experiments and leads to the best speedup values for all the tested cases. It's also near the maximum LP problem size that can fit and be processed conveniently within the available memory of the GTX 760 card (2GB), which is the main card used in the experiments made over our fully hybrid platform (presented in section VII). Further experiments involving quite larger LP problems over the GTX Titan X card (which offers a substantially larger amount of memory, i.e. 12GB) are of high priority in our future work.

In Table III, in the first columns the performance measurements for our OpenMP (CPU-only) implementation are shown. Specifically, the execution time per iteration is given for varying number of cores (from 1 up to 8) as well as the corresponding speedup (Sp) values achieved in each case. On the other hand, in the last two columns we give the execution time per iteration achieved by the GPU-only implementation with the GTX 760 GPU, as well as the corresponding speedup achieved over the CPU-only implementation for each different number of cores. In Table IV the relevant measurements are presented for the GTX TitanX GPU, in an equivalent manner.

As it can be seen the speedup achieved with the GTX 760 GPU ranges from 1.94 (compared to the 8-core CPU-only implementation) to 14.06 (compared to the 1-core/sequential implementation), whereas the speedup achieved with the GTX TitanX GPU ranges from 3.20 to 23.22 respectively. These speedup values are quite satisfactory and they validate the worth of using desktop-level GPUs for this kind of scientific computations, although their DP performance is relatively low. They are also comparable to other relevant approaches in the literature, and quite better than the ones of [20]. For example in

[19] a speedup of 12.5 is achieved over the sequential execution, with a GTX 260 GPU (which has a DP performance of ~90 GFLOPS). Note also that our CPU-only implementation is a highly efficient/scalable one, since the efficiency values (obtained if we divide Sp by the corresponding number of processors in each case) are over 90% in all cases and the speedup remains particularly high (7.26) even for 8 cores.

TABLE III. SPEEDUP FOR GTX 760 GPU IMPLEMENTATION

P	CPU (multi-threaded)		GPU (760)	
#cores	Time/iter	Sp	Time/iter	Sp
1	2.8915	1.00	0.2056	14.06
2	1.5139	1.91	0.2056	7.37
3	1.0135	2.85	0.2056	4.93
4	0.7674	3.77	0.2056	3.73
5	0.6245	4.63	0.2056	3.04
6	0.5250	5.51	0.2056	2.56
7	0.4519	6.40	0.2056	2.20
8	0.3985	7.26	0.2056	1.94

TABLE IV. SPEEDUP FOR GTX TITANX GPU IMPLEMENTATION

P	CPU (multi-threaded)		GPU (TitanX)	
#cores	Time/iter	Sp	Time/iter	Sp
1	2.8915	1.00	0.1245	23.22
2	1.5139	1.91	0.1245	12.16
3	1.0135	2.85	0.1245	8.14
4	0.7674	3.77	0.1245	6.17
5	0.6245	4.63	0.1245	5.02
6	0.5250	5.51	0.1245	4.21
7	0.4519	6.40	0.1245	3.62
8	0.3985	7.26	0.1245	3.20

TABLE V. EXECUTION TIMES FOR CPU+GPU IMPLEMENTATION

portion	CPU+GPU(760)		CPU+GPU(TitanX)	
(θ)	4 cores	8 cores	4 cores	8 cores
0.0	0.7674	0.3985	0.7674	0.3985
0.1	0.6817	0.3591	0.6753	0.3526
0.2	0.6070	0.3177	0.5953	0.3136
0.3	0.5288	0.2793	0.5167	0.2703
0.4	0.4572	0.2370	0.4493	0.2326
0.5	0.3909	0.1984	0.3824	0.2015
0.6	0.3337	0.1602	0.3250	0.1707
0.7	0.2598	0.1765	0.2482	0.1339
0.8	0.1853	0.1883	0.1788	0.1015
0.9	0.2022	0.2027	0.1142	0.1176
1.0	0.2056	0.2056	0.1245	0.1245

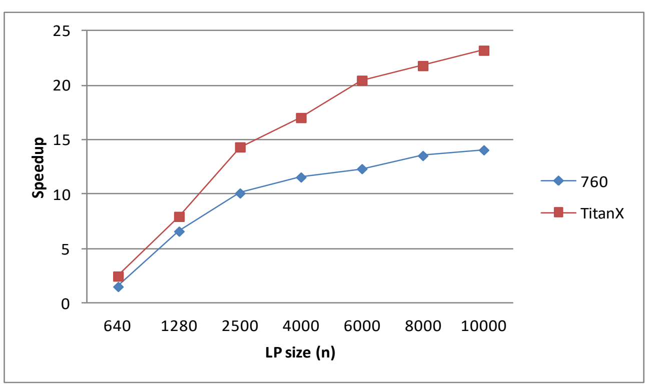

Fig. 1. Speed-up curves for different LP sizes

Additionally, in Fig.1 the behavior of our GPU-only approach over different sizes of LP problems is shown, in terms of the corresponding speedup curves). The experiments have been performed over randomly generated dense LP problems ranging in size from 640x640 to 10000x10000, of similar properties as in [19,33], and with double precision arithmetic. Note also that the speedup values have been computed (without loss of generality) comparing to the 1-core/sequential implementation. As it was expected the speedup increases with the increase of the problem size. Moreover, the speedup reaches a sufficiently high value (near the maximum) for LP problems greater or equal to 2500x2500, whereas it decreases sharply for smaller LP problems. This happens because as the problem size decreases the shared computational load also decreases a lot, and the total CPU-GPU communication overhead (and/or the corresponding reduction overhead) naturally becomes the dominant factor with regard to the total processing time.

2) Performance of the Hybrid OpenMP+CUDA Scheme

In our second set of experiments we measure the performance of our hybrid CPU/GPU implementation and we show its superiority over the GPU-only implementation, which was the faster among the other two. The measurements were taken by varying the load distribution factor (portion θ) of the simplex tableau, from 0 (equivalent to the CPU-only approach) to 1 (equivalent to the GPU-only approach) by steps of 0.1.

In Table V, the corresponding execution times are given for both the tested GPUs, supposing they share the computational load (according to the varying value of θ) with 4 and 8 CPU cores, over the randomly generated 10000x10000 LP problem; which gives the better performance. As it can be seen, in all cases there is at least one value of θ that leads to better execution time than the GPU-only implementation. This clearly validates the worth of using both resources (CPU and GPU) concurrently, instead of the GPU alone. Moreover, the maximum improvement is achieved for 8 CPU-cores, where we have an improvement of 22.1% (from 0.2056 to 0.1602) for the GTX 760 GPU and 18.5% (from 0.1245 to 0.1015) for the GTX TitanX GPU. In terms of speedup values the above improvements imply an additional speedup improvement of 1.28 and 1.23 for our two different test cards respectively. These achievements are comparable to the ones presented in other recent works in the literature [14,16-17].

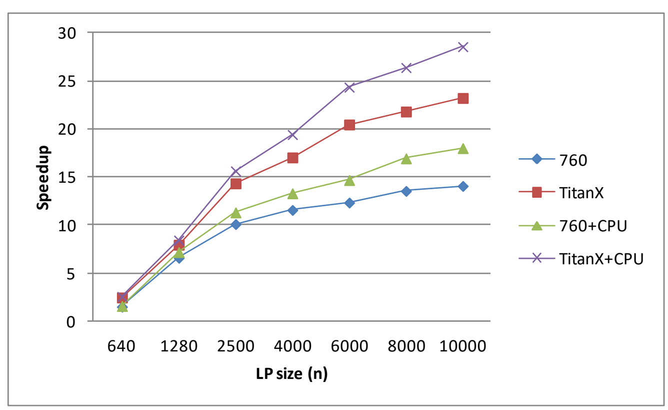

Fig. 2. Speedup curves for CPU/GPU collaboration

Furthermore, the value θ that leads to the larger improvement for 4 CPU-cores is 0.8 for the GTX 760 and 0.9 for the GTX TitanX GPU, whereas the corresponding values for 8 CPU-cores become 0.6 and 0.8 respectively. The fact that are all greater than 0.5 is not surprising since the GPU-only implementation leads to significant speedup over the CPU-only implementation, itself; near or greater than 2 in any case (even for 8 cores). Thus, it's naturally expected that in order to gain some additional improvement from CPU/GPU collaboration, the larger portion of the simplex tableau should be offloaded to the GPU. Intuitively, we can say that if the GPU-only implementation leads to a speedup of 's' compared to the corresponding CPU-only implementation, in order to improve the execution time by applying CPU/GPU collaboration, we should assign to the CPU certainly less than the '1/s' portion (practically much less) of the total computational load. Also, as the number of the CPU-cores increase the maximum improvement that can be achieved naturally increases too, since a greater portion of computational load can be assigned to the CPU with equivalent performance as it was in GPU.

Also, in Fig. 2, the behavior of the hybrid CPU/GPU approach for different sizes of LP problems is shown. Specifically, the execution times and the speedup values (over the 1-core/sequential implementation) have been measured for the randomly generated LP problems ranging in size from 640x640 to 10000x10000, and the corresponding speedup curves have been drawn along with the speedup curves of Fig. 1. All the measurements have been taken for 8 participating CPU cores and for the value θ that maximizes the performance in each case. As it can be seen the maximum achieved speedup decreases with the decrease of the problem size, for both the tested GPUs. This is naturally explained again by the fact that as the problem size decreases the shared computational load decreases analogously, and the CPU-GPU communication overhead becomes more crucial for the total processing time. Note that in the CPU/GPU collaboration scheme there is additional CPU-GPU communication (i.e. per iteration) beyond the initial offloading overhead.

VII. Fully Hybrid Parallelization

Finally (standing as the most important contribution of our work), we've appropriately integrated our basic hybrid schemes into one fylly hybrid design, and we've performed a number of compementary experiments in order to demonstrate the worth of use of our parallel approaches in a fully hybrid parallel platform, i.e. a multi-node environment with multicore nodes and also equipped with one CUDA enabled GPU. As it has already been mentioned in Section V, our CPU/GPU collaboration approach can fit in a straightforward manner to our MPI+OpenMP approach, in the case of multi-node environments. More concretely, we first have to share the whole simplex tableau and broadcast the right-hand constraints vector to all the processors, according to the algorithmic approach presented in Section IV. Then each processor can execute the CPU/GPU collaboration algorithm presented in Section V on the local part of the simplex tableau that it has received. Furthermore, additional (MPI-based) communication steps between all processors have been introduced in each iteration.[3] Our test equipment for this set of experiments is the same as for our first set of experiments (up to 8 Intel 3.0GHz quad-core processors with 4GB RAM and gigabit ethernet network connection), with each node also equipped with a GTX 760 NVIDIA GPU. Based on the above platform, we've run experiments over the set of very large NETLIB problems used for the experiments in paragraph VI-A; where the MPI+OpenMP scheme is used on the same platform, however without the GTX 760 GPUs. The corresponding results are presented in Table VI, for the cases of 16 (4 nodes/processors) and 32 (8 nodes/processors) cores in total, together with the corresponding results of Table II for comparative reasons.

As it can be seen in Table VI, the combined use of the GTX 760 GPUs in each node introduces a substantial improvement on the speedup and efficiency values for both the cases of 4 and 8 nodes/processors[4]. This improvement increases as the size of the problem gets larger, and it rises up to 15,9% (the efficiency increases from 70.3% to 81.5%) for STOCFOR3 (which is the larger LP problem in our experiments) over 8 nodes/32 cores. This is naturally explained by the fact that in larger problems the computational load is much larger within each node/processor, so a substantial improvement on their execution time can influence significantly the total performance, especially in the case of prior downgrade due to increased communication overhead. For smaller problems (e.g. FIT2P and 80BAU3B) the improvement is quite smaller (however clear in all cases) since the speedup and efficiency values for these problems is quite high even without the use of the GPUs. Also the corresponding improvement decreases a little as the number of nodes decreases, e.g. for STOCFOR3 it becomes equal to 11.7% over 4 nodes/16 cores (the efficiency increases from 81% to 90.5%). This happens for similar reasons as above, i.e. because for less number of nodes the communication overhead is quite smaller, so the total speedup and efficiency values are quite higher and the substantial improvement in the execution times of the computational tasks cannot influence the total performance in the same degree.

[3] In order the globally max negative coefficient be computed and the winning column/row be broadcasted.

[4] Note that as it comes out from Table III (comparing to the use of 4 CPU cores), we can have a speedup of 3.73 (0.2056 vs. 0.7674) by using a GTX 760 GPU, whereas we can have an additional 10% (0.1853 vs. 0.2056, see Table 5) by using the 4 CPU cores and the GTX 760 GPU in collaboration.

TABLE VI. PERFORMANCE OF THE FULL HYBRID SCHEME WITH GTX 760 GPUS

Linear Problems	MPI+OpenMP				MPI+OpenMP+Cuda (GTX 760)			
	4x4=16 cores		8x4=32 cores		4x4=16 cores		8x4=32 cores	
	Sp	Ep	Sp	Ep	Sp	Ep	Sp	Ep
FIT2P (3000x13525)	15.25	95.30%	29.50	92.20%	15.66	97.90%	30.43	95.10%
80BAU3B (2263x9799)	14.93	93.30%	28.64	89.50%	15.47	96.70%	30.18	94.30%
QAP15 (6330x22275)	14.48	90.50%	27.10	85.20%	15.25	95.30%	29.50	92.20%
MAROS-R7 (3136x9408)	14.13	88.30%	26.27	82.10%	15.18	94.90%	28.86	90.20%
QAP12 (3192x8856)	13.97	87.30%	25.70	80.30%	15.06	94.10%	28.54	89.20%
DFL001 (6071x12230)	14.05	87.80%	25.95	81.10%	15.06	94.10%	28.61	89.40%
GREENBEA (2392x5405)	13.58	84.90%	24.38	76.20%	14.85	92.80%	27.58	86.20%
STOCFOR3 (16675x15695)	12.96	81.00%	22.50	70.30%	14.48	90.50%	26.08	81.50%

VIII. CONCLUSION

A highly scalable parallel implementation framework of the standard full tableau simplex method on a hybrid experimental platform has been presented and evaluated throughout the paper, in terms of typical performance measures. Specifically, we have designed, implemented and evaluated a highly efficient hybrid parallelization scheme over a real hybrid parallel (distributed memory, multicore) platform, with use of the standard Netlib test linear problems. The proposed hybrid scheme involves the use of OpenMP for the parallelization over the cores of each node and MPI for the communication between the nodes themselves, and as shown in all the experiments it leads to particularly high speedup and efficiency values even for very large / huge LP problems. It has also been shown to perform considerably better than other competitive approaches of the literature. Further, our hybrid MPI+OpenMP scheme is then suitably extended in order to gain improved performance when a CUDA-enabled GPU is also involved in the hybrid environment. A robust hybrid CPU multithreading/ GPU offloading scheme is proposed that can efficiently use the CPU cores and the GPU concurrently. A GPU-offloading only scheme has also been implemented for comparison purposes. In the corresponding experiments the proposed CPU/GPU-collaboration scheme proves to be superior to the GPU-only scheme, with an additional speedup of up to 1.28 being achieved for randomly generated LP problems of size 10000x10000. The performance of both the CPU/GPU-collaboration and the GPU-only schemes are comparable to other relevant implementations in the literature, whereas they are also clearly superior to the OpenMP-based CPU-only implementation (even for 8 cores). Finally, and the most important, we have integrated our proposed schemes into a *fully hybrid* one, and we present some very encouraging experiments which lead to quite significant improvements (up to 15,9%); when this scheme is used over a *fully hybrid* multi-node platform, for large and very large LP problems. In all the experiments we've used desktop-level GPUs in order to emphasize the capability of using the GP-GPU computing model for scientific applications on desktop environments too.

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Modern Data Formats for Big Bioinformatics Data Analytics

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***Abstract*—Next Generation Sequencing (NGS) technology has resulted in massive amounts of proteomics and genomics data. This data is of no use if it is not properly analyzed. ETL (Extraction, Transformation, Loading) is an important step in designing data analytics applications. ETL requires proper understanding of features of data. Data format plays a key role in understanding of data, representation of data, space required to store data, data I/O during processing of data, intermediate results of processing, in-memory analysis of data and overall time required to process data. Different data mining and machine learning algorithms require input data in specific types and formats. This paper explores the data formats used by different tools and algorithms and also presents modern data formats that are used on Big Data Platform. It will help researchers and developers in choosing appropriate data format to be used for a particular tool or algorithm.**

***Keywords*—Big Data; Machine Learning; Hadoop; MapReduce; Spark; Bioinformatics; Microarray; Data Models; Data Formats; Classification; Clustering**

I. Introduction

In upcoming era, a lot of data will be generated in various fields such as Computer Science, Electrical, Mechanical, Management Science, Mathematics and Bioinformatics. Today, data in these fields is being generated very quickly due to advancement in technology and development of new techniques and tools. Speed of data generation increases in seconds day by day. There is a big challenge to handle and manage such large volume of data. To overcome this problem many tools are designed that handle, manage and store the data in any field.

The term Big Data is well-defined as the data becomes too large that is difficult to handle, process, store and manage. A lot of data is generated from Twitter, Skype, Google, Facebook, Walmart, IOT applications, Yahoo and Youtube. Data has been produced in all sectors like education, professional services, banking and finance. Such large amount of data requires better storage and analysis. Big Data consists of five characteristics like Variety, Velocity, Veracity, Volume and Potential Value. The last characteristic is very vital. Real Time analysis plays an imperative role in Big Data. ML (Machine Learning), Data Mining and Cloud computing are important aspects of Big Data applications. Major challenges and risks of Big Data are cost, flexibility, accuracy, scalability and performance.

With the passage of time, data has rapidly increased in the Bioinformatics field such as public health care data, imaging data, clinical data, sequencing data, genome data and protein data. Large amount of data is also generated from relationships such as gene-disease, protein-protein and DNA-protein etc. In clinical domain, data of many patients is collected for intelligent decision making. This data needs to be stored and analyzed in an efficient way that would be helpful for making best decisions. In imaging domain, huge amount of data about medical images is collected and shared in an effective way. Imaging informatics is beneficial for patient's recovery. Public health care domain consists of prediction and finding of infectious diseases using Big Data tools and technologies [1]. All the data in these domains need better storage facility.

A Format (Model) is a predetermined layout for data. A computer program takes data as input in a certain format, processes it, and gives data after processing that is called information as output in the same or another format.

Machine Learning plays an important role in Bioinformatics field. ML (Machine Learning) Algorithms and Techniques are used for Classification and Clustering of proteins data, sequencing data, genomics data etc. A lot of ML Algorithms such as kNN (k Nearest Neighbor), SVM (Support Vector Machine), Logistic Regression, Naïve Bayes, k-means, k-median, GLM (Generalized Linear Model), Decision Tree and Random Forest are available that perform Classification and Clustering tasks for Bioinformatics datasets.

It stores data in the form of key value. There are two stages map and reduce stage.in the map phase, input data stored in HDFS (Hadoop Distributed File System). Mapper processes that data and creates multiple chunks. Then, Reducer processes that input data coming from mapper and provides a set of outputs. Output files are stores in HDFS. Many Machine Learning Classification and Clustering Algorithms are implemented in Hadoop MR. MR used mahout library for analysis of these Algorithms.

Many tools are available for large data storage, management and analysis. Most important tool is Apache Hadoop, a shared nothing open source architecture that distributes and stores huge datasets across multiple clusters. Hadoop provides features of fault tolerance, data locality, security and reliability. Hadoop components (modules) are HDFS (Hadoop Distributed File System) and MR (MapReduce). HDFS is file storage system for large datasets in Hadoop. It distributes jobs in name node and data node in reliable manner. MR is a framework that is developed for parallel execution of tasks for large datasets by using job tracker and task tracker. Many tools like HBase, Hive, Pig and Apache Spark are built on top of Hadoop. HBase is based on google big table for random read/write access to large data in NoSQL data store. It implements partition tolerance and consistency in the CAP theorem. It replaces RDBMS (Relational Database Management System) and provides the facility of automatic sharding. Hive is a system that translates MR (MapReduce) tasks. It provides the capability of large data storage in embedded, local and remote mode. Pig is used for scripts. It is executed in local and MapReduce mode [2]. It consists of many built-in-functions and operators such as arithmetic, Boolean and comparison, ORDER BY and GROUP BY for large datasets. Apache Spark is especially designed for large data analysis. It takes the benefit of our built-in libraries such as Mlib, GraphX, Spark Streaming and Spark SQL. It consists of transformations, caching and actions. It is faster than MapReduce.

In MapReduce, programming is very difficult for processing and analysis. In many circumstances, batch processing does not fit results less Performance. Spark reduces these limitations due to in-memory computations. Scala language performs superlative role in the analysis on Spark Framework. Spark also provides shell facility in java, python and scala language. There are three ways for creating RDD (Resilient Distributed Dataset) such as parallelizing, referencing and transformation from existing RDD. DAG (Direct Acyclic Graph) is very important in Spark. A lot of transformation methods are available in Spark such as map (), filter (), flatMap () and reduceByKey (). Many methods are exist in Spark for actions like count (), collect () and foreach (). Many RDD persistent storage level are available in Spark that is used according to need for analysis. Broadcast and accumulator variables are very significant for different operations.

Many data formats (Models) are available for any type of data storage. Some data formats are Comma Separated Values (CSV), Tab Separated Value (TSV), Text Format, XML, JavaScript Object Notation (JSON), Attribute-Relation File Format (ARFF), Sequence File Format and Zip file format. Specific data Format is used for specific tool for large Bioinformatics data storage. Some modern data formats (Models) also exist for large data storage that are supported by Hadoop and Apache Spark framework. These Formats are key value, Compressed Row Storage (CRS), Sparse Vector, Avro, Parquet and ORC (Optimized Row Compressed). Some Formats are used for the storage of Bioinformatics data like BAM (Binary Alignment Map), Fastq Format, FASTA Format and VCF (Variant Call Format). Some specific Formats are used for graph processing in Hadoop such as Vertex Input Format, Edge Input Format, Vertex Output Format and Edge Output Format. Many ML Algorithms and Techniques are implemented in Hadoop MapReduce and Apache Spark. These ML Algorithms are implemented in Hadoop for Bioinformatics datasets. Text Input Format is default Format for Hadoop Platform. Specific Format is used for Bioinformatics data in Hadoop MapReduce and Spark framework. Data Conversion tools are also available that convert data from one format to another specific format. These tools are Data Converters, FME data conversion and integration tool, Altova MapForce, TCS, Sqoop, Avro2parquet, Apache Drill and Format Converter.

The objectives of this study are:

- To explore the Modern Data Models (Formats) for Large Bioinformatics data storage
- To analyze the appropriate Data Models for implementation of Machine Learning Algorithms in Hadoop and Spark Framework for large Bioinformatics Data
- To present the future research directions for using Modern Data Models in the implementation of Machine Learning techniques on Hadoop and Spark Framework
- Evaluation of existing Data Models (Formats)

The rest of the paper is structured as follows: Section II enlightens the related work in this field. Section III presents Data Models (Formats). Section IV signifies Modern Data Models for the implementation of Machine Learning Algorithms in Hadoop and Spark for large Bioinformatics datasets. Section V describes tools for migration and conversion of Data Models. Section VI presents discussion about Data Models and illustrates their performance comparison.

II. Related Work

A. *Data Formats for Implementation of Machine Learning Techniques and Algorithms in Hadoop MapReduce*

Ali et al. [3] provide brief description of Machine Learning clustering and classification Algorithms and techniques used in big data tools such as Hadoop and Spark for large scale dataset of Bioinformatics. They also describe the performance comparison of different Machine Learning Techniques and Algorithms in the perspective of Hadoop and Spark. Abdulla et al. [4] have proposed C4.5 Decision Tree Algorithm that is implemented in MapReduce Framework using text input storage Format for measuring customer behaviour and visualization is performed using CSV (Comma Separated Value) Format by the usage of D3.js (JavaScript Library) that provide superlative results for decision making analysis. Esteves et al. [5] have developed Mahout (open source) Framework that is based on Hadoop MapReduce platform for k means, fuzzy k means and meanshift clustering for large datasets. In his work, vectors are converted to SequenceFile Format that is used as an input to the MapReduce Framework. The output files are also in the SequenceFile Format. Mahout scaling tests are performed on Amazon EC2 and best performance was produced. Stupar et al. [6] have proposed RankReduce approach that is based on LSH (Locality Sensitive Hashing) Algorithm for the implementation of multiple kNN queries on the top of MapReduce Framework. LSH will help to process the kNN queries for large datasets that provide better search accuracy results. In his work, Selected Buckets from the LSH Algorithms are used as an input to the MapReduce Framework with a lot of input splits using Input Format class and reads feature vectors are stored in BinaryFormat. Storage datasets are in BinaryFormat (Avro) for implementation of MapReduce Framework. Dai et al. [7] have developed Naïve Bayes Classification Algorithm that is combined with rough set theory for text Classification using large datasets that are implemented in MapReduce Framework. This new designed Algorithm was implemented on the cloud platform for the text Classification to achieve best accuracy and recall rate. The input is in text input Format that is given to Naïve Bayes Technique with the help of rough set. Text Input Format is used for input of preprocessing in MapReduce Framework. ZHANG et al. [8] have proposed MapReduce programming model for RBM (Restricted Boltzmann Machines) and DBN (Deep Belief Nets) in Deep Learning Technique to achieve good performance, accuracy and scalability for large datasets. RBM and DBN contains layers in which MapReduce tasks are implemented with the usage of Key Value Format within each layer. Results show that less training time is required with distributed RBM and DBN than simple RBM and DBN respectively. Ericson et al. [9] have developed Granules and Hadoop comparison platform in which Classification Algorithms (Complementary Bayes and Naive Bayes) and Clustering Algorithms (Latent Dirichlet Allocation, k means, Dirichlet and Fuzzy k means) supported by Mahout that is implemented for large datasets. Mahout used SparseVector Format for storing data internally. Results show that Granules system perform better than Hadoop platform for same Mahout Benchmark. Al-Madi et al. [10] have proposed MR-CGSO (glowworm swarm optimization Clustering) that is implemented in Hadoop MapReduce Framework using k-Median Clustering for large datasets that produce better Scalability, Speed and Accuracy. Key Value Format is used to store datasets in MapReduce Framework. Sarwar et al. [11] have proposed review study about Bioinformatics Tools. They demonstrate the implementations of Tools for Alignment Viewers, Database Search and Genomic Analysis on Hadoop and Apache Spark Framework using Scala language.

B. Data Formats for Implementation of Machine Learning Techniques and Algorithms in Apache Spark

Yaqi et al. [12] have proposed Apache Spark Framework and implemented the Machine Learning Algorithm kNN using that Framework. Aliyun E-MapReduce cloud Framework is used for insulator leakage current data. Spark-kNN is faster than MapReduce. Monitoring data managed with the help of RDD (Transformation and Actions). In the Spark-kNN Algorithm, input training data is used in CSV Format and output is also in CSV Format. Results show that Spark-kNN perform better for large datasets and reduce the execution time. Armbrust et al. [13] have proposed Apache Spark module Spark SQL which include Catalyst that provide Machine Learning features. Spark SQL has strong integration with MLIB such as to train logistic regression with the help of HashingTF (frequency featurizer) to get a feature vector. It consists of relational processing. Spark SQL data storage is in columnar Format (Parquet). Bifet et al. [14] have developed StreamDM on the top of Spark streaming Library that is used in Data Mining and Machine Learning for real time analysis. A lot of stream data such as sensor and credit card transactions stored and analyzed in an efficient manner. For this purpose, many Machine Learning Algorithms and Techniques such as Naïve Bayes, Decision Trees and Bagging classifier are implemented in Spark using StreamDM Library. In his work, sparse instances stored in LibSVM Format and dense instances are stored in CSV text Format. Meng et al. [15] have developed Spark Machine Learning Library (MLIB) for many Classification and Clustering Algorithms. MLIB support LIBSVM data storage Format for the implementation of Machine Learning Techniques and Algorithms such as Decision Tree, k-means, linear models and Naïve Bayes. In [16], a model has been developed that is known as GLM (Generalized Linear Model) in SparkR on the Apache Spark Framework for airline dataset. R language and Learning Library (MLIB) are used for Machine Learning. Preprocessing of dataset are stored in CSV Format by using “spark csv” package for evaluation of large scale GLM.

C. Data Formats for Implementation of Machine Learning Techniques and Algorithms in Hadoop for Bioinformatics

Ravi. R et al. [17] have proposed a system in which Machine Learning Algorithm “Scalable Random Forest” is used to select and classify the appropriate features for large datasets. This Algorithm was implemented in Hadoop MapReduce Framework by using many-many data linkage. In his work, tabular data is stored in CSV (Comma Separated Value) file Format (consisting of many records) in the plain-text form (sequence of characters). File is accessed by using blobstore (Google App Engine objects). By using many-many model, best Performance was achieved with the usage of sample dataset having 29567 rows. Karim et al. [18] have developed a method for Association Rule Mining BMR (Bio-MapReduce Framework) for large Microarray datasets. For the implementation of BMR Algorithm, writer use key value Format for input and output. Results show that BMR method performs better than traditional Algorithms. Rehman et al. [19] have explained importance of Scala language for Bioinformatics Tools/ Algorithms. They demonstrates the supported languages for Motif Finding Tools, Multiple Sequence Alignment Tools and Pairwise Alignment tools.

III. Data Models (Formats)

A lot of Data Formats and Data Models are available for storage of big data in efficient way.

A Format for representing a data set should be:

- Compact enough to save storage for large data sets.
- Readable by various tools or softwares.

- The Format represents all categorical and numerical features so the Data Format should be rich enough.
- Be local so that parts of the data can be independently transferred.
- Data Format should not be changed capricious by tools or softwares.

There are several Formats used to represent the data sets such as CSV, TSV, TEXT, JSON, ARFF, Sequence file Format etc.

A. *Comma Separated Values (CSV):*

In relatively short amount of time data can be swapped and transformed using several spreadsheet tools, in Comma Separated values Format. Each and every record is in one line commas separate fields from each other and prominent and irregular whitespaces are ignored. It is commonly used Format in Hadoop platform. CSV format is described in Figure. 1.

```
Title, Author, ISBN14, Page

1990, Shahzad, 978-0563457465, 67

Brave new world, Atif, 978-0564657465, 676

Eats shoots and leaves, Abbas, 97-0563657465, 66
```

Fig. 1. Comma separated Values

B. *Tab Separated Value (TSV):*

Tab separated value is common method to exchange data among spreadsheets, databases and word processor with Mail-merge functions. Each and every record is illustrated as a single line. Every single field value is represented as a text. Fields in a record or file are delimited from each other by a tab character [20]. TSV format is described in Fig. 2.

Sample Peak	Sample File Name	Size	Height	Area	Data	Point
"A, 2"	point.fsa	13.43	30	340	1340	
"A, 20"	point.fsa	15.56	55	480	1373	
"A, 21"	point.fsa	19.56	35	3067	1391	
"A, 22"	point.fsa	12.60	40	120	1402	

Fig. 2. Tab separated values

C. *Text Format:*

In plain text data is represented only in readable characters while graphical representation and other objects such as images can't be represented in text Format. There are limited number of characters available to control common arrangement of text such as tabular characters and line breaks. Text format is described in Fig. 3.

```
package javaapplication4;
import java.util.Scanner;

public class Usman {


    public static void main(String[] args) {

        int a;
       float b;
       String s;

       Scanner i = new Scanner(System.in);
             System.out.println("Enter a string");
       s = i.nextLine();
             System.out.println("Enter an integer");
       a = i.nextInt();
             System.out.println("Enter a float");
       b = i.nextFloat();

       System.out.println("You entered string "+s);
       System.out.println("You entered integer "+a);
       System.out.println("You entered float "+b);


    }
}
```

Fig. 3. Text format

D. *XML:*

Extensible Markup Language (XML) used to prepare Formats of data which can be easily shared over World Wide Web or anywhere using standard ASCII text. Log files mostly available in the form of XML file Format [21]. XML format is described in Fig. 4.

```
<?xml version="1.0" encoding="utf—8" standalone=" yes"?>
<Table >
<product >
<product_id>2</product_id>
<product_name>product 2</product_name>
<product_price>3000</product_price>
</product>
```

Fig. 4. XML format

E. *JSON:*

JavaScript Object Notation (JSON) is used as trivial data swapping Format among different applications and tools. It is relatively easy and simple for humans to read and for machines to generate and parse files in this Format. It is based on text Format which is completely independent form of language. All of these characteristics mark JSON a superlative data exchange Format. JSON format is described in Fig. 5.

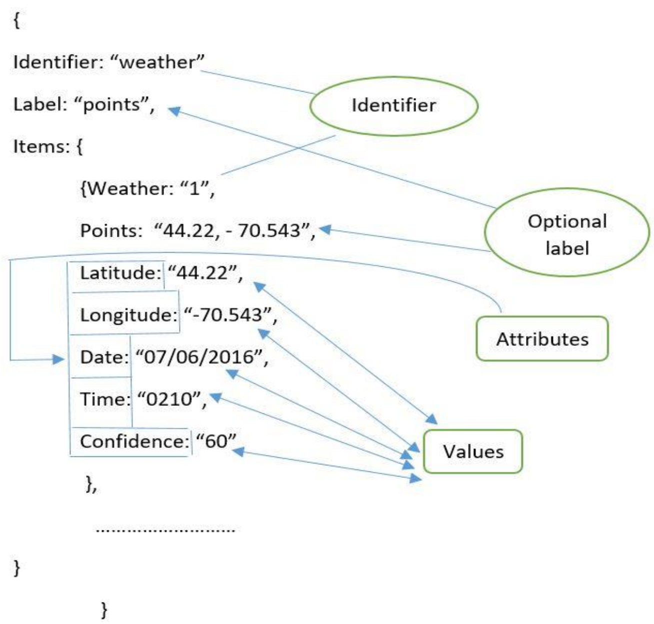

Fig. 5. JSON format

F. ARFF:

Attribute-Relation File Format (ARFF) contains ASCII coding scheme which illustrates multiple cases that share common features. ARFF have two different units: 1) Header information 2) Data information. The Header section of these files consist of the name of association, an array of traits and types. The ARFF Data unit consist of the affirmation line and concrete instance lines [22]. ARFF is described in Fig. 6.

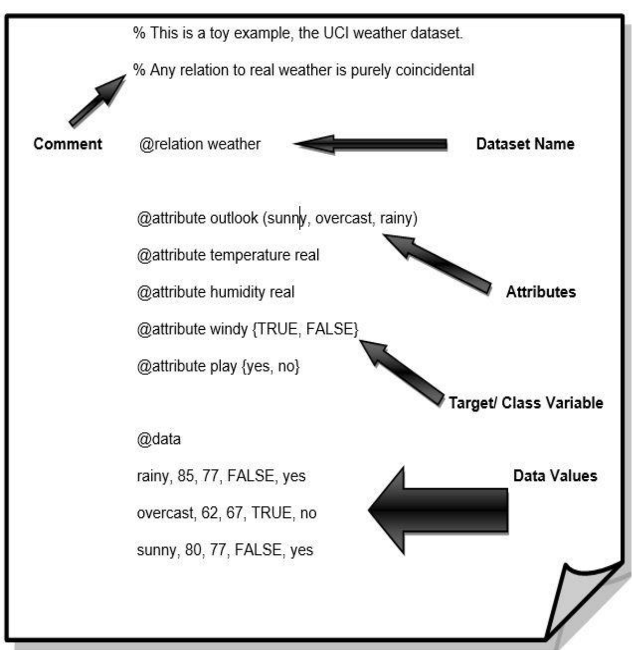

Fig. 6. Attribute-Relation File Format

G. Sequence File Format:

It is a plane file which consists of binary key/value pairs. Sequence file is mostly used in MapReduce form of input/output file Formats. Temporary output of mapper function in MapReduce paradigm also stored in Sequence file Format. There are three classes available for writing, reading and storing the data. Sequence file format is described in Fig. 7.

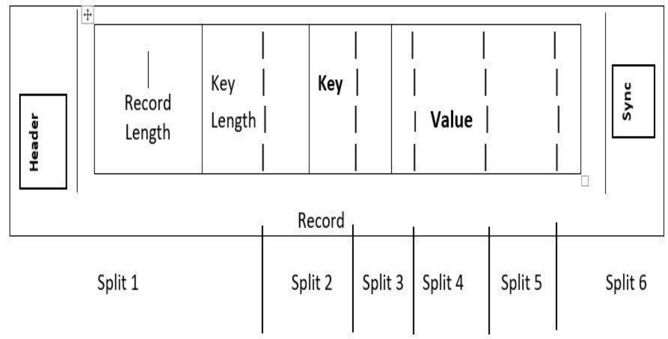

Fig. 7. Sequence File Format

H. Zip file Format:

Zip file Format is basically only a very thin wrapper around the file Formats which is used to prevent files from splitting. Each and every file in zip file is a separate zip entry and all files in zip file can be unzipped or extracted using its original file name and decompresses the contents of file [23]. Zip file format is described in Fig. 8.

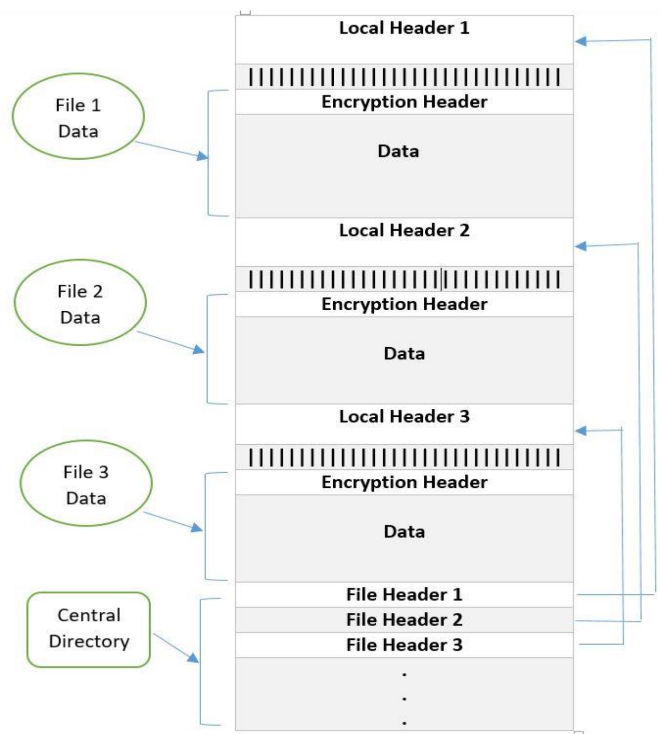

Fig. 8. Zip file format

I. SQL Database Table:

In SQL database table, data is stored in the form of relations or tables, each and every relation consist of rows and columns. Each and every entry in SQL database table has unique attributes such as entries may in the form of characters, numeric values or dates etc. SQL database tables are used generally to store structured data.

IV. Modern Data Models (Formats)

A lot of Data Formats exist that are supported by Hadoop Platform for large data storage. Some of these Data Formats are commonly used for general purpose e.g. Text Input Data Format, Sequence File Format, CSV Data Format and JSON Format. Some of them are Modern Data Formats that are supported by Hadoop e.g. Key Value Format, CSR (Compressed Sparse Row) Format, Sparse Vector Format, Binary Format (Avro), LibSVM Format, Columnar Format (Parquet) and ADAM (Avro+Parquet). Data formats used in different machine learning algorithms and techniques for big data analytics are described in TABLE I.

A. Key, Value Pair Format:

In this Format, every text string signifies key and value separated with separator that is used in Hadoop MapReduce Framework for large data storage. In MapReduce, most widely used Format for large Bioinformatics data storage is key value. Hadoop has default data storage Format in Text Input Format. When Machine Learning Algorithms are implemented in MapReduce, mostly used Format is key value. Key value format for input is described in Fig. 9 and key value format for output is described in Fig. 10.

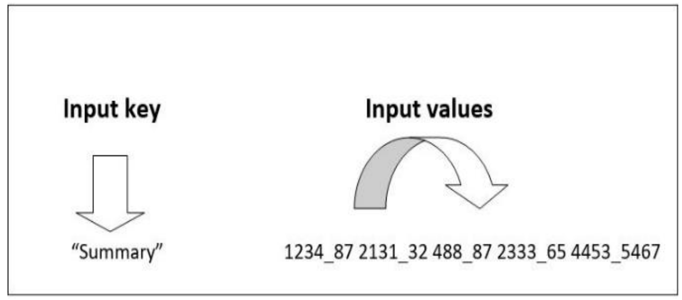

Fig. 9. Input key value pair format

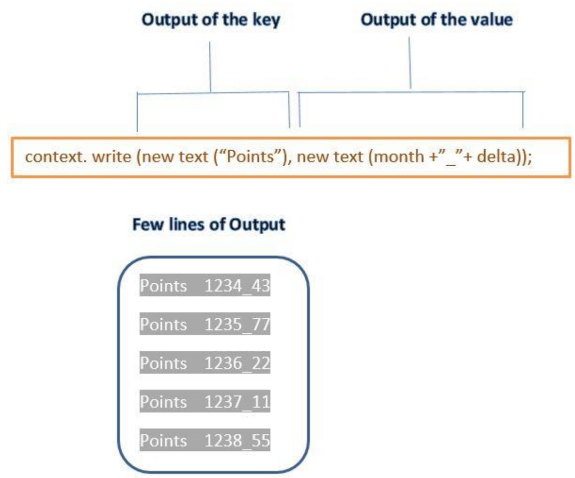

Fig. 10. Output key value pair format

TABLE I. Data Formats Used in Big Data Machine Learning Techniques

Machine Learning (Techniques and Algorithms)	MapReduce (Mahout Library)	Spark (MLib Library)	Bioinformatics using Big Data (Bioinformatics+Hadoop)
NB (Naïve Bayes Bayesian Algorithm)	Text Input Format	LibSVM Format	ADAM (Avro and Parquet) Format
GBT (Gradient Boosted Tree Ensemble Algorithm)	(Key, Value) Pair Format	Parquet	-
Streaming K-means Clustering	(Key, Value) Pair Format	SparseVector Format	-
SVM (Support Vector Machine)	CSR (Compressed Sparse Row) Format	Parquet	ADAM (Avro and Parquet) Format
K-means Clustering	SequenceFile Format OR SparseVector Format	LibSVM Format OR SparseVector Format	-
Adaptive Model Rules	-	-	-
GLM (Generalized Linear Model)	-	CSV Format OR Avro	-
LR (Logistic Regression)	(Key, Value) Pair Format	Columnar Format (Parquet)	ADAM (Avro and Parquet) Format
Deep Learning	(Key, Value) Pair Format	JavaScript Object Notation (JSON) Format	-
Random Forest (Ensemble Algorithm)	(Key, Value) Pair Format	Parquet OR Avro	CSV (Comma Separated Value) Format
k-Median Clustering	(Key, Value) Pair Format	SparseVector Format	-
kNN (Instance based Algorithm)	BinaryFormat (Avro) OR (Key, Value) Pair Format	CSV Format	ADAM (Avro and Parquet) Format
Association Rule Mining (Apriori Algorithm)	(Key, Value) Pair Format	LibSVM Format	Vertical data layout Format
Decision Tree	CSV (Comma Separated Value) Format	LibSVM Format	-
Linear Regression	(Key, Value) Pair Format	LibSVM Format	ADAM (Avro and Parquet) Format

B. CSR (Compressed Sparse Row) or CSR (Compressed Row Storage) or Yale Format:

It includes matrix that consists of 3 one-D (one Dimensional) arrays of non-zero elements (dense Matrix) in the form of rows. In Compressed Column Storage (CCS) Format, Columns stored in the Matrix instead of rows. When SVM Algorithm is implemented in MapReduce Framework for large Datasets, CSR or CCS Format is used. CSR format is described in Fig. 11.

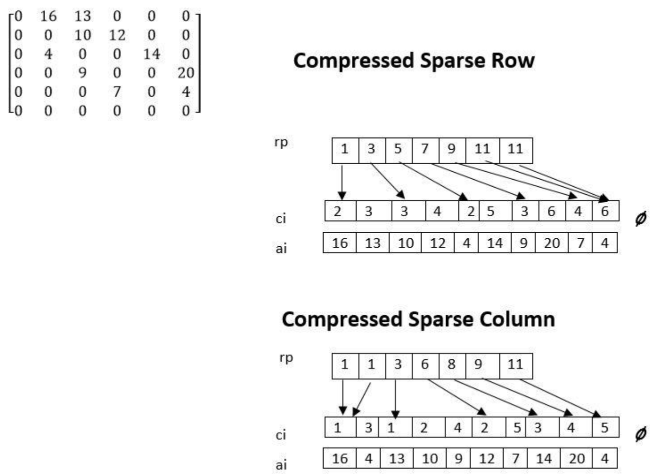

Fig. 11. Compressed Sparse Row

C. Sparse Vector Format:

It includes one-D (one-Dimensional) array of zero elements (Sparse Matrix). Elements of Sparse Vector are represented by Linked list. We can create Sparse and Dense Vectors in Spark Framework using MLib (Machine Learning Library). Sparse Vector Format is generally used for storage of Clustering data. Sparse vector format described in Fig. 12.

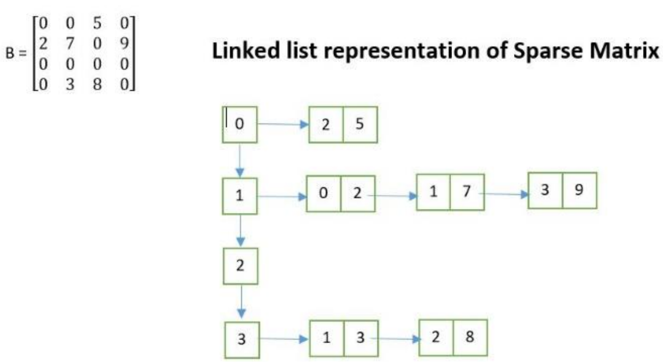

Fig. 12. Sparse vector format

D. LibSVM Format:

It is used by MLib (Machine Learning Library) in Apache Spark. This Format is used for Classification and Regression purpose for the storage of sparse data such a way that non-zero values are involved in large Dataset. In this Format, every line consist of an instance and it is end with '\n' character. Label consist of target value for Regression. It is supported by multi-class, not for one class SVM.

It is helpful for sparse training data. In this Format, first value of first line describes the dataset label. Then, index is representing after blank space. After the colon, value is given of specific index. In each line, specific label is given for dataset.

It is open source library that is used in ML Classification, Clustering and Regression. It compresses the dataset size. Reducing the size of dataset is very important for improving better analysis. It is efficient for both binary and multi-class Classification. Main feature of libSVM is that to provide GUI (Graphical User Interface). libSVM package includes C++ and JAVA source code library. File extensions are zip or tar.gz file for libSVM data storage Format. LibSVM format is described in Fig. 13

```
-1 4:1 19:1 21:1 30:1 38:1 41:1 54:1 65:1 69:1 74:1 76:1 79:1 80:1 85:1
-1 5:1 9:1 18:1 24:1 28:1 32:1 41:1 55:1 66:1 75:1 82:1 88:1 91:1 105:1
-1 5:1 19:1 22:1 31:1 43:1 46:1 52:1 58:1 66:1 67:1 77:1 82:1 87:1 99:1
-1 6:1 7:1 16:1 21:1 37:1 44:1 48:1 65:1 68:1 71:1 78:1 79:1 81:1 85:1
+1 7:1 12:1 14:1 33:1 38:1 41:1 56:1 66:1 69:1 77:1 79:1 80:1 91:1 99:1
```

Fig. 13. LibSVM format

E. Avro Format:

It is row based binary serialization Format. It represent encodings such as Binary and JSON (for web applications) [24] [25]. Avro depends on schema and frequently used Format in Apache Spark for large Bioinformatics (Genome) data storage. Avro integrated with Dynamic languages and support for Dynamic Typing. Avro format described in Fig. 14.

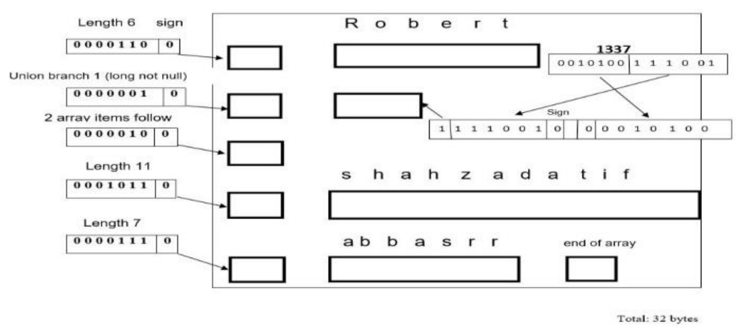

Fig. 14. Avro format

F. Parquet format is columnar data storage Format:

Parquet is columnar data storage Format: In this Format, Binary data stored in the form of columns. It is very effective and provides best query Performance on Hadoop platform. Like Avro Format, Parquet is supported by Apache Spark Framework for the storage of large Bioinformatics data. Parquet format is described in Fig. 15.

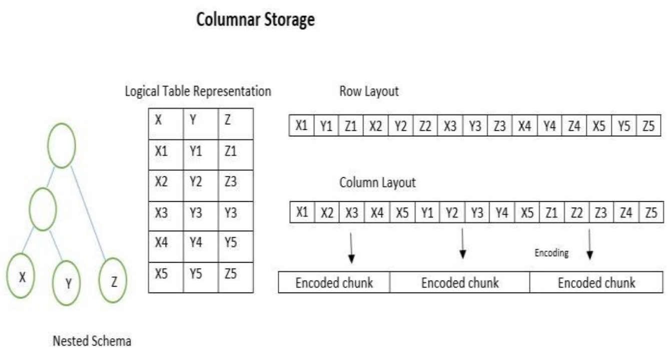

Fig. 15. Parquet format

G. ORC (Optimized Row Compressed) Format:

It is used for relational data storage in Hive Framework that consumes minimum space. It performs better without compression than other Data Formats in Hive. It consumes less execution time for reading, writing and accessing Hive data. ORC format is described in Fig. 16.

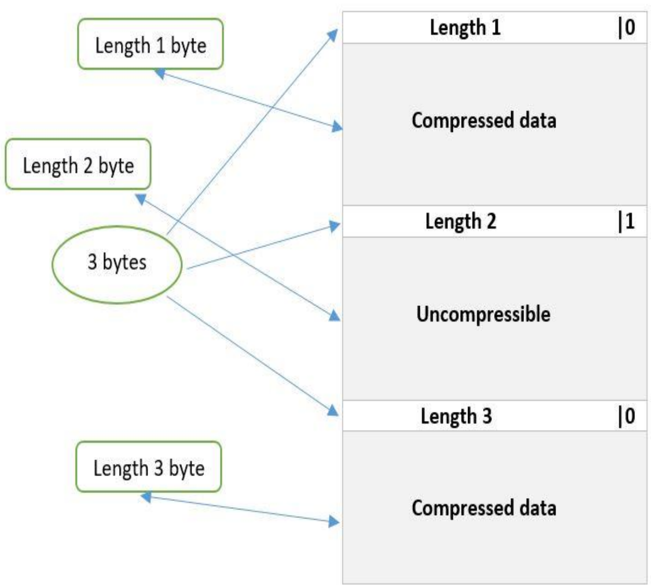

Fig. 16. Optimized Row Compressed format

H. BAM (Binary Alignment Map) File Format:

It is used for the storage of text data into Sequence (Aligned or Unaligned) for Genome in single node processing for direct access [26]. Data cannot be stored in HDFS without accessing BAM Library. When data is stored on Hadoop platform, Spark queries are used for sequencing data [27]. BAM file format is described in Figure. 17.

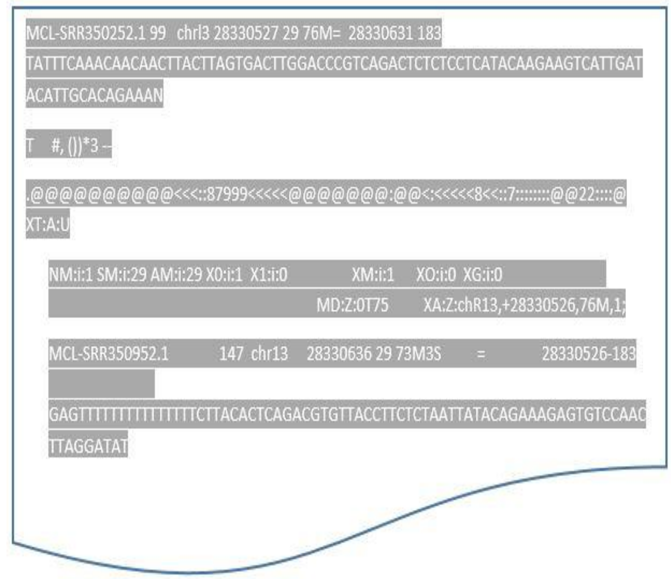

Fig. 17. Binary Alignment Map format

I. Fastq Format:

It is text Format for storage of DNA, RNA and Genome sequence data with their quality. Fastq format is described in Fig. 18.

It is used in multiple and sequence alignment for Bioinformatics data storage. In this dataset Format, first line represents @ character that is sequence identifier, second line starts with sequence letters, third line starts with + character, fourth line describes quality scores for sequence letters given in second line. Quality score based on ASCII (American Standard Code for Information Interchange). This format helpful for comparing multiple sequences. Fastq compression files are in GNU zip format. Compression of quality scores is very significant for reducing storage requirements. File extensions for Fastq data storage are .fq and .fastq.

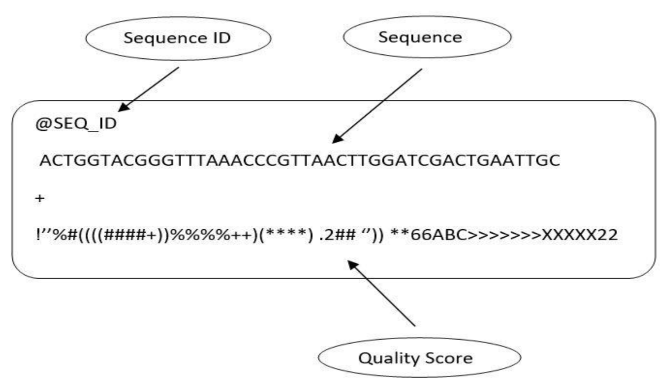

Fig. 18. Fastq format

J. FASTA Format:

It is store the Nucleotide Sequence Biological information. In this Format, multiple sequences exist. This Format starts from > symbol that determines the sequence name and output the sequence according to this name. FASTA format is described in Fig. 19.

In this Format, first line represents > symbol or ; (semicolon) depicted header line that is sequence identifier, second line starts with sequence letters. Length of each line sequence less than 80 characters. Sequences are described by amino acid codes. Compression is very important for FASTA like Fastq. File extensions for Fastq data storage are fasta, fna, ffn and frn. Blank spaces are not all permitted in the middle of sequence.

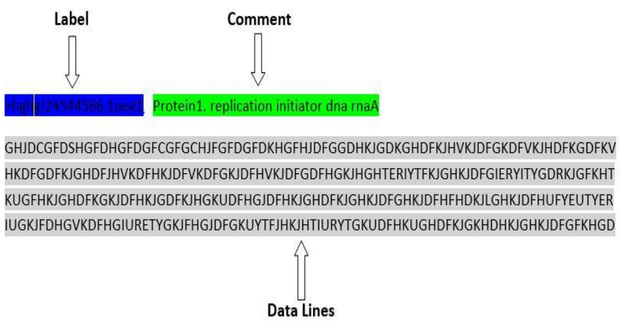

Fig. 19. Fasta format

K. VCF (Variant Call Format):

It is designed for the storage of large Genomics data in the form of text including some special keyword # in MapReduce or Spark Framework. In VCF, every line is represented in the array. VCF provides better Speed when large genome data is stored in Spark instead of MapReduce. Spark Transformations are performed directly from VCF. VCF is described in Fig. 20.

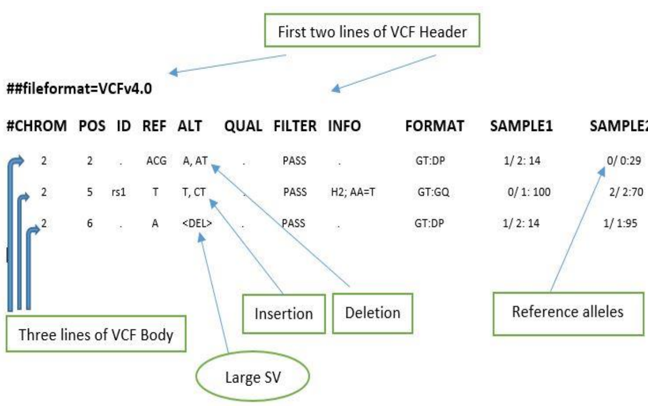

Fig. 20. Variant Call Format

L. Graph Format:

Giraph packages include input Formats such as Vertex Input Format (for Directed edges) and Edge Input Format (for Relational storage) [28]. Their output Formats are Vertex Output Format (for representing writing data for every vertex) and Edge Output Format (for representing writing data for every edge) [28].

M. Audio and video Format:

When video comes from medical and clinical data in Hadoop platform that data is converted in to MPEG-2 Format which is specially design to perform complex tasks on videos through video Transcoders. This MPEG-2 Format converts that video Format into specific sequence file Format that take binary key value pairs to Hadoop platform through Mappers for better results and get better performance [29] [30]. Like video Formats, audio data first converts into MPEG-2 through transcoders and then that MPEG-2 converts to sequence file to perform big data tasks on Audio files.

V. TOOLS FOR DATA FORMAT CONVERSION

When large Bioinformatics data is stored in Hadoop MapReduce or Apache Spark Framework, then this data will be stored in one specific Hadoop supported Format. Some Data Formats are not supported by Hadoop Platform. To reduce this problem, conversion tools are used that convert Data Format from one form to another. Many conversion tools are used that convert Bioinformatics Data Formats into Spark supported Data Formats. Most important conversion tool is TCS that transform data from Relational Databases to Hadoop Platform. When Machine Learning Algorithms and Techniques are implemented in Apache Spark, Avro and Parquet are supported Formats. In this situation, ADAM stack plays a significant role in Spark Framework.

There are many tools that are used for conversion of large dataset from one format to another. Some tools are Data Converters, FME data conversion and integration tool, Altova MapForce, SQL database table, TCS, Sqoop, Avro2parquet, Apache Drill, Format Converter, ADAM, Apache Giraph and GraphChi.

A. Data Convertors:

Data convertors is a Python Library and a command line tool that is used to perform routine data conversion tasks easily. Data convertors help data scientists to perform commonly tasks very efficiently and easily for example moving data between tabular Data Formats, converting a csv file to JSON object or an Excel spread sheet to csv [31].

B. FME data conversion and integration tool:

FME is the only spot-on spatial ETL (extract, transform and load) platform that is used to cope with the spectrum of data interoperability challenges completely and easily, including proprietary managing and evolving Data Formats. FME data converters also help in restructuring, adapting to new schemas, distributing and integrating the data.

With the help of the power and flexibility of FME platform, it is easy and quick to enable spatial data translation and migration projects, exchange spatial data, distribute data to multiple users and transform data from one Data Format / model to another. FME data converter supports hundreds of Formats and data validation too [32].

C. Altova MapForce:

MapForce is a multi-purpose IDE that is used to transform data from one schema to another schema or from one Format to a number of file-based Formats or other specific Format without writing any program code, conveniently and easily. MapForce determines the structure of data or gives an option to provide the schema of data from user. MapForce supports a lot of variety of Data Formats to work with. MapForce also gives graphical view of the data to the user for mapping transformations among different Data Format files [33] [34].

D. SQL database table:

Most of Machine Learning tools takes different types of Data Format as input. In most cases, the dataset is not existing in a single file and dispersed across diverse sources such as CSV, Text and TSV etc. For combining all of the available Formats in a single Format, a tool is required to collect, filter, intersect and transform data. When data is large in size and the modifications are multifaceted such as combination of quite a lot of sources, purifying a subsection of dataset or dealing with a huge number of rackets or rows, a more dominant tool like RDBMS is required. MYSQL is an excessive tool to organized data into one Format that are sparse across very different sources or Formats [35].

E. TCS:

It is secure data migration tool that migrate large data from Relational Databases and File Systems to Hadoop platform such as HDFS, HBase and Hive. This tool is cost effective and efficiently transform data from one form (multiple sources) to another form [36].

F. Sqoop:

It is import and export Hadoop tool that migrate large data from Relational Databases to Hadoop platform in HDFS, HBase and Hive. It imports data into HBase and Hive [37]. Sqoop does not support for Parquet Format export but support for Avro Format export.

G. Avro2parquet:

It is a data conversion tool that is based on Hadoop MapReduce Framework that easily convert data from Avro (Row-Oriented form) Format into Parquet (columnar form) Format. This tool works in the form of key value pair such as (GenericRecord, NullWritable) in Avro container [38].

H. Apache Drill

It is a SQL (Structured Query Language) query engine that supports HDFS, HBase, MongoDB and Amazon S3 on Hadoop platform and also include many Built-in-Functions for many data type conversions [39]. Drill is used when CSV or TSV (Tab Separated Value) files are converted into Parquet Format because Parquet offers best Performance than CSV or TSV test files [40].

For converting CSV files into Parquet Format in Spark Framework, first of all spark-csv package is used to load CSV data in Spark data frames, then these frames are saved to Parquet Format [41]. In Spark Framework, MLib (Machine Learning Library) contain Utilities such as ‘MLUtils’ that are used to convert matrix and vector columns into new spark matrix and vectors.

I. Format Converter:

It is a tool that convert the DNA, RNA and Proteins Sequences into specified Format for Bioinformatics data. In this tool, we give the input and output Formats and also gives our sequence. For example, FASTA is converted to CSV Format.

J. ADAM:

It is open source protocol stack that includes API’s and set of Formats used in Apache Spark Framework for processing and storage of large Genomics data [42]. ADAM is implemented on top of Parquet (for accessing database such as Impala) and Avro (for explicit schema access in any language such as Python, Scala, C++ and Java) [42].Existing Formats such as BAM/SAM/VCF are not scale with large Bioinformatics data due to limited Scalability using BAM and deficiency of explicit schema [42].

K. Apache Giraph:

It is an open source system on the top of Hadoop I/O Format API for large processing of graphs on Hadoop Platform. It automatically includes existing Formats of Hadoop.

L. GraphChi:

It is a system for large processing of graphs in which ML Algorithms are executed on large graph only on single computer [GraphChi paper ref]. It reduces the several problems for graph processing and storage that occurs in Hadoop Platform. It takes less Execution time than the time taken by the Hadoop and Spark for graph processing [43]. GraphX is a built-in Library for large and faster graph processing in Spark Framework.

VI. Discussion

There are many Modern Data Models (Format) that are supported by Hadoop and Apache Spark for applying Machine Learning Algorithms on large Bioinformatics data. It is very important to choose a specific Data Format that is suitable for efficient processing and storage of huge Bioinformatics data.

The objective is to select a data format that takes less space and provides great performance. The comparison of Performance and Speed of different data formats is described in TABLE II.

Now we will discuss about Performance of existing Data Models that are used on Hadoop or Spark Framework for applying Machine Learning Algorithms on large Bioinformatics data. Sequence File Format provides better performance for faster datasets than using CSV or Text Formats. Supported platforms for Sequence File Format are MapReduce and Hive but it does not perform well for large datasets. MapReduce and Hive provide support for CSV, Text and JSON Formats, whereas Weka provides support for ARFF.

Avro Serialization Format provides best performance when we have data of multiple Rows instead of Columns. It is less efficient than Parquet Format and ADAM stack. Better speed has been achieved using Parquet Format than Avro (Serialization) Format in Hadoop and Spark Framework [44]. In case the data contains many columns then Parquet or ORC Format should be used that provide best speed and performance. If we have many rows, then Avro is best Choice [44]. Actually, Parquet compress data that has advantages of save the space. Supported Platforms for Avro and Parquet Formats are Hadoop MapReduce, HBase, Hive, Pig and Spark. ORC Format supports for indexing and better for query processing. Supported Platforms for ORC Format are Hadoop MapReduce, Hive, Pig and Spark but it is not supported by HBase.

Machine Learning Classification and Clustering play an imperative role in Bioinformatics. Microarray (Genomics) data will be classify into binary and multi-classes with the help of ML Classifier. K-means and k-median Clustering are very beneficial for Bioinformatics data. Better analysis will be perform by using ML classifiers in Apache Spark and Hadoop MapReduce framework for Bioinformatics data. Apache Spark use mlib library and MapReduce use mahout library for analysis of Bioinformatics data.

For application of Machine Learning Algorithms and Techniques in Hadoop or Spark, LibSVM Format and ADAM Tool are frequently used for large Bioinformatics (Genomics) data. LibSVM plays an important role in ML Classification and Clustering. ADAM takes great benefit from Parquet and Avro by using Apache Spark in the application of ML Algorithms for large data Genomics. ADAM has better performance and execution time (Speed) than traditional BAM/SAM or VCF for large Bioinformatics data. Supported platform for ADAM is Apache Spark.

Following guidelines may be used for choosing a specific data format:

- If multiple Queries are running in Impala, then Parquet Format will be used and ORC (Optimized Row Columnar) Format will not be used.
- If running Multiple Hadoop MapReduce tasks in pipelining, then Sequence File Format will be used.
- If running large Queries in Hadoop Platform, then Apache Parquet (columnar) Format is used.

TABLE II. PERFORMANCE COMPARISON OF DIFFERENT DATA MODELS (FORMATS)

Data Models (Formats)	**Performance**	**Speed**	**Supported Platforms**
CSV	Better than JSON file format	Less than Sequence file format	MapReduce/Hive
Text	Less than CSV format	Less than Sequence file format	MapReduce/Hive
Sequence	Better for small datasets	Faster for small datasets but not for large datasets	MapReduce/Hive
JSON	Less than CSV format	Less than CSV format	MapReduce/Hive
ARFF	Better than CSV format	Less than Sequence file format	Weka
Avro (Serialization)	Less than Parquet and ADAM Stack. Best for multiple Rows.	Less than Parquet. Less Scalable for many Columns.	Hadoop MapReduce, HBase, Hive, Pig and Spark.
Parquet	Better than Avro. Best for multiple Columns. Less than ADAM Stack. Not support for indexing.	Better than Avro. Less Scalable for many Rows.	Hadoop MapReduce, HBase, Hive, Pig and Spark.
ORC (Optimized Row Compressed)	Better than Avro. Support for indexing Best with Hive	Better than Avro. Best for Querying processing.	Hadoop MapReduce, Hive, Pig and Spark. Not Support for HBase
ADAM Stack	Better than simple Avro, Parquet and VCF.	Better than simple Avro, Parquet and VCF.	Best support for Apache Spark.

VII. CONCLUSION

Bioinformatics research involves large volumes of data and complex data analytics. Most of the tools in bioinformatics use iterative machine learning methods. These tools can be scaled to handle large volume of data by using parallel and distributed computing models as provided in Hadoop and Spark. Big data tools and platform use different data models and formats than used by traditional bioinformatics tools.

Data model or format plays an important role in data analytics. It affects the understanding of data, representation of data, space required to store data, data I/O during processing of data, application of machine learning or mining algorithm on data, intermediate results of processing, in-memory analysis of data and overall time required to process data. So, a careful selection of data model or format is required for conducting any data analysis experiment.

In this paper, state of the art data models and formats are explored. Each format is elaborated with its salient features and storage mechanism. Particularly, data models for big data platform are presented that can be used to conduct bioinformatics experiments. Data models are also discussed in relation to implementation and application of machine learning algorithms. Finally, modern data sets are compared on the basis of their performance on big data platform.

This study will help researchers and data scientists in getting firsthand knowledge of state of the art data formats and in better planning and accomplishment of data mining experiments.

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Proactive Intention-based Safety through Human Location Anticipation in HRI Workspace

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***Abstract*—The safety involved in Human-Robot Interaction (HRI) is an important issue. This is the key point for the increase or decrease in HRI activity. A novel solution concerning the safety of HRI is proposed. The solution considers the near future human intentions. A set of possible human intentions is known to the robot. The robot also knows the places that can be visited by the interacting human according to his current intention. The proposed solution enables the robot to avoid a potential collision by anticipating the future human location and dividing the workspace into safe and unsafe zones. The solution contributes for the improvement of HRI safety measures but further efforts are required for achieving an enhanced safety level.**

***Keywords*—Intention Recognition; Human-Robot Interaction; Human-Robot Interaction Safety; Unsafe Zone; Workspace**

I. Introduction

The increase in the robotics research has increased the presence of robots in our daily life. The existence of robots in industry is increasing day by day [1]. This increase triggers the already active research area of Human-Robot Interaction (HRI) and has set a rapid pace to achieve milestones in order to meet expectations. In the field of HRI, there are different sub-research areas in focus. One of the important sub-research areas of HRI is the HRI safety. Simple and light weight robots may not be harmful to the human during HRI but the large and powerful robotic arms moving at high speeds can be harmful to the human working in the shared vicinity. In the industry, the robotic arms are mostly fenced where the humans are not allowed to enter [2]. In case if the human enters the area, the robot is switched off or the speed of the robot is decreased. Therefore it is still a question that human and robot can work / coexist together without any threat to the human.

Different approaches have been proposed to solve the safety problem for HRI. Safety measurement concerning HRI can be broadly divided into two categories, i.e., collision avoidance and after a potential collision detection reducing the collision intensity. There exist different kinds of approaches for avoiding a collision during HRI, e.g., camera based solutions. Camera based approaches come under collision avoidance. HRI workspace can be monitored by the range and vision sensors. The speed of robot can be decreased due to the presence of the human or the robot's path can be differently planned. Decreasing the speed of the robot or simply stopping is the only solution but is not an efficient one. Reconsideration of path is acceptable but it is not risk free. The chance of collision exists if the monitoring is performed using the vision or range sensors. Vision based HRI safety is not reliable as there can be many issues while working with the camera, e.g., human occluded by objects / robot, camera failure, etc. That may cause the collision between the human and the robot. The camera approaches also involve image reconstruction for human localization, e.g., [3] reconstructs the unknown objects (humans, etc.) with a known environment, with the aim of surveillance / human-robot coexistence. Some of the camera based approaches constitute a safety circle / sphere around the human in the vicinity of the robot, e.g., in the approach given in [4] a safety circle is used to delimit the robot motion. The approach in [1] used the safe guard zone strategy, i.e., if a human is detected in the safeguard zone then robot's control sequence is altered to ensure HRI safety. In [6] pre-collision strategies are discussed to avoid collision between the human and the robot. The focus of the approach in [6] is control strategies based on explicitly defined measure of danger while in [7] pedestrians behaviour prediction is done to ensure safety.

Other approaches involve torque sensing in the joints of the robot to decrease the intensity of collision between the human and the robot, e.g., [8]. The safety solutions for HRI also involve the approaches that use mechanical design of the robot. The approach in [8] applies the whole body robot viscoelastic covering. The approaches [9] and [10] use distributed parallel actuations as a mechanical design solution for HRI safety. Similarly approach [11] proposes mechanical safeguarding measures. The study presented in [12] estimates contact forces through depth sensor (Kinect). Two control schemes are introduced for generalization of impedance and direct force control paradigms. Another approach presented in [13] uses RGBD camera and to compensate its shadowing effect a series optical distance sensors is used. Robot Operating System (ROS) is used as a platform to run the codes for behavior prediction of the co-worker(human), robot path planning and collision detection.The approaches [3,14] use inertia reduction and force controller saturation filter in order to reduce the impact of force if the collision has occurred. The approach in [15] presents design strategies of human symbiotic robot. A danger evaluation method is developed in [16] using the potential impact force. The danger index is calculated by the product of factors that affect potential force between the human and the robot. The factors involve relative distance between the human and the robot, relative velocity, inertia and stiffness of the robot. The approach described in [17] discussed the HRI safety using the human intention. The focus of the approach is the human-intention-recognition based approval of the robotic action. It means that the robot checks before performing an action that its action that it is to perform in next 2-3 seconds will be accepted / allowed by the interacting human or not. The proposed solution discusses a previously unaddressed issue concerning HRI safety. The issue corresponds to the anticipation of future human location with respect to the current human intention.The HRI safety may be improved by predicting the possible human location(s) in HRI workspace, i.e., the robot can anticipate the future human location and actions and thus the robot can plan the path avoiding any expected collision.

The rest of the paper is organized as follows: In Section II, a general introduction to mechanism used to recognize the human intentions is described [18]. Section III discusses the proposed approach for a potential collision avoidance between the interacting human and the robot. Section IV describes the experiments performed using the proposed approach. The conclusion and the future work are discussed in the Section V.

II. Intention Recognition

A Finite State Machine (FSM) represents the action sequence concerning a unique human intention [18]. A probabilistic weight is associated to each FSM that represents how closely the intention represented by the FSM relates to the currently estimated human intention. The high weight of a FSM means that the FSM closely relates to the currently estimated human intention and vice versa. A FSM is shown below in Fig. 1.

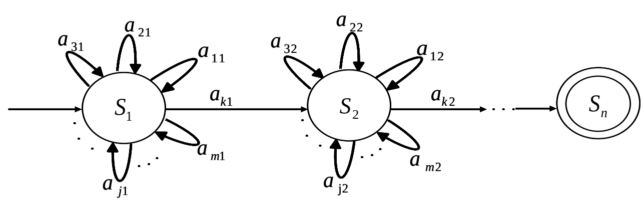

Fig. 1. A Finite State Machine corresponding to a unique human intention [18]

The probabilistic value $P(a_j|S_i)$ of each action a_{ji} at the state S_i describes how likely an action a_{ji} is for the state S_i of the FSM. The action a_{ki} represents an action that has highest probability for the state and the state transition only occurs if it occurs as shown in Fig. 1. All the other actions a_{ji} has the low values at the state S_i therefore they lead to the same state S_i and no transition occurs as shown in Fig. 1. The formal description of the FSM given in Fig. 1 is descreibed.

A FSM is a tuple of Q, $\sum$, q_0, F, and δ . The symbols Q and $\sum$ represent sets of states and actions respectively. The symbols q_0 and F represent start and final state of a FSM respectively and the symbol δ represents the state transition from S_i to S_i or S_{i+1}.

$$FSM = < Q, \Sigma, q_0, F, \delta >$$
$$Q = \{S_1, S_2, S_3, ..., S_n\}$$
$$\Sigma = \{a_1, a_2, a_3, ... a_m\}$$
$$\forall S_i \in Q \wedge \forall a_x \in \Sigma \text{ it holds that } \sum_{x=1}^{m} p(a_x|S_i) = 1$$
$$\forall S_i : \exists a_k \in \Sigma : \underset{j=1, j\neq k}{\overset{m}{\forall}} a_j \text{ it holds that } \left[p(a_k \mid S_i) > p(a_j \mid S_i) \right]$$
$$\delta : Q \times \Sigma \rightarrow Q$$
$$\delta(S_i, a_j) = S_i \text{ and } \delta(S_i, a_k) = S_{i+1} \qquad i = 1, ..., n$$
$$q_0 = 1$$
$$F = \{S_n\}$$

The sum of probabilities of all the actions for a state adds up to 1 and for each state there exist an action with the highest transition probability for that state and leads to the next state.

The flow of the algorithm for probabilistic intention recognition using finite state machines is given in Fig. 2. It is shown in Fig. 2 that an intention is recognized if the concerned FSM reaches its final state and it has the highest weight as compared to other FSMs.

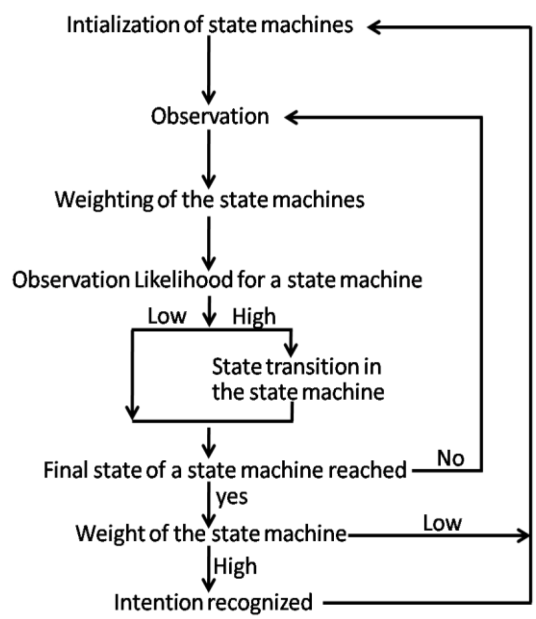

Fig. 2. Flow diagram of algorithm for probabilistic intention estimation [18]

III. Human Location Estimation

Grid based approach for safe HRI is proposed, where the HRI workspace is divided into a grid of cells (lines). The paths that may potentially be visited by the human and the robot are calculated and estimated. The path of robot is easy to calculate as the destination location for the robot is given.

The destination location for the robot depends on the current task assigned to the robot. Any of the existing path planning [19] algorithms can be used to calculate the optimal less optimal alternative paths for the robot to complete the current task. The path that may be followed by the human given the human intention is estimated. For the considered problem it is assumed that the human follows the optimal path from its current location to the destination location. The destination location of the human is estimated by the human intention. The human intention is recognized using the algorithm discussed in Section II [18]. It is assumed that the human follows the straight line (optimal) from his start location to his goal location.

1 - Input : Human location (L), Human Intention (I)
2 - Output : Possibly secure HRI
3 - Intialization :
4 - P_{robot} : *Path of the robot w.r.t robot task*
5 - P_{est} : *Estimated human path w.r.t I*
6 - Procedure :
7 - HRI workspace $\rightarrow G$
8 - **if** $(\psi_{coll}\ (P_{robot}, P_{est}))$
9 - **if** $(\psi_{exists}\ (P_{robot,alternative}))$
10 - **if** $(\psi_{exists}\ (P_{robot,alternative} > 1))$
11 - **return** $P_{robot,optimal}$
12 - **end if**
13 - **return** $P_{robot,alternative}$
14 - **end if**
15 - **wait(** $\psi_{empty}\ (G, P_{est})$**)**
16 - **end if**
17 - **execute(** P_{robot} **)**

Algorithm 1. Possibly secure HRI

Thus straight line is used as a heuristics to calculate the anticipated human path. The straight line heuristic is used to estimate the human path if there is no obstacle between the start and destination location of the human.

In case, if one or more obstacles exist between the start and goal location of the human then Manhattan distance can be used to estimate the path. After performing the three subtasks, i.e., the robot's path calculation, the human path estimation and the discretization of HRI workspace into grid, it is checked if there exist a collision between the calculated robot and estimated human path (Algo.1, line 8).

The collision checking and the auxiliary tasks required for the collision checking are presented in Algo. 2 and Algo. 3. In case if there exist no collision between the optimal robot path and the estimated human path then the robot simply executes its motion command and completes its task (Algo.1, line 8, 17). If there exist a collision then it is checked that if there exist alternative collision free path(s) for the robot (Algo.1, line 9).

1 - Input : L, I
2 - Output : Occupancy values $(O_{i,j})$ **for Grid** (G)
3 - Procedure :
4 - HRI workspace $\rightarrow G$
5 - $P_{est} = \psi_{path}(L, I)$
6 - *for* **each cell** $C_{i,j}$
7 - $O_{i,j} = \psi_{occ}(G, P_{est})$
8 - *end for*
9 - *while (TT*
10 - $if(\neg\psi_{comp}(P_{est}, P_{act}))$
11 - $P_{est} = \psi_{path}(L, I)\psi_{occ}(G, P_{est})$
12 - *for* **each cell** $C_{i,j}$
13 - $O_{i,j} = \psi_{occ}(G, P_{est})$
14 - *end for*
15 - *end if*
16 – *end while*

Algorithm 2. Expected collision checking using the anticipated occupancy values

If more than one alternative paths exist then the optimal alternative path is selected (Algo.1, line 10-11). Otherwise the only existing alternative path is used to execute the motion command (Algo.1, line 13). If there is no alternative path then the robot waits till the robot path has no collision with the human (Algo.1, line 15). It means that the human has performed his task by following completely / partially the estimated path. At that time the human has no such intention that there exist a collision between the robot path and the estimated human path.

The collision check is performed using the occupancy values of the grid G, given in Algo. 2. The occupancy values of the grid cells are calculated with respect to the human intention. The human path is estimated based on the current location of the human L and the current human intention I (Algo. 2. line 1). The estimated path of the human is comprised of cells in a grid (Algo. 2. line 5). The occupancy value of each cell $C_{i,j}$ is calculated with respect to the estimated path P_{est} (Algo. 2. line 6, 8). The occupancy values $O_{i,j}$ of the cell $C_{i,j}$ is used to determine potential collision. After the calculation of occupancy value $O_{i,j}$, it is continuously monitored if the human follows the estimated path P_{est} (Algo. 2. line 9-16). If the human does not follow the estimated path P_{est} but the deviation from the estimated path P_{est} within allowed limits then the recognition of current human intention and re-estimation for the anticipated path of the human is not performed. The limit values correspond to the soft threshold values defined manually. In case if the intention of the human is changed and the estimated human path P_{est} is totally different from the path P_{act} that is actually followed by the human then once again the current human intention is recognized and the human path is estimated using the current human intention and the current human location (Algo. 2. line 10-11). The new occupancy values are calculated based on the new estimated path (Algo. 2. line 12-14). The continuous monitoring of the human concerning the estimated path is performed till the human performs the current task according to its current intention. The calculation of cell occupancy is explained in Algo. 3. The cell occupancy is calculated for each cell $C_{i,j}$ of the grid G (Algo. 3. line 4-8). A 2D Gaussian is placed on each cell of the grid that belongs to the estimated path P_{est} of the human path. Thus a series of Gaussian exist in a sequence of connected cells that belong to the estimated path P_{est}.

1 - Input : $L, I, C_{i,j}$

2 - Output: $O_{i,j}$ for $C_{i,j}$

3 - Procedure :

4 – *for* each $C_{i,j}$ $\quad i = 1,...,m \wedge j = 1,...,n$

5 - *for* each $C_{x,y}$ $\quad x = a,...,b \wedge y = c,...d$

$a \geq 1 \wedge b << m \wedge c \geq 1 \wedge c << n \wedge C_{x,y} \in P_{est}$

6 - $C_{mean} = \text{arg\_min}(dist(C_{i,j}, C_{x,y}))$

7 - *end for*

8 - $O_{i,j} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(C_{i,j} - C_{mean})}{2\sigma^2}}$

9 – *end for*

Algorithm 3. Cell occupancy calculation

The occupancy value at these cells is the highest as compared to the neighboring cells. For each neighboring cell $C_{i,j}$ it is first searched that what is the nearest cell that belongs to the estimated human path P_{est} (Algo. 3. line 6). Then using that cell ($C_{x,y} \in P_{est}$) the occupancy value $O_{i,j}$ of cell $C_{i,j}$ is calculated using Gaussian probability density function (pdf) (Algo. 3. line 8). The zero man Gaussian probability density function is considered. The term $C_{i,j}$ - C_{mean} corresponds to the distance between the cell $C_{i,j}$ and the nearest cell that belongs to the estimated human path.

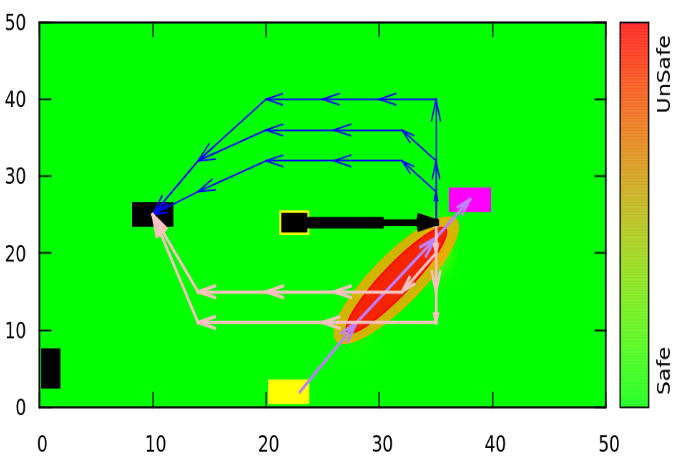

Fig. 3. All possible paths

IV. EXPERIMENTACTION

The experiments focus on the human safety during the human movement in the HRI workspace. The experiments are conducted in a simulated environment. The human movement, robotic motion and the existence of the static objects in HRI are simulated by the grid cells with specific occupancy values. The human location, the start and destination of the robotic arm with respect to a certain task are given in the simulated experiments. Ten to twenty repetitions have been performed for the validation of each discussed scenario.The robot can calculate all the possible and feasible (taking into account the robot arm singularities) paths to reach the destination. These calculated paths may not relate to all the expected scenarios in which we want to test our approach. Therefore we consider those paths that are according to the possible expected scenarios. Thus specific paths are selected for robot arm movement.

It is assumed that there is no obstacle in the human intended path (collision free). The only collision that can occur is with the robot. For the sake of simplicity, only the robot is considered to be a dynamic entity in the HRI. The mid-point line algorithm is used to calculate the human intended path from the current human location to the predicted human destination. The destination is predicted according to the estimated human intention. For the sake of simplicity, the mid-point line algorithm is used to select the cells that will be occupied by the human during the human motion.

A grid based HRI workspace is used. A grid of 50 x 50 cells is used to simulate the HRI workspace. Robot is placed at the location starting at (22, 25) on grid and its arm is at (35, 25). Robot destination is an object placed at position starting at (8, 25). Robot controller is at location starting from (0, 3). The current human location starts at (20, 0). The estimated human intention is to reach a table placed at location starting from (37, 37).

With respect to the above described grid, human and robot location, the human intended path and the robot's possible paths, there exit different HRI scenarios with respect to human-robot collision and different robot paths. The different HRI scenarios are given below

1) *First optimal path*
2) *Colliding first optimal path*
3) *Colliding first and second optimal path*
4) *All colliding paths*

In the middle of the Figures 3-9 the brown color box with the bold black color arrow represents the robot (robotic arm) and the span of its arm. The head of the bold arrow represents the location of the tool tip of the robot and the brown box in the middle represents the place where the robot is situated. The small arrows indicate the possible paths of the tool tip of the robot. The white color arrow represents a secure and optimal path. The normal red arrows represent the possibly insecure paths. The paths represented by the arrows correspond to the trajectory followed by the robot from its current location of tool tip to the destination concerning the robotic task except the purple arrows which show the estimated path that may be followed by the human according to his recognized intension. The human is currently at the location represented by the yellow box at the bottom of the figure. A Gaussian is placed on each point (grid point, i.e., box) of the estimated human path and a zone is calculated with respect to the presence probability of the human. The grid cells are considered as the mean μ that are expected to be visited by the human as she follows the estimated path. The Gaussian based probability is calculated for each cell that belongs to the estimated human path. It means that sequence of Gaussian probabilities is calculated for the estimated human path. The vertical bar on right side in the Figures 3-9 represents color based gauge for dangerous and safe zones. The pure red color represents the color of most dangerous zone and the pure green color represents the safest zone with respect to robotic arm's movement.The red or reddish regions (box / boxes) represent the high risk region with respect to the probability of the human presence and the greenish or green regions represent low risk or safe zones depending upon the probability of the human presence in the concerning region.

Any robot path that has intersection with the area other than green is considered insecure with respect to the possible human collision. The insecurity increases as the color of grid cell changes from green to red.

1) First optimal path

Figure 3 shows the first scenario. There exist five possible paths that are represented by the blue and pink arrows. The paths are selected as discussed earlier in Section IV. The two paths shown in Figure 3 (pink at the lower half) passes through danger zone, and three are in safe area (blue in upper half of Fig. 3). The robot selects the minimum distance path which is also safe as shown in Figure 4 with white color arrows.

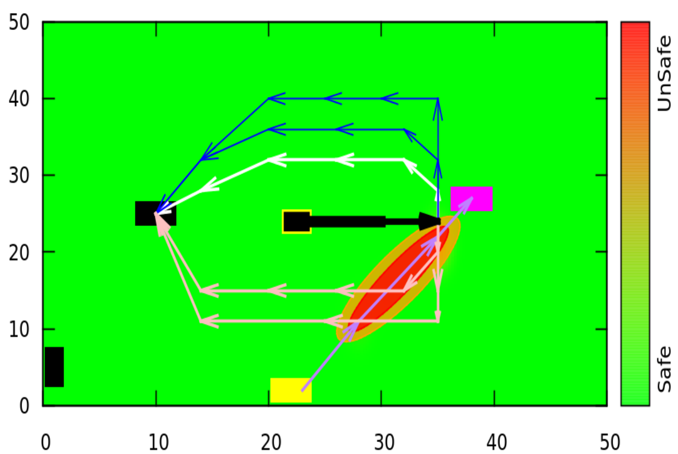

Fig. 4. Simple no collision in First optimal path

2) Colliding first optimal path

The second scenario is represented by Figure 5. There exist four possible paths, two paths (bottom in Figure 5) are in danger zone and two (upper in Figure 5) are in safe zone. The paths (bottom in Figure 5) are in danger zone as they have got some overlapping region with the human's expected path.

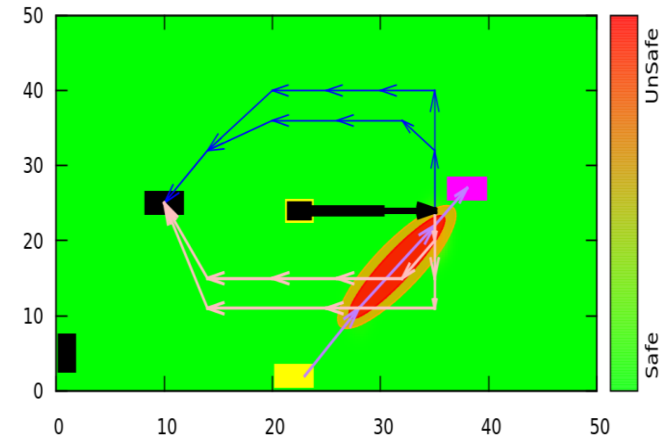

Fig. 5. Collision in the first optimal (shortest distance) path

The robot starts with the shortest distance path between source and destination. The robot considers the minimum distance path (red arrows in Figure 6) but it is in danger zone so it is rejected. The robot considers the second optimal (shortest distance) path. The path (highlighted as white in Figure 6) is second optimal but secure thus it is selected for navigation.

3) Colliding first and second optimal path

In Figure 7 three robotic paths are shown. The two paths (at bottom in Figure 7) are in danger zone due to the intersection with the reddish region and one (top in figure) is in safe region.

The robot considers the minimum distance path that is shown in the middle of Figure 8. The path is in danger zone and thus it is rejected. The robot then considers the second minimum distance path (lowest in Figure 8). The path (lowest in Figure 8) is also rejected as it passes through the danger zone. The robot considers the third optimal path. The path (highlighted as white in Figure 8) is safe and thus selected for robotic navigation.

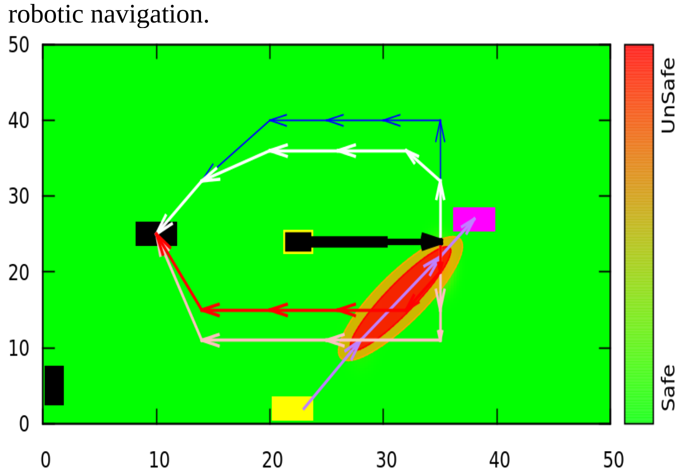

Fig. 6. Selection of second optimal secure path for robotic navigation

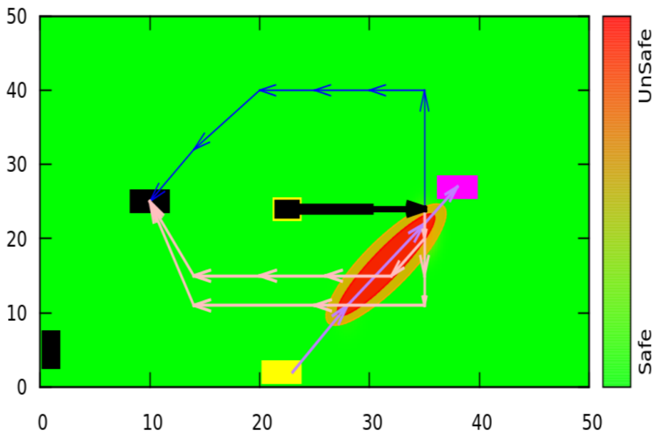

Fig. 7. Collision in all the optimal paths

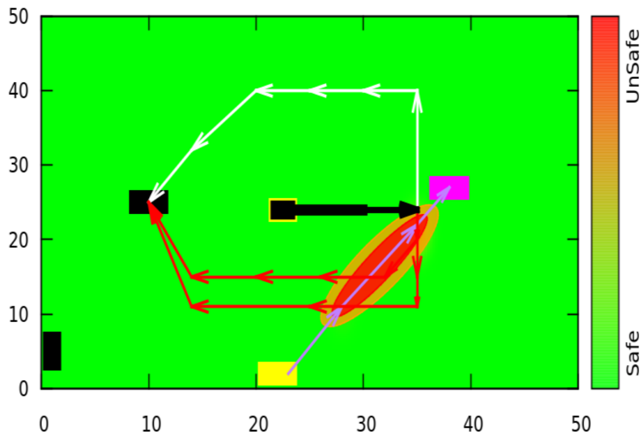

Fig. 8. Selection of the least optimal but safe path for navigation

4) All colliding paths

The Figure 9 shows the fourth scenario. There exist two paths for robotic arm to reach the destination object, and both the paths pass through the danger zone. The robot does not have any safe path to navigate thus the robot has to wait until the human changes his intention or performs the intended task. If there are *n*-1 colliding paths and n^{th} path is least optimal but secure (without collision) then the least optimal (n^{th} path) will be elected.

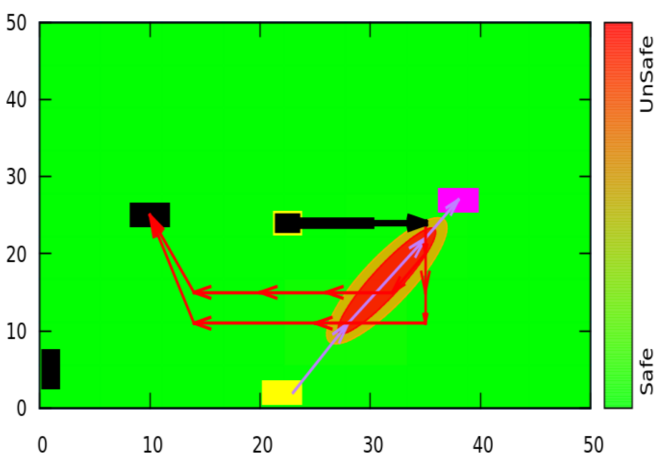

Fig. 9. No safe path for robotic navigation

V. Conclusion and Future Directions

In this paper we propose a novel approach for avoiding an expected collision between the human and the robot working in the shared workspace. The focus of the approach is on the human intention, i.e. given the human intention the intended human paths are estimated. The estimated paths are considered as danger zones for the robot to enter in the region(s). The presented approach focuses on the future expected human-robot collision(s). Thus the provided solution to avoid the expected collision can improve the human-robot interaction safety. The experiment section discusses different safety scenarios that may occur in a human-robot interaction workspace. The robot trades off between safety and optimality (minimum distance) while selecting the path for its navigation.

In order to further improve the HRI with respect to safety the robot speed will be changed so that the robot does not need to wait if no safe path exists. In case, if the robot can easily pass the intersection region without colliding with the human by increasing the speed then the robot can increase its speed. For this purpose, the occupancy grid values will be changed with respect to the current human existence, i.e., if the patch of intended path is at some specific distance from the current human then that patch is safe for robot to pass through if the robot moves with a specific faster speed.

Further to make the experiments realistic the upcoming research work will also include dynamic objects other than human and robot. The upcoming research will also focus on the cases e.g., if there exist more than one dominant human intentions and abrupt changes in human intention. The research experiments will involve more realistic path calculation approaches, e.g., A* search algorithm with the intention influence. The future experimentation would involve more concrete experiments with more concrete scenarios from day-to-day life.

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Impact of Story Point Estimation on Product using Metrics in Scrum Development Process

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***Abstract*—Agile Software Development techniques are worldwide accepted, regardless of the definition of agile we all must agree with the fact that agile is maturing day by day, suppliers of software systems are moving away from traditional waterfall techniques and other development practices in favor of agile methods. There are numerous types of methodologies, domains/ methods in agile for which are to be selected according to the current situation and demand of the current project. As a case scenario in the following research will discuss scrum as a development technique in which we will focus on the effort estimation(s) and their effects by discussing distinct metrics. Mainly estimation refers directly to cost, time and complexity during the life cycle of project. Metrics will help the teams to better understand the development progress and building releasing (releases) of software easier in a fluent and robust way. The following paper thus identifies aspects mainly ignored by the development team(s) during estimation.**

Keywords—product backlog; sprint backlog; backlog Item; front end designer; product Owner; agile software development; scrum master; product owner; sprint planning; velocity chart; Agile methodology; Effort Estimation; Story Points Estimation

I. Introduction

Scrum is a light weight process having a series of fixed length iterations known as sprints. In February 2001, about 17 developers published a Manifesto for Agile Methodology after discussion [16]. Actually they wanted a light weight method in which teams can work easily and comfortably.

According to Agile Alliance, the definition of agile based software development is that Agile based software development is a term for an arrangement of strategies and practices in view of the qualities and standards communicated in the Agile Manifesto.

Scrum simply gave our teams the self-determination that we needed to do our best work while helping our executives to get the business results they wants. Scrum has multiple basic roles and Team works with distinct artifacts PBL (Product Backlog) and SBL (Sprint Backlog). Scrum is assisted by the Scrum ceremonies that keep every team member aware of what is going on with the product, especially with the key reason of client awareness. Scrum is a transparent iterative technique that is openly disclosed to every member of the product, so here follows the purpose of metrics. Metrics don't take effect until the meaningful estimation of every BL-Item (Product Backlog Item) or SB-Item (Sprint Backlog Item) is not done. Metrics plays a key role towards the Journey starting from product planning till product success.

The technical question arises here is that, before starting every project, how a product owner can tells the customer that, how much cost is required to complete the project and how much time it will take? To answer this question, a lot of research has been made and researchers presented many techniques and methods to calculate the effort, cost and duration required for a software system. "Effort and cost estimation" is the terms that is used by researchers to calculate the cost and duration required to complete the project. But software project in agile software development still fails. Failure of the projects has many reasons:

- Poor estimation (cost and effort)
- Neglecting certain risk factors that can be occurred during project life cycle

In traditional methodologies metrics are playing key role to keep everyone focused toward the goal, Our research will conclude that whether the estimations and measuring metrics being used in scrum following industries produce key benefits that keep the team on track or either they help the team to have a clear understanding of Sprint Scope, Goal, and Quality Delivered to Customers. In traditional approaches, Metrics depicts the team's ability to understand and predict each and every member's capabilities. Here our focus is on correct Estimation technique and the metrics used in development market better results or not.

In this paper our focus is on the effort estimation and its effects that are used for transforming the requirements, skills and equipment's in terms of how much the project will cost and how much effort and time it will take to done. In simple we will discuss better way to estimate and will find how it will contribute to the product development and client satisfaction.

The rest of the paper has following section: Section II provides the Methods and Materials based on the existing research in this domain. Section III highlight the existing problems in this, Section IV presents Scrum Methodology, section V Software Metrics in Scrum, Section VI provides the Validation Results in this while section VII concludes the research and outlines future work.

II. Methods and Materials

Research work has been done to improve the estimation of cost and effort but those work lakes the capability of Metrics. Rashmi Popli et al. [2] proposed the solution in which they determined total number of stories according to the customers and users requirements to find out total story points after that they calculated effort, cost and duration required for the project by determining the introductory speed of the project. They also proposed activity diagram for agile estimation.

Evita Coelho et al. [3] discussed estimation based on story points. According to authors story point estimation team should know the acceptance criteria on which the project will be approved. Team should also focus every new feature and estimate the features that can be selected in upcoming release and then team should identify the length of iteration. Author's states to estimate the story points, velocity of the team should also be calculated. They further discussed 3 techniques to measure the velocity of a team. These techniques are:

- Measuring the velocity of the team from historical data
- Run some iterations and then measure the velocity by using the result of those iterations
- If there is no historical data is present then forecasting can be used

After measuring velocity, team should prioritize user stories on the basis of some criteria after that, estimate delivery date, from the length of selected iteration.

Nils C. Haugen [1] studied empirically of using planning poker for the estimation of user stories. He focused only extreme programming and observed a team working on a project in extreme programming. Team played a planning poker game. He also took an unstructured group estimation process and then compared the results.

Kjetil Moløkken-Østvold [6] et al. combined their estimates with planning poker. They discussed different techniques and prepared research questions. Author proposed solution that will studied on a company and then they calculate estimation accuracy by using a formula on the basis of which they give results.

On the other side metrics measure the software development process and team's quality of work. Metrics allow you to better understand the progress of project and assist in better management of development process [16]. Metrics provide us guide lines about what we are doing and what we will do [24]. Downey and Sutherland [16] came up with a number of fundamental measurements which are significant and can be utilized for management. Metrics are categorized into three groups as predictability in terms of project, team productivity, and quality of product. These metrics provide several favors toward ASD(Agile Software Development) such as better tracking of project progress, monitoring product quality, prediction and project management [28].So, it is convenient to find out the suitable group of metrics, criteria's, and measurement scales, which are best to incorporate with ASD [30].

III. Problems in Existing Methods

All existing techniques ignore the developer skills in task estimation. Agile team members came up with different skill sets [16]. All have their own way of thinking and level of experience. If we estimate tasks on the basis of senior resources although that is against the team work and scrum but industry is working like that, reality is not every task will be done by senior members. Generally, if a senior member will take 1 day to complete a certain task then junior member can take 2 days for that task which will cause the sprint delay and ultimately it became difficult for team to meat project deadlines. Existing techniques did not talk about QA personals and PO but focus point is on developers. We visited some organizations, which were following agile; we asked questions from team members of different organizations for their estimation of story points. According to the answers we got, we noticed that this is the serious problem that in organizations, story points for testing are not added.

IV. Scrum Methodology

Scrum is an agile framework for completing the complex and innovative scope of work.This frame- work is extremely simple. Scrum always gives freedom to business so that one can customize the process according to the requirement of product and the market. It cuts off the complexity of management and let the team focus on the product delivery. Scrum has three basic roles: SM, PO and Team

- ***Product Owner:*** The PO is the person who has vision for the product to be developed and the authority. PO is responsible for continuous team work and priority. It is the responsibility of PO to full fill the PBL and SBL.
- ***Scrum Master:*** The SM is just an expediter for both team and product owner. The SM does not manage the team. The SM works to tackle with impediments that cause failure in achieving sprint goals.
- ***Team:*** The dev team is self-organized to complete their committed work. A Scrum development team consists of about seven fully dedicated members (officially 3-9) for projects in software; a typical team includes a mix of software engineers that generally are architects, programmers, analysts, QA experts, testers, FED and UI designers.

There are different Artifacts of scrum which are follows

- *Product Backlog* (The PBL is the cumulative list of desired deliverables for the product).
- *Sprint Backlog* (The SBL is the team's to-do list for the sprint prioritized by PO).
- *Product Increment* (At the end of the sprint new increment started).

There are also 4 types of Scrum Ceremonies which are follows

- Sprint Planning Meeting (Time Frame =4hours (2 weeks sprint) main goal is what and How).
- Sprint Review/Demonstration Meeting (Time Frame=1.5hours (2 weeks sprint) main goal is to demonstrate last sprint work to PO).
- Daily Scrum Meeting (Time Frame =15mins brief progress on sprint by each individual team player).
- Sprint Retrospective meeting (Time Frame=15-20mins team discussion what good and bad happened in the last sprint and do we need any improvements).

Scrum gives free hands to manage timeframes according to the business needs.

V. Software Metrics in Scrum

Generally software metrics quantify the characteristics of software in terms of LOC (source lines of code), complexity (code), Bugs per lines of code, coupling, and cohesion. But here when teams are working in sprints, our main focus is on productivity and defining metrics to measure that. The team has a list of items to work on in the PBL which are picked during the sprint planning meeting, their requirements are refined and when the team is satisfied with their understanding of the tasks, it commits them for the upcoming sprint cycle. By using each sprint item the team is able to develop metrics to determine that either they are on track to accomplish the goal or have they deviated from the measured path. It makes releasing software very easy and pre- sighted. Fig.1 illustrates the process of scrum generally followed in industries and highlights the existence of metrics and estimation in process.

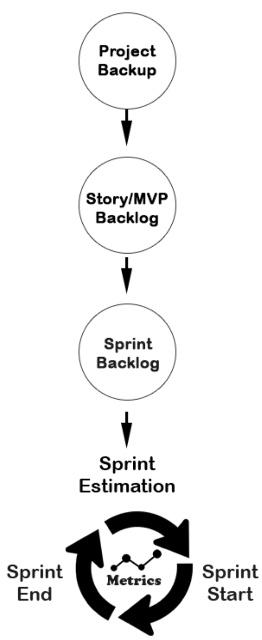

Fig. 1. According to scrum approach, sprint estimation and metrics

We have some metrics described below used in scrum widely to evaluate either they are full filling the needs or not. Every single metric mentioned below have their own quality of being suited to serve a purpose to achieve the sprint goal

- Sprint Burn Down
- Epic Burn Down
- Velocity Chart
- Control Chart

A. *Sprint Burn Down:*

Scrum team gets organized in development using this metrics. Before starting sprint in sprint planning meeting team estimates that how much work they can complete in a sprint (e.g. 2 weeks).This report tracks the work remaining to be completed for the sprint .The x-axis represents time duration of a sprint, and the y-axis refers to the amount of work left to complete in the form of story points (team measures complexity of each task). Goal is to complete all committed work by the sprint end.

Fig. 2. Sprint burn down chart using JIRA following scrum approach

We have here an example of a sprint burn down chart generated via Jira, the sprint burn down chart depicts that scrum team commits to 140 story points, here gray line is the mean line in between story points and sprint end date known as a guide line for the team. Our main focus is the red line that is showing actual status of the sprint, every day the team works on the tasks and the graph displays a downward trend. It dips only when the task from the sprint move to done status according to the definition of done by the PO.

This is the point where the role of SM is, the red line has different meanings according to behavior

- If this line goes straight that means the team has a blocker they need assistance in their sprint as shown in the Fig. 2 i.e. 25th to 29th august.
- If graph line suddenly falls at the start of the sprint means team did wrong estimation in Sprint planning meeting.
- The ideal graph is shown in Fig.2. Is from 29th august till the end of the sprint.

The Sprint burn down chart is extremely helpful for PO and SM to keep eye on team's progress.

B. *Epic Burn Down:*

Epic Burn down chart tracks the progress of development over a larger bulk of work than the sprint burn down, and guide development for both scrum and Kanban teams. As seen in fig

2, we have the original estimate and the completed work, sprint by sprint for a specific epic .Epic is a group of tasks related to one module let's call it Report.so, Report is one of the product module that takes several sprints to complete.

With the injection of fluctuating requirements into a previously-defined project, it will help us in that situation and makes everyone clear/aware of the flow of work.

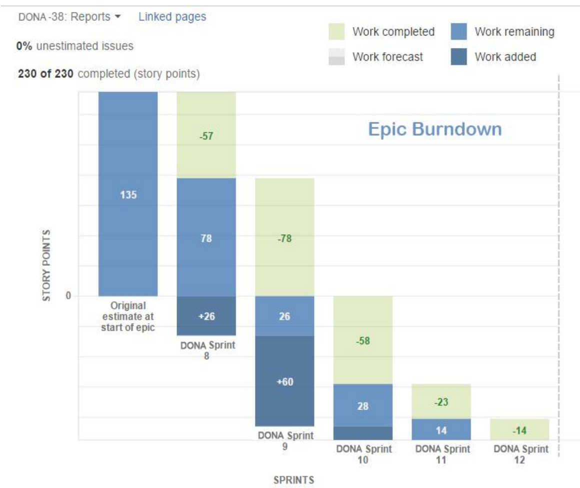

Fig. 3. Epic burn down chart using JIRA following scrum approach

Fig.3. graph shows an epic of reports that consist of 135 story points that are highlighted in the first bar among 6 sprint bars .Starting with sprint 8 of the project DONA here the sprint have 26 story points tasks newly added in and 57 got completed with 78 remaining out of 135 story points. This process is followed until all stories coming under the umbrella of Report epic got completed. As every metric have their own benefits and drawbacks this metrics doesn't show that how much story point commit by the team.

C. Velocity Chart:

Velocity Chart shows the average amount of work a scrum team completes during a sprint, measured in terms of story points and is very useful for predictions, it shows a graph between what is committed and what is delivered. It is the most accurate prediction for the team and PO about their capabilities.

Fig. 4. Velocity chart using JIRA following scrum approach

Here are some stats about this graph, VC (Velocity Chart) is a forecasting bridge of the product, and at y-axis it shows story points along with x-axis that shows sprints. The graph Grey bar'-s shows what was the commitment of team about sprint and green is what team delivered after sprint end. The key usage of this graph is to forecast how much team is capable to the SM .So, next time when the team is over estimating or under estimating sprint SM alerts the team about their capabilities. On the other hand, it helps SM about resource planning.

C. Control Chart:

Control chart focuses on the cycle time for the individual issues. Cycle Time is the total time taken to work on an issue from start till the end [5] including any extra time needed to re-open and work on it again that the team which has shorter cycle time for the issues are more likely to make a smoother and reliable delivery [5]. So this is the primary metrics of each team.

Fig. 5. Control chart using JIRA following scrum approach

Fig 5 depicts the Control chart graph, the filled in circles represent a cluster of issues and the hollow circle represent individual issues. Clicking on each issue opens up a pop up where the user can see the time the issues spent in each state (defined as per the organization's process).The control chart helps to identify the bottlenecks or any blockers the team is facing. The teams which are able to reduce the time each issue spends in a particular state are able to ensure a smoother delivery. This metrics helps SM and PO in several ways some are mentioned as:

- Analyze teams past performance.
- Measure the effect of change in process for the team.
- Provide PO, SM, and client with visibility of their team's performance.

VI. Validation

We took 2 development teams from 2 organizations. We can name teams as Team A and Team B. Both teams were following scrum. Normal working hours for a team member was 7 hours in a day. For both teams, sprint time period was 2 weeks which means each member of the teams has 10 working days.

We observed both the teams in backlog refinement and planning meeting. Teams estimated their tasks according to Fibonacci series. They started their sprint and worked on their tasks, we observed both teams during sprint. At the end of the sprint, we noticed that team members of both teams put extra efforts to complete sprint tasks. Team A was working for extra hours in last 2 days. Team B worked for extra hours on very last day for bug fixing. We tried to find out the reason behind extra efforts to complete their tasks. We took tasks estimates from both teams. Both teams were using Jira, a management tool. We gather data from sprint burn down chart using Jira. Fig. 6 and Fig. 7 respectively indicates Team A and Team B.

The tasks with their estimations for both teams are given in Table I.

TABLE I. TASKS VS ESTIMATIONS FOR BOTH TEAMS

Team A		Team B	
Task No.	Estimates	Task No.	Estimates
1	5	1	8
2	5	2	5
3	8	3	5
4	8	4	13
5	8	5	5
6	5	6	8
7	13	7	8
8	2	8	8
9	8	9	5
10	5	10	8
11	3	11	8
12	8	12	13
13	8		
14	5		
15	3		
16	2		

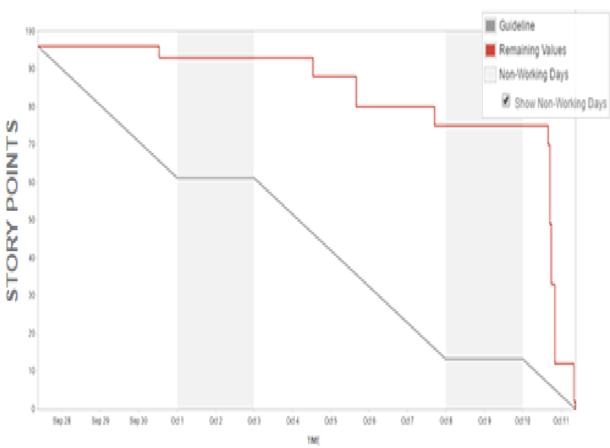

Fig. 6. Burn down chart for Team A

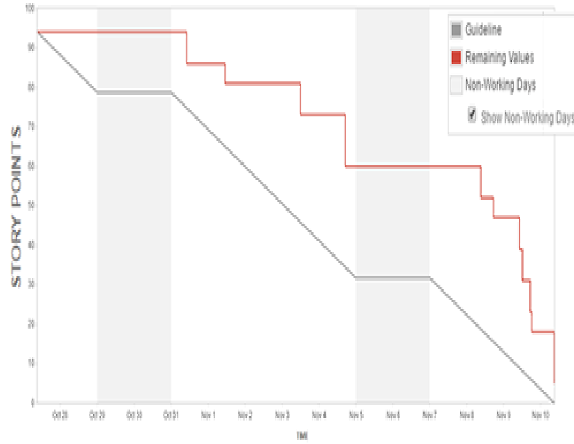

Fig. 7. Burn down chart for Team B

In above figures, grey colored line indicates the ideal state of sprint and red line shows the progress of team during the sprint. Red line progresses when a task moved to done status. In both figures progress state (red line) of sprint, is so much different from ideal line.

We used these burn down charts to compare estimations with the original effort done by team members on the tasks. We tried to identify why the tasks took so much time to complete. Meanwhile it comes up in noticed that tasks were completed by developers in time and complexity of tasks for developers was similar to the estimations given in Table I. After discussion with team we identified that developers completed their tasks but task's status cannot be changed to done because of testing by quality engineer and product owner, which consumes a lot of time. After proper testing Bugs were also identified and developers also fixed the bugs identified by product owner and quality assurance engineer. Here we identified that estimation done by both teams for all task lacks the effort of quality assurance engineer and product owner but the teams ignored these efforts while estimating the tasks.

For 2nd sprint, we asked both the teams to consider effort put by quality assurance engineer and product owner to test the task. Now developer decided their story points for every task and then scrum master ask from QA engineer and product owner to tell the team about their efforts to test the task. For each task, story points have also been added for QA engineer and PO. After sprint planning meeting teams started their sprints and we started monitoring their performance. At the end of sprints by both teams, we compared tasks of Table I with Table II and Table III and also compared estimations of the tasks with same complexity and we found changes for the estimations. Change in estimations are show in Table II and Table III. We again checked burn down charts and found that there was major positive change in burn down charts of both teams. Fig. 8 and Fig. 9 shows the new burn down charts for both teams respectively.

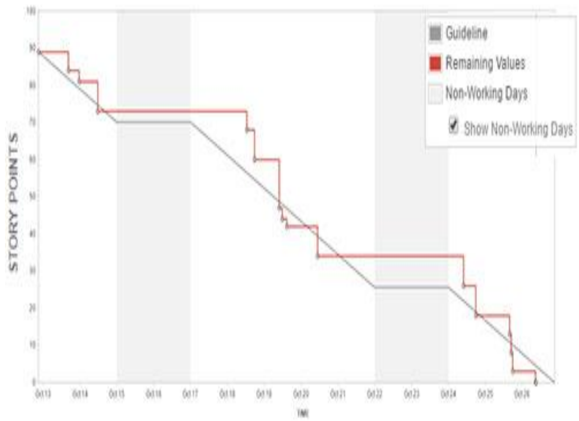

Fig. 8. Team A burn down chart

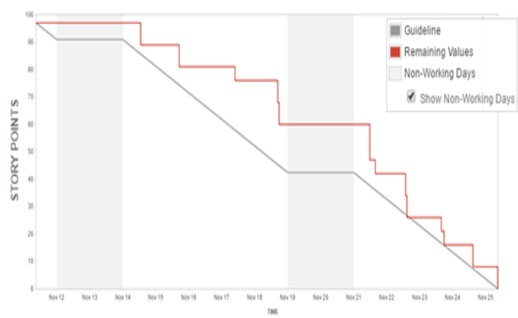

Fig. 9. Team B burn down chart

As we can see in Fig. 8 and Fig. 9, there are numerous changes observed in burn down charts as depicted in the mentioned figures, which shows the team performance throughout the sprint. Teams' progress line was close to ideal line. At the end of the sprint, both teams were relaxed and completed their tasks easily. Tasks moved accordingly and burndown chart is also improved.

TABLE II. TEAM (A) TASK VS ESTIMATIONS

Team A

Task No	Equivalent Task in Table 1.1	Estimation
1	8, 16	3
2	11, 15	5
3	8, 16	3
4	1, 2, 6, 10, 14	8
5	11, 15	5
6		2
7	3, 4, 5, 9, 12, 13	13
8	8, 16	3
9	1, 2, 6, 10, 14	8
10	1, 2, 6, 10, 14	8
11	11, 15	5
12	11, 15	5
13	11, 15	5
14	1, 2, 6, 10, 14	8
15	1, 2, 6, 10, 14	8

TABLE III. TEAM (B) TASK VS ESTIMATIONS

Team B

Task No	Equivalent Task in Table 1.1	Estimation
1		5
2	2, 3, 5, 9	8
3	2, 3, 5, 9	8
4		5
5	2, 3, 5, 9	8
6	2, 3, 5, 9	8
7	1, 6, 7, 8, 10, 11	13
8	2, 3, 5, 9	8
9	2, 3, 5, 9	8
10		5
11		5
12	2, 3, 5, 9	8
13	2, 3, 5, 9	8

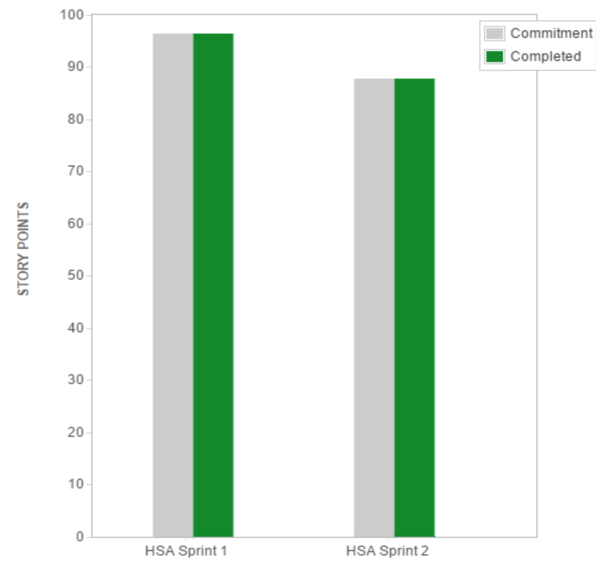

Fig. 10. Team A Velocity Chart

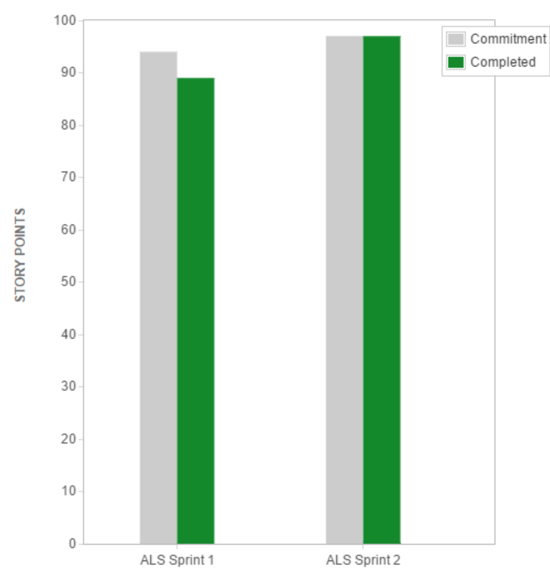

Fig. 11. Team B velocity chart

Fig. 10 and Fig. 11 are showing the velocity char for both sprints of both teams for both projects respectively. According to Table II and Table III, we can see story points has been increased and all team members will have equal opportunity to put effort on the tasks. We can concluded from these results that story points should be estimated according to developers, quality assurance engineer and product owner.

VII. Conclusion

Software systems have to ensure consistent and bug free execution at a rapid pace every time they are used especially in Agile Development. Improving software quality and performance has become a priority for almost every organization that relies on the software development. Thus the quality (estimation) issue related to the software's industry becomes more important, apparent and more technical also considering the user's requirements in this aspect.

The following work demonstrates an approach in the support of ASD especially in Scrum and comprehensively illustrate the different metrics to realize the team's work mistakes from different dimensions in the development industries. On the other side estimation of tasks, every team should also consider story points for QA engineer and Product Owner, as they also put effort on the tasks. This will be very helpful for better estimation. After every estimation, team should authenticate weather they have added points for all steps taken by the team to complete tasks. According to this paper every metrics has its own dimension that needs to be applied in the correct process. Many of Metrics calculations are strongly coupled with the story points to items in current version/Epic or sprint. Metrics play truly a key role in team development and help track the progress of the teams and any until product delivery. There are still a lot of metrics left that are related to scrum and estimations that needed to researched to introduce them into the current development scenario to boost up the agile team and process. Further, the following paper highlights the diagrammatic representation(s) of each metric with the help of Jira by Atlassian who are working in support of agile software development.

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Optimized Quality Model for Agile Development: Extreme Programming (XP) as a Case Scenario

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***Abstract*—The attributes of quality are that it is complex taxonomy, it cannot be weighted or measured but can be felt, discussed and judged. Early assessment and verification of functional attributes (requirements) are supported well by renowned standards while the nonfunctional attributes (requirements) are not. Agile software development methodologies are of high repute as the most popular and effective approaches to the development of software systems.**

Early requirements verification methodologies in Agile Software Engineering are well focused in this way and hence mainly researched have achieved in functional requirements. For early quality aspects (attributes) in order to bring quality in our design and hence development process, it is very important to consider nonfunctional requirements quality metrics (attributes). A comprehensive work is also being done to propose and validate (using iThink) different quality models which could make sure the quality of agile software products being developed, which will be though available in detail in the literature review (section II). Yet a generic and standard quality metrics model is missing in this for the agile software practices in all, which off course is further needed to make sure that the agile product being developed, will surely accomplish quality characteristics as decided by the stakeholders as well as the mentioned quality standard they are addressing. In this work we have proposed a quality metrics model that fulfills the desired quality attributes exist in ISO/IEC (Quality standards, ISO 9126, ISO 25000) in early requirements, we validated this by performing simulations in iThink technology that also ensures that the quality of item being produced to meet the described criteria.

Keywords*—Agile Software Engineering (ASE); Agile Software Development (ASD); Extreme Programming (XP); ISO; ISO 9126; ISO 25000

I. Introduction

Extreme Programming is one of a software engineering practice, articulated in 90s by Ward Cunningham, Kent Beck, and Ron Jeffries [17], the most important and noticeable among several methodologies. XP is different from traditional methodologies in a way that it emphasizes on adaptation than on prediction. In XP programming it is believed that it is more realistic to adapt different changes that appear during the whole software development process rather than specifying all the requirements at the beginning. XP provides a way for improvement and new style for development. XP aims at lowering the cost of change. The process of Extreme Programming starts with planning and then there are four steps that are followed in all iterations: designing, coding, testing, and listening. Though in the software development process, requirement management and requirement engineering practices are also very important & very critical [18].

The product quality that is being established by adopting the extreme programing methodology is also very important. Different quality models have been proposed that try to cover all the important and critical quality attributes [9] [4]. Here we have proposed a quality model specifically by considering the activities of extreme programming. The details about mentioned quality attributes, model and need for the model in this is highlighted in detail in the literature review section (section II), some limitations are given in section III, further the details about the survey that has been conducted to calculate the effect of different quality attributes are given in section IV and then a model is proposed in section V.

II. Literature Review

A. McCall Quality Model

This very first quality model was offered by Jim McCall [12], the quality characteristics of this model were categorized into three major groups. These three groups contain 11 quality attributes. First is product revision that consists of flexibility, maintainability and testability. Second is product operation which is dependent on honesty, reliability, precision, effectiveness and usability. And third is product conversion that contains the attributes reusability, transferability and interoperability. The sole aim of this model was to minimize the gap between the developers and the end users by emphasizing on the dimensions of quality. This model is suggested for generic systems, and hence the attributes that are specific for different domains are not clearly spoken in the space of the mentioned model [9].

B. Boehm Model

Boehm's quality model portrays a numerous leveled structure of attributes, each of which adds to the total quality.

Boehm's quality model [3] is fundamentally the expansion of McCall Quality model.

Utility characterizes how effortlessly, dependably and effectively programming item can be utilized, practicality characterizes how effectively modifiable and retestable the product item is and portability characterizes how the product item can be utilized after change has happened as a part of a domain [11]. Boehm distinguished seven quality components: Portability, Reliability, Efficiency, Usability, Testability, Understandability, and Flexibility [9].

C. FURPS Model

FURPS model [4], classify attributes into two unique requirements, for example, Functional Requirements (F) which is characterized by predictable input and output and Non Functional Requirements in which U represents Usability, R represents Reliability, P represents Performance (incorporates practical prerequisites) and S represents Supportability (incorporates reinforcement, essential of plan, execution, interface) [9]. One drawback of the FURPS model is that it doesn't reflect the portability perspective, which might be a vital basis for application advancement, particularly for programming based frameworks [11].

D. Dromey's Quality Model

Dromey's proposed an operational structure [15] [9] [4] for evaluating Requirement assurance, plan and practice stages. The structure involves three models, i.e. Requirement quality model, Design quality model and Implementation quality model. The top item properties for this model incorporate [11]:

- First one is correctness that checks that no defacto standard is affected and also checks the usefulness of quality characteristics.
- Second is internal measure that how well a module has been situated by future use, with proficiency, practicality, and dependability as quality characteristics.
- Third is contextual that manage the outer effects on the use of a constituent, with quality attributes in dependability, viability, reusability, and compactness.

E. IEEE Quality Model

IEEE Quality Model is mainly standard for software maintenance [6]. This model offers a process for handling and executing software maintenance actions. Standards like quality assurance, confirmation and authentication, software formation controlling in which linked processes are well-defined [9]. This model represents numerous proportions of qualitative features and signifies features that are Reliability, Functionality, Usability, Efficiency and Maintainability [9] [14].

F. ISO 9126-1 Model

ISO 9126 is a universal model for the improvement of programming [11]. ISO 9126 states and figures the product item quality regarding inner and outside programming qualities and their relationship to properties. The ISO 9126-1 quality model [9] [14] is additionally ordered into two groups. Initial one is Quality being used traits and the second that contains internal quality properties and External Quality properties. Quality being used traits is those properties that can be evaluated just when programming is satisfied and conveyed to the end client. Then again inner quality properties are those that can be measured even without executing the item, though outer quality characteristics are those that can't be measured without executing the item. ISO 9126-1 quality model contains these properties so that the item can meet the guidelines of quality.

G. Ghezzi Model

Ghezzi C. et al. [7], characterizes that center qualities manage the structure of programming which benefits the product engineers to achieve those outer qualities for which programming clients have a ton of concern furthermore conveyed both internal and external characteristics of programming which are Reliability, Maintainability, Reusability Usability, Flexibility, Portability, Accuracy, and Integrity [14].

H. Other quality models/frameworks

Richard et al [8] discussed the 24 quality attributes specifically focusing on extreme programming. In XP a customer take part with the development team so specification is not a single document. It consists of user stories, acceptance tests written by customers and unit test written for each module. Author basically applied those 24 quality attributes that were proposed by Davis [9] for a quality SRS, on a specification created with XP. However extreme programming process achieves higher values in nine attributes and drops the values in two. The most positive results were in ambiguity and understandability because in extreme programming customer is present at all times to answer every question [8].

M. Usman et al. [9] proposed a quality metric model for agile development. Eight quality attributes were considered most important for agile development. Those were availability, flexibility, testability, scalability, performance, portability, understandability and usability. And the influence of these quality attributes among individual phases of SDLC was also evaluated. Results emphasized that flexibility is the best quality attribute among all attributes and then portability and understandability. However it was suggested at the end that more quality attributes can also be included in the quality model that are maintainability and modifiability and their influence on software development lifecycle.

Robert et al. [10] presented the influence of agile development on quality inside the administrative, procedural and traditional back ground and provided business standard approvals to reduce such influences. It was suggested that IT organizations should practice quality techniques and quality frameworks like AAIM, AQT and ASSF. The agility characteristics that were described are flexibility, speed, thinness, learning and receptiveness. However this work largely concentrated on the surface of administrative and traditional impacts. More research examination and survey are needed to increase the knowledge base linked to this matter.

Deepshihka et al. [11] proposed a framework that contained some steps for the improvement of different quality models. Here author’s basically compared different quality models and found the main alterations between these models. It was found that in the 17 features only one quality feature is same in all models and that is reliability. Similarly, there are merely three features (i.e. portability, efficiency, usability) which are fitting to four quality models. Two features are mutual only to three quality models and that are functionality and maintainability. Two features fit in to two models and that are testability and reusability. And, nine features are presented in only one quality model. At the end some comments were given to these models. It was said about McCall model that it is a general model based only upon the finding of a person's questionnaire. FURPS was built for a company so it is a special purpose model, however it was suggested that a new model can be built from these quality models [9] [4] [7].

Inderpal et al. [12] compared different characteristics of different quality models and it was found that maintenance cost depends so much upon the quality of a product. Author compared different quality models and it was found that reliability is a common characteristic of all quality models. It was also suggested that different quality features can be executed with relative to cost, schedule and modification. However it was suggested at the end that it's very significant to have very decent description of software requirements to have greatest results. It should be noted that different phases that are involved in a process should be done in proper way to have quality.

Ranbir et al. [15] presented a survey of different quality models [3] [4] [12] [6] and also did their comparative analysis. To do the comparison data was collected from various organizations through questionnaire and also through different published articles. Interviews were also taken from various students. The questionnaire contained different quality attributes from different quality models and their suitability was measured and analyzed. Analysis was basically done by using different tools that help for analyzing different things and then results were presented in the form of comparison table. However, it was suggested at the end that all these quality models are working well but still there is a need a software quality model that can be applied during whole software development lifecycle.

Sanjay et al. [14] depicted various quality models and their investigative assessment, decided programming capability and its subjective attributes all the more plainly. Diverse programming quality models were suggested for programming applications by different scientists. The ISO 9126-1 model which in actuality joins the consequences of various different models has been thought as the most recognizable model and this has been broadly recognized and acknowledged as an elementary model in range of business and research. This was a comprehensive study to process the diverse components of various programming quality models and figure their near plausibility. Simultaneously, an investigation of various models which have been utilized to ascertain the quality will be inspected suitably.

Table I comprehensively highlight the comparison of different quality models/ frameworks ascribed in detail in literature in section II.

TABLE I. COMPARISON OF DIFFERENT QUALITY FRAMEWORKS [9] [11] [7] [4] [10] [3]

Quality Attributes	McCall	Boehm	FURPS	Ghezzi	IEEE	ISO 9126	Dromey	Robert et al	M. Usman et al	Micheal et al
Correctness	✓									
Efficiency	✓	✓	✓	✓	✓					
Flexibility	✓							✓	✓	
Reliability	✓	✓	✓	✓	✓	✓	✓		✓	
Testability	✓	✓							✓	
Maintainability	✓	✓	✓	✓	✓					
Portability	✓	✓		✓	✓				✓	
Functionality			✓		✓	✓	✓			
Modifiability		✓								
Performance			✓				✓		✓	
Interoperability	✓									
Security	✓									✓
Usability	✓	✓	✓	✓	✓	✓	✓		✓	
Robustness										
Accuracy				✓						
Integrity				✓						
Reusability	✓			✓				✓		
Supportability			✓							
Scalability									✓	
Process Maturity							✓			

III. LIMITATIONS OF DIFFERENT QUALITY MODELS

A few limitations have been observed in various quality models. These are followings:

One of the most significant offerings of McCall model for software quality is describing the association between SQ dimensions. Though, this model did not reflect one of the main features of software quality that is functionality. By description, functionality is what a product can do for a user. So functionality is key factor to assess the software so that it would meet the expectations of user.

Boehm proposed a quality model based on the needs of users but did not provide any recommendations for evaluating the software quality features in that model. There can be additional research done on the depth of

SQ dimensions. Hence this research displays a need to assess the software quality.

One of the major drawback of FURPS model is that it does not reflect one of the significant quality attribute portability. Portability is the ability of the software to work in dissimilar or diverse situations and environments. And user's environment might keep changing and therefore software also needs to adjust to new computing environment. Especially in agile portability can be a main attribute and for that reason cannot be ignored.

ISO-9126 appears to be more precise, comprehensive and does not fall short as other models do. But, it has not delivered the clarity of how some specific software quality attributes can be measured. This can, however, be the best model in comparison to the other proposed models.

Dromey's model tried to enhance the understanding of the association between features and sub-features. So this model could not emphasis on how to measure the software quality. It has recognized the relationship between quality features and sub-features. This research therefore studies this relationship and evaluates the software quality.

IV. Research Methodology

Taking this comprehensive research literature into account and research work done into the quality metrics in agile software engineering (XP etc.) it has been observed that the quality aspect is the most important aspect in every methodology that is used for the development of software products. Further that for bringing improvement in the quality of the product, different models have been suggested and used in the industry. Those models are helpful for achieving high quality software products but we precisely we are unable to identify in the mentioned literature and others about a model that is specific for agile methodologies and especially and precisely about the extreme programming. As we know that extreme programming is different from other previous methodologies [17], there must be a standard quality metric model that fulfills the criteria for the activities and quality attributes (metrics) of agile methods especially extreme programming. Those quality attributes that contain highest influence on the activities of extreme programming must be analyzed and measured.

A survey has been conducted through different software organizations (at Software Technology Park). The methodology used for this scenario to conduct this survey (Qualitative analysis) was that of set of questionnaires and face to face interviews (mostly open-ended). In this almost 20 different software houses/ software companies have been contacted and hence covered via this survey. The frequently asked questions were as follows:

1) Do you think that choosing the most suitable quality model is a real challenge when you are working properly in agile?

2) In order to ensure high quality product do you think the developer must concentrate on the quality of the process?

3) Is there a need of a quality model specifically for extreme programming (agile)?

4) Are there any attributes in different quality models that not need to be addressed in agile development?

Almost all the companies/software houses agreed that selecting the most appropriate model is a challenge because all those models are developed for traditional methodologies. Most of these models appear to be fully adopted in large scaled organizations or enterprises. Maybe these models could accommodate small companies or shorter version of businesses. All of the quality models emphasize too much on documentation which agile proves to be resisting due to development at a very high pace.

Almost 80% of the organizations think that there is a need of a quality model specifically for extreme programming (agile) because all the previously developed models contain so many attributes that are not needed in extreme programming (agile) so we can say that those models are complex for agile development. Secondly most of these models appears to be fully adopted in large scaled organizations or enterprises. Maybe these models could accommodate small companies or shorter version of businesses.

It is known that XP is different from all other methodologies in many ways. It basically involves user stories, customer availability, pair programming, small releases and iterations, continuous integration, unit and integration testing, acceptance testing and customer feedbacks. On the basis of these steps, we can try to define that which quality attributes are most important for XP and we can make a new quality model specifically for the products that are developed through XP approach.

Quality product is always very important and it is understood that in case to accomplish a quality product, quality of the process must be considered. Our proposed model will basically represent all the phases/steps of extreme programming and the quality parameters that are necessary to achieve the quality product.

An evaluation criteria is defined here to measure the influence of different attributes on agile SDLC.

Very Strong Effect	Strong Effect	Average Effect	Low Effect	Very low Effect
10	**8**	**6**	**4**	**2**

Almost 25 quality attributes in our questionnaire from all the quality models are considered and evaluated against all the phases involved in extreme programming (agile).

On the basis of this survey through questionnaire it has been observed that 7 quality attributes are the most important quality attributes for an extreme programming (agile) product. Those 7 attributes have the highest influence on the quality of agile process as well as on the quality of agile product.

TABLE II. Effect of Quality Attributes on Exterme Programming SDLC & Xp Product

Quality Attributes	User stories/	Design/ Release	Implementation/Pair Programming	Unit testing	Integration testing	Small Release	Acceptance testing	Final Product	Overall Influence

	Require ments	planning							
Availability	10	8	8	8	8	10	8	10	70
Efficiency	4	4	10	10	6	6	8	10	58
Usability	2	4	6	8	6	8	8	10	52
Maintainability	8	8	10	6	6	10	8	10	66
Testability	4	6	8	8	10	8	8	8	60
Flexibility	8	8	10	8	6	10	4	10	64
Portability	2	6	8	8	8	8	8	10	58

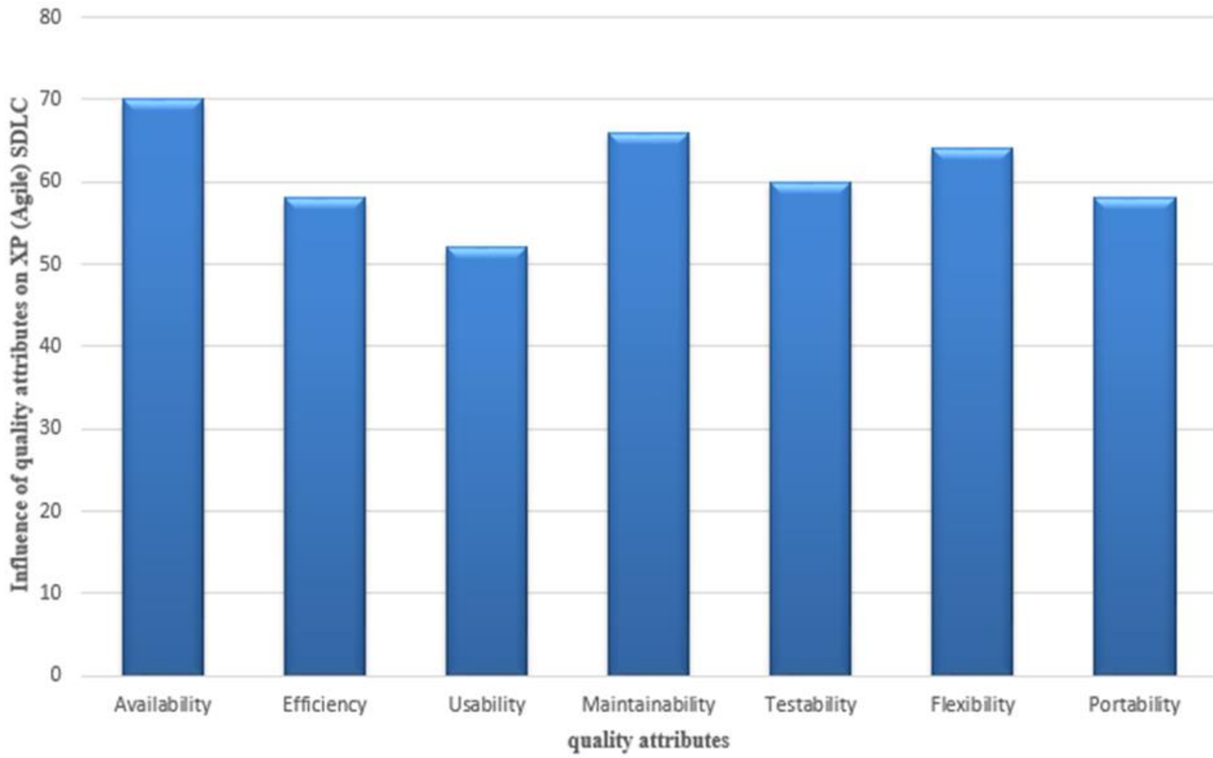

Fig. 1. Effect of quality attributes on extreme programming development process

V. PROPOSED MODEL

On the basis of these results from the survey, we have developed our quality model for Extreme Programming (Agile).

This model contains those attributes/features that have highest influence on the quality of agile SDLC and agile product. It also contains the sub features that are helpful for measuring these attributes.

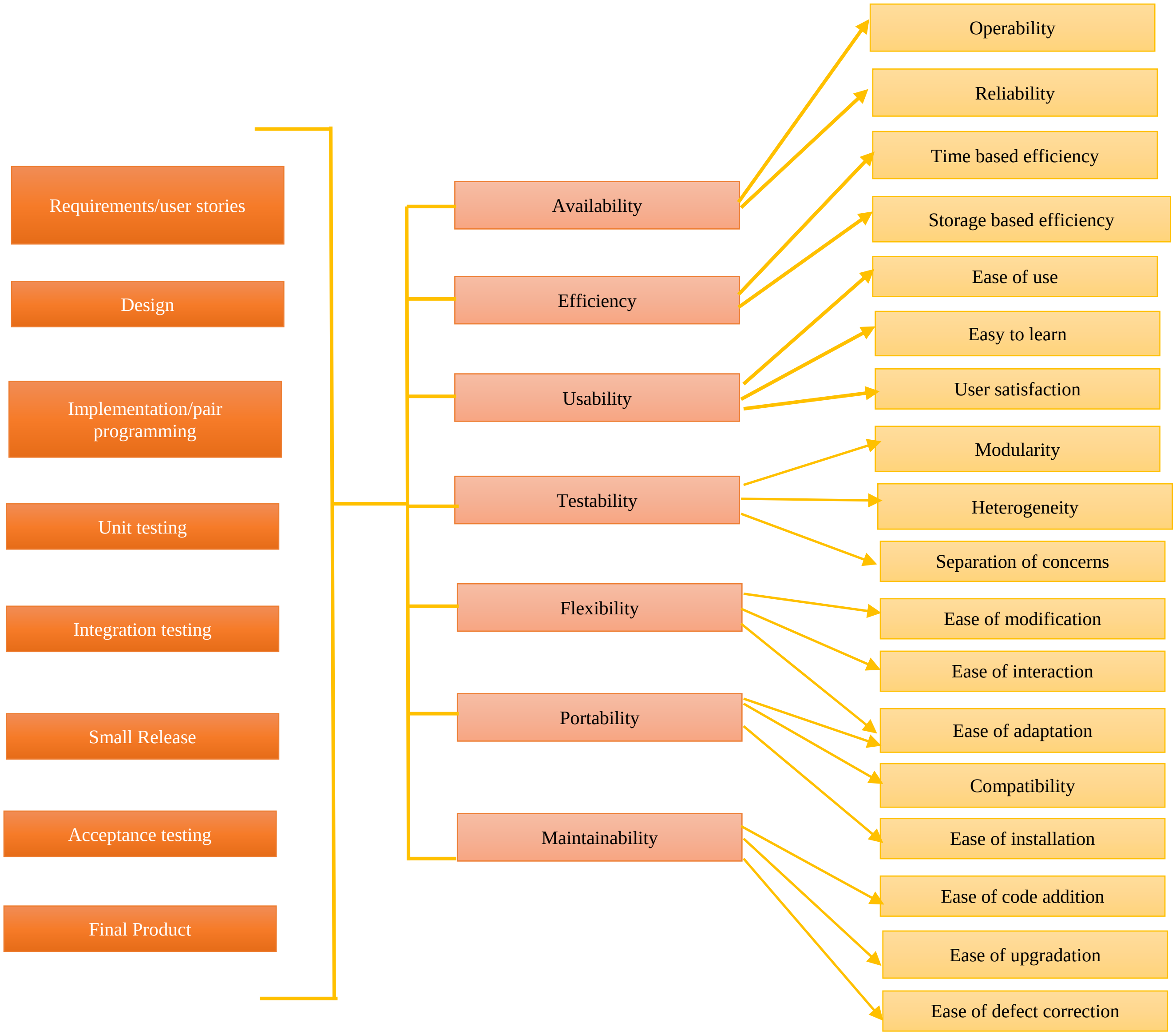

Fig. 2. Quality model for XP process & product

The quality attributes of a proposed quality model (quality model for extreme programming) are defined in a table 3.

And the sub features of proposed quality model (quality model for extreme programming) are defined in table 4.

TABLE III. DEFINITIONS OF QUALITY ATTRIBUTES USED IN PROPOSED MODEL

Availability	It refers to working ability of the application. The degree to which a system can continue to work when a major component or set of components goes down. [11]
Efficiency	A set of attributes that relate to the relationship between the level of performance of the software and the amount of resources used, under stated conditions.
Usability	A set of attributes that relate to the effort needed for use, and on the individual assessment of such use by a stated or implied set of users.
Testability	Attributes of software that relate to the effort needed for validating the modified software.
Flexibility	Flexibility refers to the ability of an application to undergo changes when required without affecting the overall application. [11]
Portability	A set of attributes that relate to the ability of software to be transferred from one environment to another. [11]
Maintainability	A set of attributes that relate to the effort needed to make specified modifications.

TABLE IV. DEFINITIONS OF SUB ATTRIBUTES USED IN PROPOSED MODEL

Operability	Attributes of software that relate to the users' effort for operation and operation control.
Reliability	A set of attributes that relate to the capability of software to maintain its level of performance under stated conditions for a stated period of time. [3]
Time based efficiency	This characteristic indicates the ability to perform a specific task at the correct time, under specified conditions. [3]
Storage based efficiency	It is the ability to store and manage data that consumes the least amount of space with little to no impact on performance; resulting in a lower total operational cost. [3]
User satisfaction	It is the degree to which a system is pleasant to use for the user.
Modularity	It is the degree to which a system's components may be separated and recombined.
Heterogeneity	It is the degree to which a system's components are separated and flexible enough so that they can be tested or used easily.
Separation of concerns	Separation of concerns (SoC) is a design principle for separating a computer program into distinct sections, such that each section addresses a separate concern.
Ease of modification	Corrections, improvements or adaptations of the software to changes in environment and in requirements and functional specifications.
Ease of adaptation	Attributes of software that relate to on the opportunity for its adaptation to different specified environments without applying other actions or means than those provided for this purpose for the software considered.
Compatibility	Software that is composed of elements that can easily combine with other elements.

We have tried to validate our model with the help of a dynamic simulation tool (iThink). The graphs generated at the end (figures 4, 5 and 6) are showing that when we increase our inflows that means when we increase rate of availability, rate of efficiency, rate of modifiability, rate of portability then we see that quality of the process increases with time and vice versa.

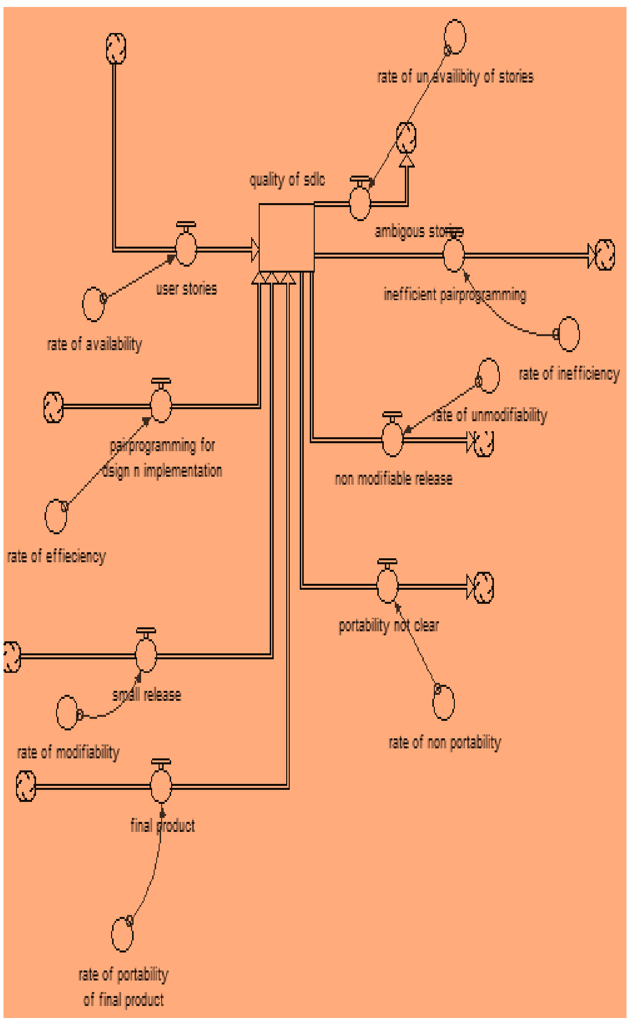

Fig. 3. Simulation validation in iThink

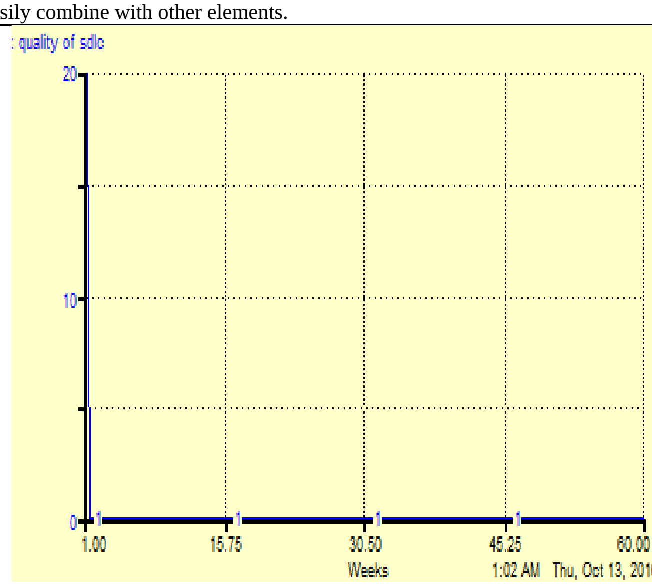

Fig. 4. Increase in Quality at early iterations

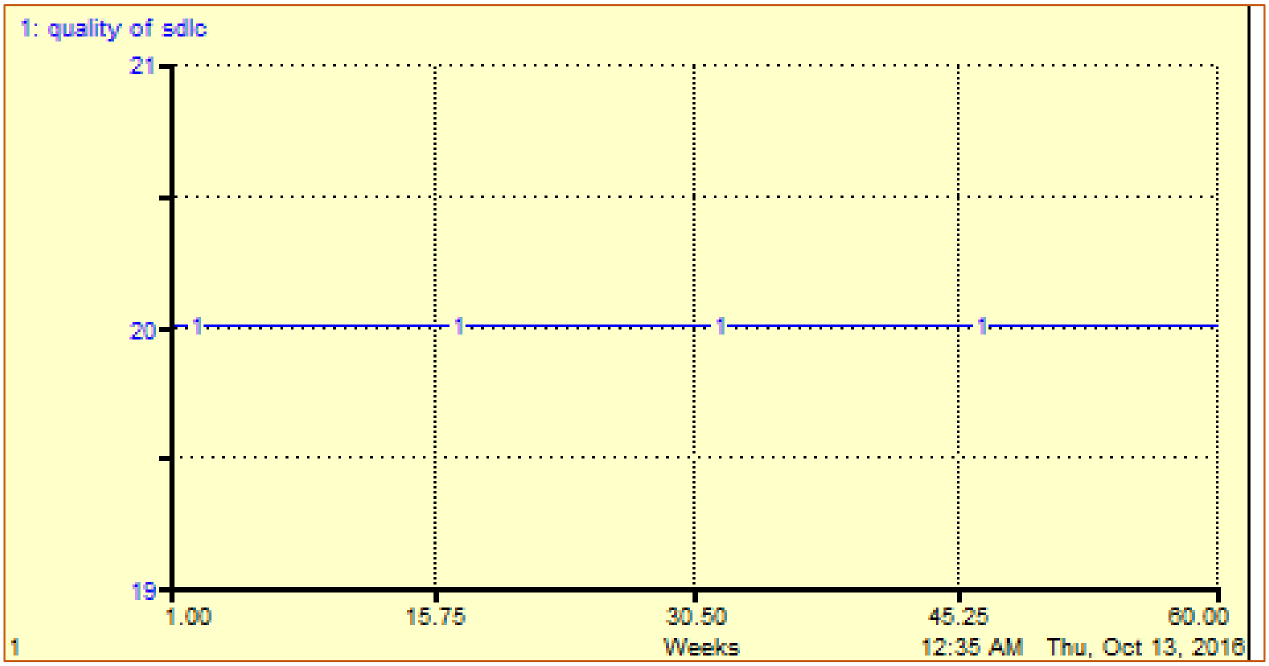

Fig. 5. To Static Quality via Attributes

And we are changing the values of different attributes then graph is changing constantly. In this way we can say that if we emphasize on a quality process and we will maintain quality steps at every development phase then quality of SDLC will continue to increase.

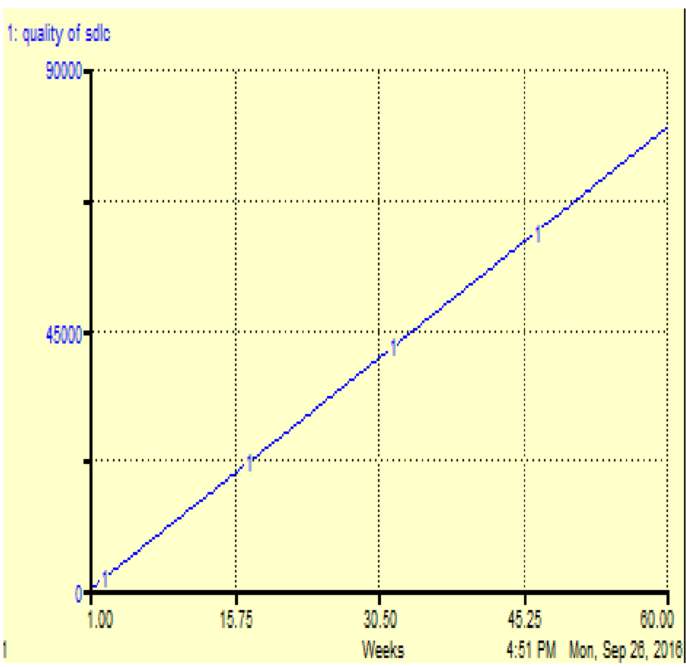

Fig. 6. Development in progress vs quality

VI. Conclusion

Software systems have to ensure consistent and bug free execution at a rapid pace every time they are used especially in Agile Development. Improving software quality and performance has become a priority for almost every organization that relies on the software development. Thus the quality issue related to the software's industry becomes more important, apparent and more technical also considering the user's requirements in this aspect. The following work demonstrates the need for and a detailed quality model for an XP process as well as for an XP product. Further this also highlight that if we want a quality product then we must concentrate on the quality of the process first and only by estimating quality attributes of a quality process (ISO 25000) we can achieve a quality product metrics (ISO 9126).

Improving software quality and performance has become a priority for almost every organization that relies on the software development. As software development grows more powerful the users demand are more powerful, sophisticated software. Thus the quality issue related to the software's industry becomes more important, apparent and more technical also considering the user's requirements in this aspect. To value customer trust and overall quality as defined by International Standards (ISO/ IEC 9126 & 25000), the quality metrics attributes must be taken into account in the planning and design of the software.

Further, in Quality estimation (metrics/ attributes) in Agile Development (XP) as we basically involves user stories, customer availability, pair programming, small releases etc., if we specify which quality attributes are most important for XP which was briefly highlighted using the proposed model. The following methodology (framework) proposed essentially represents all the phases/ steps of extreme programming and the quality parameters that are necessary to achieve the quality product in this way. As concluded already we have to subsist with this that in case to accomplish a quality product, quality of the process must be considered a prime initiative.

The following paper presents a comprehensive quality model for agile and specifically for extreme programming. All those attributes that have highest influence on the quality of agile SDLC and agile product are included and mentioned in this model. The influence and effect of each quality model has also been presented in tabular form and also in the form of graph. It has been observed availability, flexibility and maintainability has the highest effect on the quality of agile SDLC and agile product.

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The Design and Development of Spam Risk Assessment Prototype: *In Silico* of Danger Theory Variants

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***Abstract*—Now-a-days, data is flowing with various types of information and it is absolutely enormous and moreover, it is in unstructured form. These raw data is meaningless unless it is processed and analyzed to retrieve all the valuable and meaningful information. In this paper, a design and principal functionalities of the system prototype is introduced. A process of information retrieval by applying the text mining with Artificial Immune System (AIS) is proposed to discover the possible level of severity for a Short Messaging Service (SMS) spam. This is expected to be a potential tool in retrieving an implicit danger that a spam might impact to the recipients. Furthermore, the development of this tool can be considered as an emergence of another data mining tool that also exceedingly possible to be embedded with another existing tool.**

Keywords—Danger Theory Variants; Text Spam Messages; Severity Assessment; Text Mining; Information Retrieval; Knowledge Discovery

I. INTRODUCTION

At these days, numerous data are disseminating and spreading globally just within seconds. Without any means of analysis, these data possibly flow aimlessly and useless. Through data analysis, enormous data are processed and meant to be applied in various fields. As these days with technology advancement, spam messages in a form of text, images or even videos has been hassling and successfully tricks so many users. The recorded impact loss has also been significantly unpleasant [1][2][3][4]. Various safeguards have been implemented [5][6][7] to protect assets from any further loss caused by this threat but it seems persistent as an unending issue. With this fact, this paper initiative proposed a tool that might aid in lessening the impact by developing an implicit and trusted decision maker instrument.

Combining a text mining methodology with statistical analysis and inspired by Biological Immune System (BIS), this instrument is measuring the risk concentration for a text message that the potential impact likely to occur. With this information, it is to be expected that users will absolutely ignore any allure offer that would draw them to believe it without noticing it is deceitful messages.

The process of assessing the context of text messages is vital whereby the data must be prepared in a very special way before any methods can be applied. In this research, a classifier that imitates the human body defense or immune system is applied. This theory is well known as Artificial Immune System (AIS) and specifically a theory from Danger Theory and its variants are applied. This assessment task is combining text mining and statistical analysis that produced a predictive result to assist users in reacting against spam message positively. Text mining is a discipline that combines data mining and text analytics to use unstructured or textual data along with structured data for the purposes of exploration, discovery, and predictive modeling or classification [8].

In the previous research, there are many studies found for classifying and differentiate messages between legit or ham and spam [9][10][11], but no publication for measuring the possible harm that this threat could convey, especially with the employment of AIS. With the intention to step ahead, this paper will articulate the design and development of a prototype in conducting and implementing a severity assessment for a text spam message. In addition to that, this paper is a continuity study for [12] and [13] which executed to illustrate its applicability. Its aim is to establish an automated method for the experiment simulated in these papers. The developed prototype will then be further tested for a larger size of the dataset, to verify the results claimed in works [12] and [13] are consistent with the initial findings.

In the direction to have a well arrange for a content presentation, this paper is structured as follows. The main literature for the fundamental part of the study is reviewed in Section II. The variant of Danger Theory that has been applied in this study is clarified with its biological abstraction that theoretically appears to be suitable and fit to overcome this threat. Then, an integration of text mining and risk assessment has been developed as the foundation of this study is elaborated in Section III. The proposed prototype with flow diagram and pseudo-code is described in Section IV. In the last section of this paper, conclusion and potential future work are proposed.

II. DANGER THEORY OF ARTIFICIAL IMMUNE SYSTEMS

Computational intelligence has contributed numerous solutions for various fields. This theory is imitating many natural surrounding artificially that is presumed as an intelligent agent, has significantly proven its ability. One of the famous ideas is AIS that imitated the Body Immune System

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(BIS) against antigens and defense the body from any harm and danger pathogens.

The focal point of this paper is to study the Danger Theory, one of the theories that emerged from AIS. This particular theory is impersonating the behavior of dendritic cells (DCs) that is able to sense and detect malicious substance and stimulates the immune system to react [14]. In 1994, Polly Matzinger then introduced Danger Model [15] that the immune system is more concerned with the damage caused by the malignant substance than cell foreignness. In the following paragraph, 2 variants of Danger Theory applied in this study are explicated and related characteristics are identified in its employment for risk assessment task. These 2 variants are compared theoretically and experimentally in [13], particularly for this spam risk assessment study.

A. Dendritic Cell Algorithm (DCA)

The initial version of DCA has been introduced via Danger Project [16] that applied in detecting intrusion. This algorithm basically is about correlating antigen information and signal processing to assess the condition of the surrounding. DCs are antigen presenting cells (APCs) that play a crucial role in detecting danger. It is unique APCs that have the capability for capturing, processing and presenting antigen to T-cells for further action, either to stimulate or depress the immune systems.

Basically, both algorithms of DCA [17][18] and dDCA [19] are correlating data streams in the forms of antigens and signals. The outcome of this correlation will produce a result of the surrounding either it is malignant or benign. Prior to gain this results, there are 3 types of input signals that released by pathogens that could be captured by immature DCs (imDC); Pathogen Associated Molecular Patterns (PAMPs), danger and safe signals. The imDC processed all the captured signals then migrated to the lymph node and divided into 2 types of conditions, with regards to the detected danger concentration. Semi-mature DCs (smDC) brings the safe signals, while mature DCs (mDC) indicate a dangerous context of an antigen. The transformation of imDC to smDC or mDC is assessed via its anomaly metric, Mature Context Antigen Value (MCAV) [18]. This MCAV is the mean value of context per antigen type, in the form of a numerical vector and its value in between 0 to 1. The closer this values to 1, the greater the probability that the antigen is anomalous. This value also reflects the malicious degree or the concentration of the antigen.

```
input : signals from all categories and antigen
output: antigen plus context values
initialiseDC;
while CSM output signal < migration Threshold do
  | get antigen;
  | store antigen;
  | get signals;
  | calculate interim output signals;
  | update cumulative output signals;
end
cell location update to lymph node;
if semi-mature output > mature output then
  | cell context is assigned as 0 ;
else
  | cell context is assigned as 1;
end
kill cell;
replace cell in population;
```

Fig. 1. The DCA algorithm [17]. The applied algorithm for this study is depicted in Section IV.*C.3) DCA algorithm application.*

B. Deterministic Dendritic Cell Algorithm (dDCA)

The fundamental theory of DCA and dDCA has no significant difference, except for its simpler calculation to determine the anomalous level. In dDCA, anomaly metric, Kα is executed and uses the magnitudes of k values. The outcome of dDCA is tagged as anomalous when it is returned as a positive value and tagged as normal when the calculated value is negative [19].

```
input  : Antigen and Signals
output:  Antigen Types and cumulative k values
set number of cells;
initialise DCs();
while data do
  | switch input do
  |   | case antigen
  |   |   | antigenCounter++;
  |   |   | cell index = antigen counter modulus number of cells ;
  |   |   | DC of cell index assigned antigen;
  |   |   | update DC's antigen profile;
  |   |   end
  |   |   case signals
  |   |   | calculate csm and k;
  |   |   | for all DCs do
  |   |   |   | DC.lifespan -= csm;
  |   |   |   | DC.k += k;
  |   |   |   | if DC.lifespan <= 0 then
  |   |   |   |   | log DC.k, number of antigen and cell iterations ;
  |   |   |   |   | reset DC();
  |   |   |   |   end
  |   |   |   end
  |   |   end
  |   end
end
for each antigen Type do
  | calculate anomaly metrics;
end
```

Fig. 2. The dDCA algorithm [19]. The applied algorithm for this study is depicted in Section IV.*C.4) dDCA algorithm application*

III. Text Mining in Spam Risk Assessment

A. An Integration of Danger Theory and Risk Assessment

The fundamental idea about Danger Theory is how the signal processed in measuring the malicious concentration of an antigen. To apply this concept, an input signal which depicted by weight of tokens are used in signal correlation that eventually will give the malignant level of a spam message.

Conceptually comprehend that in Danger Theory; the malicious content is assessed via MCAV for DCA [17][18] and K_α for dDCA [19] which both theories considering that the closer the measured value to 1, the more malicious it is. Hence, to define input signals that eventually meet the characteristics of output signals (assessed value should be in between 0 to 1 and the closer the output signals to 1, the more malicious it would be) in this immune theory, a reliable term weighting schemes should be considered vigilantly. Selecting good features are crucial activity and require extensive domain knowledge from various aspects. As to create input signals in DCA and dDCA, a term weighting schemes are deployed. Details about this scheme are discussed in Section III.C *Feature Extraction via Statistical Analysis*.

According to National Institute of Standards and Technology or NIST [20], risk or malicious concentration is a measure of the extent to which an entity is threatened by a potential circumstance or event, and is typically a function of:

- adverse impacts that would arise if the circumstance or event occurs; and
- the likelihood or probability of occurrence.

The measurement process for this risk calculation is actually one of the crucial parts of risk analysis. With reference to [21], the spam management should be administered as proposed in risk management. In a developed and established standard of risk management [20][22], this process usually consists of 4 essential phase; risk identification, risk assessment, risk response/treatment and risk monitoring.

In this research, a risk assessment is done with regard to the established concept in common risk management, these include:

- the more frequent a term occur in spam messages, the higher the likelihood of a threat will happen; and
- the calculated weight depicts the level of possible impact implicitly.

The probability level and risk impact are depicted in the following Fig. 3 to which this is practical in assessing and prioritizing risk.

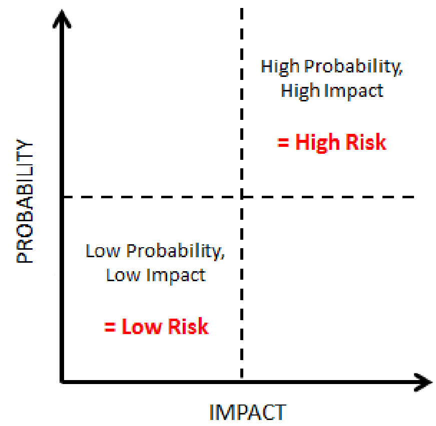

Fig. 3. The Risk Impact / Probability chart

B. The Significance of Text Pre-Processing

There are many research found that applied text mining in SMS spam classification [11][12][13][23][24][25][26][27][28]. However, application of text mining for spam messages is not limited to SMS but also include for email, webpage, and social media platform.

In the process of text mining, pre-processing or also known as the pre-treatment process is one of the important stages. The entire cycle of text categorization that involves all stages includes preparation or collection of data or documents, pre-processing, feature indexing, feature filtering, text classification with algorithm and performance measure. This complete course of action in text categorization has been extensively discussed in [29] and [30]. Messages usually consist of various types of words, which are known as part of speech. These texts may consist of adverbs, articles, conjunctions and many others that possibly not significant for the context assessment. Hence, pre-processing is a process that could distinguish between relevant and irrelevant attributes. An overview of part of speech with examples is tabulated in Table I.

TABLE. I. An Overview of Part of Speech

Part of Speech	Examples
adverbs	quickly, as
articles	a, an, the
conjunctions	and, but, however
interjections	hooray, ouch
prepositions	on, over, beside
pronouns	she, you, us

In sequence process of risk assessment implementation for a text spam message, pre-processing is one of the highly considered stages in this task. Its main objective is to obtain the key features and to enhance the relevancy between word and document and also between word and category [31]. Many researchers agreed that this particular stage consists of a few more sub-process which includes tokenization, stop word removal, stemming and capitalization. Further elaborations of stated sub-processes are discussed as follows:

- Tokenization - a document is treated as a string, and then partitioned into a list of tokens [32]
- Capitalization/case folding - it is regularly convenient to lower case every character [33]
- Stemming – word stemming refers to converting words to their morphological base forms, for example, both "clicking" and "clicked" are reduced to root word "click" [34]
- Stop word – stop word removal is a procedure to remove words that are found in a list of frequently used words like "and, for, a" [34]. The stop-words are high frequent words that carry no information (i.e. pronouns, prepositions, conjunctions etc.).

Some authors, [35] and [36] also regard pre-processing as the normalization of the noisy text. This process somehow reduces the high dimensionality of the data that commonly turn out to be the main problem in text mining. This issue can be overcome by executing pre-processing that alleviate the data sparseness problem [34]. Pre-processing also allows an efficient data manipulation and representation [32].

This effect of 'noise' is reduced by eliminating any irrelevant word during the stage of pre-processing that is necessary prior to text mining process. Even though many research claimed that this process will increase the accuracy rate [31][35][36], however in spam classification, some authors have contradicted opinion on the impact of pre-processing. Authors Almeida et al. [37][38] argued that the pre-processing has weakened its effect and degrade the classification rate. However, a simulation [28] done in the same field verified that the pre-treatment of a text would amplify the detection rate in distinguishing spam messages. In addition to that, it is also proven that pre-processing has contributed 5% improvement to accuracy value in opinion mining [35]. Besides pre-processing improve in term of classification accuracy, it also identified that would pick up the speed and tendency to reduce overfitting and overhead to computational cost [32].

C. Feature Extraction via Statistical Analysis

Term weighting methods are used to assign appropriate weights to the term. The term in a document vector must be associated with a value called weight, which measures the importance of this term and denotes how much this term contributes to the classification or categorization task [29]. Different terms have a different level of importance in a text; the term weight is associated with every term as an important indicator [31] and this is the key component applied in Danger Theory algorithm. There are a few types of analysis that can be utilized to calculate the weight, which is orthographic, statistical, semantic, syntactic and usage analysis [39].

This research applies the statistical term weighting where term weighting is based on the discriminative supremacy of a term that appears in a document or a group of documents [40]. It is considering as appropriate for this research that it is discriminating documents in between spam and ham. The higher the value the more relevant the term in spam category also indicates highly or frequently repeated in a spam message. The attributes with higher weight are considered that the messages are more relevant to spam category.

The accuracy of the classification or categorization is largely influenced by the collection of messages especially spam where the statistics are derived from. In this research experiment, 3 pre-selected terms weighting has been chosen to be compared empirically with regard to identifying which scheme is the most suitable and adequate for the immune classifier; DCA and dDCA. This statistical inference is attached to the pre-selected term weighting schemes; Term Frequency (TF), Information Gain Ratio (IG Ratio) and Chi Square (CHI^2) and much dependable on how these schemes are working and functioning. Hence, it is crucial to identify a reliable term weighting scheme which is critical for the performance of the classifier [41]. The higher the weight of an attribute (term), the more relevant it is considered as spam. All weights are normalized in a range from 0 to 1, which this is to adequate the characteristic of anomaly metrics in DCA (MCAV calculation) and dDCA (K_α calculation).

IV. *In Silico*: Prototype of DCA and dDCA

A. Computational Immune Classifier

Scientific research usually releases a prototype which intended to represent a working system of an idea rather than a theoretical one. This research objective is to produce a working prototype, which is an initial model of a risk assessment product that is designed and developed to test a concept or process in order to act as an assistant in decision making.

As early in 2006, an early version of DCA has been developed as software system to implement the innate immunity [42][43]. This program is known as `libtissue`, is being used by researchers on a project at the University of Nottingham to explore the application of a range of immune-inspired algorithms to problems in intrusion detection.

The proposed prototype for this work also will be developed as software system to apply the algorithm computationally in real world problem, which in this case is a spam problem. The adaptation of biological ideas into the application of real world problem is involved a few phases as developed by Stepney in 2004 and known as Conceptual Framework [44] approach. This methodology employs an iterative approach to the creation and testing of novel immune-inspired algorithms and consists of 4 stages that are identified as:

- observation of the biological experimentation;
- constructed computational models;
- developed, implemented and studied the biological abstraction as algorithms; and

- applied the algorithm to a specific problem, with feedback for refinement.

Besides Conceptual Framework, there is terminology of broad study categories for biological experiments. They are known in Latin as *in vivo*, *in vitro* and *in silico;* and differentiate as the following [45]:

- *In Vivo* (within the living) – refers to examination using a whole, living organism as opposed to a partial or dead organism;
- *In Vitro* (within the glass) – refers to the technique of performing a given procedure in a controlled environment outside of a living organism; and
- *In Silico* (performed on the computer or via computer simulation) – refers to characterize biological experiments carried out entirely in a computer.

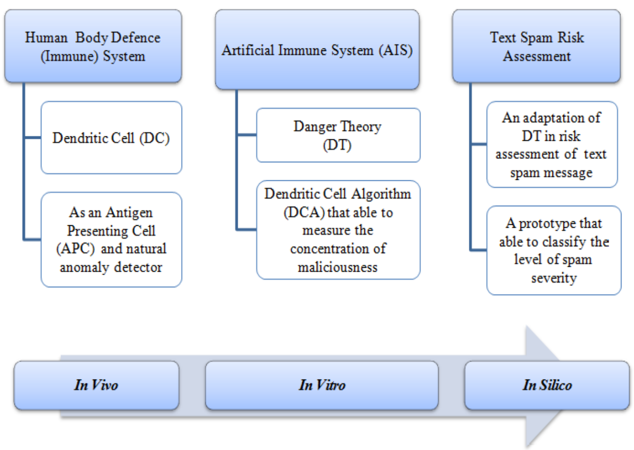

Fig. 4. A concept mapping between the biological perspectives of Human Immune System (*in vivo*); computational theory, Artificial Immune System (AIS); and the real implementation of AIS in computer security field, text spam risk assessment (*in silico*)

B. *Risk Scale for The Classifier*

DCA use 3 input signal– PAMP, Danger, Safe to produce semi-mature, *O[smDC]* and mature, *O[mDC]* as an output signal in identifying the malicious and normal cell. While dDCA only manipulates minimum 2 signals which are Danger and Safe signals. In this case, the signal value of PAMP is considered as Danger signal for the task of anomalous measurement.

Comparison to each other of semi-mature and mature output signal is used to calculate the risk into 3 distinct levels (mature signals counted as high and medium risk level, semi-mature signal as low risk). A risk scale is used in distinguishing these 3 distinct levels both for input and output signals. This scale also shows the concentration of risk level which the closer the value to 1, the more malicious it is and value that closer to 0 indicate highly safe or normal.

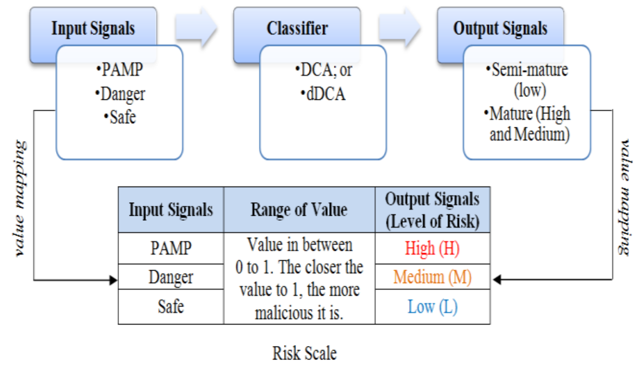

Fig. 5. The mapping of input signals and output signals with the associated risk scale

This risk scale for this experiment is developed based on Likert scale principle with 3 points, high, medium and low level to assess the severity intensity. With regard to verifying the sensitivity of different range for a risk scale, 2 different risk scales have been examined via a simulation which can be found in [12][13]. The same suggestion in executing sensitivity analysis of different weight also has been proposed in [17], to ensure that the empirically derived weights are suitable for the signal processing.

C. *Design and Development of A Prototype*

Design, develop and model evaluation of a prototype is part of data mining process. As this research is basically about retrieval information of severity intensity from text spam message, a prototype is a must tool to execute this mining task. A summary overview of the flow sequence of the entire process is as follows and the detailed explanation about this process in practical data mining can be found in [46].

An algorithm is normally described in a semiformal notation such as pseudo-code and flowcharts. Flowcharts are used mainly for the high-level description of the algorithms and pseudo-code for describing the details. Pseudo-code is a notation that uses a few simple rules and describes the algorithm that defines a problem solution. It can be used to describe relatively large and complex algorithms. It is relatively easy to convert the pseudo-code description of an algorithm to a computer implementation in a high-level programming language [47].

In this research experiments, all the processes are elaborated via flowchart diagram; the pictorial representation of the whole logic. Then, an advance description is intricate via pseudo-code to illustrate the entire process. Eventually, the whole process will be developed as a set of the prototype, implemented using programming language, which is considered as our future works. The developed prototype of the model then will be embedded in a data mining tool and consequently will be evaluated in terms of its practical functionalities and performance.

The proposed prototype of measuring the intensity or degree of severity for a text spam message consists of 6 phases, as shown below:

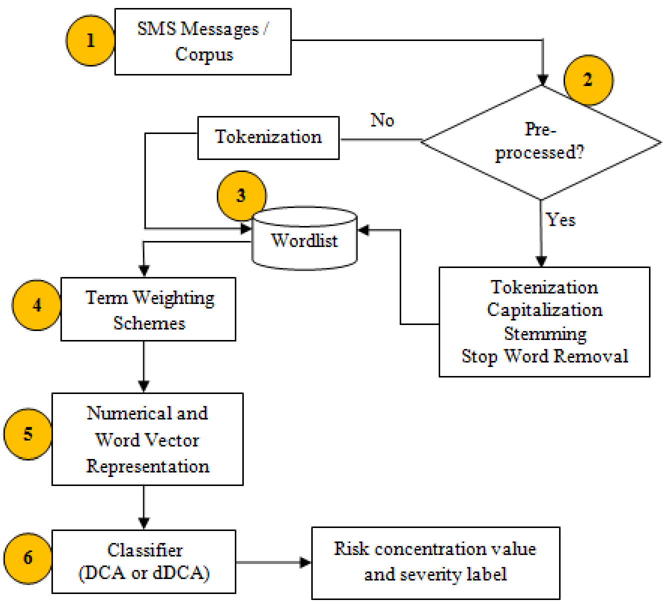

Fig. 6. An overview of the framework for implementation of a risk assessment in text spam message

TABLE. II. RISK ASSESSMENT PHASES IN TEXT SPAM MESSAGES

Phase	Process	Description
1	Preparation	Data, which consists of SMS messages (ham and spam) are collected and prepared for an initial database of the prototype. A new spam message can be processed once this initial database has been developed. Messages can be in a .txt, .doc, .docx, .xls or .xlsx files format.
2	Pre-processing	The corpus (for initial population) or text message have an option either to run through text pre-treatment or not. Tokenization is a must process if decided not to have the pre-processing in place. Otherwise, the full cycle of text pre-processing will be executed, which include tokenization, capitalization, stemming or also known as lemmatization and removal of stop word from the data.
3	Wordlist	This wordlist database contains tokenized words with the information of its total and document occurrences and its frequency in spam and ham document category.
4	Term Weighting Schemes	TF, IG Ratio, and CHI^2 are the available term weighting schemes and act as feature selection methods. These schemes will calculate the importance of every word in the corpus that indicates its relevance to the spam (risk) category. The value derived statistically from this method is further implemented as an input signal in the classifier. This information is stored as an internal database library. All schemes calculate tokenized word as in between 0 to 1 which suggested that the closer the value to 1, the closer it is to malicious level.
5	Numerical and Word Vector Representation	Calculated value for every term in the previous phase then will be mapped to the risk scale. Every derived value will represent the term's severity degree, i.e high, medium, low. The range for risk scale is user-defined.
6	Classification	This phase consists of 3 sub-process which are: Signal processing – identified input signals in a spam message will be correlated and processed depends on chosen classifier i.e DCA or dDCA; Context assessment – the content of the spam message is assessed for its risk concentration level in numerical value; and Risk flagging – classified risk level i.e high, medium, low will be marked to spam message accordingly.

The following paragraphs will elaborate on prototype processes which cover the algorithm design, general process, DCA and dDCA immune classifier. These processes of designing and development of a research prototype would include flow chart and pseudo-code. Later this design will be utilized in developing the prototype using programming language.

1) Algorithm Design For The Prototype

As explained in the previous section, an algorithm is described in a semiformal notation in a form of flow charts and pseudo-code. Prior to having these 2 items established, a step by step process or a brief review is required in order to guide the whole process in design and development of a prototype.

The following is the wide-ranging steps to implement the design and development of the entire system, which also directly related to Fig. 6 and Table II.

- Create initial population

a) collect dataset corpus

b) text pre-processing

c) assign input signals value for antigen (via statistical analysis)

d) store antigen value

- Calculate the severity level

a) receive a new spam message

b) text pre-processing

c) map the identified antigen with the stored input signals value (refer library database)

d) calculate the severity level using classifier (DCA or dDCA)

e) map the calculated output signals with developed risk scale and identify the level of risk

f) mark the spam messages with the risk-level flag accordingly

- Action to response

a) according to identified risk level, response against spam could be deleted, escalate to authority body, re-calculated the risk level (for the case of false positive), or do nothing

2) General Process of the Entire Proposed System

a) Flow Diagram

The entire process for the proposed prototype which has been explained in the previous paragraph is depicted as a flow diagram in Fig. 7.

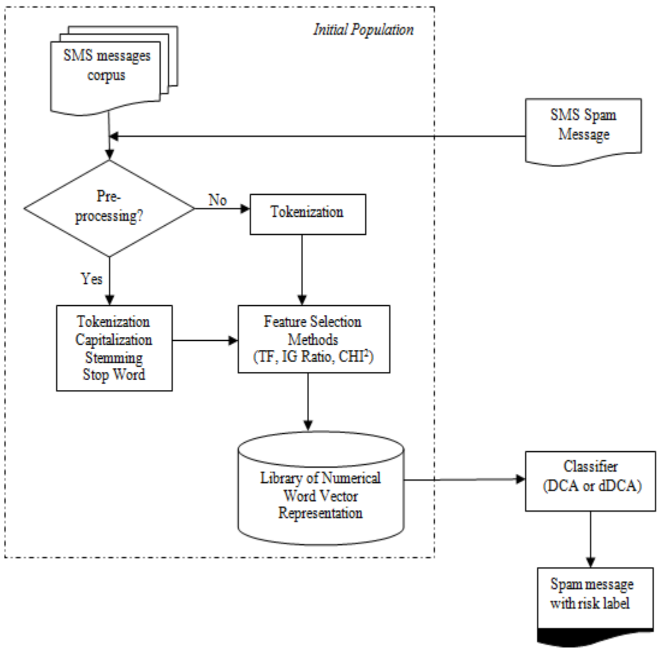

Fig. 7. A flow diagram for general architecture of the entire proposed prototype

b) Pseudo-code

The following is the pseudo-code that describing the flow diagram in Fig. 7 for the whole processes involved in the proposed prototype in general.

Input; M: SMS messages (S: Spam messages; H: Ham messages)
Output; O: Spam messages with marked risk level

1 Begin (while TRUE)
2 Read SMS messages
3 For without pre-processing, execute only tokenization on SMS messages
4 Or else for with pre-processing, execute the full-text pre-treatment (tokenization, capitalization, stemming and remove stop word)
5 Calculate and assign value for tokenized term (provided as input signals in classifier)
6 Determine spam's risk level (High, Medium or Low)
7 Display the flagged spam message with its associated risk label (print the result)
8 End

3) DCA algorithm application

a) Flow Diagram

The processes involved for the classifier DCA is depicted as a flow diagram in Fig. 8.

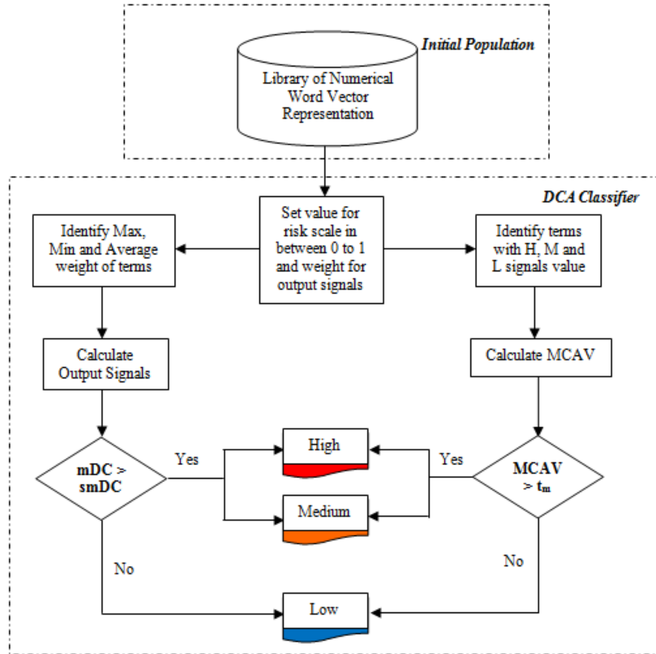

Fig. 8. A flow diagram for DCA classifier process

b) Pseudo-code

The following is the pseudo-code that describing the flow diagram in Figure 8 for the processes involved in DCA classifier.

Input; M: SMS messages (S: Spam messages; H: Ham messages)
Output; O: Spam messages with marked risk level

1 Begin (while TRUE)
2 Read SMS messages
3 For without pre-processing, execute only tokenization on SMS messages
4 Or else for with pre-processing, execute the full-text pre-treatment (tokenization, capitalization, stemming and remove stop word)
5 Calculate and assign a value for tokenized term via term weighting schemes method (provided as input signals in classifier). Store all derived antigen and signal values in library
6 Set value for risk scale with 3 different levels in between 0 to 1 (as in Figure 5) and weight to transform input signal to output signal
7 Identify maximum, minimum and average value for input signal and calculate output signals, *O[mDC]* and *O[smDC]*
8 Identify words with high, medium and low signals value and calculate MCAV
9 Identify anomaly threshold, t_m and compare with MCAV
10 Determine spam's risk level (High, Medium or Low) whenever these conditions are both fulfilled.
   - *O[mDC]* > *O[smDC]* and MCAV > t_m . this is to indicate that spam message is malicious and MCAV result should return a value as High or Medium
   - *O[mDC]* < *O[smDC]* and MCAV < t_m - this is to indicate that spam message is benign and MCAV result should return a value as Low

   Refer Fig. 5 for mapping the MCAV value with the level of risk.
11 Display the flagged spam message with its associated risk label (print the result)
12 End

4) *dDCA algorithm application*

a) Flow Diagram

The processes involved for the classifier dDCA is depicted as a flow diagram in Fig. 9.

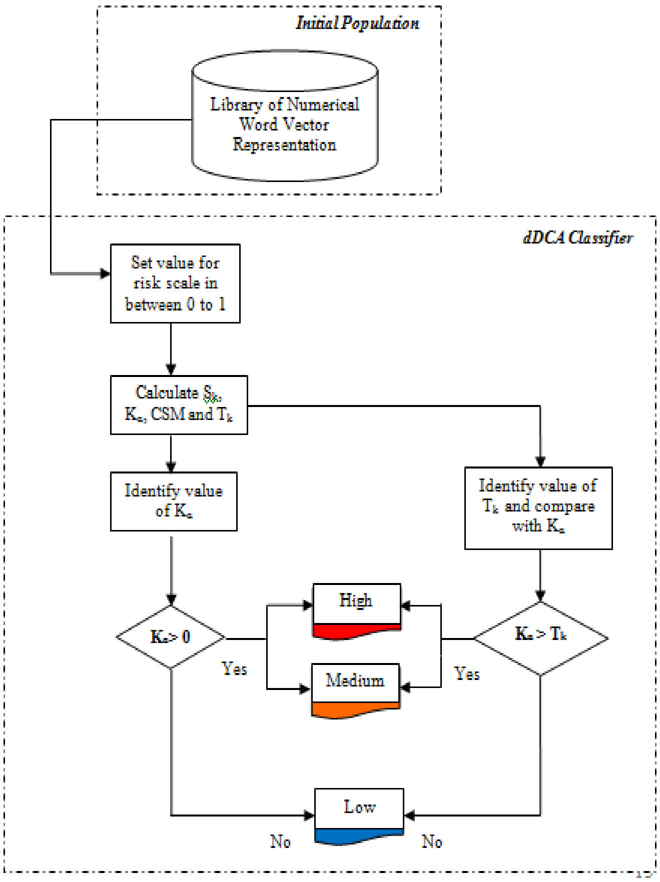

Fig. 9. A flow diagram for dDCA classifier process

b) Pseudo-code

The following is the pseudo-code that describing the flow diagram in Fig. 9 for the processes involved in dDCA classifier.

Input; M: SMS messages (S: Spam messages; H: Ham messages)
Output; O: Spam messages with marked risk level

1. Begin (while TRUE)
2. Read SMS messages
3. For without pre-processing, execute only tokenization on SMS messages
4. Or else for with pre-processing, execute the full-text pre-treatment (tokenization, capitalization, stemming and remove stop word)
5. Calculate and assign a value for tokenized term via term weighting schemes method (provided as input signals in classifier). Store all derived antigen and signal values in library
6. Set value for risk scale in between 0 to 1 (Fig. 5)
7. Calculate:
   - the sum of all input signal, S_k;
   - K_α, magnitudes of k value;
   - Costimulation output signal, CSM; and
   - Threshold, T_k.
8. Determine spam's risk level (High, Medium or Low) whenever these conditions are both fulfilled.
   - $K_\alpha > 0$ and $K_\alpha > T_k$ - spam message is tagged as the malicious message; or
   - $K_\alpha < 0$ and $K_\alpha < T_k$ - spam message is tagged as the benign message.
9. Display the flagged spam message with its associated risk label (print the result)
10. End

D. Performance Measurement

All further experiments are measured using True Positive (TP) value as the measurement metric for accuracy classification rate. TP value reflected the correct classification of spam messages according to its risk level and context of the spam message. TP calculated as a ratio in percentage (%), whereby its total number of correctly risk-classified messages is proportional to the total number of all messages that has been assessed. All messages are referring to the total number of truly-classified and falsely classified spam messages.

$$TP = \frac{\sum correctly\ risk\text{-}classified\ messages}{\sum all\ messages} \quad (1)$$

V. Conclusion and Future Works

This developed prototype of a data mining tool can be considered as unsupervised as it is designed and developed inspired by Danger Theory idea that does not require training or learning process. Text data is generally viewed as categorical data and its weight derived from statistical analysis is the signal value in numerical value. In this task, text data is the antigen and the weight is signal value correlated to assess and predict the maliciousness of a message. Since the manual simulation as clarified in [12] and [13] has been executed using RapidMiner for its weight value of terms (input signals) and text pre-processing, this proposed prototype will be developed in a high-level programming language and further embed in RapidMiner. Subsequently, the developed prototype will be tested with a larger dataset of SMS and deploy with another form of text messages such as Twitter, to verify its consistent and reliable results as discovered in [12] and [13]. Development of this prototype in the mobile platform is also encouraged to demonstrate the performance and functionalities.

This potentially discovered knowledge through this mechanism is valuable to be applied in various fields. The remarkable findings are potential to be enhanced in another field of data mining study, such as computational linguistics.

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Impact and Challenges of Requirement Engineering in Agile Methodologies: A Systematic Review

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***Abstract*—Requirement Engineering is one of important stage in development life cycle. All requirements required for development of product is collected in this phase. A high standard product can be developed by agile methodology in less budget and time. Importance of agile practices have been enhanced since it offers assist cooperation too software engineering. Being basic phase of software engineering, requirement engineering has different processes. The elements of direct correspondence is one of spry way which not at all like to other conventional and traditional approaches .Although a lot of research has been done on agile practices and role of requirement in agile methodologies but still there is need of studies on change manage management ,requirement prioritization, prototyping and nonfunctional requirement in agile methodologies. Aim of this review paper is to present the limitations in presentation of requirement engineering phases in agile practices and what are the issues and challenges that agile person faces in implementation of agile practices. Many research studies from different sources have been reviewed on basis of inclusion and exclusion criteria. Most RE activities has been discussed in review. Evidence helps to prove that how RE process was performed in scrums. Mostly research has been conducted on general agile methodologies, few authors specified RE practices in other methodologies of agile. Finding of this research is the work of researchers that will be beneficial for those who are interested in finding interesting area of research in this field because many techniques of agile (extreme programming, crystal methodology, lean) requires further study and practical results as clarified by studies.**

Keywords*—Requirement Engineering; Traditional approaches; Agile methodologies; Challenges in RE; Requirement prioritization; Nonfunctional Requirements; Dynamic system development method; Scrum; Extreme programming

I. Introduction

A. Requrement Engineering

Before broadly descriptive, let us have a debate with respect to requirement engineering. It is basically a procedure including documentation, legitimate association, and collection of all necessities of a framework. In this practice, the product need is distinguished; without this procedure, making extraordinary progress in providing efficient software might be incomprehensible. Despite the fact that process of requirement engineering requires a lot of time, it is the best way to get best out of likelihood for the efficient product to meet the conditions and requirements [1]. In this manner, requirement engineering performs a key part in development of software. Requirements Engineering (RE) is a main area in software production and engineering. A high quality RE procedure often dominates an effective project .Traditional Software Engineering (SE) usually includes the RE process which consist of requirements elicitation, analysis, documentation, management and validation [2]. According to Kotonoya et al. most issues associated to the RE are resultant from the inadequacy or irregularity of specifications and requirements and conflicts between product stakeholders [3]. Effective RE requires a better consideration of the domain area, the circumstances in which the framework will run, and requirements of the product's stakeholders including developers, designers, end users and customers [4].

B. Agile

Definitions of Agile development software grown in the 90s as a response against conventional methodologies that were regarded as substantial, rigid and not supportive for essential tasks of developer. In 2001, research of the Agile Manifesto [5] was a landmark for development of Agile Software. Practices were proposed by 17 different groups for improvement in software development by using practices and methodologies of Agile. Purpose of Agile development methods was to provide product within budget, on schedule, satisfaction of customer and high quality. Agile methodology includes many techniques and methods. Frequently used methods are Scrum, Extreme Programing, Adaptive Software Development, Dynamic Systems Development Method and crystal family.

1) Extreme Programming (XP): Extreme Programming (XP) depends on values of correspondence, simplicity, courage, and criticism [6]. Purpose of XP is to associate old and tested methods in manner that they strengthen each other.

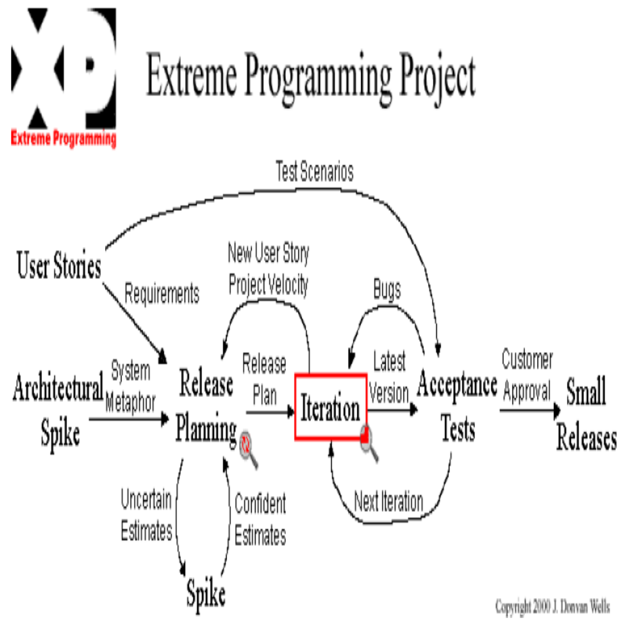


Fig. 1. Extreme programming [6]

Whole team works together by using practices and feedback makes it possible to know status of work. XP discusses general practices and processes of software product development and what could possibly be done during procedure, it does not unequivocally discuss requirement techniques in detail. A few extreme programming techniques (or methods utilized as a part of these practices) can be contrasted and compared with minor adapted requirements procedures. XP utilizes story cards for requirements gathering. A user story describes business value feature to clients. Use cases are depiction of interactions of users and system and don't required need to give business value. Before writing of story cards, clients need to consider what they anticipate that the system will do (brainstorming). When we think about specific functionality, more ideas and stories are emerged. Customer prioritizes stories on the basis of implementation efforts and time for next iterations. Comparison of extreme can be done with evolutionary prototyping and requirements. The distinction amongst XP and prototyping is that XP requires mature substantiated code while prototypes can be "threw together". Clients can survey and test the usefulness and outline of the delivered software and examine issues that need to be changed or included in next iteration.

2) Scrum: Scrum is a used for management of development process by applying concepts on adaptability, efficiency and flexibility from industrial process control hypothesis. Scrum concentrates on team work and product quality in versatile environment. [7, 8]. Sprints, product backlog and daily scrums are core techniques of Scrum. Product backlog plays distinct role in scrum with respect to requirement engineering. Necessary requirements for product, prioritized functions, features and bugs are part of Product backlog. The software product backlog accumulation can be contrasted and compared by inadequate, versatile and implementation document. For each sprint, tasks having high priority are added to sprint backlog without any alterations, however requirements can be reprioritize for next iteration of sprints. Ultimately a meeting is held on sprint review that exhibits the innovative requirements to the client and requests input. All information assembled from the meeting on sprint review and product backlog is utilized in next meeting of sprint. The sprint audit meeting can be contrasted and compared to review of requirements and evolutionary prototype. Fig of frame work is given below[9].

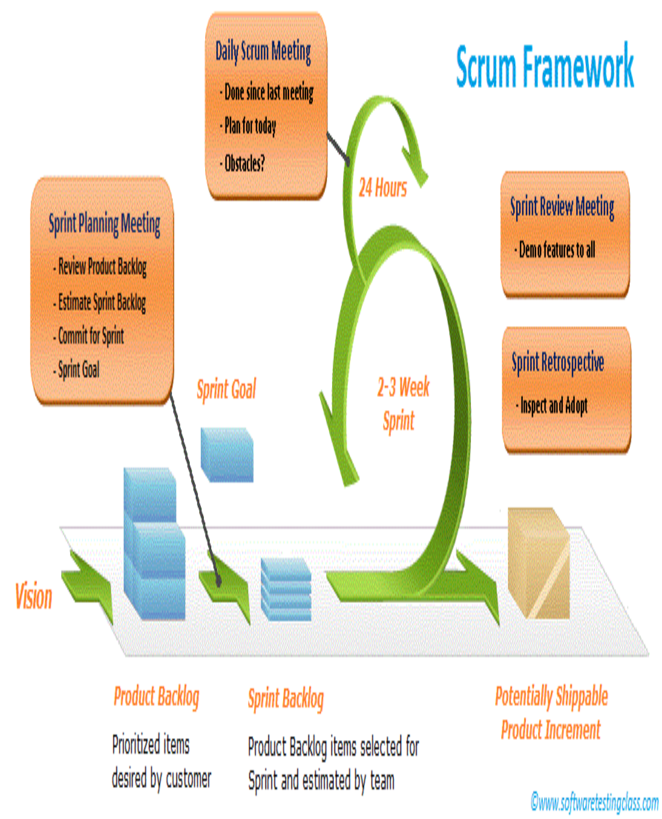
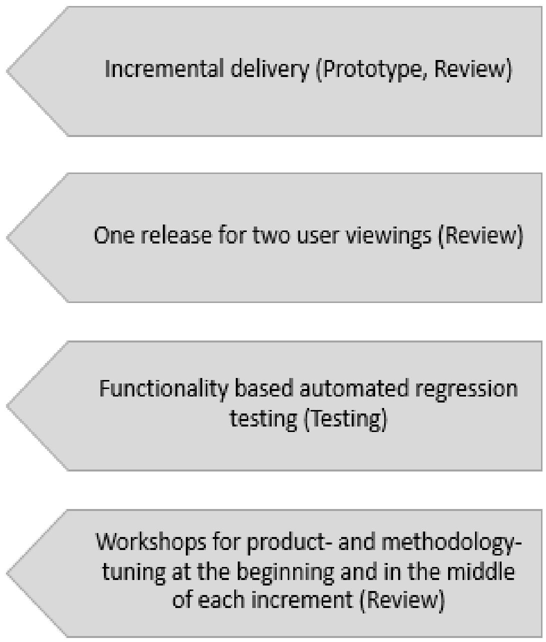


Fig. 2. Scrum framework [9]

3) Crystal: Crystal Methodology are a group of various systems from which the proper techniques can be selected for each software product/project. Followers of this family can be deviate to fit in different circumstances. Indication of ”heaviness” is practiced by different color indexing of members of crystal family. Frequently used colors are yellow, clear, red, orange, blue, magenta and violet. [10]. Up to now three Crystal procedures (blue, violet and magenta) have been utilized .Some Orange policy standards and Crystal Clear can be analyzed and compared with RE methods given below.[9][30].

4) Dynamic System Development Method (DSDM):

DSDM explicitly highlights the use of JAD sessions and emphasizes prototyping [11]. Dynamic Systems Development Method (DSDM) gives a structure for rapid development of application.[11]. Business study and feasibility study are two initial phases of DSDM. Only base requirements are gathered in these two phases and other requirements are gathered in development phase. There is no restriction in use of any technique for development however, testing is practiced in duration of complete life cycle phase. Developers and users both are involved in incremental testing (functional, technical).



II. Literature Review Process

Systematic literature review of related papers has been made as directed in B. Kitchenham et al [12] in 2008 shown in fig. A review has been planned to analyze the studies conducted in domain of requirement engineering in agile mythologies. Review has been made on basis of requirement techniques, agile practices, published year and methodology used so that research trend can be find out in this area. Keywords were identified for searching criteria of research and journal paper in this field .inclusion and exclusion criteria of papers selected, research questions are identified for analysis of research.

A. *Review Planning:*

A literature review was planned out in order to analyze the study in different phases of software requirements with the help of agile methodologies and challenges.

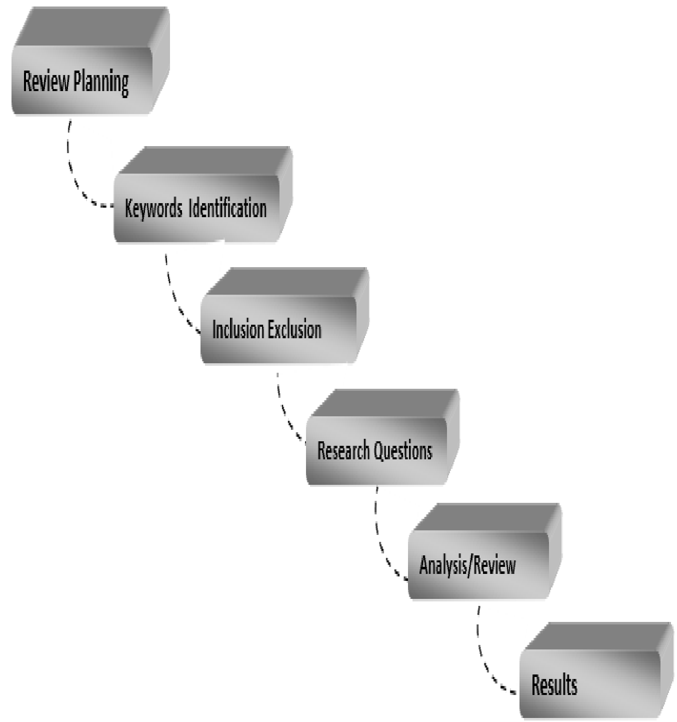


Fig. 3. Review process

B. *Keywords Identification/Selection:*

Research keywords were identified related to agile practices such as agility, agile, Scrum, XP ,crystal programming, usability, requirement management in agile, requirement quality, change management in agile and requirement engineering. These keywords were searched in combination of each other and single terms.

TABLE I. Keywords

Requirement Engineering	Requirement Elicitation, Analysis, Requirement Management, Requirement Validation, Usability, Change management, Traditional agile approaches, traditional model
Agile Approaches	Agile software development, Extreme programming, crystal programming, lean, crystal programming, traditional model, Agile in large organizations, advantages and disadvantages of agile, challenges and Dynamic Systems Development Method

After identification of keywords, search engine were selected for searching review studies .IEEE explorer, science direct, googler scholar,ACM and Taylor & Francis are search engines used for review of papers and journals.

C. Inclusion and Exclusion:

After selection of keywords and search databases, selection of primary review is required. A lot of material has been published in this topic we needed to refine the selected study by addition and removal of material so that purpose of study can be fulfilled. The reviews were chosen in the wake of taking after the incorporation and rejection criteria given below.

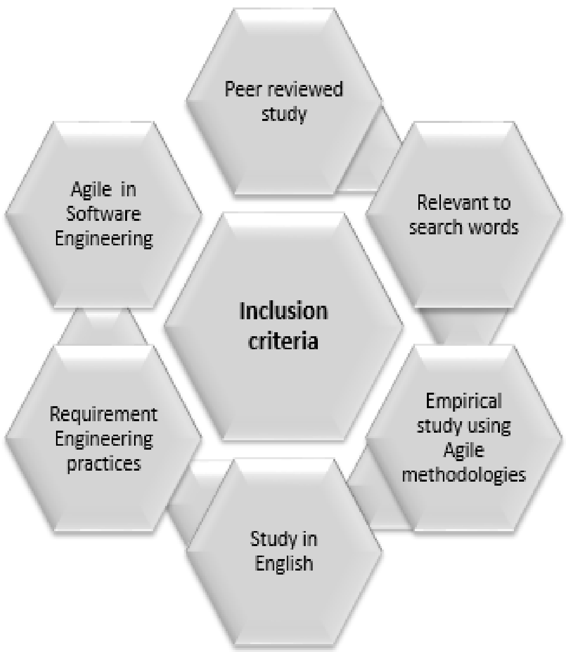


Fig. 4. Inclusion Criteria

1) Inclusion: Inclusion criteria includes Peer reviwed study, relevant to search keywords, empirical study using agile methodologies,Study conducted in English language,studies including requirement engineering practices and agile in software engineering as depicted in fig.3

2) Exclusion: After searching a lot of paper and review we excluded irrelevant material on basis of exclusion conditions and criteria. Especially studies who don't directly focus on Agile practices in requirement engineering, tutorials, editors and weblinks are excluded. Figure of selected study is gien below.

3) Research Questions:

- What are requirement Engineering practices used in Agile?
- What are issues, limitations and challenges in agile requirement engineering?

Complete selection process of literature review is given below.

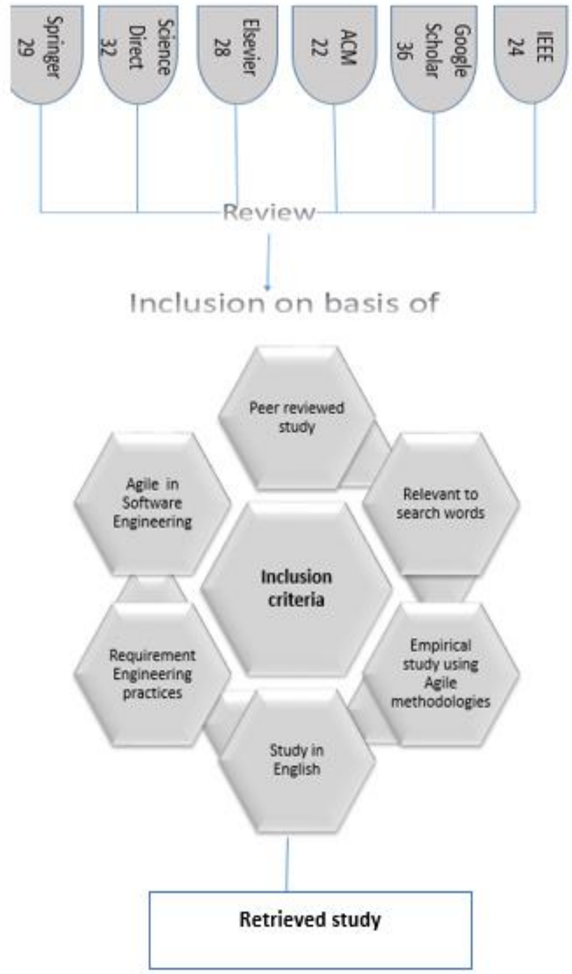


Fig. 5. Literature Review Selection Process

III. LITERATURE REVIEW

A. RE practices in Agile:

Bose, Kurhekar and Ghoshal (2008) [13] focused modifications in requirements engineering to be implemented in agile practices. They proposed that stakeholders should be involved for different point of views for requirements gathering and interviews should be conducted. There should be verification and validation of early description of functional and non-function requirements involved. Moreover, they specify that requirements traceability should be ensured by adoption of requirement management, which is critical when the requirements are probably going to be changed. We can get continuous feedback from customers by agile requirement; however limits of agile practices are not well defined.

Silliti and Succi in 2005[14] depict the approaches of agile to deal with requirements management and elicitation. Purpose of these practices is to delete out dated requirements and add new one by continuous interaction with customers. Interaction between the Agile developers and the clients must be immediate and with no go-betweens and complete development team should be involved for requirements elicitation and gathering. In beginning of each iteration requirements can be changed and prioritized so conclusion is that requirements are effectively managed in small teams by agile practices and customer involvement reduces wastage of time in requirements during production.

According to Eberlein and Leite (2002) [15] the requirements are ineffectively handled in four agile practices- requirements management, validation and verification, nonfunctional requirements and customer interaction but can be ignored in agile domain. Requirement management is basis for managing changes in customer requirements so agile methods must ensure it. For improving quality of agile process requirements validation is applied with requirements verification. According to authors techniques are needed to identify nonfunctional requirements. [16]. However, more focused has been given to customer involvement and interaction but different techniques of interviews and context free questions should also be included.

Paetsch, Eberlein and Maurer (2003) [17] look at the distinctions and comparisons between Agile approaches and traditional RE approaches and attempt to discover what advantages of RE techniques can applied to Agile approaches. According to them there is least involvement of customers in tradition al RE approach (only involved in early stages) whereas agile involves stakeholders throughout in agile process. They conceived that agile approaches are lessdocumented and traditional approaches are well documented in detail. Traditional RE approach uses diverse levels of abstraction models while Agile uses throw away model. Agile methods use index cards for requirement management and change management has great importance in traditional approach. In their opinion, is that the RE stages are repeated and merged in most iterations and not clear in agile. Recommendations of authors are need of documentation in agile environment for future maintenance and implication of distinct phases of RE. [33]

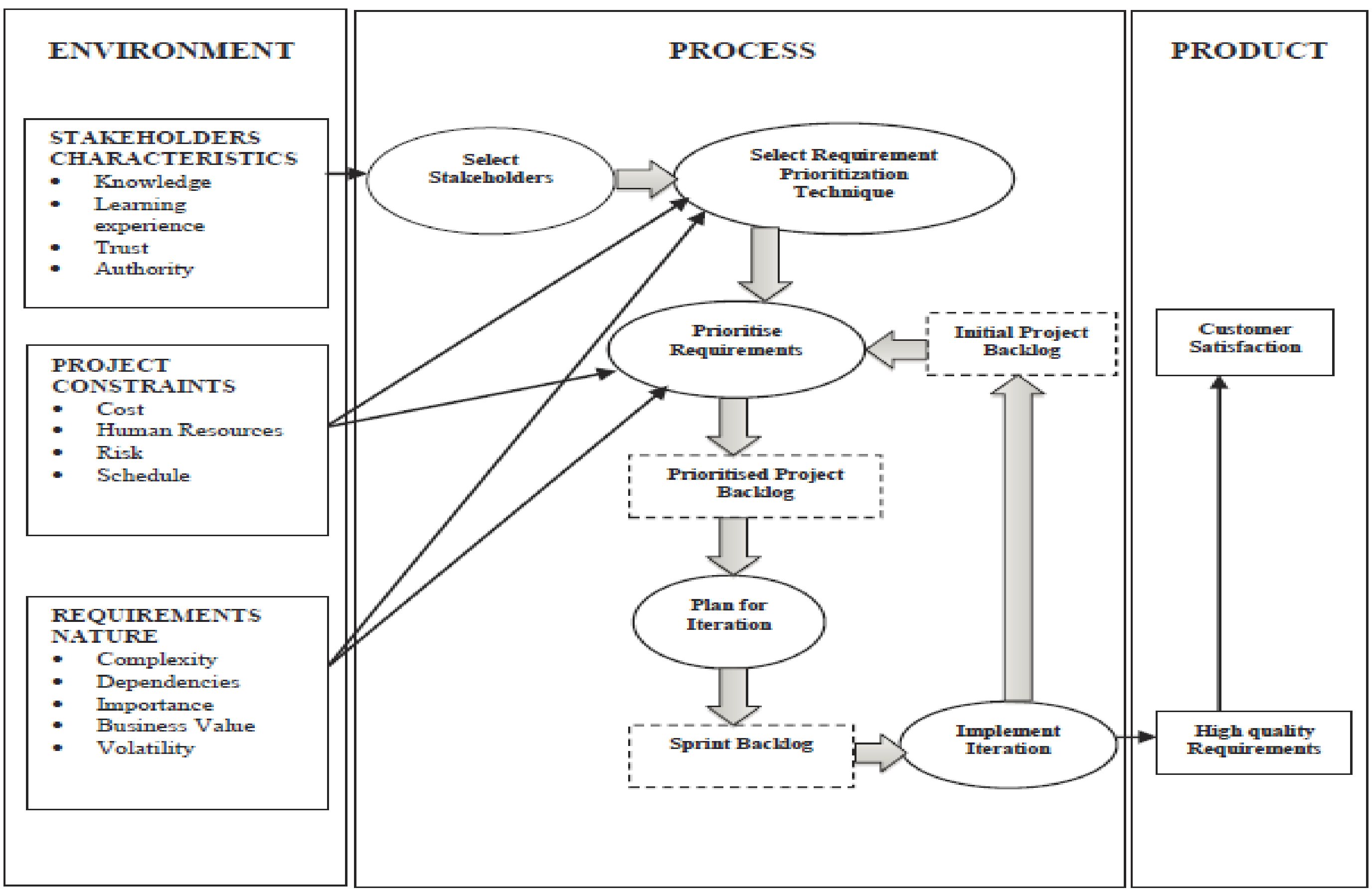


Fig. 6. Frame work of requirement prioritization [18]

B. Requirement Prioritization in agile:

The progress of innovation and business needs have activated client prerequisites to evolve almost each day. It is in this manner difficult to satisfy the necessities on the double. Agile practices have been acquainted with relieve such issues by actualizing client necessities incrementally and iteratively. Author has discussed about the variables that must be thought about while performing requirement prioritization in agile practices. This is essential as erroneous requirement prioritization may build the cost of advancement and prompt project and framework disappointments. In this review, the contributing components concerning viable requirement prioritization in writing were grouped through substance examination as a theoretical system. The studies demonstrate that there are three angles required in requirement prioritization prepare in lithe improvement [18].

Choosing a gathering of unmistakable necessities to be executed in iterations is considered as fundamental in agile practices. This can be accomplished by execution of requirement prioritization. Conceptual framework of requirement prioritization is depicted in fig [18].

Some of challenges in agile requirement prioritization are depicted in fig below.

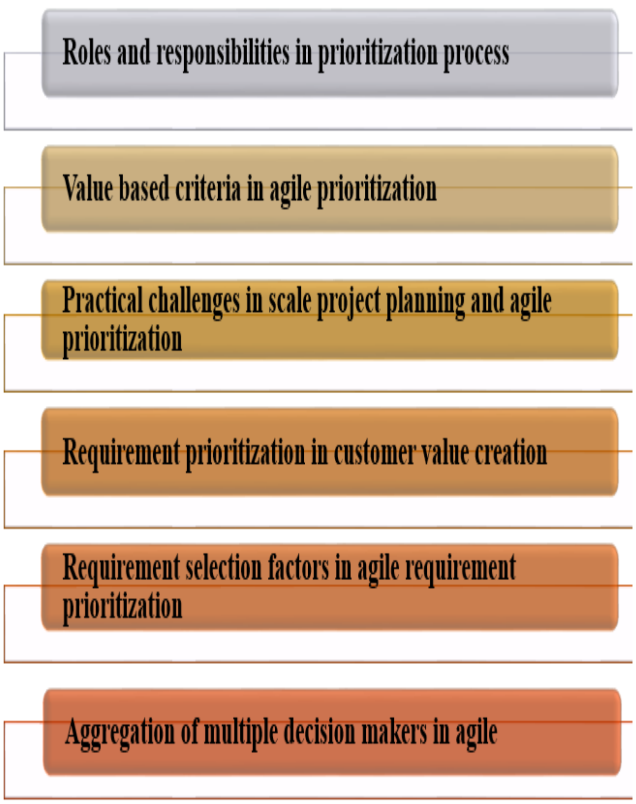


Fig. 7. Challenges in requirement prioritization

C. Uses of Agile Requirement Enginerring

Tomayko (2002) [19] perceives 12 extreme Programming groups and discovers that agile prototype answer queries about requirements content. Customers accordingly will recognize what else they need and dispose of the obligation of giving correct requirements. Another advantage of agile approach is that requirements (unstable state) are pre tested for detection of faults in extreme programming however, changes in architecture causes incorrect estimation and extra cost in requirements elicitation in agile environment.

16 software development establishments were examined by Cao and Ramesh (2008) [22] for advantages and disadvantages of 7 agile approaches. Iterative requirement engineering, face-to-face correspondence over specification in written form, utilization of review meetings and acceptance tests, prototyping, test bases development, constant planning for change requirement management and prioritization of requirements [25]. They dissect both of the advantages and difficulties of these practices and recommend that they are neither beneficial nor useless to establishments and can be used on basis of project specifications and conditions.

A goal sketching method was introduced by Harrison and bones in 2007 [24]. First they create unclear goal graph for basic understanding of functionality then development of stages similar to scrum started. Graph consists of many stages termed as stage graph and refines all stages of development. Stage graph is updated during stages and system with completed graph is updated at the end of last stage by using iterative developments. Testing of these practices has been done in industrial organizations.

Model of Agile Requirements Abstraction, a model of 4 abstraction level agile was presented by Birgisson, Svensson, Hedin and Regnell (2008) [26]. Feature level, product level, component level and function level are 4 levels from general to specific. Whenever Requirement engineering phases use ARAM model, these phases use three steps: Elicitation step, placement step and workup step. Collection of real requirements is included in elicitation, placement include identification of abstraction level of requirements and old and new requirements are combined by identity numbers in workup step.ID numbers are assigned with respect to algorithm in prioritization of requirements for scrum backlog. Documentation can be part of these steps if traditional methods are practice in this model. These agile practices are just assumed within the groups so the clients just observe the delivered outcomes as developments and don't need to be required in the RE procedure. Evidence shows that how RE process was executed in scrums. Most of research has been conducted on general agile methodologies, few authors specified RE practices in Scrum .Moreover the greater part of the accessible scholars discussed elicitation stage of requirement engineering ,other phases requirement management, prioritization , validation and management are rarely cited.

D. RE Practices in Agile:

Following are requirement engineering practices used in agile methodology reflected in review study.

TABLE II. REQUIREMENT ENGINEERING PRACTICE IN AGILE

Requirement Engineering practices in Agile	Author
Direct Communication Team members and client directly communicate with each other, significant feature of agile in RE.	Zhu, Y, (2009). Cao, L. C. L., & Ramesh,B (2008)
Client interaction and participation Main reason of success of project and less failure effects need of identification of customers for clear and prioritized requirements.	Farid, W. M., & Mitropoulos. (2012) Daneva, M., van der Veen, E, Amrit, C, Ghaisas, S., Sikkel (2013)
Provision of User stories Customer requirements require user stories. It develops understanding b/w stakeholders. These stories has changed trend from documentation to discussion	Daneva, M., van der Veen, E., Amrit, (2013) Ghaisas, S., Sikkel, K., Kumar Bjarnason, E., Wnuk, K., & Regnell (2010)
Prioritization of Requirements Requirement prioritization focuses on risk and business value and part of each iteration in agile whereas one time is performed in traditional approaches.	Cao, L. C. L., & Ramesh, B.(2008) Daneva, M., van der Veen, E., Amrit, C., Ghaisas, S., Sikkel, K., Kumar (2013)
Emergence of Requirements Requirement develops over time in agile practices due to frequent interaction between stakeholders opposite to traditional approach. It removes ambiguity in requirements in less time.	Cao, L. C. L., & Ramesh, B. (2008) Ramesh, B., Baskerville, R., & Cao, L. (2010).
Features update in change management It is challenge for traditional approach .Its dynamic nature can add or drop features in agile requirements.	Cao, L. C. L., & Ramesh, B. (2008)
Continuous planning There is always continuous planning to adjust new upcoming requirements and change management.	Jun, L., Qiuzhen, W., & Lin, G. (2010).
Requirement Analysis pairing Stakeholders can perform many roles by pairing of requirement analysis.	Yu, Y., & Sharp, H. (2011)
Shared conceptualization To support RE activities in requirements gathering, requirements evolving for agile practices.	Abdullah, N. N. B., Honiden, S., Sharp, H., Nuseibeh, B., & Notkin, D. (2011)
Refactoring of code To change and improve structure of develop code for adaptation of changes in volatile requirements.	Gandomani, T. J., Zulzalil, H., Ghani, A. A. A., & Sultan, A. B. M. (2013)
Prototyping To review requirement with clients, to get feedback from clients, prioritization and refinement in requirements.	De Lucia, A., & Qusef, A. (2010).
Pre testing To write tests before functional codes, enhances feedback by test cases. Another approach is ATDD.	Haugset, B., & Stalhane, T. (2012).
Requirement management We can easily update features in agile requirements by requirements management.	Cao, L. C. L., & Ramesh, B. (2008). Ramesh, B., Baskerville, R., & Cao, L. (2010).
Review meetings Acceptance tests and meetings are developed requirements and product backlogs .Meetings are held to review these backlogs	Carlson, D., & Matuzic, P. (2010).

F. RE Issues/chaleenges in Agile Methodology:

Following are requirement engineering challenges that can be described in Agile

TABLE III. RE CHALLENGES IN AGILE

Features	Details	Challenge
Direct Communication	Communication between clients and teams members, minimum documentation in Agile.[20][21]	How to track changes in requirements?
Large interaction of clients.	Client interaction is required for large amount of feedback	Large work load
Change requirements	Handle changes	Work again and again
Negligence of NFR	User stories just store functional requirements	Security and usability
Estimation of Budget, time	Cant estimate due to changes requirements	Overrun and high cost project
Innovation in requirement engineering	Creativity in requirement engineering	Creativity issue in agility and in release
Missing Requirements	How to discover missing requirements?	A large no of iterations for missing requirements
Conflicting requirements	Conflict and ambiguity in requirements	A large no of iterations

IV. ASSESMENTS AND FINDINGS

Hasnain in 2010 [27] given a efficient review to describe customers, users, agile techniques and specialized issues recognized in published literature review from 2002 to 2008.According to them review demonstrates that requirement engineering methods are reviewed in generic agile approaches and these practices are not reviewed in specific agile methodologies like extreme programming, test driven development , crystal programing. Finding of Ramesh [28] in her survey prescribed that exploratory and experimental results are more required agile practices particularly in extreme Programming (XP) [16], crystal programming and Scrum [17].

Silva and Martin [31] provided systematic review about user centered design and agile practices integration. Usability issue, related to design of agile methodology was discussed in literature review [31]. Finding of review identified that agile team can resolve usability issue by adopting specialist of user-centered design. These practices have been identified in agile techniques like big design up front, little design up front and testing of user.

Barlow and Lowry [32] valued the impact of the use of agile practice in large level projects. The survey gave the design framework of a system that conveys methodologies to large projects for implementing agile practices. The survey outcomes help the designers and developers to implement development practices in large organizations. Agile performance in three constraints time, scope and cost is depicted in Fig.7 [9]. Scope of Agile is most beneficial in IT organizations as shown in fig.

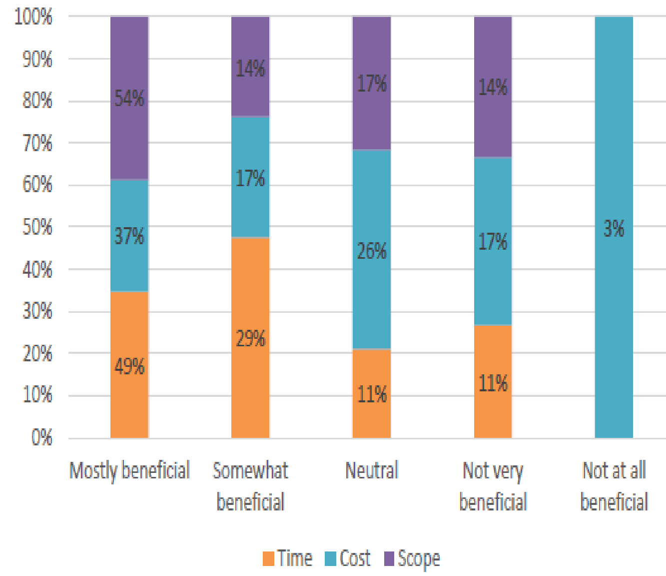


Fig. 8. Agile in tripe constraints [9]

Usability, performance and security of system described by nonfunctional requirements are less focused in Agile practices NFRs that decide the ease of use, security and execution of the framework are anticipated to find solution of issue in agile practices. [31,32]. Most of authors concentrated on specific nonfunctional requirement e.g. security [33][34] and propose structures for supporting elicitation of security requirements while others referred ,modeling framework as component of requirement engineering in order to integrate nonfunctional activities into agile practices.

V. CONCLUSION AND FUTURE WORK

In the previous decade, agile practices has picked up a huge worldwide recognition related to software development because of its center idea of esteeming people and connections, working program, client cooperation, and reacting to change. We firmly trust that agile consummately fits the changing way of RE, along these lines bringing lithe into the universe of RE will ensure a more noteworthy and a speedier achievement. Theses research papers represent a systematic review of agile methodologies, its limitations and challenges in requirement engineering. Systematic literature review of related papers has been made as discussed in B. Kitchenham et al [12] in 2008. About more than 60 research papers were searched, exclusion criteria was applied to shortlist relevant research papers. Paetsch, Eberlein and Maurer [17] look at the distinctions and comparisons between Agile approaches and traditional RE approaches and attempt to discover what advantages of RE techniques can applied to Agile approaches RE stages are repeated and merged in most iterations and not clear in agile. Recommendations of authors are need of documentation and prioritization in agile environment for future maintenance and implication of distinct phases of RE Finding of this research is the work of researchers that will be beneficial for those who are interested in finding interesting area of research in this field because many techniques of agile (extreme programming, crystal methodology, lean) requires further study and practical results as clarified by studies. When processes are not well defined and clarified, conflicts in requirements causes problem. There is need of proper framework for prioritizing requirements in agile environment. Nowadays, Organizations are more focusing on providing requirements focus on value of customers and organization viewpoint because of time limitations, concentrate on cost saving and satisfaction of consumer By prioritizing requirements , business value based on customer needs can be established. There is need of process with defined criteria and process that can help in well prioritized backlog.

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Classifying and Segmenting Classical and Modern Standard Arabic using Minimum Cross-Entropy

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***Abstract*—Text classification is the process of assigning a text or a document to various predefined classes or categories to reflect their contents. With the rapid growth of Arabic text on the Web, studies that address the problems of classification and segmentation of the Arabic language are limited compared to other languages, most of which implement word-based and feature extraction algorithms. This paper adopts a PPM character-based compression scheme to classify and segment Classical Arabic (CA) and Modern Standard Arabic (MSA) texts. An initial experiment using the PPM classification method on samples of text resulted in an accuracy of 95.5%, an average precision of 0.958, an average recall of 0.955 and an average F-measure of 0.954, using the concept of minimum cross-entropy. PPM-based classification experiments on standard Arabic corpora showed that they contained different types of text (CA or MSA), or a mixture of the both (CA and MSA). Further experiments with the same corpora showed that a more accurate picture of the contents of the corpora was possible using the PPM-based segmentation method. Tag-based compression experiments (using tags produced by parts-of-speech Arabic taggers) also showed that the quality of the tagging (as measured by compression quality) is significantly affected when tagging either CA and MSA text. The conclusion is that NLP applications (such as taggers) should treat these texts separately and use different training data for each or process them differently.**

Keywords—text classification; Arabic language; Classical Arabic; Modern Standard Arabic

I. Introduction

Text classification is the process of automatically assigning a document to different predefined classes or categories to reflect their contents [1]. Text classification is important in various areas such as natural language processing (NLP), text mining, information retrieval, machine learning, etc. [2]. It also can be applied in a large variety of applications such as spam filtering [3], author identification [4]–[6], gender identification [7], [8], sentiment analysis [8]–[11], dialects identification [12], [13], and so on.

The massive increase in the size of text accessible on the internet during the last two decades has drawn the attention to the importance of text classification [2]. This increase of data on the Web has produced the need for methods to extract the required information from text documents, and therefore, generating unique difficulties for the text classification problem especially when considering applications requiring analysis of big data [2], [14].

Text classification can be implemented using various algorithms, for example, Naïve Bayes and the chain augmented Naïve Bayes probabilistic classifier [15], [16]. Other algorithms such as support vector machines, or SVM, [17], generalized instance sets [18], k-nearest neighbors algorithm [17], neural networks [19] and Generalized Discriminant Analysis, or GDA, [20] have been used to classify English text. Various algorithms have also been applied to other languages such as Chinese [17], [21] although there has been noticeably less research done with the Arabic language.

Most of those text classification algorithms handle text documents as a “bag-of-words” where a set of words or tokens are used to interpret the text and which rely on using their frequency in some manner [22], [23]. The traditional approach to text classification goes through four steps: first, pre-processing of the text where the words (or tokens) and sentences in the training files are segmented [1], [24]; second, using word/token counts to extract or select different features; thirdly, applying one of the machine learning algorithms mentioned earlier; and finally, performing the same feature extraction on the test data and applying the learned model to the extracted features to predict the class for the test data [1], [24].

During the process of analyzing the text, a complication occurs when the phenomenon of code-switching arises. This is where a text contains more than one language or variations of the same language. This phenomenon has been the subject of extensive linguistically oriented study in the past [25], [26]. This paper tackles the problem of mixed texts by segmenting those variations. Text segmentation is the task of automatically separating the text into identified or coherent parts [27]. Compared to text classification, text segmentation can be used to produce a more accurate estimate of each class, category or topic located inside the text rather than assigning a class or set of classes to the entire text as a whole.

يحضر برشلونة عرضا كبيرا لتعزيز الجبهة اليمنى التي تعاني بعد رحيل البرازيلي داني ألفيش إلى
يوفنتوس ، وصرف في السنوات الأخيرة ١٦٧ مليون دولار لشراء مدافعين لم يكن أغلبهم على قدر التوقعات

Fig. 1. A sport news from aljazeera.net [66] in MSA text

يُبكون من تبكي السماواتُ يومَه   ومن قدِ بكته الأرض فالناس أكمد
وهل عدلت يــومـا رزيةَ هالك   رزيـــة يـــوم مـــات فـيــه محمد

Fig. 2. A Classical Arabic Poem

Many segmentation algorithms, such as the TextTiling algorithm [28] and the dotplotting algorithm [29] rely on measuring the variation in word usage to predict potential boundaries in the text, where a vast difference in word usage is a positive sign. Kozima [30] introduced an algorithm that traces the coherence of a document by applying a semantic grid in a "lexical coherence profile". A statistical approach was proposed by [27] for text segmentation, where the algorithm builds a model from selected informative features, then the model is used to predict where boundaries happen in the text.

The work in this paper instead uses an approach based on the Prediction-by-Partial Matching (PPM) compression scheme as the basis of both text classification and segmentation. This Markov-based approach effectively uses character-based language models and has been employed in many NLP tasks in the past often with state-of-the-art results or results competitive with traditional schemes [1], [31]–[36].

Compared to the traditional way of text classification, compression-based language modelling is a character-based approach, whereas traditional text classification is a word-based approach which is language-dependent that tends to overlook both the contextual information of the text and the word order [1], [2]. The use of language modelling for text classification takes into consideration the contextual information in the text when building the language model and avoids the need for pre-processing of the text usually required by most classification algorithms [1], [2]. The use of Markov-based approximations standard in character-based language modelling avoids the issue of explicit feature selection that is applied in traditional classification and segmentation algorithms which may discriminate some important features of the text [1], [37]. The segmentation process performed in this study applies a Viterbi-style algorithm which produces an accurate estimate of each class, category or topic located in the text [34].

TABLE I. THE MOST UNIVERSALLY USED LANGUAGES

Rank	**Language**	**Users (millions)**
1	Mandarin	1051
2	English	508
3	Hindi	497
4	Spanish	392
5	Arabic	330
6	Russian	277
7	Bengali	211
8	Portuguese	191
9	Malay	159
10	French	129

The Arabic language "العربية" is acknowledged to be one of the most largely used languages, with 330 million people using the language as their first language, as shown in Table 1, plus 1.4 billion more using it as a secondary language [38]. The majority of the speakers are located across twenty-two nations, primarily in the Middle East, North Africa and Asia, and the United Nations considers the Arabic language as one of its five official languages. The Arabic language is part of the Semitic languages that includes Tigrinya, Amharic, Hebrew, etc., and shares almost the same structure as those languages. It has 28 letters, two genders – feminine and masculine, as well as singular, dual and plural forms. The Arabic language has a right-to-left writing system with the basic grammatical structure that consists of verb-subject-object and other structures, such as VOS, VO and SVO [39]–[41].

The non-colloquial written text for the Arabic language can be divided into two types: Classical Arabic and Modern Standard Arabic [42]–[45]. The Classical Arabic (CA) epoch is usually measured from the sixth century which is the start of Arabic literature. It is the language of the Holy Quran, the 1,400-year-old primary religious book of Islam with 77,430 words [46] and other ancient Islamic books from that era, such as the Hadith books [47]. With the beginning of journalism and the spread of literacy in the eighteenth century came Modern Standard Arabic or MSA. MSA is the language of the current printed Arabic media and most Arabic publications. (See Figure 1 for an example).

Almost all Arabic language NLP tasks are performed for MSA [48]. One example of those tasks is parts-of-speech tagging of Arabic language. Most of the popular Arabic parts-of-speech or POS taggers were trained on MSA text [36], [49], and therefore, the performance of the taggers will be best when tagging MSA text [36]. Contrastingly, tagging Classical Arabic text using MSA POS taggers will significantly reduce the quality of the tagging [47].

Some Arabic corpora, such as the Bangor Arabic Compression Corpus (BACC), is a mixture of both CA and MSA text. An example is the BACC sub-corpus *arabicbook1*, which contains both recent novels with ancient Arabic poems. (See Figure 2 for one example). The results of using such a corpus in order to perform various NLP tasks, such as POS tagging, as stated before, will vary and will not be consistent and reliable. Therefore, there arises a need to accurately classify CA from MSA within the text.

This paper explores the approach of classifying the Arabic text using PPM. It will first explain the PPM text compression scheme and its use for compressing, classifying and segmenting natural language text. Secondly, it will detail findings of PPM character-based modelling experiments used to classify and segment Arabic text. Thirdly, the results and limitations of those experiments are discussed in detail. Finally, the conclusion is presented.

II. Minimum Cross-Entropy as a Text Classifier

The PPM scheme uses an online algorithm that compresses the natural language adaptively as the text is processed sequentially. PPM usually processes character streams, although there are word-based and tag-based (i.e. using POS tags) variations. The standard character-based model uses the prior context of already received characters to foretell the imminent one. The word-based PPM model uses a series of already seen words to help predict the upcoming word but resorts to a character-based encoding for unseen words. The tag-based model, which is used in the last experiment, effectively encodes two streams, the stream of POS tags and the stream of words, by using the previously seen tags and words to predict the upcoming tag and word [50].

The basis of the classification and segmentation schemes in this paper use the character-based approach for compressing the Arabic text [1]. The essence of this approach depends on the concept of entropy as a measurement of the message's "information content" [51], and on the notion that the upper bound of the entropy can directly be estimated by compressing the text [52].

The fundamental coding theorem in information theory [51] states that an entropy of a sequence of text, or message, is the lower bound to the average number of bits per character required to encode that message [34].

$$H(P) = -\sum_{i=1}^{k} p\,(x_i) log\; p(x_i)$$

where there are k number of potential characters with the probability distribution $P = p(x_1), p(x_2),..., p(x_k)$ and the probabilities sum to 1 and are independent. The measurement of the uncertainty associated with the selection of the characters is represented by the entropy, where the higher the entropy, the higher the uncertainty. The message's "information content" can also be measured by the entropy, as the more probable the messages, the less information is conveyed compared to less probable ones [34].

A general case for a language with probability distribution can be extended from the previous equation for a text sequence $T = x_1, x_2, \ldots, x_m$ of length *m*:

TABLE II. Processing the String أبجدبهوبأأبجد using PPM

Order 2 Prediction	c	p	Order 1 Prediction	c	p	Order 0 Prediction	c	p
‘جد’ → ب	1	1/2	‘ج’ → د	2	3/4	→ ج	2	3/26
→ esc	1	1/2	→ esc	1	1/4	→ د	2	3/26
‘دب’ → ه	1	1/2	‘د’ → ب	1	1/2	→ و	1	1/26
→ esc	1	1/2	→ esc	1	1/2	→ ب	4	7/26
‘وب’ → أ	1	1/2	‘و’ → ب	1	1/2	→ ه	1	1/26
→ esc	1	1/2	→ esc	1	1/2	→ أ	3	5/26
‘بج’ → د	2	3/4	‘ب’ → ج	2	3/8	→ esc	6	3/13
→ esc	1	1/4	→ ه	1	1/8			
‘به’ → و	1	1/2	→ أ	1	1/8			
→ esc	1	1/2	→ esc	3	3/8			
‘بأ’ → أ	1	1/2	‘ه’→ و	1	1/2			
→ esc	1	1/2	→ esc	1	1/2			
‘هو’ → ب	1	1/2	‘أ’ → ب	2	1/2			
→ esc	1	1/2	→ أ	1	1/6			
‘أب’ → ج	2	3/4	→ esc	2	1/3			
→ esc	1	1/4						
‘أأ’ → ب	1	1/2						
→ esc	1	1/2						

Order -1 Prediction	c	p
→ A	1	1/|A|

$$H(L) = \lim_{m\to\infty} -\frac{1}{m}\sum p\,(x_1, x_2, \ldots, x_m)\; log\; p(x_1, x_2, \ldots, x_m).$$

This describes the entropy of a language which is defined to be the limit of the entropy when the size of the message becomes large. The probability distribution for the source language L is usually not identified or known. Nevertheless, applying a model M as an approximation to the probability distribution gives the upper bound to $H(L)$ [34]:

$$H(L, M) = -\sum P_M\,(x_1, x_2, \ldots, x_m)\; log\; P_M(x_1, x_2, \ldots, x_m)$$

where $P_M(x_1, x_2, \ldots, x_m)$ is used to estimate the probabilities. $H(L, M)$ is described as the *cross-entropy* which is higher than or equivalent to the entropy $H(L)$, as this is based on the source itself which is the best possible language model:

$$H(L) \leq H(L, M).$$

Compressing the text can be used to estimate an upper bound to the entropy of a message [52]. Considering the number of bits needed to encode a sequence of text to be $b_M(x_1, x_2, \ldots, x_m)$, when using some model M to estimate the probabilities, then:

$$H(L, M, T) = \lim_{m \to \infty} \frac{1}{m} b_M(x_1, x_2, \ldots, x_m)$$

where the number of bits per character needed to encode a long text message T formed from L is $H(L, M, T)$.

The cross-entropy is important as it presents a measurement of how great the estimated model is performing on the test text; the less inexact the model is, the closer the cross-entropy is to $H(L)$. Furthermore, by measuring the cross-entropy for every possible model, the cross-entropy provides a valuable measure for analysing the correctness of the competing models. The model that has the least cross-entropy is judged to be the "best" or most appropriate. The information is derived from a semantic label which is associated with each model which reflects the class or type of data that was used to train the model. Simply, the label linked with the "best" model is selected and used to classify the text:

$$\hat{\theta}(T) = \mathrm{argmin}_i \, H(L, M, T).$$

The following section presents one specific method, which is based on the PPM text compression, used to measure the cross-entropy [34].

III. PPM-based Compression for Natural Language Text

PPM is an adaptive online system used for compressing text by predicting the upcoming symbol or character using the prior context with a given maximum fixed length. It applies a Markov-based *n*-gram method which utilises a back-off mechanism similar to that proposed by Katz [53]. Nonetheless, backing-off is referred by PPM as "escaping" and it was developed before the mechanism that Katz proposed. Cleary and Witten [54] first proposed PPM in 1984 when they described the two character-based PPM variants, PPMA and PPMB. Two further character-based variants of PPM, PPMC and PPMD, were introduced by Moffat and Howard in 1990 and 1993 respectively [55]. The main difference among these four versions of PPM is the calculation of the escape probability which the smoothing mechanism needs for backing off to a model's lower order. Many trials have been performed on character streams which have shown that PPMD ordinarily gives better compression results when compared with the results of other PPM variants [56].

As mentioned before, PPM has been successfully implemented in various fields of NLP. It produces state-of-the-art text compression results for many languages as detailed in the reports mentioned in [31], [36], [57]. PPM has been used as the basis for an effective method for performing Chinese word segmentation where spaces (as word separators) are inserted into Chinese text which has no spaces [33]. Other studies such as [31], [34]–[36], [57], [58] have reported using PPM for different languages for other NLP tasks such as cryptology, code switching, authorship attribution, text correction and speech recognition.

The next equation defines the probability p for the next character φ when using PPMD [34]:

$$p(\varphi) = \frac{2c_d(\varphi) - 1}{2T_d} \tag{1}$$

where d represent the currently used coding order, the total amount of times that the current context has occurred is indicated by T_d and $c_d(\varphi)$ represents the total number of occurrences for the symbol φ in the current context. The estimation of the escape probability e by PPMD is as follows:

$$e = \frac{t_d}{2T_d} \tag{2}$$

where the total amount of times that a unique character has occurred following the current context is represented by t_d. Most experiments have reported that using the maximum order of 5 to be the most efficient, as PPMD starts with that order first to encode the incoming character [34] before escaping down to lower orders if necessary.

If the forthcoming symbol was predicted by the current model and the model contained it, then its probability in the current maximum order, 5 in this case, will be used to transmit it. If the forthcoming symbol was not found in the model, then the encoder will escape to the next lower order model, 4 in this case. This process of escaping will be repeated until the model finds that symbol or prediction. If the model does not contain the symbol, then the encoder will back off to a default order of -1 where the same probability is used for all symbols in the alphabet [34].

To describe character-based encoding in further detail, the way PPM models a given sequence of text is presented in Table 2. This example uses a specific variant of PPM prediction method, PPMD, to model the string *أبجدبهوبأأبجد*. As stated, a model's maximum order of 5 is proven to be efficient, but a maximum model order of 2 is used in this example for illustration purposes. In the table, *c* shows the count, *p* expresses the probability and the size of the alphabet used is represented by $|A|$ [33]. For this example, let the next character be letter ب. This character has been seen once before ('جد' → ب) for the order two context 'جد' and consequently it has a probability of ½ (utilising equation (1) as the count is 1). Accordingly, the encoder will use 1 bit to encode the character ب. However, if the forthcoming character in the order two context had not been seen before, (i.e. assume the following letter was أ rather than ب), an escape process to a lower order will be performed, the escape probability will be ½ (from equation (2)), and the model will use a lower order of 1.

During the process of the model's backing off, the new order will be adopted to calculate the probability, and in this instance, there is no character أ that appears after د. Consequently, another escape probability of $\frac{1}{2}$ will be encoded by the model, and the current context is decreased to the order 0 context (the null context). This order, where the probability will be $\frac{5}{26}$, is used to encode letter أ. The whole cost of foretelling the last letter is $\frac{5}{26} \times \frac{1}{2} \times \frac{1}{2}$, which costs the encoder approximately 4.4 bits to encode it. Furthermore, if the next character has not been seen already in the context, for example letter ع, starting from the maximum order of 2 and escaping down to -1, the model encodes the escape probability three times using the following probabilities: $\frac{1}{2} \times \frac{1}{2} \times \frac{3}{13} \times \frac{1}{256}$. This is because order -1 is applied to encode this character and using an 8-bit encoding for the Arabic text (say), the alphabet size is 256. This results in approximately 12.1 bits being required to encode it [34].

(PPM when used for compression uses arithmetic coding [59] to ensure that the cost of encoding is close to the theoretical cost of $\log_2 p$ bits for some probability p, although physical coding is not required for the classification and segmentation applications used here since the theoretical encoding cost can be computed directly instead without the need for physical encoding tor these applications).

IV. PPM Classifier and Segmenter Evaluation Experiments

This section reports the experiments that were performed as part of the evaluation of the PPM classifier and segmenter when applied to Arabic text. Four experiments were conducted: (A) initial classification experiments; (B) classification of mixed Arabic corpora; (C) segmentation of mixed Arabic corpora; and (D) tagged-based compression experiments of Arabic text. The first experiment used 200 files for the initial evaluation process. The second experiment examined the result of classifying a number of Arabic mixed corpora. The third experiment performed text segmentation on the same Arabic mixed corpora using a Viterbi-style algorithm that finds the most probable sequence of segmented characters. Lastly, the final experiment conducted tag-based compression experiments using the previous outcomes. The Arabic mixed corpora which were used were the Bangor Arabic Compression Corpus (BACC) [57], the Universal Dependencies (UD) project corpus [60], Arabic in Business and Management corpus (ABMC) [61] and the Arabic Learner Corpus [62].

Segmenting Arabic text increases the performance of some NLP applications such as parts-of-speech tagging. As stated before, most Arabic NLP tasks are trained and built for MSA. The performance of such a task drops when applied to Classical text [47]. The object of the research described here is to classify and segment CA and MSA using the PPM character-based compression algorithm. The experiments in this paper used two language models, one for CA and another for MSA. Published Arabic corpora that contain mostly the required type of Arabic text were used to train the two static models.

The MSA model was trained using Corpus A [58]. The corpus was recently published, and most of its genres covers several current MSA areas such as business, cinema, opinions, conferences, economics, politics and more. The text in the corpus was collected from the bilingual newspaper Al-Hayat website, and from the open-source online corpus, OPUS [63].

The second model used in this paper was trained using CA text from the King Saud University Corpus of Classical Arabic (KSUCCA). According to the author [64], the foremost purpose of the creation of this corpus is for analysing the lexical meaning of the Holy Quran. The corpus is relatively large and it contains over 50 million words, split into six genres such as Literature, Linguistics and Science. To generate a relatively similar size as the first model (as this helps improve classification accuracy), the sub-genre Religion was not included in the training process. To obtain a more robust evaluation and ensure the training text used for the models was separate from the testing text, a tenfold cross-validation technique was used for the classification experiments.

Both the PPM language modelling and the segmentation were performed using the Text Mining Toolkit described in [65]. This toolkit allows *static* models to be created from training text. That is, once the models have been created, they can be used to prime the model(s) used by the application and are subsequently not altered during the compression, classification or segmentation processes.

A. *Initial Classification Experiments*

This initial experiment was conducted to evaluate the PPM classifier based on four evaluation criteria and using 200 test files in the evaluation process. The testing files were divided into two groups, each with 100 files. The first group comprised 100 files that contained CA text randomly gathered from the Holy Quran, Islamic books such as Ibn Qayyim and Ahmad ibn Hanbal and poems from the famous Arab poet, Al-Mutanabbi. The second group comprised 100 files containing MSA text randomly collected from popular Arabic news websites such Aljazeera.net [66], BBC Arabic [67] and skynewsarabia [68] and recently published novels.

Four evaluation criteria (Accuracy, Recall, Precision and F-measure) were used to evaluate the classification results using the following equations:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$Recall = \frac{TP}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$F - measure = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

where *TP* is the true positives which are the number of cases where the prediction matches the type of Arabic text and *TN* is the true negatives which represent the number cases where the prediction does not match the type of Arabic text, and *FP* and *FN* are the false positives and false negatives respectively, as shown for the confusion matrix in Table 3.

TABLE III. CONFUSION MATRIX

	Predicted CA	Predicted MSA
Actual CA	TN	FP
Actual MSA	FN	TP

Classifying the Classical and MSA text using the PPM compression algorithm obtained an accuracy of 95.5%, an average precision of 0.958, an average recall of 0.955 and an average F-measure of 0.954. The results in Table 4 show that the PPM classifier predicted all the 100 files that contain CA text and 91 out of 100 files which have MSA text.

TABLE IV. PPM CLASSIFICATION RESULTS

	Predicted CA	Predicted MSA
Actual CA	100	0
Actual MSA	9	91

TABLE V. CLASSIFICATION RESULTS OF UD

Genre	Corpus Size	Classical model Compression (bytes)	Modern model Compression (bytes)	Classical bpc	Modern bpc	Predicted Type
AFP	138,223	35,788	33,149	2.07	**1.92**	MSA
UMH	426,811	106,478	97,517	2.00	**1.83**	MSA
XIN	158,997	40,660	36,709	2.05	**1.85**	MSA
ALH	108,599	27,419	25,536	2.02	**1.88**	MSA
ANN	130,068	32,847	31,227	2.02	**1.92**	MSA
XIA	293,104	74,650	67,550	2.04	**1.84**	MSA

TABLE VI. CLASSIFICATION RESULTS OF ABMC

Genre	Corpus Size	Classical model Compression (bytes)	Modern model Compression (bytes)	Classical bpc	Modern bpc	Predicted Type
Economic News	2,201,462	544,181	496,183	1.98	**1.80**	MSA
Management	1,358,576	317,477	275,826	1.87	**1.62**	MSA
Stock News	890,493	224,493	199,571	2.02	**1.79**	MSA

B. Classifying Mixed Arabic Corpora

Classifying corpora of unknown origins, or for which it may be suspected may have a mixture of CA and MSA text, will help Arabic NLP researchers to confirm their content. The experiment reported in this section investigated whether it was possible to accurately perform a document level text classification of some Arabic corpora. Table 5 displays the results of this experiment for the UD corpus, Table 6 for the ABMC, Table 7 for the Arabic Learner Corpus and Table 8 for the BACC corpus. The tables list the size of the files compressed files, the size of the compressed output files (in bytes), the compression ratios (in bits per character or 'bpc') and the type (CA or MSA) predicted from the model with the best compression.

TABLE VII. CLASSIFICATION RESULTS OF ARABIC LEARNER CORPUS

Genre	Corpus Size	Classical model Compression (bytes)	Modern model Compression (bytes)	Classical bpc	Modern bpc	Predicted Type
Arabic Learner Corpus	2,806,467	620,563	630,306	**1.77**	1.80	CA

TABLE VIII. CLASSIFICATION RESULTS OF BACC

Genre	Corpus Size	Classical model Compression (bytes)	Modern model Compression (bytes)	Classical bpc	Modern bpc	Predicted Type
arabicbook1	829,036	187,362	192,804	**1.81**	1.86	CA
arabicbook2	884,273	202,343	206,271	**1.83**	1.87	CA
arabicbook3	977,286	223,451	229,887	**1.83**	1.88	CA
arabichistory	30,251,137	5,750,445	7,838,286	**1.52**	2.07	CA
arabicliterature	18,594,383	3,846,029	4,877,075	**1.65**	2.10	CA
arabicpoems	46,929	11,701	12,313	**1.99**	2.10	CA
artandmusic	41,770	9,665	9,137	1.85	**1.75**	MSA
articles	101,641	22,982	21,630	1.81	**1.70**	MSA
bookcollection	197,935,882	40,631,602	48,551,255	**1.64**	1.96	CA
culture	34,188	7,867	7,363	1.84	**1.72**	MSA
economic	15,352	3,583	3,066	1.87	**1.60**	MSA
education	26,418	6,078	5,504	1.84	**1.67**	MSA
political	46,884	10,995	9,785	1.88	**1.67**	MSA
press	536,692	122,961	111,260	1.83	**1.66**	MSA
sports	31,059	7,225	6,659	1.86	**1.72**	MSA
stories	1,022,476	242,699	237,372	1.90	**1.86**	MSA

The steps of the experiment are as follows:

- Using the two static models created earlier for priming, two compressed files are generated by compressing the Arabic texts using an order 5 PPMD character-based compression scheme.
- Then, the cross-entropy or the size of the two compressed files are compared and the class label of the

text, in this case CA or MSA, is chosen from the file with the smallest compressed size.

The classification results from these tables show that the sub-genre of some Arabic corpora, such as the BACC in Table 8, contain different types of Arabic text. Other corpora, such as the Arabic Learner Corpus in Table 7, have similar compression sizes which provides an indication that they contains mixed text of both CA and MSA.

TABLE IX. SEGMENTATION RESULTS OF UD

Data set	Number of words	Number of Classical words	Number of Modern words	Classical (CA) %	Modern (MSA) %
AFP	11,369	594	10,775	5.22%	94.78%
UMH	34,765	2,053	32,712	5.91%	94.09%
XIN	12,666	554	12,112	4.37%	95.63%
ALH	9,019	1,078	7,941	11.95%	88.05%
ANN	11,152	2,252	8,900	20.19%	79.81%
XIA	23,930	617	23,313	2.58%	97.42%

<\Classic> به إلا ضربا من الحلم أو الكابوس حدقت به فاضت عيناها واصفرت وجنتاها ارتجفت أصابعها<Classic>
<\Modern> أنت تريد بناء دولة خارج الزمان والمكان وتترك فلسطين لماذا لا تقدم هذا الاقتراح إلى إدارة السجن<Modern>
<\Classic> الحسنة وادفع الشبهات الغليظة النتنة والأفكار الباطلة وأخرج الناس من ظلمات الجهلة إلى نور النيرة <Classic>
<\Modern> كنت مع زملائي سفرت إلى الرياض للدراسة عندما وصلت إلى المطار رأيت أجانب من البلاد المختلفة <Modern>

Fig. 3. Random segmented samples from The BACC

TABLE X. SEGMENTATION RESULTS OF ABMC

Genre	Number of words	Number of Classical words	Number of Modern words	Classical (CA) %	Modern (MSA) %
Economic News	169,374	12,200	157,174	7.20%	92.80%
Management	121,603	7,192	114,411	5.91%	94.09%
Stock News	87,943	53	87,890	0.06%	99.94%

C. Segmenting Mixed Arabic Corpora

The compression results from the last classification experiment show that some Arabic corpora contain mixed CA and MSA text. To produce a more accurate estimate of CA and MSA text, this experiment performed a text segmentation using a Viterbi-style algorithm that finds the most probable sequence of characters of each class, category or topic in the text [33] where all possible switching of encoding models are considered.

This experiment was conducted as follows:

- The same Text Mining Toolkit was used to segment the text file at the character level to insert labels (tags), either CA or MSA, inside the text. The segmentation in this step was applied using the Viterbi-style algorithm [33]. Figure 3 shows a sample from the segmented files.
- Then, a post-processing of the resulting file was performed to count all the terms of each label and for separating the two types of text into two files for additional experiments.

Table 9 displays the outcomes of this experiment for the UD corpus, Table 10 for the ABMC, Table 11 for the Arabic Learner Corpus and Table 12 for the BACC corpus. The tables list the numbers of words in the segmented files for both Classical (CA) and Modern (MSA) texts and the percentages of each.

The results from the previous tables indicate that some Arabic corpora contain mixed CA and MSA text, and the PPM compression models can be used to produce an accurate estimate of the extent of both Arabic text types. The illustration of the segmentation process is shown in Figure 3 which shows randomly selected segmented samples from two of BACC sub-genre, *arabiclearnercorpus* and *arabicbook1*. The sample demonstrates typical output of the segmentation process which produces a more accurate picture of the textual contents.

TABLE XI. SEGMENTATION RESULTS OF ARABIC LEARNER CORPUS

Genre	Number of words	Number of Classical words	Number of Modern words	Classical (CA) %	Modern (MSA) %
Arabic Learner Corpus	287,107	161,897	125,210	56.39%	43.61%

D. Tag-based Compression Experiments

Most Arabic language NLP tasks are made for processing MSA [48], and POS tagging of Arabic language is one example of those tasks. Since most popular recognised Arabic POS taggers were trained on MSA text [36], [49], the tagging of mixed corpora text will vary in quality and will not be consistent and reliable. The final experiment was conducted using tag-based compression on mixed Arabic corpora, selected using the previous outcomes in order to evaluate the process of both the tagging and classification.

The experiment was performed as follows:

- First, both CA and MSA files identified from experiments (B) and (C) were tagged using the MADAMIRA [69] Arabic tagger.
- The tagged files were then post-processed where terms and tags were extracted into one file for the next step.
- The tagged files were then compressed using a tag-based compression scheme and the results compared with the compressed files created using a character-

based compression scheme to evaluate the compression quality.

TABLE XII. SEGMENTATION RESULTS OF BACC

Genre	Number of words	Number of Classical words	Number of Modern words	Classical (CA) %	Modern (MSA) %
arabicbook1	85,441	65,867	19,574	77.09%	22.91%
arabicbook2	89,015	61,645	27,370	69.25%	30.75%
arabicbook3	104,055	83,503	20,552	80.25%	19.75%
arabichistory	3,350,365	3,348,513	1,852	99.94%	0.06%
arabiclitriture	1,983,790	1,978,670	5,120	99.74%	0.26%
arabicpoems	4,701	4,151	550	88.30%	11.70%
artandmusic	3,985	528	3,457	13.25%	86.75%
articles	9,624	1,792	7,832	18.62%	81.38%
bookcollection	20,725,720	19,836,491	889,229	95.71%	4.29%
culture	3,107	476	2,631	15.32%	84.68%
economic	1,376	3	1,373	0.22%	99.78%
education	2,437	33	2,404	1.35%	98.65%
political	4,317	62	4,255	1.44%	98.56%
press	50,977	4,351	46,626	8.54%	91.46%
sports	2,875	221	2,654	7.69%	92.31%
stories	111,809	28,664	83,145	25.64%	74.36%

Table 13 lists the results of the experiment which shows in the second column the percentage improvement in compression for the tab-based compression scheme over the character-based compression scheme, and the type of text (CA or MSA) in the third column that was confirmed in the earlier experiments. A positive percentage improvement indicates the tag-based compression was better, and a negative improvement indicates the character-based compression was better.

The results in Table 13 show that utilising the tags to compress the BACC sub-corpus *'arabicliteriture'*, which was found to consist of 99.74% Classical Arabic text, decreases the compression percentage by 4.38% (compared with the character based compression scheme). However, using the same compression model to compress the ABMC sub-corpus 'Economic-News', which was found to consist of 92.80% MSA text, increases the compression percentage by 6.50% (compared with the character based compression scheme). The difference in compression quality provides an indication that the quality of tagging for the CA text has dropped, compared to the quality of tagging for the MSA text, because the compression size has increased.

TABLE XIII. TAG-BASED COMPRESSION ON CA AND MSA TEXT

Corpus	Tag-based Compression Improvement	Text Type
BACC - arabichistory	-5.07%	CA
BACC – arabiclitriture	-4.38%	CA
BACC – bookcollection	-3.56%	CA
ABMC – Economic News	6.50%	MSA
Corpus A – books	2.76%	MSA

V. CONCLUSION

Classification of Classical Arabic (CA) and Modern Standard Arabic (MSA) text was performed on sample texts using a PPM character-based compression scheme achieving an accuracy of 95.5%, an average precision of 0.958, an average recall of 0.955 and an average F-measure of 0.954. Three further experiments were implemented in this study to analyse mixed Arabic corpora. First, a classification of Arabic corpora was performed and the results showed that different sub-genres of some Arabic corpora contain different types of Arabic text since the compression size for other corpora indicated that the texts were a mixture between CA and MSA. Then a segmentation of the same corpora was accomplished using a Viterbi-based algorithm and the results indicated that segmenting the text produces a more accurate estimate of CA and MSA text. Finally, tag-based compression experiments (using parts-of-speech taggers) were performed to evaluate the tagging quality and the results showed a difference in compression quality between CA and MSA texts. This provides an indication that the quality of the tagging is affected when either CA and MSA text is being tagged therefore showing that NLP applications (such as taggers) should treat these texts separately and use different training data for each or process them differently.

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A Recent Study on Routing Protocols in UWSNs

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***Abstract*—Recent research has seen remarkable advancement in the field of Under Water Sensor Networks (UWSNs). Many different protocols are developed in the recent years in this domain. As these protocols can be categorized in a variety of ways according to the mechanisms and functionalities they follow, hence it becomes important to understand their principal working. In this research we have introduced three analysis methods; Clustering based, Localization based and Cooperation based routing by selecting some recent routing protocols in the field of UWSN and presented a comparative analysis according to the categories in which they lie. This research has been taken theoretically and is qualitative one. Also a detail analysis of their key advantages and flaws are also identified in this research.**

Keywords—UWSN; routing protocol; relay node; sink

I. Introduction

In the past decades researchers have shown a lot of interest in the field of UWSNs, because of its wide range of different applications. UWSNs is actually a sub area of Wireless Sensor Networks (WSNs), which facilitate on radio communication with high-precision of information to a sink node from any of the source node. UWSN is a representation of three dimensional information as like marine rescuing and tracking of submarine and exploration of oceans [1].

UWSN is being used for several applications such as environmental monitoring, reconnaissance data acquisition and tactical surveillance. The sensors are interconnecting with wireless links which further propagate optical and radio signals using acoustic signals affected by heavy amount of scattered and absorption loss. These acoustic signals are imposed by different challenges on communication protocol like high error bit rate, limiting bandwidth and delay in long propagation [2]. UWSNs consist of underwater acoustic sensor nodes. In addition to compare with new approaches to ocean-column and ocean-bottom monitoring, UWSNs are used for collecting real time information gathering from a specific area which increase the efficiency of applications like warship monitoring for real time, oceanic graphical data collection, offshore exploration, disaster prevention and environmental monitoring [3].

Each sensor is attached with acoustic modem for low bandwidth and an antenna [4]. UWSN consisting of number of sensor nodes have sink(s) placed at the surface of the water. Here the transmission of data can be obtained by different parameters such as optical, radio or sound waves. Light waves and frequency are not as much suitable due to the high absorption, attenuation and scattering as there is very large area for monitoring in sea so distance transmission creates problems [5]. UWSNs are used for the monitoring requirement of aqueous environment where the acoustic sensors gather interesting information and forward this data to the end node using any specific routing technique [6]. Figure 1 shows the general phenomena of UWSNs.

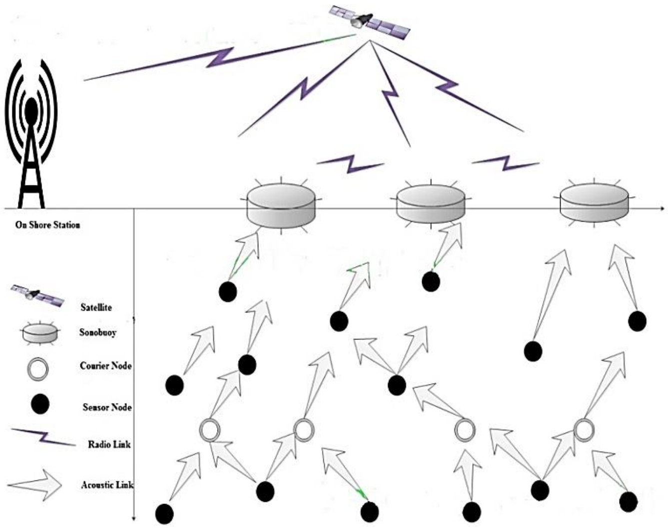

Fig. 1. Underwater Sensor Network Architecture

Communication among signals is not feasible due to the absorption of high radio signals and rapid attenuation in UWSNs. Hence, low absorption rate is required at that stage where the acoustic signals are used much in a wide range and due to these reasons such as end-to-end delay of signals and low bandwidth, the routing mechanism becomes a very major issue or challenge in UWSNs [7]. UWSN performs monitoring task in collaboration over a specified are consisting of vehicles and sensors. For the high data rate of transmission in underwater communication, acoustic waves are the most desirable source [8]. UWSN is a study of art approaches to explore potential information. Underwater communication has different specifications like low bandwidth capacity, mobility, propagation delay, memory and battery limit. Recent researches for investigating the underwater behavior were based on territorial technology of UWSNs. As water is used as medium of transmission and the required signals to transmit data so UWSNs shows different structure design as comparison to terrestrial network. In USWNs different schemes have been proposed for efficient and cooperative routing having transmission with usage of sink followed by relay/nodes [9]. The node mobility changes the structure of topology in underwater environment with respect to water current and water pressure. Dynamic node movement has also been proposed by several authors. The existing problems in mobility of nodes has already discussed in [23].

II. Routing Protocols

Many researchers have proposed different techniques and protocols to achieve performance and stability of network. Some of them recently introduced are summarized and discussed below as a comparative study. All the below mentioned protocols are divided into 3 major categories:

1) *Clustering-based routing*
   a) *Round-Based Clustering*
   b) *SEEC*
   c) *EBECRP*
2) *Localization-free routing*
   a) *EE-DBR/D-DBR*
   b) *BTM*
   c) *iAMCTD*
   d) *AEDG*
3) *Cooperation-based routing*
   a) *Co-UWSN*
   b) *Co-DBR*
   c) *SPARCO*
   d) *DEADS*

III. Clustering-based Routing

A. *Round-Based Clustering*

A Round Based Clustering Scheme is proposed where redundant data transmission has been resolved in the network as this scheme offers reduced network lifetime. The proposed scheme works in rounds, which consisted of four phases that are: data aggregation, clustering, cluster-head and initialization. The proposed scheme increased network throughput as well as give guarantee of sink to receive minimum percentage of data at the base station, demonstrated by simulation results. The cluster heads were chosen by a self-selection process which was based on distance to the base station and residual energy [10].

B. *SEEC*

Regarding efficient energy, many routing protocols are proposed in UWSNs. A health protocol named Sparsity-aware Energy Efficient Clustering (SEEC) is introduced which specifically search sparse regions of network. In SEEC with the assist of Density Search Algorithm and Sparsity Search Algorithm, the region is divided into equal size of sub regions and search dense and sparse regions of the network field. SEEC achieved stability of network in dense region of the network with optimal number of cluster where a static cluster is represented by each dense region [11].

C. *EBECRP*

In UWSN because of harsh environment of underwater battery replacement is an expensive task such as where nodes attach with limited battery power. Therefore a Balanced Energy and an energy Efficient consumption Cluster Based Routing Protocol (EBECRP) has been introduced in UWSN. In depth based routing generally the nodes lying near the sink nodes die early because of unbalancing load over node near sink, so EBECRP avoids this depth based routing and balancing load over all nodes using mobile sinks. For maximum energy consumption this protocol used clustering concept for reducing multi-hop where cluster head being selected for collecting data from one neighbor node into locally compressed communication for reducing global communication. For reducing number of transmission clustering based technique is used as here which frequently changes the position of sink using mobile sink nodes. EBECRP have achieved several parameters like network life time and having maximum stability period [12].

IV. Localization-Free Routing

A. EEDBR/D-DBR

As depth-based routing protocol (DBR) [13] uses depth information only which is more practical for UWSNs. However, depth information is not enough to restrict packets to be forwarded within a particular area. Packets may be forwarded through multiple paths which might affect energy wasted and increased end-to-end delay. In this paper, the authors introduced underwater Time Of Arrival (ToA) ranging technique to address the problem. To maintain all the original advantages of DBR, they made the following contributions: Energy-Efficient Depth-Based Routing protocol EE-DBR which decreased the redundancy of cost energy in some blind zones; low-latency depth-based routing protocol D-DBR which is able to deliver a packet via an optimal path. The EEDBR/D-DBR is found more successful by simulations up to 90% when greater than 400 numbers of nodes are used. As EEDBR/D-DBR having greater successive delivery ratio in dense network so it dramatically consumed energy. Everywhere EE-DBR will be the better choice wherever energy is considered as a target parameter like data sampling of long-time marine hence also providing better performance in the same way [14].

By using ranging technique of ToA distance is measured by propagation between two nodes. EEDBR aims to decrease redundancy forwarding of multipath and considered the following equations

$$(\mathrm{dis}^2 - \Delta d^2) + (R - \Delta d)^2 > R2 \quad (1)$$

where dis is distance between node A and sensor node S, depth difference is denoted by Δd and maximum transmission by R, node is able to figure out Δd and dis while receiving packet, so EE-DBR in build zone eliminates redundancy cost energy of sensors and D-DBR directed packets to sink through an optimal path and reduced propagation delay and hop numbers in the scenario of single sink, following equation is considered

$$F(d, \theta) = \omega_1 f(d) + \omega_2 g(\theta) \quad \theta \in [0, \Pi] \quad (2)$$

Where, $g(\theta)$ is defined as angle holding time, $f(d)$ as sum of depth holding time , in this way author implemented directional depth-based routing, while sink node float on surface [14].

B. BTM

Balance Transmission Mechanism (BTM) elaborates direct acoustic transmission when in multi-hop transmission consumption of local excessive energy is required. BTM [15] chooses single hop or multi-hop transmission of mode to thesink on the same energy level of underwater sensor networks. Different hop by hop schemes have been introduced for a multi-hope UWSN where data packets forwarded by downstream nodes works as ACKs for the previously transmitted data packets. Another scalable and for providing time efficient routing a protocol is been introduced as a dynamic addresses based hop-by-hop routing protocol for UWSN [15].

For broadcasting backwards the EL notice packet (ELNP), while network collapse; the maximum energy consumption is defined as

$$E_{bb} = \frac{\sum_{i=2}^{N}(2\mathrm{i}-1)P_0 r^k a^r}{n} \quad (3)$$

where the number of the nodes is $(2i - 1)$ in Slice i, total maximum time of broadcasting backward ELNPs in slice is given as $(2i-1)/n$ and in Slice i average distance of sending backward the ELNP is r.

In slice the remaining maximum energy of 1 node can be determined as $(i-1)\mathrm{E}_0/m$, while network collapse, then remaining pessimistic energy of total nodes is determined as

$$E_{pr} = \frac{\sum_{i=2}^{N}(2\mathrm{i}-1)(i-1)E_0}{m} \quad (4)$$

The wasted maximum energy in this scheme is dissipated as

$$Ew = Ebb + Epr \quad (5)$$

This algorithm introduces efficient routing algorithm in the phase of route-set-up, where routing algorithm near the optimum transmission selected a relay node. Balance transmission algorithm balanced energy consumption. By the current EL of successor nodes the underwater sensor nodes decides their transmission mode. To be balance the energy consumption for better energy consumption optimal classification number of EL is being evaluated [15].

C. iAMCTD

AMCTD [16] is an earlier protocol which maximizes the network life time due to exploits the adaptive mobility of courier nodes. AMCTD'S performance is far better than EEDBR and DBR, however it had deficiency which further removed by an Improved Adaptive Mobility of Courier Nodes in Threshold-Optimized DBR Protocol (iAMCTD) which is routing protocol overcome to AMCTD uses forwarded function for time critical applications for UWSN [17]. iAMCTD exploits network density to tackle the problem of path loss, flooding and latency propagation. In sparse condition the energy consumption is decreases of low depth nodes and minimizes end-to-end delay due to courier nodes of efficient node [17]. In terms of distance and frequency the acoustic link channel is described in iAMCTD, faced transmission of redundant data which further resulted in major energy consumption

D. AEDG

Some existing proposed schemes collected data from the Member Nodes (MNs) and transmitting this to Mobile Sink (MS) using GNs, where nodes of Received Signal Strength Indicator (RSSI) values been selected as Gateway Nodes (GNs) . Authors in [18] described several factors which affects in the underwater communication environment. Routing task is more challenging in underwater environment as compared to terrestrial WSNs hence An Efficient Data Gathering

(AEDG) as a new routing protocol been introduced in UWSNs for the reliable data delivery of data. AEDG implies Autonomous Underwater Vehicle for collecting data from gateways while associating sensor nodes with the gateway to prolong network lifetime and used Shortest Path Tree (SPT) algorithm [18].

V. Cooperation-based Routing

A. Co-UWSN

Cooperative routing protocol involves sink node or relay node for data transmission. In Co-UWSN due to cooperation at node level, the energy consumption is minimized and throughput becomes high. The main purpose of Co-UWSN the cooperative routing protocol between nodes is utilized in data transmission of more than one node. In Co-UWSN, a Cooperation Based mechanism is introduced having minimum path loss over link, single and multi-hop merits were utilized for routing data via underwater networks. Here a cost function has mentioned to select the very best route to sink calculated on the basis of their residential energy and their distance from the sink. Co-UWSN reduces effects of path loss and enhanced stability of the network [19].

In Co-UWSN, Depth of sensors are updated and informed to neighbors and when sink broadcast a packet of information containing node ID, depth and energy status, sink sends a help message to all nodes to have the vital information of all nodes. By employing a hello packet by each node is identified by its neighbor in the transmission range while maintain a separate queue under depth threshold of neighbors for identifying finest forwarder to transmit data and Weight is calculated by each node by the given formula

$$W_i = \frac{(\max(p(d_{S1R1},f),p(d_{S1D1},f))+\max(RE_{R1}RE_{D1})}{\boldsymbol{min}|d_{S1R1}|2\text{ , }|d_{S1D1}|2} \quad (6)$$

B. CoDBR

In order to have reliability and efficient throughput a Cooperative Depth Base Routing (Co-DBR) is introduced for UWSN which employs cooperation in DBR. Cooperative transmission technique is introducing physical layer aspects of Under Water Acoustic Communication (UWAC) which further demonstrate the point-to-point counterparts for superiority of cooperative UWAC. The Underwater Decode and Forward and Underwater Amplify and Forward are two asynchronous cooperative data transmission techniques used for improving performance of network [20]. Co-DBR showed 98% more packet acceptance ratio, 90% less packet drop and 83% more throughput in stable region as compare to non-cooperative schemes. Because of its less packet drop CoDBR is proved to be more beneficial for critical mission applications [20].

C. SPARCO

Recently Stochastic Performance Analysis with Reliability and Cooperation (SPARCO) is cooperation based routing protocol for UWNs for enhancing the performance, SPARCO came in UWSNs for cooperative communication of energy efficiency routing schemes. In SPARCO, an approach is suggested with much low path loss to forward information linking with feature using single and multi-hop in addition the proposed protocol used a cost function for finding most suitable path for sink. The outage probability is totally dependent on the depth of the ocean at any instant and noise factors and attenuation occurring in the ocean currents. In terms of SNR, it can be written is [21]

$$P_{\text{outage}} = P\{\hat{P}(t) < 2\pi Hexp(\frac{2^{\left(\frac{R}{B}\right)}+SL+p(d,f)}{20})\} \quad (7)$$

where H is depth of water and (d, f) is denoted as distance and frequency, SPARCO solves problems of Attenuation, bandwidth, noise and reliability.

D. DEADS

Many unintended sensor nodes transmit signals to be overheard in the broadcast nature of wireless communication which is an advantage of cooperative communication. An alternative mechanism been proposed to minimize the effect of fading over multi-hop communication. Many protocols have been proposed so far for the cooperative communication in UWSNs to improve the system performance including cooperation at MAC layer. A new scheme further developed using two relay nodes either Multiple (DEADS-MRC) or Single Relay Communication (DEADS-SRC) for some enhancement of UWSNs to maximize throughput, to minimize Bit Error Rate and to conserve energy however sink mobility is not been yet considered as cooperative routing, hence DEADS aim is to bring efficiency due to sink mobility, dominating set based cooperative routing and to have network reliability [22].

VI. Conclusion & Future work

In this paper different surveys of different routing protocols have been conducted for the new researchers working in the area of UWSNs. Many protocols are presented for energy efficiency, time efficiency and stability of network to maximize throughput and to minimize the delay in forwarding data to the sink node which are further mentioned in Table 1. Routing protocols employing depth based routing, localization based, cooperation based or clustering based all of these techniques have been defined. We have mentioned different advantages and flaws of these routing protocols introduced recently for data transmission in UWSNs. Some protocols that are recently produced reduce energy consumption and enhance network stability of underwater networks but the research continues to work on high energy consumption and higher throughput; reduced transmission loss, processing overhead and redundant data transmissions.

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TABLE I. COMPARISON OF UWSN ROUTING PROTOCOLS

Protocol Name	Key Parameters	Achievements	Disadvantages/ Flaws
EEDBR/D-DBR [14]	• Minimize energy consumption • Minimum end to end delay	• Minimize Energy Consumption • Delivery Ratios • End-to-End Latency	• Collision due to Redundant Data transmission
Round-Based clustering [10]	• Residual energy nodes • Clustering based routing	• Energy consumption • Network life time improved • Throughput and	• Computation overhead • Transmission delay
BTM [15]	• Energy Consumption • Path Loss and Bandwidth	• Network Life Time • Balanced energy consumption	• Transmission delay
Co-UWSN [19]	• Depth based • Multi-hop Cooperation	• Minimum transmission loss • Network lifetime and high stability	• Increased end to end delay
Co-DBR [20]	• Depth based routing with • Cooperation, Localization	• Network reliability and throughput efficiency • Reduced packet drop	• Greater end-to-end delay • Unbalanced energy consumption
iAMCTD [17]	• Network Density Link Status • Residual Energy Depth • Reduce transmission loss	• High energy efficiency • High stability period • Minimize end-to-end packet delay • Maximize network Lifetime	• Minimum throughput • Control packets over headed
AEDG [18]	• Data gathering with multi gateways • Routing query and feedback from sink	• High energy efficiency • High stability period • High network throughput	• High end-to-end delay • Minimum throughput • Increase energy consumption
SPARCO [21]	• Signal to Noise Ratio • Path Selection	• Enhanced stability period • Increase network life time • Throughput increases	• Energy Consumption
SEEC [11]	• Clustering based routing • Sparse regions of equal size	• Minimizes network energy • Consumption with balanced scheme	• Minimum throughput
DEADS [22]	• Depth residual energy	• Network reliability and Network efficiency • Increased throughput • Reduced packet drop	• Processing Overhead • Short stability period • High energy consumption • Short stability period
EBECRP [12]	• Clustering based routing	• Maximum throughput • Maximum energy consumption	• Computation due to cluster head selection

A Framework to Reason about the Knowledge of Agents in Continuous Dynamic Systems

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***Abstract*—Applying formal methods to a group of agents provides a precise and unambiguous definition of their behaviors, as well as verify properties of agents against implementations. Hybrid automaton is one of the formal approaches that are used by several works to model a group of agents. Several logics have been proposed, as extension of temporal logics to specify and hence verify those quantitative and qualitative properties of systems modeled by hybrid automaton. However, when it comes to agents, one needs to reason about the knowledge of other agents participating in the model. For this purpose, epistemic logic can be used to specify and reason about the knowledge of agents. But this logic assumes that the model of time is discrete. This paper proposes a novel framework that formally specifies and verifies the epistemic behaviors of agents within continuous dynamics. To do so, the paper first extends the hybrid automaton with knowledge. Second, the paper proposes a new logic that extends epistemic logic with quantitative real time requirement. Finally, the paper shows how to specify several properties that can be verified within our framework.**

***Keywords*—Epistemic logic; Reasoning; Hybrid Automata; Agents**

I. Introduction

Multi-agent systems (MAS) consists of several independent agents where the task of some agents may depend on the task of others [1]. Thus, to model intelligent systems, knowledge is an important property to consider.This reasoning has become one of the main concerns in artificial intelligence and MAS [2]. Reasoning is either about the agent itself or about other agents in the MAS. Many efforts from different disciplines have tackled issues involving reasoning about agents' knowledge [3], [4], [5]. To reason about knowledge of agents, several theories and logics have been proposed. Among of them, a logic of knowledge or the so called epistemic logic [6]. Epistemic logic is a type of modal logics [7].The suitability of epistemic logic in a wide range of applications [8] makes it of great importance. The main goal of using epistemic logic in MAS is to model the agents' knowledge either about itself or about other agents. For example, " if $agent_1$ sends a message S to $agent_2$, then eventually, $agent_2$ will know S" , and $agent_1$ knows that $agent_2$ knows S.

To deal with specific type of applications, many techniques have been proposed for extending epistemic logic. Examples of these techniques are the attempts to generate temporal epistemic logics to reason about knowledge changing over time. In order to construct this kind of extension, epistemic logic framework is fused into a kind of temporal logics [9]. Examples of this integration can be seen in[3], [10]. In [3], the epistemic logic is extended with alternating time temporal logic[11]. Also, in [10], the epistemic logic is combined with temporal logic. Temporalization can be seen as an approach for adding a temporal logic on top of another logic and thus having a new logic with temporal features [12]. The importance of reasoning about dynamic knowledge comes from its existence in many of the real life applications. In spite of its suitability in many applications, temporal epistemic logic is still not efficient to be applied in a certain type of applications like robotics and networking. Such type of applications requires a model of time and a model of how the agents' actions are changing through time. Also, knowledge that has time constrains cannot be specified by temporal epistemic logic. An example of time constrained knowledge is $agent_1$ knows that message S will be received within 5 seconds.

According to [13], hybrid systems are systems with combined continuous and discrete state variables. Examples are embedded software in airplanes and medical devices. As hybrid systems involve both the discrete and continuous dynamics of systems, they are naturally used to model many application scenarios [14]. Over the past few decades, hybrid automata [15] have been introduced as a formal model for hybrid systems. Hybrid automata integrate differential equations and finite automata in a single formalism. Generally, the discrete dynamics of hybrid systems are modeled using finite automata whereas the differential equations represent the continuous changes of physical variables. A simplified version of hybrid automaton called timed automaton [16] is also used to model MAS [17]. Timed (finite) automaton is a simple and powerful way used to represent time constrains through real valued clocks [16]. On the other hand, several logics have been introduced in the literature to model the qualitative behaviors of systems. The semantics of many of these logics have been interpreted on the underline operational semantics of hybrid automata.

In spite of the many proposed logics, these logics are not efficient when it comes to express the agents' knowledge about other agents in a continuous dynamic environment. Thus, integrating epistemic logic with qualitative logics of hybrid systems seems to be very appropriate to overcome the shortcomings of the existing logics. However, the epistemic logic assumes only discrete time model which is not adequate when modeling agents' behaviors within continuous dynamics.

Thus, this paper proposes a novel framework that formally specifies and verifies the epistemic behaviors of agents within continuous dynamics. The framework of this paper is two fold. First the hybrid automaton is protracted with knowledge. Second, a new logic is proposed to augment epistemic logic with quantitative real time requirement. Furthermore, the paper shows how to specify several properties that can be verified within the proposed framework.

The rest of this paper is organized as follows. Section II summarizes the related work to the problem of specifying MAS requirements. After that, the concept of hybrid automata is introduced and slightly redefined in section III. The formal syntax and semantics of hybrid automata are also highlighted. Section IV, introduces the hybrid interpreted systems that will be used as the underline semantics of the proposed Logic. Section V defines the syntax and semantics of the proposed logic ERCTL. Section VI illustrates how to specify certain requirements on an example. in section VII, the implementation of the proposed framework using constraint logic program (CLP) is shown. Finally, conclusion and future work are summarized in section VIII.

II. Related Work

The modal logic of knowledge was first introduced by Hintikka in 1962 [18]. According to the logic of Hintikka, knowledge and belief are treated as modalities. The syntax and semantics of this logic was the core for foundation of epistemic logic. Epistemic logic is a type of modal logic concerned with reasoning about knowledge [19], [8]. Generally, epistemic logic in MAS began to get more attention in the early 60^{th} of the previous century. Among several types of epistemic logic, Dynamic Epistemic Logic (DTL) is widely conceived as a logic that is able to model how agents update their knowledge in MAS [20]. As agents in MAS evolve over time, the temporal properties of agentsâ knowledge are of great importance. Thus, Epistemic Temporal Logic (ETL) is employed to model these properties [3], [9], [10]. In [3], the epistemic logic is extended with alternating time temporal logic[11]. In [10], epistemic logic framework is fused into a kind of temporal logics [9]. There is a close relationship between dynamic and temporal epistemic logics. The authors in [21] have presented an illuminating survey about these logics.

Extensive research efforts have been seen to tackle the problem of modeling the qualitative behaviors of systems. Examples of these efforts are Timed Propositional Temporal Logic(TPTL) [22], Explicit Clock Temporal Logic [23], [24], Metric Temporal logic (MTL) [25], Metric Interval Temporal Logic (MITL)[26], Computation Tree Logic(ICTL) [27] and RCTL [28], Real-Time Computation Tree Logic (RTCTL) [29], and Timed Computation Tree Logic (TCTL) [30]. These logics are considered as extensions of temporal logics. In contrast to this paper, the previous logics are not able to express epistemic knowledge.

On the other hand, finite state automata provide the most elegant model for memory structures of reasoning agents [10]. Timed automata are also proposed as extensions of finite state automata to model time constrains [16], [31], [32]. In order to overcome the inadequacy of epistemic temporal logics in expressing real time behavior of agents, many real time epistemic logic approaches have been introduced [33], [34], [5], [4]. These logics use timed automata to express and model the agents while the classical interpreted systems of epistemic logic are extended by adding the operational semantics of timed automata. Timed automaton is considered as a simplified version of hybrid automaton which integrates differential equations and finite automata in a single formalism [15]. To specify the behaviors of MAS situated in a dynamic environment, many hybrid automata approaches have been presented in the literature [35], [36], [37], [38], [39]. Our work in this paper augments the hybrid automaton with knowledge to formally specify and verify the epistemic behaviors of agents within continuous dynamics. A new logic that extends epistemic logic with quantitative real time requirement is employed for this purpose.

III. Background

The concept of hybrid automata along with their constrains are introduced here in details. An example from [40] is used for illustration. Several definitions are presented to describe the constrains that appear within the hybrid automata.

Definition 1 (Linear Constraints and Evaluation): Let $\mathbb{R}$ denotes a set of real numbers, $\mathbb{R}^{\geq 0}$ is a set of non-negative real numbers, χ is a set of variables with an element $x \in \chi$, $\omega = \sum_{i=1}^{|\chi|} a_i \cdot x_i$, with $x_i \in \chi$, is a combination of variables in the set χ, where $a_i \in \mathbb{R}$, and b $\in \mathbb{R}$, $\sim_c \in \{>, \geq =, <, \leq\}$. The grammar of all linear constraints $\Phi(\chi)$, with a typical element $\varphi \in \Phi(\chi)$, is defined as follows:

$$\varphi ::= \ \omega \sim_c b \mid \varphi \wedge \varphi \mid true$$

Let $v \in \mathbb{R}^{|\chi|}$ be the values of the variables in χ and v_i be the value of the ith component of v. we call $v \models \varphi$ if v fulfills the constraint φ, and is defined using the grammar:

$\varphi = true.$		
$\varphi = \sum_{i=1}^{\vert\chi\vert} a_i \cdot x_i \sim_c b$	iff	$\sum_{i=1}^{\vert\chi\vert} a_i \cdot v_i \sim_c b\ \ holds.$
$\varphi_1 \wedge \varphi_2$	iff	$v \models \varphi_1\ and\ v \models \varphi_2.$

Definition 2 (Dynamical Constraints and Evaluation): Let $\dot{\chi}$ be a set of the first derivatives of the variables within χ with typical element $\dot{x} \in \dot{\chi}$ and $b \neq 0, c \in \mathbb{R}$, $\sim_d \in \{=, \leq, \geq\}$. Let $\mathbb{D}(\chi \cup \dot{\chi})$ be the set of constraints over the variables in $\chi \cup \dot{\chi}$ with typical element $d \in \mathbb{D}$. The set of all possible dynamical constraints is defined as follows:

$$d ::= \ \dot{x} \sim_d c \mid \dot{x} + b \cdot x = c \mid d \wedge d \mid true$$

Let $f : \mathbb{R}^{\geq 0} \rightarrow \mathbb{R}^{|\chi|}$ be a differentiable function and $f'(t)$ be the differentiation of f with respect to time $t \in \mathbb{R}^{\geq 0}$. We call $f \vDash_* d$, if the function f fulfills d defined by the grammar:

$d = true.$		
$d = \dot{x} \sim_d c$	iff	$f'(t) \sim_d c\ \ holds.$
$d = \dot{x} + b \cdot x \sim_d c$	iff	$f'(t) + b \cdot f(t) \sim_d c\ \ holds.$
$d = d_1 \wedge d_2$	iff	$f \vDash_* d_1\ and\ f \vDash_* d_2.$

Definition 3 (Hybrid Automaton): A hybrid automaton is defined as the tuple HA $= (Q, \chi, Ins, Flow, \eta, E, q^0, v^0)$ where:

- Q is a finite set of locations.
- χ denotes a set of real variables.

- $Ins : Q \rightarrow \Phi(\chi)$ denotes the function that allocates the constraint $Ins(q)$ for every $q \in Q$.
- $Flow : Q \rightarrow \mathbb{D}(\chi \cup \dot{\chi})$ is the function that allocates the constraints $Flow(q)$ for every $q \in Q$.
- η is a finite set of events.
- $E \subseteq Q \times \eta \times \Phi(\chi) \times 2^{\chi} \times Q$ is a transition relation among control locations.
- $q^0 \in Q$ denotes the initial location of the hybrid automaton.
- $v^0 \in \mathbb{R}^{|\chi|}$ denotes the initial values of the variables in χ.

Every $e \in E$ is denoted as $q_1 \xrightarrow{a,\varphi,X} q_2$, where q_1 and q_2 is the start and the end locations respectively, $a \in \eta$ is an event, φ denotes the enabling condition of e, and $X \subseteq \chi$ denotes the set of real variables to be reset.

Definition 4 (State): At any time $t \in \mathbb{R}^{\geq 0}$, a state $\sigma \in Q \times \mathbb{R}^{|\chi|} \times \mathbb{R}^{\geq 0}$ of HA is conventionally denoted as the tuple $\sigma = \langle q, v, t \rangle$, where $q \in Q$ and v is the value of the real variables at time t. A state $\sigma = \langle q, v, t \rangle$ satisfies a constraint $\varphi \in \Phi(\chi)$ at point t, conventionally written as $\sigma \models^t \varphi$, iff $v \models \varphi$. A state $\sigma = \langle q, v, t \rangle$ is called admissible iff $\sigma \models^t Ins(q)$. Two states $\sigma_1 = \langle q_1, v_1, t_1 \rangle$ and $\sigma_2 = \langle q_2, v_2, t_2 \rangle$ are equivalent denoted as $\sigma_1 \equiv \sigma_2$ iff $q_1 = q_2 = q$ and $\sigma_i \models^{t_i} Ins(q), i \in \{1, 2\}$.

A labeled transition system between states is usually used to describe the semantics of HA. The transition between any two admissible states $\sigma_1 = \langle q_1, v_1, t_1 \rangle$ and $\sigma_2 = \langle q_2, v_2, t_2 \rangle$ is defined either by a discrete or a delay transition as follows:

Discrete transition for $a \in \eta$, $\sigma_1 \xrightarrow{a} \sigma_2$ iff $t_1 = t_2$ and there exists $q_1 \xrightarrow{a,\varphi_1,X} q_2 \in E$ such that $v_1 \models \varphi_1$, and $v_2 \models Ins(q_2)$.

Delay transition for $\delta \in \mathbb{R}^{\geq 0}$, $\sigma_1 \xrightarrow{\delta} \sigma_2$ iff $q_1 = q_2$, $\delta = (t_2 - t_1)$ is the time duration passed in location q_1, there is a differentiable function f having $f \vDash_* Flow(q_1)$ and $f(t_1) = v_1$ and $f(t_2) = v_2$, and for all $t \in [t_1, t_2]$, $f(t) \models Ins(q1)$.

Now, the states and the transitional rules between states are totally defined and thus we are ready to define the dense state space as follows:

Definition 5 (dense state space): The dense state space of HA can be defined as the tuple $(\theta, \sigma^0, \longrightarrow)$, where $\theta = Q \times \mathbb{R}^{|\chi|} \times \mathbb{R}^{\geq 0}$ is the set of all states, $\sigma^0 = \langle q^0, v^0, 0 \rangle$ is the initial state such that v^0 is the value of the variables in χ in the control location q^0 at $t = 0$ with $v^0 \models Ins(q^0)$, and $\longrightarrow \subseteq \theta \times (\eta \cup \mathbb{R}) \times \theta$.

When a hybrid automaton is run, a sequence of state transitions is generated. In the following, we define the path and the run.

Definition 6 (Path and Run): A path $\rho = \sigma_1\sigma_2\sigma_3, \ldots,$ of $\mathbb{HA}$ denotes a finite or infinite sequence of admissible states, where the transition between any two consecutive states is associated either by a discrete or delay transition. Let $\Pi(\mathbb{HA})$ denotes the set of all paths of $\mathbb{HA}$. A run of $\mathbb{HA}$ denotes a path ρ beginning with the initial state σ_0.

Each path $\rho \in \Pi(\mathbb{HA})$ generates infinite number of reachable states due to the delay transitional rules. An appropriate method to represent those infinite state is to use a symbolic representation using mathematical intervals. Let us call the mathematical interval a *region*, and it is defined as follows:

We write a run ρ as $\rho = \Gamma_0, a_1, \Gamma_1, a_2, ...,$ a sequence of regions, where each $\Gamma_i \subseteq Q \times \mathbb{R}^{|\chi|} \times \mathbb{R}^{\geq 0}$ is the maximal sub-sequence of admissible states such that for all consecutive states $\sigma_j, \sigma_{j+1} \in \Gamma$, it holds that $\sigma_j \xrightarrow{\delta} \sigma_{j+1}$. Additionally, a transition between two consecutive regions Γ_i and Γ_{i+1}, conventionally written as $\Gamma_i \xrightarrow{a} \Gamma_{i+1}$, is enabled, if there exist two states $\sigma_i \in \Gamma_i$, $\sigma_{i+1} \in \Gamma_{i+1}$ such that $\sigma_i \xrightarrow{a} \sigma_{i+1}$. Conventionally, Γ is writen as $\Gamma = \langle q, V, T \rangle$, such that T denotes the total duration time of all states in Γ and V denotes the tuple of intervals values of the variables throughout the time interval T. Let Γ^0 denotes the initial region obtained from the intial state σ^0 using delay transitions.

Definition 7 (Reachability): A certain region Γ_i is reachable in a run $\rho \in \Pi(\mathbb{HA})$, if $\Gamma_i \in \rho$. A state σ_j is reachable, if there is a reachable region Γ_i with $\sigma_j \in \Gamma_i$.

Now, the dense state space can be generalized by a region state space as follows:

Definition 8 (region state space): A region state space of HA can be defined as the tuple $(\Delta, \Gamma^0, \longrightarrow)$, where Δ is the set of all possible regions, $\Gamma^0 = \langle q, V, T \rangle$ is the initial region formed by a delay transitions from the initial state $\sigma^0 \in \Gamma^0$, and $\longrightarrow \subseteq \Delta \times \eta \times \Delta$ is the transition relation defined as $\Gamma^1 \xrightarrow{a} \Gamma^2$ iff there exist $\sigma^1 \in \Gamma^1$ and $\sigma^2 \in \Gamma^2$ such that $\sigma^1 \xrightarrow{a} \sigma^2$.

A. Automata Composition

A MAS is generally modeled by various parallel hybrid automata representing the agents. Communication among the agents is achieved using synchronized events. The overall behavior of the entire MAS can be described using the parallel composition. A two hybrid automata can be composed as follows:

Let $\mathrm{HA_i} = (Q_i, \chi_i, Ins_i, Flow_i, \eta_i, E_i, q_i^0, v_i^0)$ $1 \leq i \leq 2$ be two hybrid automata, with $Q_1 \cap Q_2 = \varnothing$,

Definition 9 (Parallel Composition): The parallel composition of HA_1 and HA_2 is a hybrid automaton $\mathrm{HA} = (Q, \chi, Ins, Flow, \eta, E, q^0, v^0)$, where $Q = Q_1 \times Q_2$, $\chi = \chi_1 \cup \chi_2$, $Ins = Ins_1 \wedge Ins_2$, $Flow = Flow_1 \wedge Flow_2$, $\eta = \eta_1 \cup \eta_2$, $q^0 = (q_1^0, q_2^0)$ $v^0 = (v_1^0, v_2^0)$, and a transition in E is defined as follows: $q_1 \xrightarrow{a,\varphi_1,X_1} q_1' \in E_1$ and $q_2 \xrightarrow{a,\varphi_2,X_2} q_2' \in E_2$

- $a \in \eta_1 \cap \eta_2$ is a joint event, then $(q_1, q_2) \xrightarrow{a,\varphi_1 \wedge \varphi_2, X_1 \cup X_2} (q_1', q_2') \in E$.
- $a \in \eta_1 \setminus \eta_2$, then then $(q_1, q_2) \xrightarrow{a,\varphi_1,X_1} (q_1', q_2) \in E$.
- $a \in \eta_2 \setminus \eta_1$, then then $(q_1, q_2) \xrightarrow{a,\varphi_2,X_2} (q_1, q_2') \in E$.

A run of any two composed automata, denoted as $\sum_{H_1 \circ H_2}$, is the sequence $\Lambda_0, a_1, \Lambda_1, a_2, ...$ of compound regions, where a transition between two regions relates according to the definition of the transitional relation defined previously. Each global regions takes the form $\Lambda = \langle \Gamma_1, \Gamma_2 \rangle$, where $\Gamma_i = (q_i, V_i, T)$.

Again, the regions state space $(\Delta, \gamma^0, \longrightarrow)$ is similar to its previous definition, except that each element $\Lambda \in \Delta$ is a global region, and γ^0 is the initial global region for each automaton.

Let $loc_i : \Delta \to Q_i$ be a function that takes a global region and returns the current location of the agent i, and $Loc : \Delta \to Q$ a function that returns the locations of the m agents. Let $duration(\Gamma) :\subseteq \mathbb{R}^{\geq 0}$ be a relation that returns the time interval of a region Γ; i.e for $\Gamma_i = (q, V, T)$, $duration(\Gamma) = T$.

IV. Hybrid Interpreted System

Interpreted Systems [2] are usually used as the formal semantics that describe the temporal epistemic language. Therefore, the interpreted systems is extended to be adapted on hybrid automata as well.

Let AG denotes a set of m agents such that each agent is represented as a hybrid automaton $\mathrm{HA_i} = (Q_i, \chi_i, Ins_i, Flow_i, \eta_i, E_i, q_i^0, v_i^0)$, $1 \leq i \leq m$, and their parallel composition in $\mathrm{HA} = (Q, \chi, Ins, Flow, \eta, E, q^0, v^0)$. Let $Prop_i$ be a set of Propositional variables for each agent $1 \leq i \leq m$, and $Prop = \bigcup Prop_i$. Let $Val_i : Q_i \to 2^{Prop_i}$ be the valuation functions for the ith agent, which assigns the truth value of $Prop_i$ to the locations. Let $Val : Q \to 2^{Prop}$ is the valuation function for the m agents, such that $Val(q) = \bigcup Val_i(q_i)$. Then, the hybrid interpreted system is defined as follows:

Definition 10 (Hybrid Interpreted System): A hybrid interpreted system is the tuple $\mathbb{M} = (\Delta, \Gamma^0, \longrightarrow, \simeq_1, \simeq_2, \ldots, \simeq_m, \nu)$, where

- $\Delta, \Gamma^0, \longrightarrow$ are defined as the definition in region state space.
- $\simeq_i \subseteq \Delta \times \Delta$ is the epistemic indistinguishably (accessibility) relation for agent i defined by $\Gamma^1 \simeq \Gamma^2$ iff $loc(\Gamma^1) = loc(\Gamma^2)$ and for each state $\sigma_j \in \Gamma^1$ there exists a state $\sigma_k \in \Gamma^2$, such that $\sigma_j \equiv \sigma_k$. $\simeq_i$ is an equivalence relation.
- $\nu : \Delta \to 2^{Prop}$ is the valuation function that is defined by extending the definition of Val such that $\nu(\Gamma) = Val(loc(\Gamma))$.

The epistemic relation $\simeq$ defined previously is standard in epistemic logic under interpreted systems. More details and examples about this relation can be found in [41]. The knowledge of a group of agents can be defined as:

Definition 11 (Group epistemic relation): Let AG be a set of m agents, and $\kappa \subseteq$ AG, we define a group epistemic relations on a group of agents κ as follow:

- Everybody knows: $\simeq_\kappa^E = \bigcup_{i \in \kappa} \simeq_i$. We have $\Gamma \simeq_\kappa^E \Gamma'$ iff for all $i \in \kappa$, then $\Gamma \simeq_i \Gamma'$.
- Distributed knowledge: $\simeq_\kappa^D = \bigcap_{i \in \kappa} \simeq_i$. We have $\Gamma \simeq_\kappa^D \Gamma'$ iff there exists $i \in \kappa$, then $\Gamma \simeq_i \Gamma'$.
- Common knowledge: $\simeq_\kappa^C = (\simeq_\kappa^E)^+$, where $^+$ denotes the reflexive transitive closure of the underlying relation.

V. The Proposed Logic (ERCTL)

The syntax and semantics of the proposed ERCTL are formally described in this section. As previously mentioned, the proposed ERCTL extends the logic RCTL [28] by adding knowledge operators. We first begin by describing timed variables that might appear in a formula to quantify its timing.

Definition 12 (Clocks): Let $\mathbb{T} \subseteq \chi$ denotes a set of non-negative real variables called *clocks*, and $\Phi(\mathbb{T})$ denotes a set of constraints over $\mathbb{T}$. Let $\xi : \mathbb{T} \to \mathbb{R}^{\geq 0}$ denotes the valuation ξ of the clocks $\mathbb{T}$. For $\pi \in \Phi(\mathbb{T})$, we call $\xi \models \pi$, if ξ satisfies π.

A. Syntax of ERCTL

Let L denotes a set of propositions representing the locations, η denotes a set of propositions representing the events, χ denotes a set of real variables, $\mathbb{T} \subseteq \chi$ denotes a set of clocks, $\Phi(\chi)$ and $\Phi(\mathbb{T})$ denote the set of all constraints on the variables in $\chi, \mathbb{T}$ respectively. Let AG be a set of m agents, with $\kappa \subseteq$ AG. Let $y \in \mathbb{T}$, $l \in L$, $a \in \eta$, $\phi \in \Phi(\chi)$, $\pi \in \Phi(\mathbb{T})$, $i \in$ AG, and $\kappa \subseteq$ AG.

Definition 13 (ERCTL Formulas): The set of ERCTL formulas is defined inductively as follows:

$$\Psi ::= p \mid a \mid \phi \mid y.\Psi \mid \pi \mid \neg\Psi \mid \Psi_1 \wedge \Psi_2 \mid \exists(\Psi_1 U \Psi_2) \mid \forall(\Psi_1 U \Psi_2) \mid \mathbb{K}_i\Psi \mid \mathbb{E}_\kappa\Psi \mid \mathbb{D}_\kappa\Psi \mid \mathbb{C}_\kappa\Psi$$

In addition to the standard Boolean connectives, the previous syntax includes the path quantifiers $\forall$, denoted in all possible paths, and $\exists$, denotes that there exists a path (more details about path quantifiers can be found in [42]). Furthermore, the syntax of ERCTL defines two fragments: RCTL and an epistemic one. The RCTL fragment includes formulas of the form $y.\Psi$ representing *"the formula Ψ is true at certain time represented by the clock y"*. The epistemic fragment of ERCTL includes formula of the form $\mathbb{K}_i\Psi$ to represent "*agent i knows that* Ψ", $\mathbb{E}_\kappa\Psi$ to represent "*everyone in group κ knows that* Ψ", $\mathbb{D}_\kappa\Psi$ to represent *"it is distributed knowledge in group κ that Ψ is true"*, and $\mathbb{C}_\kappa\Psi$ standing for *"it is common knowledge in group κ that Ψ"*.

The other common formulas are defined as follows:

- $\exists\Diamond\Psi$ is equivalent to the formula $\exists(true\, U\Psi)$.
- $\forall\Diamond\Psi$ is equivalent to the formula $\forall(true\, U\Psi)$.
- $\bar{\mathbb{K}}_i\Psi$ is equivalent to the formula $\neg\mathbb{K}_i\neg\Psi$.
- $\bar{\mathbb{E}}_\kappa\Psi$ is equivalent to the formula $\neg\mathbb{E}_\kappa\neg\Psi$.
- $\bar{\mathbb{D}}_\kappa\Psi$ is equivalent to the formula $\neg\mathbb{D}_\kappa\neg\Psi$.
- $\bar{\mathbb{C}}_\kappa\Psi$ is equivalent to the formula $\neg\mathbb{C}_\kappa\neg\Psi$.

B. Semantics of ERCTL

Let AG denotes a set of m agents such that each agent is represented by a hybrid automaton $\mathrm{HA_i} = (Q_i, \chi_i, Ins_i, Flow_i, \eta_i, E_i, q_i^0, v_i^0)$, $1 \leq i \leq m$, and their parallel composition in $\mathrm{HA} = (Q, \chi, Ins, Flow, \eta, E, q^0, v^0)$. Let $\mathbb{M} = (\Delta, \Gamma^0, \longrightarrow, \simeq_1, \simeq_2, \ldots, \simeq_m, \nu)$ be a hybrid interpreted system. Let $\Pi(\mathbb{HA})$ denotes the set of all regions produced from the runs of hybrid automaton with a typical region $\Gamma = (q, V, T) \in \Pi(\mathbb{HA})$

Definition 14 (Satisfaction Relation ERCTL): Let Ψ is a ERCTL formula, The satisfaction relation $\langle \mathbb{M}, \Gamma \rangle \models \Psi$ denotes that Ψ is true at a region Γ in the model $\mathbb{M}$ and is defined as follows:

- $\langle \mathbb{M}, \Gamma \rangle \models p$	iff	$p \in \nu(\Gamma)$.
- $\langle \mathbb{M}, \Gamma \rangle \models a$	iff	there $is\ \Gamma' \in \Pi(\mathbb{HA})\ with\ \ \Gamma \xrightarrow{a} \Gamma'$.
- $\langle \mathbb{M}, \Gamma \rangle \models \phi$	iff	there $is\ \sigma_k = (q_k, v_k, t_k) \in \Gamma, \sigma_k \models^t \phi$.
- $\langle \mathbb{M}, \Gamma \rangle \models y.\Psi$	iff	there $is\ \sigma = \langle q, v, t \rangle \in \Gamma$ such that $Evl(y) = t\ and\ \sigma \models^t \phi$.
- $\langle \mathbb{M}, \Gamma \rangle \models \pi$	iff	there $is\ \xi \in duration(\Gamma)$ such that $\xi \models \pi$.
- $\langle \mathbb{M}, \Gamma \rangle \models \neg\Psi$	iff	$\langle \mathbb{M}, \Gamma \rangle \not\models \Psi$.
- $\langle \mathbb{M}, \Gamma \rangle \models \Psi_1 \wedge \Psi_2$	iff	$\langle \mathbb{M}, \Gamma \rangle \models \Psi_1$ and $(\mathbb{M}, \Gamma) \models \Psi_2$.
- $\langle \mathbb{M}, \Gamma \rangle \models \exists(\Psi_1 U \Psi_2)$	iff	there is a run $\Pi \in \Pi(\mathbb{HA}), \Pi = \Gamma_0, \Gamma_1, \cdots,$ with Γ=Γ_0, for some $j \geq 0$, $\langle \mathbb{M}, \Gamma_j \rangle \models \Psi_2$, and $\langle \mathbb{M}, \Gamma_k \rangle \models \Psi_1$ for $0 \leq k < j$.
- $\langle \mathbb{M}, \Gamma \rangle \models \forall(\Psi_1 U \Psi_2)$	iff	for every run $\Pi \in \Pi(\mathbb{HA}), \Pi = \Gamma_0, \Gamma_1, \cdots,$ with Γ=Γ_0,for some $j \geq 0$, $\langle \mathbb{M}, \Gamma_j \rangle \models \Psi_2$, and $\langle \mathbb{M}, \Gamma_k \rangle \models \Psi_1$ for $0 \leq k < j$.
- $\langle \mathbb{M}, \Gamma \rangle \models \mathbb{K}_i\Psi$	iff	for all $\Gamma' \in \Delta$ with $\Gamma' \simeq_i \Gamma$ then $\langle \mathbb{M}, \Gamma' \rangle \models \Psi$.
- $\langle \mathbb{M}, \Gamma \rangle \models \mathbb{E}_\kappa\Psi$	iff	for all $\Gamma' \in \Delta$ with $\Gamma' \simeq^E_\kappa \Gamma$ then $\langle \mathbb{M}, \Gamma' \rangle \models \Psi$.
- $\langle \mathbb{M}, \Gamma \rangle \models \mathbb{D}_\kappa\Psi$	iff	for all $\Gamma' \in \Delta$ with $\Gamma' \simeq^D_\kappa \Gamma$ then $\langle \mathbb{M}, \Gamma' \rangle \models \Psi$.
- $\langle \mathbb{M}, \Gamma \rangle \models \mathbb{C}_\kappa\Psi$	iff	for all $\Gamma' \in \Delta$ with $\Gamma' \simeq^C_\kappa \Gamma$ then $\langle \mathbb{M}, \Gamma' \rangle \models \Psi$.

Intuitively, the formula $\mathbb{K}_i\Psi$ holds in a region Γ within the hybrid interpreted system $\mathbb{M}$ if Ψ holds in all regions that are indistinguishable for the agent i from Γ. The formula $\mathbb{E}_\kappa\Psi$ holds in a region Γ within the hybrid interpreted system $\mathbb{M}$ if Ψ is true in all regions that a group κ of agents is unable to distinguish from the Γ.The formula $\mathbb{D}_\kappa\Psi$ holds in a region Γ within the hybrid interpreted system $\mathbb{M}$ if the combined knowledge of all agents in κ implies Ψ. The formula $\mathbb{C}_\kappa\Psi$ holds in a region Γ within the hybrid interpreted system $\mathbb{M}$ if everyone knows that Ψ holds at Γ, and everyone knows that everyone knows that Ψ holds at Γ, etc.

Definition 15 (Satisfiability of Formulas): Let AG denotes a set of m agents such that each agent is represented as a hybrid automaton $\mathrm{HA_i} = (Q_i, \chi_i, Ins_i, Flow_i, \eta_i, E_i, q^0_i, v^0_i)$, $1 \leq i \leq m$, and their parallel composition in $\mathrm{HA} = (Q, \chi, Ins, Flow, \eta, E, q^0, v^0)$. Let $\mathbb{M} = (\Delta, \Gamma^0, \longrightarrow, \simeq_1, \simeq_2, \ldots, \simeq_m, \nu)$ be a hybrid interpreted system, A ERCTL formula Ψ is satisfiable in $\mathbb{M}$ iff $\langle \mathbb{M}, \Gamma_0 \rangle \models \phi$, where $\Gamma_0 \in \Pi(\mathbb{HA})$ is the initial region.

VI. Specification of Requirements

As the proposed ERCTL combines the expressive power of RCTL and epistemic logic, we will focus on the expressive power of ERCTL to specify those properties that combine both logics together. To exemplify the expressive power of the proposed ERCTL, we specify properties on a slightly modified version of railroad crossing system found in [43]. More details about this illustrative example can be found in [40].

A. Example

The example shown in figure 1 consists of three agents, namely the *Train*, the *Gate*, and the *Controller*. The main goal is to track the trains crossing an intersection. The gate guards the intersection and it closes or opens based on a train status which is approaching or leaving the intersection. The gate is completely monitored by the controller. The controller receives signals from the train and accordingly sends lower or raise commands to the gate. Let the train is initially 1000 meters away from the gate and moves at a speed of 50 m/s. There is a sensor positioned at a distance of 500 meters on the track. The sensor detects that the train is approaching and thus sends an *app* signal to the controller. After sending the *app* signal, the train slows down according to the differential equation $\dot{x} = -\frac{x}{25} - 30$. After a duration of 5 seconds, the controller sends a *lower* command to the gate, which in turn starts to lower down at a rate of -20 degrees per second. After the train crosses the gate, it accelerates following the differential equation $\dot{x} = \frac{x}{5} + 30$. Another sensor is positioned at a distance of 100 meters after the crossing to detect the train when it is leaving. This sensor sends an *exit* command to the controller. After 5 seconds, the controller starts to raise the gate to its normal position.

By using ERCTL, we can specify a property Ψ that cannot be expressed by the standard RCTL or epistemic logic. To clarify more, we consider the following example:

$$\Psi = \exists\Diamond\mathbb{K}_{Train}(t_1.app \wedge \exists\Diamond(\neg t_2.to\_close \wedge t_2 \leq t_1 + 10)) \tag{1}$$

Formula 1 specifies that there exists a behavior in the system such that the *Train* knows a situation in which it sends *app* and then the *Gate* eventually will not be closed within 10 sec.

$$\Psi = \mathbb{K}_{controller}(t_1.lower \rightarrow \forall\Diamond(to\_close \wedge t_2 \leq t_1 + 5)) \tag{2}$$

Formula 2 specifies that the *Controller* agent knows that when it sends a *lower* command, the agent *Gate* will send *to_close* command within 5 sec. and thus the agent *Gate* eventually will not be closed within 10 sec.

$$\Psi = \forall\Box\mathbb{K}_{Train}(t_1.app \rightarrow \forall\Box(t_2.(x > 100) \wedge t_2 \leq t_1 + 5)) \tag{3}$$

Formula 3 specifies that the agent *Train* always knows that whenever it approaches the gate, its distance to the gate is always greater than 100 meters for 20 time units.

In order to formally verify a certain property using model checking within the proposed ERCTL, we should focus on fragment of ERCTL that can be checked with reachability. Several requirements of interest can be specified as kind of reachability. Generally, a formula Ψ is reachable, if it is possible to reach a state holding Ψ. Thus the reachability of the property Ψ aims to find if it is possible to find a region within the run of agents in which the formula Ψ is satisfiable?. This can be achieved using ERCTL as follows:

$$init \rightarrow \exists\Diamond\Psi \tag{4}$$

init in formula 4 indicates the conjunctions of the initial states of the system under investigation. The reachability of a certain formula is usually computed starting with the initial region of a region-space exploration of a model and extending the reachability on transitions until reaching fixed regions. In

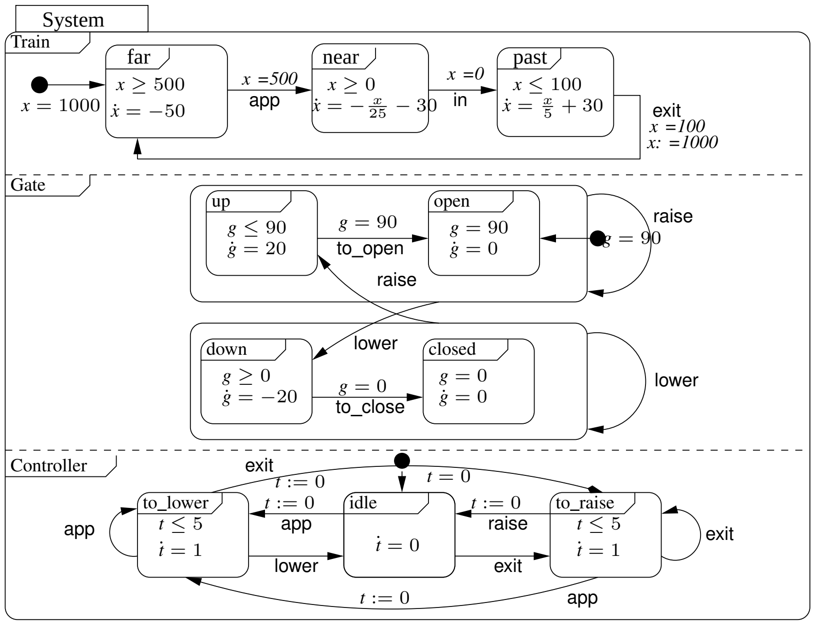

Fig. 1. Modeling of the train gate controller Example as hybrid automata [40].

[44], a semi-decision algorithm for computing the reachability of regions of a hybrid automaton is introduced by one of the authors. This algorithm is shown in Fig. 2. In Fig. 2, if the initial region is Γ_0, *produce(R)* denotes the set of reached regions attached to the region *R* with a discrete step.

```
W :=produce(Γ0)
Reachable := Γ0
while W ≠ ∅ do
take R from W
if R ∉Reachable then Reachable :=
Reachable ∪ R
end if
W := W ∪ (produce(R)\ W)
end while
```

Fig. 2. Computation of the reachability analysis [44] .

Checking the reachability for a property within the underline transition system of hybrid automata is generally undecidable except for certain classes of hybrid automata[45]. Consequently, the decidability problem is inherited in ERCTL.

VII. Reachability as CLP

In this section the implementation of the proposed framework using constraint logic program (CLP) [46] is shown. CLP has been chosen to implement the proposed framework for many reasons. First, hybrid interpreted system can be described as a constrained system. These constraints represent the continuous dynamics e.g., the invariants, the flows, and transitions. Second, constraints can be used to represent specific parts of the state space easily. Third, there are operational semantics similarities between *CLP* and the hybrid Interpreted System. Moreover, constraints allow us to concisely represent regions symbolically as mathematical intervals where an appropriate constraint solver used to reason about the reachability of a particular state inside this interval. Moreover, the Logic programming parts allows us to implement the knowledge efficiently.

The implemented prototype is built using ECLiPSe Prolog [47]. The definitions of both the formal syntax and semantics of hybrid automata and the enrichment of knowledge are followed. An overview of the implementation is given here. Let's start with modeling the locations and their constraints using the predicate *epistemicAutomaton* as shown in fig.3. *epistemicAutomaton* denotes the epistemic automaton and *Location* denotes the current location of the automaton. $Vars$ represents the variables participating in epistemic automaton and $Vars0$ represents their corresponding initial values. $Ins(Vars)$ is the list of invariant constraints on the variables in $Vars$ within the control location. Whereas, $Flow(vars)$ represents the list of constraints flows on the variables $Vars$ with respect to initial time $T0$ at the start of the continuous flow and $Time$. *initKnow* represents knowledge at the location. The knowledge remains unchanged during the continuous evolution. finally, *Event* represents the fired event during the run.

The transition systems are then encoded into the predicate *evolve* as shown in fig.4, that describes the two kind of transitions. The automaton evolves with either continuous or discrete transitions depending on the occurring constraints during the run. It is important to note that , within the discrete step, the knowledge is updated from a state to another by appending the knowledge of the first state *Know1* with the shared knowledge *Shared*, coming from the other automata, to produce the knowledge *know2*. Once the epistemic automata have been modeled, an overall state machine is constructed with the aim to execute the model. To achieve this goal, a reachability predicate is implemented as shown in Fig. 5.

The *reachability* is a state machine employed to generate the behaviors of the concurrent epistemic hybrid automata. It starts with the definition of each participating epistemic hybrid automaton with its initial variables, timing, and knowledge. As soon as the *reachability* has been defined, the entire model is

```
epistemicAutomaton(Location,Vars,Var0,T0,Time,initKnow,Event):- Flow(Vars), Ins(Vars),Time $>=T0,
initKnow=[automaton knowledgeshared knowledge],Event &::event.
```

Fig. 3. Epistemic automaton definition

```
evolve(epistemicAutomaton(State,Startstate,Know),(State,Newstartstate,Know),Shared,T0,T,Event) :-
continuous(epistemicAutomaton(State,Startstate,Know),(State,Newstartstate,Know),Shared,T0,T,Event);
discrete(epistemicAutomaton(State,Startstate,Know1),(State,Newstartstate,Know2),Shared,T0,T,Event);
```

Fig. 4. Transition system implementation

```
reachability((L1,Var01,know1),(L2,Var02,know2),...,(Ln,Var0n,known),T0,[Reg|NxtReg],PastReg)
:- epistemicAutomaton(L1,Var01,Know1),(State1,Newstartstate1,Know11), Shared,T0,T,Event),
epistemicAutomaton(L2,Var02,Know2),(State2,Newstartstate2,Know12), Shared,T0,T,Event), ....,
epistemicAutomaton(Ln,Var0n,Known),(Staten,Newstartstatne,Know1n), Shared,T0,T,Event),
evolve(epistemicAutomaton(L1,Startstate,Know1),(State1,Newstartstate1,Know), Shared,T0,T,Event),
evolve(epistemicAutomaton(L2,Startstate,Know2),(State2,Newstartstate2,Know), Shared,T0,T,Event), .....,
evolve(epistemicAutomaton(Ln,Startstate,Known),(Staten,Newstartstaten,Know), Shared,T0,T,Event),
reachability((State1,Newstartstate1,Know11),(State2,Newstartstate2,Know12),..,(Staten,Newstartstaten,Know1n),
Newstarttime,PastReg)).
```

Fig. 5. A reachability to the execution of epistemic hybrid automata.

invoked for the purpose of running and verification. By using the CLP model, we are able to verify the properties described in VI.

VIII. Conclusion

In this paper, we have introduced a new logic called ERCTL that extends the logic RCTL with epistemic modalities. This extension allows us to formally specify several qualitative epistemic requirements of MAS evolving in continuous dynamical environment. The fundamental underline Interpretation model of the logic was hybrid automata. The later, were extended to produce the so-called interpreted hybrid system that forms the basic Interpretation model for both the epistemic part and the real time continuous dynamic part. The paper showed how to specify several interesting requirements using ERCTL. To put the formal verification into consideration, we showed how to implement the proposed work using constraints logic programming CLP. As converting a model to CLP is a tedious work, it's worth developing to incorporate the ERCTL in the model checking tool [48].

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A Lexicon-based Approach to Build Service Provider Reputation from Arabic Tweets in Twitter

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***Abstract*—Nowadays Social media has become a popular communication tool among Internet users. Many users share opinions and experiences on different service providers everyday through the social media platforms. Thus, these platforms become valuable sources of data which can be exploited and used efficiently to support decision-making. However, finding and monitoring customers' opinions on the social media is difficult task due to the fast growth of the content. This work focus on using Twitter for the task of building service providers' reputation. Particularly, service provider's reputation is calculated from the collected Saudi tweets in Twitter. To do so, a Saudi dialect lexicon has been developed as a basic component for sentiment polarity to classify words extracted from Twitter into either a positive or negative word. Then, beta probability density functions have been used to combine feedback from the lexicon to derive reputation scores. Experimental evaluations show that the proposed approach were consistent with the results of Qaym, a website that calculates restaurants' rankings based on consumer ratings and comments.**

Keywords*—Reputation; Sentiment Analysis; Arabic Language; Saudi Dialect; Social Media

I. Introduction

Nowadays Social media has become a popular communication tool among Internet users. Many users share opinions on different service providers everyday through the social media platforms such as Twitter [a] and Facebook [b]. These platforms become valuable sources of data that can be exploited and used efficiently to support decision-making. For example, it is worthy for a customer who wants to buy a product to search information on the social media trying to find other consumers' opinions on the product.

However, finding and monitoring customers' opinions on the social media is difficult task due to the fast growth of the content. A study conducted in [1] shows that 85% of residents of Saudi Arabia use social media and the highest rates of Twitter usage are in the Middle East (based on a survey of more than 152,000 internet users across 31 markets). Figure 1 illustrates percentage of total users who subscribed in Twitter per country in 2015. It is clear that Saudi Arabia has the highest Twitter users by 53%.

The aim of this study is to develop a reputation approach based on sentiment analysis of Arabic tweets in Twitter. Such an approach is important because the huge amounts of valuable information contained in the social media cannot be readily analyzed manually. In this paper, a lexicon-based approach has been proposed to build service providers' reputation from social media. More specifically, the Beta reputation system [2] has been adapted to calculate service provider's reputation from tweets in Twitter. To do so, a Saudi dialect lexicon has been developed as a basic component for sentiment polarity. The proposed lexicon is used to classify words extracted from Twitter into either a positive or negative word. Then, the beta probability density functions have been used to combine feedback from the lexicon to derive reputation scores. Experimental evaluations show that the proposed approach were consistent with the results of Qaym, a website that calculates restaurants' rankings based on consumer ratings and comments.

The remainder of the paper is organized as follows. A review of the literature is presented in Section II. A Saudi dialect lexicon is introduced in Section III. The proposed lexicon-based approach for reputation calculation using Arabic tweets in Twitter is explained in Section IV. Experimental results are reported in Section V and discuss some relevant issues in Section VI. Finally, Section VII concludes the paper.

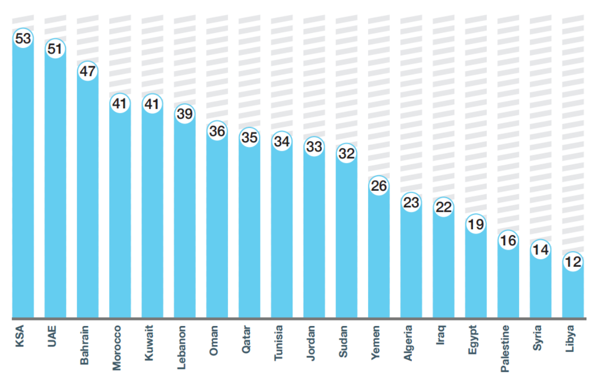

Fig. 1: Arabic subscribers in Twitter per country [7]

II. Literature Review

A Reputation system provides a promising way for building trust between service providers and consumers. Most reputation systems gather user feedback, such as ratings or reviews, then aggregate them into a single value to represent a reputation score [8], [9]. This type of system is called a feedback-based reputation system [4]. One main obstacle for feedback-based reputation models is sparsity of ratings [2], [3], [19]. That is, there is insufficient data to build the reputation score. This is because usually users have no direct incentive

[a]https://twitter.com
[b]https://www.facebook.com

for providing ratings, thus they abstain to leave their ratings after service usage [2].

SocialTrust is a proposed reputation system that has three chief components. First, social networks which is a network of friends and partners. Consequently, each node preserves two lists of mutual-trusted nodes. Each node needs to keep its friendship with other by producing no harm to them and like to have more partners to gain more benefits. Second, a trivial reliable server selection is made to choose a client of the highest local ranking offered by other services. Third, reputation evaluation is based on the amount of credits that each node has collected through rating. Reputation evaluation is used to adjust reputation reward or punishment after a transaction [10]. This reputation system is implemented for peer to peer networks.

A probabilistic graphical reputation model is created to embody the relationship between social brands and users [11]. It collects the network information as well as the feedback of the users. This model reduces unfair outcome from a single user and a single comment. It jointly concludes the brand reputation. The implementation of this model is based on a parallel block-based Markov Chain Monte Carlo (MCMC) sampling method. The model is assessed by using a large amount of Facebook data. However, this model is very complicated and impractical.

Another reputation model is based on mining textual feedback of services to build an expectations model for each consumer is proposed in [12]. This model is created for e-commerce settings and the research is based on real data gained from eBay. It is based on textual feedback not rating.

To easily monitor the reputation of a company in the Twitters, a strategy that arranges a set of tweets into diverse clusters based on the tweets topics is developed in [13]. The acquired clusters are prioritized into different priority ranks. A cluster with high priority represents a topic which may affect the reputation of a company, and deserves instant attention.

E-Bay [c] and Amazon [d] are two common reputation systems in online e-commerce. In the e-Bay reputation system, a buyer can give feedback about the sellers service quality after each transaction and the system stores these ratings in a centralised manageable data storage. It calculates the feedback score by subtracting the negative ratings from the positive ratings and displays this score on the website.Amazon.com is one of the worlds leading online retailers. Amazon allows its users to review each product or service they receive. The reviews can then be accessed by all users. An average score for each product is calculated based on the reviews.

Foursquare [e] is a discovery service application which provides search results for its users. The application reads the users location and his request (e.g. restaurant) and provides data on nearby services meeting his requirements that other users trust. The application provides recommendations based on the user's current location.

Qaym.com [f] is a website that allows Saudi consumers to evaluate restaurants. It allocates rankings for each restaurant based on the customers comments, which are then used to define tags that describe the characteristics of the restaurant and supplemented by consumer ratings. The website then calculates the restaurants ranking based on consumer ratings and comments.

In this study, a reputation approach based on sentiment analysis of Arabic tweets in Twitter is proposed. More specifically, service provider's reputation is calculated from the collected Saudi tweets in Twitter. To do so, a Saudi dialect lexicon has been developed as a basic component for sentiment polarity. The proposed lexicon is used to classify words extracted from Twitter into either a positive or negative word. Then, beta probability density functions have been used to combine feedback from the lexicon to derive reputation scores.

III. Developing a Lexicon for Saudi Dialect

A. Lexicon Definition

A lexicon is a list of words in a language. The Cambridge Dictionary [g] defines lexicon as "a list of all the words used in a particular language or subject, or a dictionary." It may be general or domain-specific. The interest words are usually open-class or content words, such as nouns, verbs, and adjectives, rather than closed-class or grammatical function words, such as articles, pronouns, and prepositions. It may also include multi-word expressions such as fixed phrases, phrasal verbs, and other common expressions (Happy End). Each word or phrase in the lexicon is described in a lexical entry; exactly what is included in each entry depends on the purpose of the particular lexicon [14].

B. Importance of Lexicon

Broadly, there are two major categories for sentiment analysis: supervised and unsupervised approaches. In the supervised approach, data marked with its class (positive or negative) and used as training data for classification using one of the machine learning algorithms like Nave Bayesian Classifier, Support Vector Machine (SVM), Maximum Entropy [15]. One of the flaws of supervised approaches is that they require a carefully selected training set with highly accurate annotations. The unsupervised approach, on the other hand, is based on building a lexicon to infer class of each word. The advantage of this approach is that it is domain independent. However, building a high quality lexicon usually requires significant effort [6].

People on social media use their local dialect rather than Modern Standard Arabic (MSA) [16]. Therefore, in this paper, a Saudi dialect lexicon from Saudi tweets is developed to help calculate the reputation score for an entity.

C. Saudi Dialect Lexicon

Lexicon Structure: In this paper, a lexicon of Saudi dialect is developed. The developed Lexicon is composed of Saudi tweets as it is specialized in the Saudi dialect. A lexical entry in our lexicon is either a word or phrase which demonstrates how Saudis express their opinions on an entity. The word can

[c] http://www.ebay.com
[d] https://www.amazon.com
[e] https://foursquare.com
[f] http://www.qaym.com
[g] http://dictionary.cambridge.org

be a noun, verb, pronoun, adjective, adverb or interjection. Examples of word in Saudi dialect are نقمة, نعمة, زينة and افضل. A phrase is a group of words that express a concept and is used as a unit within a sentence. Examples of Saudi phrases are شي يصيح, نقطة ضعفي and آخر مرة. Some common phrases are used with clear sentiments, for example لن اكرر التجربة, to handle negating sentences.

The proposed lexicon is a two column file: a word/phrase and a score. The score captures the polarity of the word/phrase and it takes one of the two values: positive (+1) or negative (-1). Table 1 shows some examples about the Saudi dialect with their polarities.

Lexicon Building: Extracting sentiment from text is a complex task due to the significant amount of Natural Language Processing (NLP) required [6]. This task becomes even more difficult when dealing with morphologically rich languages such as Arabic language [15], [16] and when processing brief, noisy texts such as "tweets" or "Facebook statuses".

Broadly, there are two lexicon building techniques, manual building and automatic building [17]. In this paper, a semi-automatic building technique was adopted. Initially, the lexicon was built manually by collecting tweets and classifying ther words in positive or negative polarity. After that, the proposed algorithm will enrich the lexicon by new words automatically each time a reputation calculation request submitted to the system (explained in details in Section 4). Finally, the new words will be classified manually by the lexicon moderator.

Given the limited work done for Arabic text in the field of sentiment analysis, especially for the Saudi dialect, two lists were manually built about Saudi dialect: one for the most occurring positive sentiment words, and one for the most occurring negative sentiment words. A NodeXl [h], a free open source to explore network graphs, was used to collect tweets written in the Saudi dialect from Twitter. Then, every word that has a sentiment (positive or negative) have been extracted. Consequently, 762 positive words/ phrases and 662 negative words/phrases have been collected. For each positive and negative sentiment, a PHP code scans the tweets and uses two different mechanisms, one for the extraced words and the other for the extracted phrases (see Algorithm 1 in Section 4).

The sentiment of each word was identified using crowd sourcing technologies [18]. That is, the list of extracted words were sent to three workers (Saudi people) to give a coarse sentiment label (positive, negative, or neutral) to each word. Then, a voting was used for final classification. Since each word was labeled by three workers, it is easy to determine if the target word represent a positive, negative or neutral word (i.e. if two out of three chose the same polarity).

IV. A Lexicon-based Approach to Build Reputation from Social Media

The proposed system consists of four main components: data collection, data pre-processing, sentiment analysis and reputation calculation. They are illustrated below in Figure 2.

[h]http://nodexl.codeplex.com

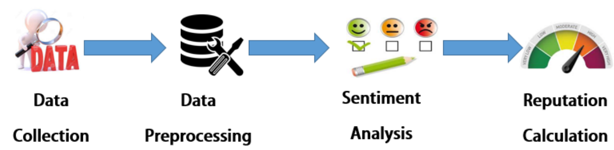

Fig. 2: Proposed system components

A. Data Collection

The collected data in the proposed system is tweets. They are collected automatically using Apache Nutch [20]. The Apache Nutch is a complete open source Web crawler written in Java. It is highly scalable and built over Hadoop Map/Reduce. It is used in distributed architecture and can automatically grab webpage hyperlinks. In the proposed system, the Apache Nutch was modified to crawl only Arabic tweets.

The Apache Nutch can copy all of the visited pages for searching and reduce the maintenance work. It is highly modular and most of its functions can be changed via plugins. It contains a data repository with two databases: web page status database and link database. The link database can be symbolized as web graph to grab web content and parses data. For good performance, it supports multi-threaded and multi-protocol.

B. Data Preprocessing

For data preprocessing, Apache Solr [21] is used. It is a fast open-source Java search server that allows easy creation of search engines for websites, databases and files. The basic component of the Apache Solr that makes it able to perform searches rapidly is the index it creates and uses to search the text. The index inverts a keyword-centric data structure based on the words in the pages. This index is stored in an index folder in the data folder.

When data is added to the Apache Solr, it passes through a series of transformations before being added to the index. This is regarded as the "analysis phase". Examples of these transformations are removing suffixes and prefix of Arabic words, removing stop-words, splitting words into sub-words that help to match delimiters with words.

The first step to work on the Apache Solr is to define kinds of fields using a file called schema.xml. The supported field types in the Apache Solr are: float, long, double, date, and text. This study is dealt with text filed since the collected data are "tweets". Each filed has an analyzer and tokenizer [23]. While the analyzer examines the field text and generate a "token stream", the tokenizer breakdowns the filed data into lexical units.

The Apache Solr offers support for the Light-10 (PDF) stemming algorithm. This algorithm describes character normalization and stemming. To provide flexibility, the stemming algorithm divided into two filters as in Figure 3:

1) solr.ArabicNormalizationFilterFactory, and

TABLE I: Examples of the Saudi Dialect

(a) Word Sentiment

Word	Polarity
ابغا	+1
تحفه	+1
بايخ	-1
ادمان	+1
حسافه	-1
اطلق	+1
سخيف	-1
تعيس	-1
اردا	-1
ابداع	+1

(b) Phrase Sentiment

Phrase	Polarity
لا يعلا عليه	+1
الله يديم النعمه	-1
لا يفوتك	+1
اموت فيه	+1
يحوم الكبد	-1
ما فيه مثله	+1
ما ينفع بريال	-1
مالت عليهم	-1
لا يعلا عليه	+1
لا طعم و لا ريق	-1

2) solr.ArabicStemFilterFactory

Note that light stemming eliminates only the common affixes (prefixes and suffixes) without altering the origin (root) of a word.

```
<analyzer>
  <tokenizer class="solr.StandardTokenizerFactory"/>
  <filter class="solr.ArabicNormalizationFilterFactory"/>
  <filter class="solr.ArabicStemFilterFactory"/>
</analyzer>
```

Fig. 3: Indexing Arabic Content in Solr [22]

C. Sentiment Analysis

Sentiment analysis has recently become one of the growing areas of research related to text mining and natural language processing [5], [6]. It is a type of natural language processing for tracking the mood of the public about a particular product or topic. Not surprisingly, the most important indicators of sentiments are sentiment words. These are words that are commonly used to express positive or negative sentiments. For example, in Saudi dilaect زين, نعمه and أعشق are positive sentiment words, while شين, مخيس and معفن are negative sentiment words. Apart from individual words, there are also phrases and idioms, e.g., مالت عليه. Sentiment words and phrases are instrumental to sentiment analysis for obvious reasons. A list of such words and phrases is called a sentiment lexicon.

Since sentiment words are often the dominating factor for sentiment classification, it is not hard to imagine that sentiment words and phrases may be used for sentiment classification in an unsupervised manner. It performs classification based on some fixed syntactic patterns that are likely to be used to express opinions. The syntactic patterns are composed based on part-of-speech (POS) tags.

Another unsupervised approach is a lexicon-based which uses a dictionary of sentiment words and phrases with their associated orientations [24]. This method was originally used in sentence-level sentiment classification [25].

In this study, the lexicon-based approach has been adapted for sentiment analysis. That is, the developed Saudi dialect lexicon is used to classify the extracted words into either positive or negative word. To do so, a PHP plugin was integrated into the Apache Solr to enter the keyword (i.e. the targeted entity) and submit it to the Apache Solr to search for the relevant tweets. The different ways of typing any product in Saudi society are written in an excel file which is converted to a text file for use by the Apache Solr during the search and query processes. This file is added to the Apache Solr configuration to be used for synonym purposes. Finally, the PHP code scans the tweets to identify the sentiment words based on the collected sentiment words in the Saudi Lexicon. This way the meaning of each sentiment word is interpreted, which is the core of sentiment analysis.

D. Reputation Calculation

In this paper, the Beta reputation system that proposed by Josang and Ismail in [2] has been adapted to calculate the reputation of service provider. The reputation function is based on the Beta Probability Density Function. It is used to show the probability distributions of binary events. The binary events in this study are positive or negative sentiment. It is a mathematical base that is used to represent the reputation ratings based on feedback (tweets). It is based on posteriori probabilities of binary events to convey beta distributions [2]. It is a continuous function which uses two parameters α and β.

In the proposed approach, the extracted words from the collected tweets are viewed as a set of Bernoulli trials: positive word/phrase or negative word/phrase, and then modeled as Beta distributions:

$$R = \frac{\alpha}{\alpha + \beta} \tag{1}$$

Where $\alpha = r + 1$ and $\beta = s + 1$, and r is the observed number of positive words and s the observed negative ones.

The ratio of α and β determines where in the interval [0,1] the reputation score peaks, and a high α will cause the score to occur close to 1.

The idea of adding 1 to r and s (and thus 2 to $r + s$) follows Laplace's rule of succession for applying probability to inductive reasoning [26]. This rule reflects the assumption of an equi-probable prior, which is commonly adopted in probabilistic reasoning. That is, having no information about an entity, (i.e. $r = 0$ and $s = 0$), R is calculated as: 1 / (1+1) =0.5, suggesting that a positive and negative word about the entity is equally likely. For example, suppose that α equals to 8 and β equals to 2. In this case, 10 words were extracted from the collected tweets and the reputation of the given entity can be calculated as follow: $R = 8/(8 + 2) = 8/10 = 0.8$

Note that in this study rating nearer to "1" donates good reputation score and vice versa. Algorithm 1 shows pseudo-Code for a lexicon-based approach to calculate the reputation score in detail.

Algorithm 1 Reputation Calculation Algorithm

```
1:  Input: T a set of tweets extracted from Twitter,
        L a Saudi Dialect Lexicon.
2:  Output: R Reputation Score.
3:  Process:
4:  α = 0
5:  β = 0
6:  for each t_i do
7:     for each w_i do
8:        if w_i ∈ γ then
9:           if w_i.Polarity = +1 then
10:             α = α + 1
11:          else
12:             β = β + 1
13:          end if
14:       else
15:          ξ ← w_i
16:       end if
17:    end for
18: end for
19:
20: for each p_i ∈ ψ do
21:    for each t_i do
22:       if p_i ∈ t_i then
23:          if p_i.Polarity = +1 then
24:             α = α + 1
25:          else
26:             β = β + 1
27:          end if
28:       end if
29:    end for
30: end for
31: R = α / (α+β)
32: Return R
```

In this research, the lexicon-based approach is used to compute the reputation score of a given service provider. The developed lexicon L:=(γ, λ , ψ , ξ) where γ is a set of positive and negative words in the Saudi dialect lexicon, λ is a set of neutral words (i.e. neither positive nor negative), ψ is a set of positive and negative phrases, and ξ is a set of non-known words that need to be checked by the lexicon moderator and added to one of the first two groups.

The input for the proposed algorithm are T and L (Line 1) and the output is the reputation score R (Line 2). T is a set of tweets that have been collected from Twitter about a target entity and L is the developed Saudi dialect lexicon.The algorithm uses two variables: α and β, the former is for calculating total number of positive ratings (Line4) and the later is for calculating total number of negative ratings (Line5). The algorithm then scans all the words in T (from Line 6 to Line 18). That is, for each tweet t_i, it checks each single word w_i (Line 7) and if it has a positive sentiment (Line 9) it adds 1 to α (Line 10), otherwise it adds 1 to β (Line 12). In case of having a word that does not exist in the lexicon, the word will be added to ξ (Line 15). The second part of the algorithm (from Line 20 to Line 30) scans all the phrases in ψ (Line 20) to check whether the phrase is existed in the collected tweets or not. That is, for each tweet (Line 21), it checks if the given phrase (p_i) exists in the tweet (Line 22) α will be increased by 1 if the phrase's polarity equals to +1 (lines 23 and 24), otherwise it adds 1 to β (Line 26). The lines from 20 to 30 are repeated for all phrases in the lexicon. Once the algorithm has scanned all of the collected words and the lexicon phrases, it moves to calculate the reputation score by dividing the total number of positive ratings (α) by the sum of positive and negative ratings (Line 31) and then returns the result to the requester (Line 32).

To explain the importance of having list of neutral words in our lexicon, a specific example is introduced. Suppose that 500 words were extracted from 100 tweets about service provider $SP1$. According to Algorithm 1, the 500 words will be compared with the constructed lexicon. Assume that only 100 words exist in the lexicon. According to the proposed algorithm, 400 words will be added to the waited list (ξ) in order to be compared with the neutral list (λ). Now, assume that 300 words out of the 400 words have already existed in the neutral list. These words will be consequently removed from the waited list. Finally, the remaining 100 words will be manually classified by the lexicon moderator as either positive or negative. Thus, having the neutral list in the proposed lexicon decreased the moderators effort by almost 75% (i.e. instead of classifying 400 words, the moderator classified only 100 words). Note that, in general, the proposed lexicon will build itself over each time a new reputation calculation request submitted to the system.

V. Experimental Evaluation

This section presents an empirical evaluation of the lexicon-based approach. A set of experiments were conducted to evaluate performance our proposed approach against the sentiment analysis approach.

A. Data Set

The data set used in this experiment was automatically collected from Twitter using Apache Nutch [20]. In this study, Apache Nutch was modified to crawl only the Arabic tweets on Twitter. To identify Saudi tweets, the collected tweets were filtered based on user location.

For the purposes of this study, 550 tweets were collected from Twitter regarding 9 restaurants (see Table 2). The collected data was injected into Solr to implement the data preprocessing. The entered tweets were indexed for fast and efficient retrieval by the Solr indexer.

TABLE II: Number of Collected Tweets for Each Restaurant

Entity	Number of tweets
Restaurant 1	56
Restaurant 2	59
Restaurant 3	58
Restaurant 4	64
Restaurant 5	55
Restaurant 6	72
Restaurant 7	68
Restaurant 8	66
Restaurant 9	52
Overall tweets	550

B. Evaluation Metrics

In this study, the lexicon-based approach has been evaluated using three metrics: precision, recall and reputation score.

Precision: The frequency with which retrieved documents or predictions are relevant or 'correct', and is properly a form of Accuracy. It is also known as Positive Predictive Value (PPV) or True Positive Accuracy (TPA). In the field of information retrieval, precision can be defined as the fraction of retrieved documents that are relevant to the query [27]. More specifically, precision can be calculated as follows:

$$Precision = \frac{TP}{TP + FP} \tag{2}$$

Where TP is the true positive and FP is the false positive. In our context, the retrieved documents are sentiment words that were extracted from the collected tweets. For example, suppose that 100 words were extracted from Twitter and 25 were mistakenly retrieve (they either do not express sentiment or were misclassified). In this scenario, the precision is as follows: 75/(75 + 25) = 0.75.

Recall: The frequency with which the relevant documents are retrieved or 'recalled' by a system. It is also known as Sensitivity or True Positive Rate (TPR). In the field of information retrieval, recall is the fraction of the documents that are relevant to the query that are successfully retrieved [27]. More specifically, recall can be calculated as follows:

$$Recall = \frac{TP}{TP + FN} \tag{3}$$

Where TP is the true positive and FN is the false negative. For example, suppose that the collected tweets contain 100 sentiment words and only 60 were extracted and retrieved. In this case, the recall can be calculated as follows: 60/(60 + 40) = 0.60.

Reputation Score: In this work, the ratings are represented by the extracted words from the collected tweets. More specifically, the reputation score is calculated using equation1. For example, if 95 positive words and 15 negative words were extracted from the collected tweets, then the reputation score is computed as: 95/(95 + 15) = 0.86.

C. Experimental Results

In this section, a set of experiments were conducted to evaluate the performance of the proposed approach. First, for validity purposes, calculating reputation based on words extracted from the collected tweets was examined against a sentiment analysis approach (i.e. using sentence-level rather than word-level). Second, the proposed system was used to calculate the reputation scores of the restaurants. Finally, how the reputation of the restaurants might be fluctuated over time and how this fluctuation may affect the user's decision was demonstrated.

Experiment 1: Word-level vs. Sentence-level: To prove the concept, an evaluation of the proposed approach is presented in this section. A comparison between the proposed approach (word-level) against a sentiment analysis (sentence-level) was conducted. For simplicity, in the sentiment analysis approach, each collected tweet was manually classified as positive, negative or neutral.

To explain how to calculate the reputation score using the two approaches, a specific example is introduced. In this example: "مطعم لوسين يجنن وأفضل مطعم" means "Lusin restaurant is amazing and it is the best restaurant". Two sets of calculations were performed to determine the reputation score for the restaurant.

- Sentence-level: this approach attempts to label the whole sentence as positive or negative sentiment. Thus, it assigned a score of +1.
- Word level: this approach counts the number of positive and negative words in the sentence. In our example, there are only two positive words ("amazing" and "best"), hence, it assigned a score of +2.

For the sake of this experiment, tweets about 5 different restaurants were collected from Twitter. On average, 60 tweets were collected about each restaurant. The reputation scores of the four restaurants were calculated based on the two approaches and the result is shown in Figure 4.

Figure 4 shows results of the word-level approach against the sentence-level approach (sentiment analysis approach). It is clear that the calculated reputation scores for the five restaurants are close to those scores calculated by the sentence-level approach. For example, restaurant 1 has the highest scores in both approaches (0.96 using our word-level approach and 0.98 using sentence-level approach). More importantly, the order of the five restaurants is equivalent by the two approaches. In addition, how the Foursquare Application rates these restaurants was investigated and restaurant 1 was founded as the best one, which supports the results of the two approaches. Furthermore, the order of the restaurants was similar to their order in the Foursquare application. Note that since the calculation of the

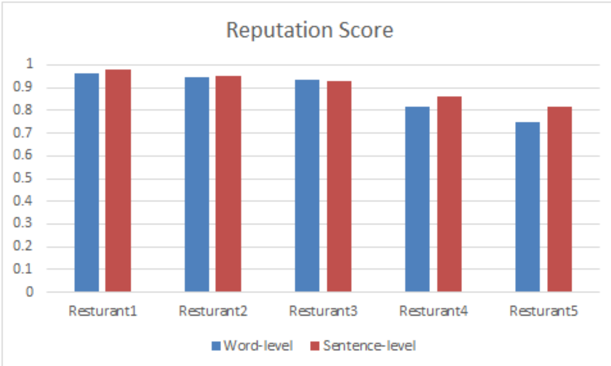

Fig. 4: Reputation scores of word-level vs. sentence-level

two approaches was conducted manually, the precision and recall for the two approaches was 100%.

In addition, compared to other websites which evaluate restaurants in Saudi Arabia, the proposed reputation system gave similar results to Qaym. For example, it was found that restaurant 2 is better in evaluation than restaurant 3, which supports the results of the proposed approach.

Experiment 2: Reputation calculation using a lexicon-based approach: In this experiment, reputation scores of the five restaurants were calculated using a lexicon-based approach. The lexicon-based approach was implemented using PHP language [i]. The proposed approach scans the collected tweets to extract the sentiment words and uses the Saudi Lexicon to classify them as positive or negative. The reputation scores of the five restaurants were recalculated using the lexicon-based approach and the results shown in Table 3 and Figure 5.

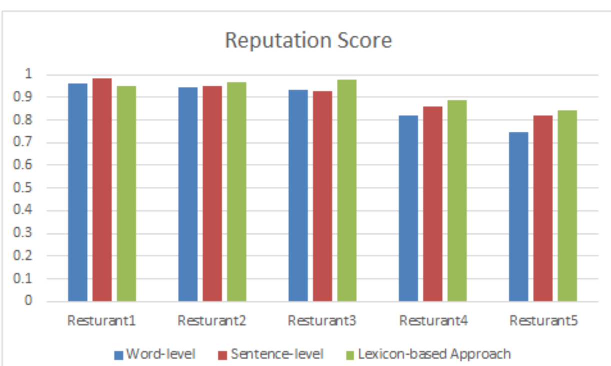

Fig. 5: Reputation scores using the lexicon-based approach

In Figure 5, it is clear that the reputation scores of the five restaurants using our proposed approach is similar to the reputation scores calculated by the two other approaches. However, looking closely at the scores reveals that the order of the restaurants has changed. That is, while restaurant 1 was recommended as the best one by the two other approaches, it was ranked third by the lexicon-based approach. It is important to emphasize that the lexicon-based approach is highly sensitive to the content of the Saudi dialect lexicon. The next experiment explains the reasons behind the change of the restaurants order between the proposed approach and the two other approaches.

[i]http://php.net/manual/en/langref.php

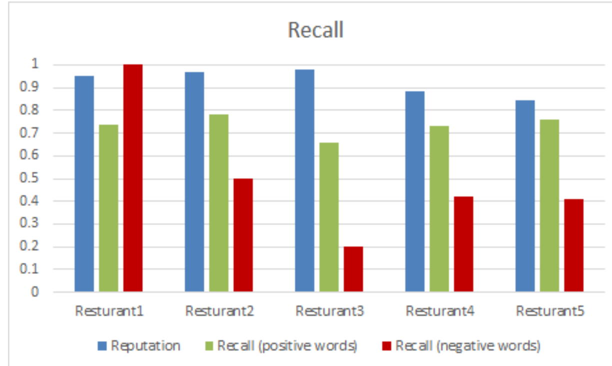

Fig. 6: Recall of positive and negative words against reputation scores

Experiment 3: Calculation of Recall and Precision: While recall is the frequency with which the relevant documents are retrieved or 'recalled' by a system, precision is the frequency with which the retrieved documents or predictions are relevant or 'correct'. In the proposed approach, the reputation score will be directly affected by the frequency of the extracted words (recall) and their correctness (precision). Table 4 and Figure 6 show recall values that are associated with each restaurant's reputation score. Note that precision and recall of positive and negative words were calculated separately in order to clearly understand the difference in the restaurants' ranking between the proposed approach and the other approaches.

Figure 6 shows that the recall of negative regarding restaurant 1 is slightly higher than that of the recalls of other restaurants (i.e. all negative words against the restaurant have been retrieved). In addition, approximately 19 positive words were missed, making the recall of the positive words relatively poor (74%). However, although the recall of the positive words for the claimed best restaurant (number 3) was the lowest (66%), the majority of the negative words were not discovered (almost 80% of the negative words) leading to the highest reputation score. Overall, it is evident that the reputation scores were significantly influenced by the recall values for positive and negative words. That is, if the recall of positive words reaches 1 while the recall of negative words drops towards 0, then the reputation score will be increased and vice versa. In an optimal case where the recall of positive and negative words equals 1, the reputation score computed by the lexicon-based approach will be equivalent to the word-level approach. This will happen when the Saudi dialect lexicon becomes complete and accurate.

Table 5 and Figure 7 illustrate the precision of positive and negative words for the five restaurants. It is clear that the precision values for the five restaurants are quite high compared to the recall values, therefore, the reputation scores were influenced by the low recall values. As mentioned previously, once the Saudi dialect lexicon becomes complete and

TABLE III: Reputation Scores of Lexicon-based Approach vs. Sentiment Analysis Approach

Restaurant	Manual Calculation Word-Level	Manual Calculation Sentence-Level	Automated Calculation Lexicon-based Approach
Restaurant 1	0.961	0.981	0.949
Restaurant 2	0.945	0.949	0.966
Restaurant 3	0.932	0.928	0.979
Restaurant 4	0.818	0.859	0.885
Restaurant 5	0.746	0.818	0.844

TABLE IV: Recall of Positive and Negative Words for the Five Restaurants

Metric	Res1	Res2	Res3	Res4	Res5
$TP + FN$	75	71	69	63	50
TP	56	56	46	46	38
Recall (positive words)	0.74	0.78	0.66	0.73	0.76
$TP + FN$	3	4	5	14	17
TP	3	2	1	6	7
Recall (negative words)	1	0.5	0.2	0.42	0.41
Overall Recall	0.76	0.77	0.64	0.68	0.67

TABLE V: Precision of Positive and Negative Words for the Five Restaurants

Metric	Res1	Res2	Res3	Res4	Res5
$TP + FN$	55	56	45	43	35
TP	56	56	46	46	38
Precision (positive words)	0.98	1	0.97	0.93	0.92
$TP + FN$	3	2	1	5	7
TP	3	2	1	6	7
Precision (negative words)	1	1	1	0.83	1
Overall Precision	0.983	1	0.979	0.923	0.93

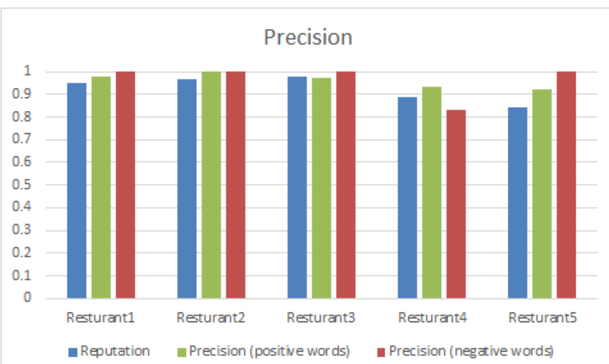

Fig. 7: Precision of positive and negative words against reputation scores

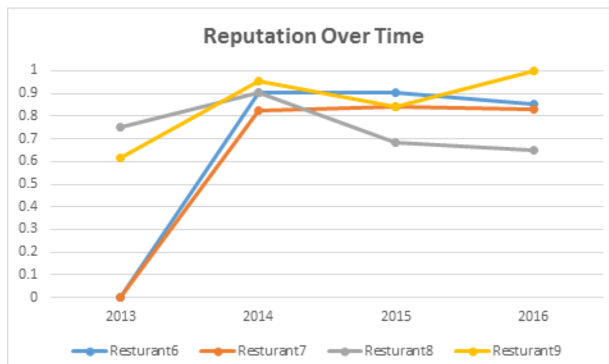

Fig. 8: Classification Accuracy

accurate the reputation scores of the given entities will be more accurate.

Experiment 4: Reputation fluctuation over time: There are many factors that might positively or negatively affect the reputation score of a given entity, which are reflected in people's opinions towards the entity. For example, it is expected that the reputation of a restaurant that offered a delicious food might be affected when the restaurant's chief moves to another restaurant.

The aim of this experiment is to examine how the reputation score can be affected over time. Therefore, 303 tweets were collected about an additional four restaurants (restaurant 6, restaurant 7, restaurant 8 and restaurant 9). Tweets were collected from a period of four years for each one and the annual reputation score was calculated. Note that in this experiment the lexicon with additional positive and negative words was updated to improve the recall and precision of our proposed approach. Figure 8 presents the results of this experiment.

In Figure 8, it is obvious that the reputation scores of the four restaurants fluctuated over the four years. While the restaurant 8 was the best one in 2013, its reputation started decaying in 2015 (it dropped to become the worst one). Conversely, restaurant 9 started with low reputation and gradually built its reputation to become the best one in 2016. In addition, it is evident that restaurants 6 and 7 deliver consistent services over time. This is reflected by the stability of their reputations over 2014, 2015 and 2016. Note that there was no data for these two restaurants in 2013 and zero values in this year simply mean that they had no reputation.

Fig. 9: Reputation of the four restaurants over the four years

Old feedback may not always be relevant to the reputation score, because the quality of the restaurant, for example, may change over time. One possible way to handle this issue is by introducing a forgetting factor. The main idea for the forgetting factor is to give the old feedback less weight than the new one when calculating the reputation score. The forgetting factor can be adjusted according to the expected rapidity of change in the observed entity. As Figure 9 shows, if the historical data that collected over the four years was considered, restaurant 6 would be nominated as the best restaurant (its reputation is 89%). However, if only the recent feedback that gathered on the last year (2016) was considered, then restaurant 9 will be the best one. It is important to emphasize that the data on 2016 only covers three months (from January to March).

VI. Discussion

In this paper, the word polarity was represented in the same level (+1 for positive word and -1 for negative word), and the reputation score is calculated by counting the number of positive and negative words using the beta probability density function. However, categorizing all the words at the same level is rather limited and does not allow to specify the level of polarity effectively. For example, it is unfair to assign the two words رائع and زين at the same level of polarity (i.e. +1). Also, it was approved that users tend to repeat the letter more than once to emphasize the meaning or feeling in social media [24]. Saudi users, for example, often duplicate letters to express overstatement of their opinion. They repeat the letter of ي in the word لذيييذ which means delicious. This word is exactly similar to the word لذيذ, but with more emphasize of feeling. Thus, It might be more appropriate to consider different levels of polarity instead of categorizing all the words at the same level. That is, in categorizing the polarity of the two words, the word with repeated letter would be assigned higher level of polarity. A method proposed in [28] can be used for inferring the polarity degree of a word from its statistical association with a set of positive and negative paradigm words.

In reputation calculation, the beta probability function was adopted. However, it is limited to work with only two values (positive or negative). In the other words, this model excludes the possibility of providing word polarities with graded levels such as praise, positive, slightly positive, ..etc. In principle this model is unable to distinguish between polarized ratings. One possible solution is to build the reputation score based on the Dirichlet probability distribution which is a multinomial Bayesian probability distribution as in [29]. The multinomial aspect of Dirichlet probability distribution means that any set of discrete rating levels can be defined. Hence it provides great flexibility and usability in dealing with multilevel of word polarity.

Although sentiment words and phrases are important for sentiment analysis, only using them may lead to inaccurate classification. For example, in our lexicon احب is a positive word but negation لا احب will change it to a negative one. Also, words in Arabic can have a different meanings based on their context. For example the word يم has two meanings in the Saudi dialect; delicious or towards a direction or place. These words influence the precision of our lexicon and increase the probability of a false or misleading detection. Approaches proposed in [34]–[36] can be applied to determine the correct polarity of the words by take into account the context of the words .

The proposed approach establishes service provider's reputation from extracted peoples opinions from Twitter. However, people can be misused by organizations to write fake opinions (i.e. spammers tweets) [32]. For example, a seller of musical instruction DVDs was penalized $250,000 by the U.S. Federal Trade Commission after being accused of using partners to write positive reviews of the companys products on various websites [33]. Such fake opinions for sure will affect the calculated reputation score and mislead the consumer to select unreliable service provider. The proposed techniques in [30] and [31] can be used to detect and remove spam tweets to produce more reliable reputation scores.

VII. Conclusions

In this paper, a lexicon-based approach to calculate reputation score from Twitter was proposed. A Saudi dialect lexicon from Saudi tweets was developed to improve addressing the sentiment of the Arabic tweets. The experimental results show that the proposed approach was efficient and gave similar results to sentiment analysis approach. Also, the result was consistent with the result of Qaym in evaluating the same selected restaurants.

A possible extension of the proposed approach is to consider multilevel of word polarity rather than binary level. Also, spam detection techniques can be applied to detect and remove spam tweets in order to produce more reliable reputation scores.

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A Two Phase Hybrid Classifier based on Structure Similarities and Textural Features for Accurate Meningioma Classification

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Abstract—**Meningioma subtype classification is a complex pattern classification problem of digital pathology due to heterogeneity issues of tumor texture, low inter-class and high intra-class texture variations of tumor samples, and architectural variations of cellular components. The basic aim is the achievement of significantly high classification results for all the subtypes of meningioma while dealing with inherent complexity and texture variations. The ultimate goal is to mimic the prognosis decision of expert pathologists and assist newer pathologists in making right and quick decisions. In this paper, a novel hybrid classification framework based on nuclei shape matching and texture analysis is proposed for classification of four subtypes of grade-I benign meningioma. Meningothelial and fibroblastic subtypes are classified on basis of nuclei shape matching through skeletons and shock graphs while an optimized texture-based evolutionary framework is designed for the classification of transitional and psammomatous subtypes. Classifier-based evolutionary feature selection is performed using Genetic Algorithm (GA) in combination with Support Vector Machine (SVM) to select the optimal combination of higher-order statistical features extracted from morphologically processed RGB color channel images. The proposed hybrid classifier employed leave-one-patient-out 5-fold cross validation and achieved an overall 95.63% mean classification accuracy.**

Keywords*—*Meningioma; Computer-Aided Diagnosis; Brain Tumour Classification; Cell Segmentation; Shape Analysis; Texture Analysis

I. INTRODUCTION

Now-a-days, Computer-Aided Diagnosis (CAD) is in wide practice in clinical work for the detection and prognosis of various types of abnormalities. For this, medical images acquired in various tests by utilizing diverse imaging modalities are used. CAD has emerged as one of the key research areas in medical imaging, diagnostic pathology and radiology.

Histologic textures of tumor specimens being real-world textures are quite complex and different from synthetic textures that are captured in the controlled circumstances. The correct prognosis of tumors requires the expertise of a trained pathologist and is a time consuming task. The variability in the opinion of different pathologists and the variation in the opinion of a single pathologist at different timings may also be observed in the prognosis decision of a tumor specimen [1]. Due to these reasons, adaptive approaches and quantitative methods for computer-aided diagnosis are needed to assist histopathologists for correct diagnosis and prognosis of tumors. The CAD is highly desired to reduce the workload on pathologists by focusing on benign areas so that the pathologists can concentrate on the more difficult malignant cases [2].

Meningioma refers to a group of tumors or neoplasms, which arise from the defensive layers of the brain and the spinal cord named meninges. Meningiomas comprise 34% of all primary brain neoplasms and appear mainly in middle-aged patients with a higher prevalence among females. The World Health Organization (WHO) classification of tumors of the Central Nervous System categorized the meningioma tumor into three main grades (I: Benign, II: Atypical, III: Malignant) [3]. Almost 92% cases of meningioma tumor are diagnosed as benign, 6% cases are characterized as atypical while the remaining 2% are malignant. The WHO classification recognized nine histological variants of benign meningioma based on cytologic structure and morphologic features. The four most frequently occurring variants of grade-I meningioma are: Meningothelial - *Mn* (63%), Fibroblastic - *Fb* (13%), Transitional - *Tr* (19%) and Psammomatous - *Ps* (2%) [4]. Benign lesions have low proliferative potential and are curable through surgical resection. Unlike other benign tumors elsewhere in the human body, they may cause serious problems and even death of the patient depending on the size and location of their origin [3].

The digitized histology images of four major subtypes of benign meningioma are shown in Fig. 1. The pathologists scan histology samples under the microscope in order to discriminate different subtypes or grades on account of a diverse range of morphological characteristics. The meningioma images have high morphological variations between the images of same subtype while low variations in the underlying morphology of two different subtypes. The different subtypes of meningioma possess morphological characteristics including compact meningothelial whorls, collagen matrix, round or oval meningothelial cells, and psammoma bodies. Most of the meningioma subtypes from the same grade possess all these features with slight differences. Therefore, classification of a test image on account of these features is quite complex and challenging. *Mn* and *Fb* images are mostly misclassified due to considerable morphometric similarity with *Tr* subtype and vice versa. Similarly, nuclei of *Ps* images have a great similarity with *Mn* nuclei. Therefore, due to such similar morphological and textural characteristics, images from different subtypes of meningioma are misclassified. In addition, the overlapped nuclei, non-crisp object contours, architectural variations of cellular components, and heterogeneous or dynamic nature of tissue textures induce ambiguity in the pattern recognition procedures. These issues need to be resolved for the precise classification of real-world multi-class meningioma textures.

In this paper, the classification of histology images of benign meningioma into four major subtypes is performed. For this, structural and textural analysis techniques in addition to machine learning algorithms are exploited. A novel hybrid classification framework based on nuclei shape matching and image-level texture analysis is proposed to deal with inherent tumor textures complexity. The nuclei shape matching is performed by computing nuclei skeletons and analyzing skeletal graphs. The image-level texture analysis is performed by extracting higher-order statistical features from morphologically processed RGB color channels. An optimal feature subset is selected through a classifier-based evolutionary feature selection scheme which employed Genetic Algorithm in combination with Support Vector Machine. The selected optimal feature set is used for classification. An extensive analysis of a number of classifiers is performed and the best one is implied for meningioma subtypes classification.

The remaining sections of this paper are arranged as follows. The overview of the previous work regarding meningiomas classification is given in Section II. The detailed description of the proposed framework is presented in Section III. The experimental setup and results are presented in Section IV. The discussion on results is given in Section V. The final outcomes and an overview of the future research are given in Section VI.

II. Literature Review

In past decade, the use of pathological whole-slide images is highly investigated in many areas for automated diagnosis and classification of cancers. The cancer classification techniques can be grouped into two classes based on features extraction methods: 1) The techniques which perform structure or nuclei segmentation and make shape analysis at nuclear level. These techniques exploit geometrical or statistical texture features for confining histological characteristics of nuclei [5], [6], [7]. 2) The techniques which perform the texture analysis at image level and scan the texture patterns globally to confine the inherent spatial characteristics [8], [9], [10], [11]. The performance of these techniques mainly depend on the intrinsic complexity and nature of the problem.

A few of the meningioma classification techniques [5], [6], [7] reported in literature performed the morphometric analysis at nuclear level to explore local regions. Wirjadi et al. [5] explored a base of grey-scale and colored image features to classify normal and meningioma tumorous cells. Representative feature space is created from 6 histology images. Strange et al. [6] exploited morphology features to capture pathological characteristics for classification of meningioma images through random forest classifier. Zeng et al. [7] explored unsupervised color segmentation and shape features. Ten shape features including area, perimeter and major/minor axis length are computed and classified through *k*-Nearest Neighbor (*k*NN) classifier.

The meningioma classification techniques proposed in [10], [8], [12] employed the wavelet transform to perform multi-resolution analysis of meningioma textures at image level. It is beneficial to examine these images at multiple scales in order to capture the minor inherent texture variations. On the other hand, the computation of wavelet packet transform and best basis selection is computationally expensive, because with each wavelet level, the number of coefficients increases exponentially. Lessmann et al. [12] employed the discrete wavelet and color transforms to extract features for the clustering of meningioma subtypes. Unsupervised self organizing map is employed to visualize and explore the wavelet-based feature space. Qureshi et al. [8] proposed an Adaptive Discriminant Wavelet Packet Transform (ADWPT) technique. Grey-level co-occurrence matrix (GLCM) features extracted from the most stable subbands are classified through SVM classifier with 88% accuracy. 5-fold cross validation is performed by using one patient data for testing and data of remaining four patients from each subtype for training. Al-Kadi performed meningioma classification employing wavelet packets and Fractal Dimensions (FD) on blue color channel image. FD signatures from selected wavelet subbands are used for classification through *k*NN, naive Bayesian, and SVM classifier [10]. In another work [9], Al-Kadi explored various texture measures across blue color channel to classify meningioma subtypes through Bayesian classifier. The combination of Gaussian Markov random field and Run-Length Matrix (RLM) features selected by correlation thresholding performed better than other texture measures. Majeed et al. [11] proposed an abstract feature based evolutionary framework for meningioma classification. Abstract features are created by identifying linkages among basic RLM features and combining them into a high-level optimal feature set.

Fatima et al. proposed a novel hybrid technique for improving meningioma classification based on Texture features and Shape Analysis (TSA) [13]. The skeletons and shock graphs are computed for segmented nuclei to represent and match their basic shapes. *Mn* and *Fb* subtypes are classified with good accuracy through nuclei shape matching. For *Tr* and *Ps* subtypes, GLCM texture features are extracted and classified through multi-layer perceptron with 92.50% accuracy. The shape and texture cues are important for classification as the meningioma dataset have morphometric variations for two subtypes and highly discriminating global texture for the other subtypes. However, in this work, features were extracted only from grey-scale image. The size of train and test database was also small. The classification of an individual nuclei was performed on account of one most similar nucleus. The test image was classified based on majority voting.

All the reported meningioma classification techniques are either limited to grey-scale or a single color channel for feature extraction. While, for classification of a true colour RGB image, all the channels are imperative based on colour information contained in each channel. In some scenarios, their significance can be ranked but their individual role cannot be ignored. The meningioma classification techniques discussed above either performed nuclear level analysis or image level analysis to capture underlying texture variations. *Mn* and *Fb* subtypes have notable differences in shape of majority of nuclei while, *Tr* and *Ps* subtypes have clear image level textural differences. Therefore, to capture such type of pattern variations no classification technique exploited structural characteristics at nuclear level and textural characteristics at image

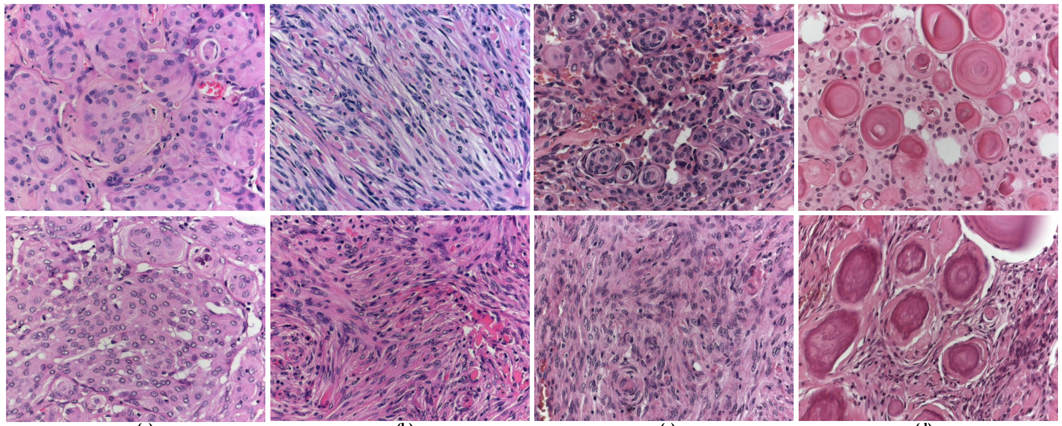

Fig. 1. Four Subtypes of benign meningioma. From (a-d) are RGB images of Meningothelial, Fibroblastic, Transitional and Psammomatous subtypes.

level in a hybrid manner to solve multi-class classification problem of meningioma.

In this paper, a hybrid classification framework is proposed for improved multi-class classification of meningioma. The hybrid framework addressed some of the limitations of previous works, including (1) use of nuclear-level (shape) and image-level (texture) features to take advantage of both simultaneously; (2) use of three RGB color channels to capture texture variations; (3) selection of kernel function of SVM based on train data classification accuracy. The main contributions of the proposed work are:

1) Use of improved segmentation procedure to get well-segmented nuclei with less possible noise to compute true representative skeletons and shock graphs
2) Use of hybrid classification measure, voting and confidence averaging for test image classification
3) Development of train database of reasonable size to represent maximum data variations with less computational cost
4) Quantification of image level higher-order texture features from three RGB color channels to exploit color information contained in each channel
5) An extensive analysis of classifiers and implication of the best one for meningioma classification

III. The Proposed Meningioma Classification Framework

In this paper, an optimized hybrid framework is proposed for classification of digitized histology samples of grade-I benign meningioma into four major subtypes. The proposed classification framework comprises two main phases. In phase-I, the meningioma images are classified on account of structural information of cell nuclei into *Mn* and *Fb* subtypes with a reliance greater than an empirically defined threshold α. In phase-II, meningioma test images from phase-I; that is, either of *Tr* and *Ps* subtypes or have labels of *Mn* and *Fb* subtypes with reliance less than threshold α are classified as *Tr* and *Ps* subtypes on account of intrinsic textural characteristics. The detailed architecture of the proposed classification framework is given in Fig. 2.

A. Phase I: Classification Based on Structural Geometry

The structural geometry offers important clues for recognition of objects, although, in many scenarios the precise extraction, characterization, and representation of objects is a quite complicated task. In meningioma histology images, the cell nuclei are the most prominent objects and seem valuable for the recognition of tumor samples. Therefore, the histology images of meningioma are processed to take benefit of nuclei structural information for correct classification.

In phase I, following major steps are performed: 1). The colored meningioma images are converted to grey-scale and k-means clustering is performed. The morphological operations are performed to remove irregularities. 2). The meningioma nuclei are extorted from segmented images in order to perform structural analysis. 3). The skeletons are formed for extracted nuclei bearing precise boundaries to acquire true estimation of nuclei basic structure. 4). The skeletons are processed to form skeletal or shock graphs. 5). The shock graphs of a test and a train nuclei are compared through a graph matching algorithm to find resemblance of two nuclei. The steps of phase I have been explained in detail in the following subsections.

1) Nuclei Segmentation and Extraction: For the segmentation and extraction of cell nuclei, colored RGB images of meningioma variants are converted to grey-scale. k-means clustering [14] is performed to partition images into primary cellular components on account of pixel values. The images are partitioned into two clusters representing nuclei (bluish region) and background (pink colored cytoplasmic region and a little white region of fat). After getting a clustered image, the morphological operations [15] of closing and holes filling are performed to refine uneven nuclei contours and to fill holes present in nuclei structures. For this, a flat disk-shaped structuring element is used with radius $R = 3$. Watershed algorithm [15] is applied to split merged and overlapped nuclei. For this, distance transform of binary image is calculated based on Euclidean distance metric. A signed distance map is then used as input to the watershed algorithm. Image erosion is performed to make boundaries smooth and wipe out noisy pixels. For this, disk-shaped structuring element is used with radius $R = 2$. An area filter of $200 - 1200$ pixels is applied to remove segmented objects of very small or large size. The border pixels are also removed to clear misleading objects.

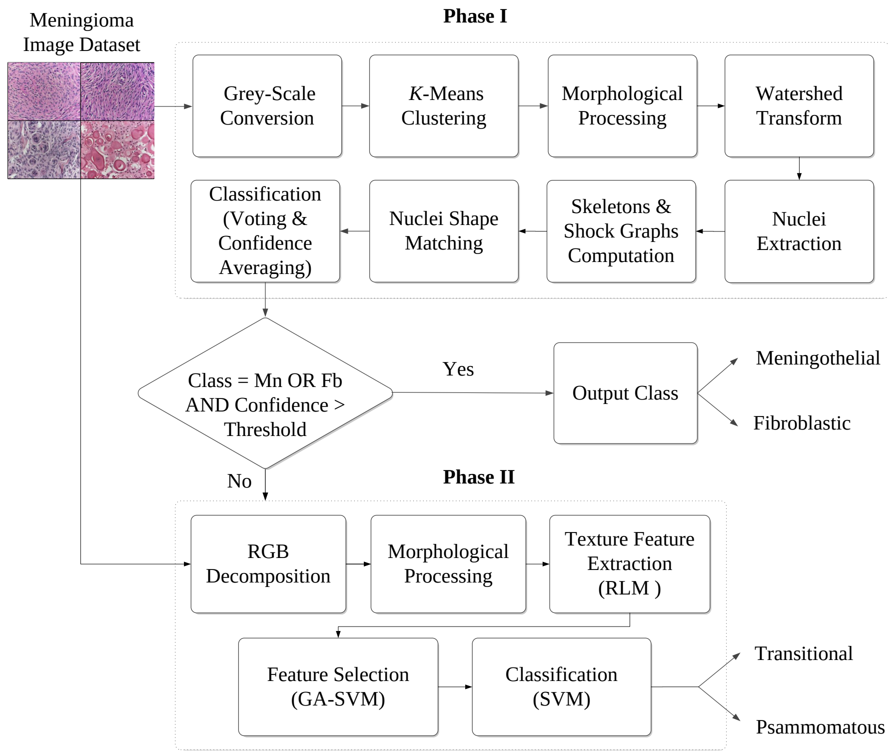

Fig. 2. Proposed hybrid framework for meningioma subtype classification

The segmented images are processed to extract well-segmented nuclei for structural analysis. Morphological features are used for nuclei filtering based on size and shape. Four morphological features (area, perimeter, eccentricity and solidity) are computed for segmented nuclei. For all the features, quartiles are formed using feature values of all the nuclei present. Two most dense quarters with maximum nuclei count are identified. The nuclei common to dense quarters of all the features are selected. These nuclei are used for skeletonization and shock graph computation. The steps performed for nuclei segmentation and extraction are shown in Fig. 3.

2) Skeletons and Shock Graphs Computation: The structural analysis techniques for the recognition of objects based on skeletons and shock graphs are proposed in [16], [17], [18]. The concept of skeleton was first introduced by H. Blum in 1973 [19] and served as a tool for shape analysis and recognition. A skeleton is defined as a smallest possible set of points or lines equidistant to the object boundaries that completely represent the basic shape of a binary object. Accordingly, skeletonization is the reduction of foreground pixels in a binary image to a minimum collection of connected pixels in order to maximally preserve the basic shape of an object. The skeletons are computed through different skeletonization techniques which use distance maps to identify ridges, calculate Voronoi diagrams and use morphological operators. A skeletal or shock graph [20] offers a dynamic representation of a skeleton with connected path of flow. A shock graph is a hierarchical, Directed Acyclic Graph (DAG) representing the decomposition of a 2-D object boundary into primary components named shocks.

The skeletonization of extracted nuclei is performed for the recognition of meningioma samples exploiting structural information. For all the nuclei extracted from each training and testing image, the skeletons are computed employing distance transform (DT) based skeletonization technique proposed in [21]. An augmented Fast Marching Method (FMM) is used to compute DT for evolution of nuclei boundaries on regular path with constant speed. The binary images of cell nuclei for four meningioma subtypes and their respective skeletons are shown in Fig. 4.

A shock graph gives better illustration of the shape of a binary object as compared to a skeleton. Therefore, after computation of skeletons for all the extracted nuclei of training and testing images, shock graphs proposed in [20] are formed to further process these skeletons for shape analysis. All the graph edges corresponding to the boundary noise are pruned to deal with noise raised due to segmentation errors.

3) Nuclei Shape Matching: The acyclic shock graphs are converted to shock trees by removing cyclic vertices using shock graph recognition grammar [22]. To perform subtrees matching in polynomial time, shock graphs are converted to finite and unique rooted trees. A comparison is made between two shock trees with the help of a tree matching algorithm in order to discover an optimal set of matching nodes. The information about two key terms is incorporated in algorithm for matching two shock trees. 1). Topological similarity of the subtrees rooted at each vertex. 2). Similarity between the shock geometry encoded at each node.

In order to measure the similarity between two nodes or vertices u and v, a low dimensional curve through their respective shock trajectories is interpolated, and assigned a cost

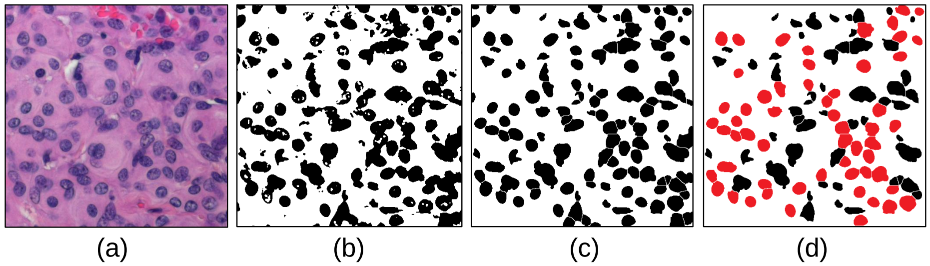

Fig. 3. Segmentation and extraction of meningioma nuclei. (a). colored image, (b). after *k*-means clustering for *k*=2, (c). after morphological operations and watershed transform, (d). final segmented image with extracted nuclei.

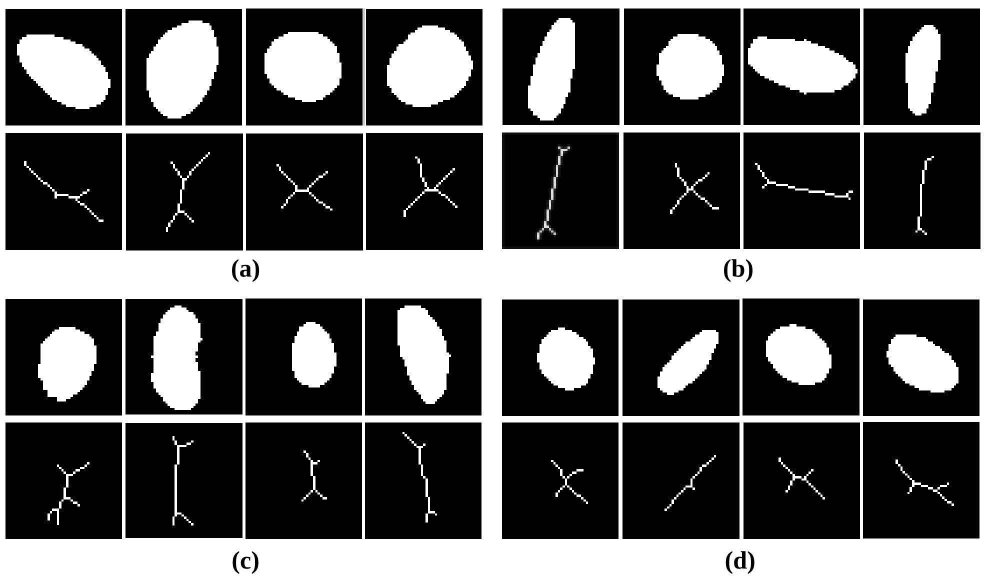

Fig. 4. The cell nuclei and the skeletons for four meningioma subtypes. From (a) to (d) are meningothelial, fibroblastic, transitional and psammomatous nuclei and their respective skeletons.

$C(u, v)$ to an affine transformation that aligns one interpolated curve with the other. $C(u, v)$ is termed as topological distance or shock distance (weight) between u and v. The depth-first search is applied in adaptive fashion to match the subtrees which effectively recomputes the branches at each node by choosing the next branch to descend in a best-first manner. The tree matching algorithm determines the minimum weight matching between two shock trees to find subtrees which are maximally similar in terms of their topological structure and geometry of their root nodes. For detailed theory on shock graphs, tree matching algorithms, and graphs recognition grammar, a reader may consult [20], [22].

4) Nuclei Classification: For nuclei classification, a train database having nuclei extracted from the segmented images of train set is created. The train database is divided into two partitions: train1 database having 75% data and test1 database having 25% data. All the nuclei from train1 and test1 database are processed to form skeletons and shock graphs (trees). The shock trees of all the extracted nuclei from the test image are matched to the shock trees of nuclei present in train database by using the tree matching algorithm.

To classify a single test nucleus from test1 database, k most similar nuclei to test nucleus are identified from train1 database. The value of k is determined in the range $\{1, \ldots, 100\}$ through cross validation. The class label of a test nucleus is assigned with majority vote from the k train nuclei with confidence C_N being the normalized frequency of class as given in equation 1.

$$C_N = \frac{c}{k}. \tag{1}$$

Where C_N is the confidence of an individual test nucleus in the range [0-1]. k is the total count of most similar train nuclei used for comparison. For each nucleus, c is the count of majority vote (i.e. count of k most similar train nuclei having the assigned class label). If there are more class labels with same value of c then one class label is selected at random. All the extracted nuclei of a meningioma test image are therefore labeled through majority vote of k similar train nuclei.

To classify a test image, class label is assigned by considering two measures, majority voting and confidence averaging of its labeled nuclei. The voting of all the test nuclei based on class label is performed and a confidence value C_{Class}, that is mean of confidence values of the nuclei belonging to a particular class is calculated as given in equation 2.

$$C_{Class} = \sum_{n=1}^{f} \frac{C_{Nn}}{f}. \quad (2)$$

Where f is the frequency of a particular class determined on account of voting of nuclei from a test image. C_{Nn} is the confidence value of a particular test nucleus.

In order to assign a class label to a test image, two scenarios are followed:

- If a particular class has the highest number of votes with the highest C_{Class} value, then assign the label of that class to test image.
- If one class has the highest number of votes but some other class has the highest C_{Class} value, then class label is assigned by performing the following steps.
  1) Sort all the classes based on C_{Class} value
  2) Select the class with the highest C_{Class} value till the class with the highest number of votes
  3) Retain the selected class having atleast 25% votes, otherwise discard the class
  4) Keep the count of nuclei n_c for the class with the lowest number of votes
  5) Sort all the nuclei of each selected class based on C_N values and retain top n_c nuclei
  6) Calculate C_{Class} value for each class by using equation 2
  7) Assign class label to the test image with the highest C_{Class} value

If classification results obtained for test1 database are satisfactory for all the classes of a dataset, then the classification framework is based on phase-I. In case of meningioma dataset, the classification results obtained for test1 database for *Mn* and *Fb* subtypes are good, while for *Tr* and *Ps* subtypes are unsatisfactory. This emphasized the need of a hybrid framework which not only focuses on local structural characteristics but also considers global texture for improved classification of weakly classified subtypes. In order to identify test samples for classification through phase II, the comparison is made on basis of C_{Class} value. The class label is declared correct for test samples that are classified as *Mn* and *Fb* with C_{Class} value greater than an empirically specified threshold α=0.5. On the other hand, the remaining test samples that are labeled as *Tr* or *Ps* or as *Mn* or *Fb* with a confidence less than threshold α are classified through phase II based on intrinsic texture. The value of threshold α is determined in the range [0-1] through cross validation on training data. The obtained value of α confirms the assignment of class label by considering more than 50% votes.

B. Phase II: Classification Based on Intrinsic Texture

In this phase, the meningioma test images that were labeled in phase I as either *Tr* and *Ps* subtypes or as either *Mn* and *Fb* subtypes with C_{Class} value less than threshold α are recognized on the basis of their inherent textural patterns. The statistical texture features are computed at different orientations to get significant textural correlations and used for classification. In phase II, the main steps performed are as follows: 1) input RGB images are decomposed into constituent color channels and grey-scale morphological operations are performed; 2) the statistical RLM features are extracted from three color channels; 3) an optimal feature subset is selected through a classifier based evolutionary feature selection scheme; and 4) finally, the selected optimal feature subset is used for recognition of unknown test samples through SVM classifier.

1) Pre-processing: All the input images are decomposed into R, G, B color components. The basic grey-scale morphological operations [15] are executed on each color channel image to highlight the basic textural trends and to eradicate superfluous details. The Morphological gradient (M_g) – the difference between dilation and erosion of an input image – is computed to pre-process meningioma images by using equation 3.

$$M_g = (I(x, y) \oplus s(x, y)) - (I(x, y) \ominus s(x, y)) \quad (3)$$

Where $I(x, y)$ is a grey-scale image and s is a structuring element determined empirically to be a square of 5x5 pixels of ones.

The red color channel images for two meningioma subtypes (*Tr* and *Ps*) and their corresponding morphological processed images are shown in Fig. 5.

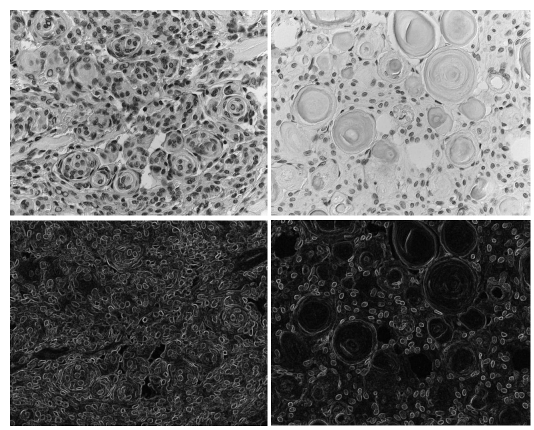

Fig. 5. Pre-processing of meningioma subtypes images. From (a-b) are red color channel images (top ones) of Transitional, and Psammomatous subtypes and their corresponding morphological processed images (bottom ones).

2) Feature Extraction: Grey-level run-length matrices basically quantize image regions in runs of pixels and compute histograms of grey-level run-lengths in various orientations. Four run-length matrices are computed at orientations (0°, 45°, 90°, and 135°) using 256 grey-levels for three R, G, B color channel images. Eleven statistical textural features are calculated from computed run-length matrices [23]. These features include: Short Run Emphasis (SRE), Long Run Emphasis (LRE), Grey-Level Non-uniformity (GLN), Run Length Non-uniformity (RLN), Run Percentage (RP), Low Grey-Level Run Emphasis (LGLRE), High Grey-Level Run Emphasis (HGLRE), Short Run Low Grey-Level Emphasis (SRLGLE), Short Run High Grey-Level Emphasis (SRHGLE), Long Run Low Grey-Level

Emphasis (LRLGLE), Long Run High Grey-Level Emphasis (LRHGLE).

3) Evolutionary Feature Selection Scheme: In the proposed framework, an evolution-based optimization search technique is employed which used classification accuracy as criterion for optimal feature selection. The Genetic Algorithm (GA) in combination with Support Vector Machine (SVM) is used to select the most relevant subset of features that improves classification accuracy on training data for *Tr* and *Ps* subtypes. There is no minimum or maximum limit on number of selected features from GA. Therefore, a heuristic search is performed in space of subsets of features where the quality of a candidate feature subset is evaluated through SVM classifier. Three kernel functions of SVM (linear, Gaussian RBF and quadratic) are explored and three optimal feature subsets are obtained.

a) Chromosome Design: A GA individual called chromosome is used to signify a feature subset from the space of all possible feature subsets. A random population of 150 chromosomes is created where each chromosome is represented through a binary string which possess a set of active or inactive genes. Active genes indexes represent the features which will contribute in the classification process. The length of each chromosome is 132, where 44 genes are reserved for features from each red, green and blue color channels respectively.

The interpretation of chromosome for the red color channel is shown in Fig. 6. Each feature has four indexes reserved for it. These correspond to the four orientations that are $0°$, $45°$, $90°$ and $135°$. The genes with "1" represent active features and "0" represent inactive features.

b) Fitness Function: Fitness of each chromosome is a measure of its goodness on classification problem. To compute this, active genes in the chromosome are employed for classification and resultant average accuracy is used as fitness of the chromosome. The fitness of each individual is evaluated through SVM classifier. The primary task of fitness function is to guide the system towards selecting the most effective features. The classification accuracy A_{CC} is the number of meningioma samples (instances) correctly classified (true positives plus true negatives) from all the classified samples and is calculated by using equation 4.

$$A_{CC} = \frac{I_{CC}}{I_{TC}} \times 100 \tag{4}$$

Where I_{CC} is the number of instances correctly classified and I_{TC} is the total number of instances classified.

c) Individual Selection: The most fit individuals are selected for genetic operations through the tournament selection operator. A set having seven most fit individuals is selected to have a contest for individual selection.

d) Recombination Operators: The genetic information is exchanged between a couple of selected chromosomes by using one point crossover operator with a suitably higher crossover rate i.e. 0.8. A uniform mutation operator is used to introduce diverse individuals by flipping binary gene values of the selected chromosomes with 0.01 probability.

e) Termination Criteria: Each run of GA is terminated when there is no improvement in fitness value for a specified number of generations. The best individual at the end of one run is hired to survive as individual in the initial population of next run. Therefore, the optimization process of GA is proceeded in the form of cascaded runs; that is, the most fit individual of the final generation of one run is seeded to the next run for incorporation as individual in the initial random population. The best individual of last run is selected as the final feature subset. A sufficient number of cascaded runs are performed for the efficient exploration of search space and avoidance of getting local optimal solution.

4) Classification of Meningioma Textures: Three kernel functions (linear, RBF and quadratic) of SVM and associated selected feature subsets are compared based on training accuracy. The kernel function and the feature subset with the highest accuracy are selected for recognition of unseen test samples. Therefore, SVM classifier with the selected kernel function is employed for classification of unseen meningioma textures. The optimal values for SVM parameters are found through grid-search method using cross validation and values with the highest cross validation accuracy are selected. The value for γ; that is, width of Gaussian function for RBF SVM, is found in the range $\{2^{-3}, ..., 2^{4}\}$ and value of cost parameter C is found in the range $\{2^{-3}, \ldots, 2^{21}\}$. For estimation of separating hyperplane, Least Squares (LS) [24] method is used.

IV. Experimental Setup and Results

A. Meningioma Dataset

The dataset used in this research is anonymized and de-identified. The diagnostic meningioma tumor samples are attained from the neurosurgical resections at the Bethel Department of Neurosurgery, Bielefeld, Germany. The routinely formalin-fixed, paraffin-embedded, Hematoxylin and Eosin (H&E) stained histological slides are examined on a Zeiss Axioskop2 plus microscope having a Zeiss Achroplan 40x/0.65 lens. Zeiss AxioVision 3.1 software and a Zeiss AxioCam HRc digital color camera (Carl Zeiss AG, Oberkochen, Germany) is utilized to capture 24 bit, true color RGB pictures in TIF format. For each subtype, histology data of five patients is collected and for each patient, four digital images having dimensions of 1300x1030 pixels are captured. First, all the digitized histology images are truncated to 1024x1024 pixels, then each truncated image is further partitioned into four images of 512x512 pixels having non-overlapping visual content. Hence, 16 images are attained for each patient and 80 images for each subtype. After processing, the final database comprises 320 images in total.

B. Classification Results

Meningioma dataset contains images of four subtypes, where each subtype have data of five different patients. Leave-one-patient-out cross validation strategy is applied by utilizing four patients of each subtype for training and one unseen patient (16 images) for evaluation. In this manner, five different folds are performed for fair evaluation of unseen test patients of four subtypes. In each fold, the dataset having data of 20 patients is divided into two sets: train set having data of 16 patients (4 patients per subtype) and test set having data of 4 patients (1 patient per subtype).

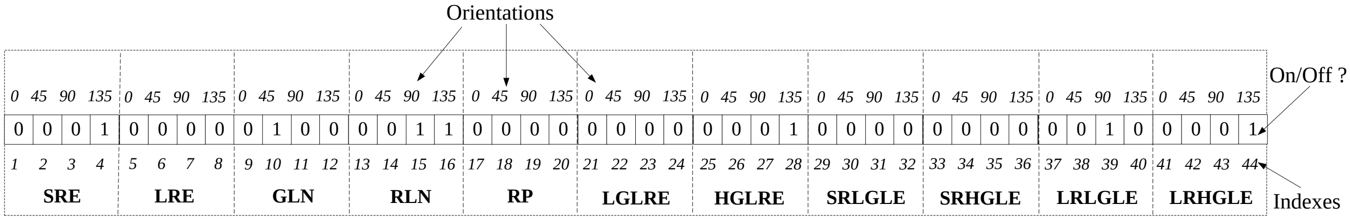

Fig. 6. Proposed chromosome structure for red color channel. Each feature is assigned four indexes corresponding to four directions, 0°, 45°, 90° and 135°. The values within the boxes show the selection or otherwise of the corresponding feature.

In phase I, five different training databases having nuclei extracted from training images are created excluding all the test images to perform five folds. From training data of four subtypes, 1024 meningioma nuclei are added to each database with an equal share of 256 nuclei from each subtype. 64 nuclei are collected from each patient with active contribution from each image. The increase in size of train database after a reasonable figure has no positive impact on classification results but negative impact on problem in terms of increased computational cost. To draw and match skeletons and shock graphs, an object recognition application named Shape Matcher 5 [25] is used. For evaluation of unseen meningioma samples, all the nuclei from a test image are compared with the entire training database to find relative similarity with each nuclei. The class label for test image is assigned based on voting and confidence averaging of all the test nuclei. The *Mn* subtype is classified with 93.75% accuracy. Likewise, the *Fb*, *Tr* and *Ps* subtypes are classified with 90%, 68.25% and 66.75% accuracy respectively. The classification results achieved through phase I revealed that the images belonging to *Mn* and *Fb* subtypes are classified with significantly high accuracy while the images from *Tr* and *Ps* subtypes with comparatively low accuracy. Therefore, it is perceived that the structural analysis of meningioma nuclei is a competent approach to discriminate *Mn* and *Fb* subtypes while it remained unable to perform well in case of *Tr* and *Ps* subtypes.

In phase II, the linear SVM with the optimal feature sets achieved an overall test accuracy of 99.38% over five folds. *Tr* subtype has 100% and *Ps* subtype has 98.75% accuracy. It is observed that there is a significant improvement in classification accuracy achieved through texture analysis at image-level for both the *Tr* and *Ps* subtypes as compared to nuclei shape matching. The classification results achieved through the proposed hybrid classifier for four subtypes of meningioma in five folds are presented in Table I.

The overall classification accuracy obtained for four subtypes of meningioma averaged over five folds is 95.63%. The mean accuracy of 93.75% is achieved for *Mn*, 90% for *Fb*, 100% for *Tr* and 98.75% for *Ps*. The proposed hybrid classification framework achieved high accuracy; that is, 90% or more for all the subtypes of meningioma.

1) Performance Comparison of Classifiers: The performance of various classifiers is investigated by classifying the feature set with all the features (132 features) through a diverse group of classifiers widely used in medical imaging applications including RBF SVM, linear SVM, Multilayer Perceptron (MLP), Random Forest, Naive Bayes and *k*-NN.

TABLE I. CLASSIFICATION RESULTS FOR FOUR MENINGIOMA SUBTYPES USING THE PROPOSED HYBRID CLASSIFIER IN FIVE FOLDS. Acc_{Mn}, Acc_{Fb}, Acc_{Tr} AND Acc_{Ps} – ACCURACY OF Mn, Fb, Tr AND Ps RESPECTIVELY. $Acc_{Overall}$ = MEAN CLASSIFICATION AACCURACY AVERAGED OVER FOUR SUBTYPES FOR A PARTICULAR FOLD. Avg = AVERAGE ACCURACY FOR FIVE FOLDS

$Fold\#$	$Phase1$		$Phase2$		$Hybrid$
	Acc_{Mn}	Acc_{Fb}	Acc_{Tr}	Acc_{Ps}	$Acc_{Overall}$
1	100	93.75	100	100	98.44
2	100	87.50	100	100	96.88
3	87.50	87.50	100	100	93.75
4	100	93.75	100	100	98.44
5	81.25	87.50	100	93.75	90.63
Avg	93.75	90	100	98.75	95.63

The classification result obtained through different classifiers is presented in Table II. The result showed that linear SVM outperformed other classifiers for both Tr and Ps subtypes while, quadratic SVM classified the Ps subtype with high accuracy.

TABLE II. CLASSIFICATION RESULTS (ACCURACY (%)) OBTAINED THROUGH DIFFERENT CLASSIFIERS BY USING COMPLETE FEATURE SET (132 FEATURES). F_o IS THE COUNT OF THE FEATURES USED. Acc_{Tr} AND Acc_{Ps} ARE % ACCURACY OF Tr AND Ps SUBTYPES. $Acc_{Overall}$ IS THE MEAN ACCURACY OF TWO MENINGIOMA SUBTYPES)

$Classifier$	F_o	Acc_{Tr}	Acc_{Ps}	$Acc_{Overall}$
SVM_{Linear}	132	**88.75**	**96.25**	**92.50**
SVM_{RBF}	132	78.75	83.75	81.25
$SVM_{Quadratic}$	132	78.75	**96.25**	87.50
MLP	132	68.75	96.25	82.50
$Random\ Forrest$	132	58.75	92.5	75.63
$Naïve\ Bayes$	132	58.75	83.75	71.25
KNN	132	48.75	97.5	73.13

Table III shows the parameter values used by each classifier.

TABLE III. VALUES OF THE PARAMETERS USED BY DIFFERENT CLASSIFIERS

Classifier	Parameter Name	Parameter Value
SVM	RBF Kernel's Gamma γ	$\gamma \in \{2^{-3}, \ldots, 2^{4}\}$
	Cost parameter C	$C \in \{2^{-3}, \ldots, 2^{21}\}$
MLP	Hidden Layers	1
	Neurons in Hidden Layer	4 (no. of classes)
	Learning Rate	0.3
	Momentum	0.2
Random Forest	$No.$ of Trees	10
kNN	$No.$ of Neighbors	1

2) Performance Comparison of Meningioma Classification Techniques: The proposed framework was compared with the recently published best techniques for the classification of meningioma dataset. The classification results are presented in Table IV. ADWPT [8] and TSA [13] techniques have performed 5-folds (leave-one-patient-out) cross validation for experimentation which is comparable with the proposed framework. The tabular statistics show that the proposed framework has shown considerable improvement in the highest overall classification accuracy along with the highest accuracy for all the subtypes of meningioma.

TABLE IV. COMPARISON OF CLASSIFICATION RESULTS AVERAGED OVER 5-FOLDS. Acc_{Mn}, Acc_{Fb}, Acc_{Tr} AND Acc_{Ps} – ACCURACY OF Mn, Fb, Tr AND Ps RESPECTIVELY. $Acc_{Overall}$ = CLASSIFICATION ACCURACY AVERAGED OVER FOUR SUBTYPES OF MENINGIOMA ACHIEVED BY ADWPT, TSA AND PROPOSED FRAMEWORK

Technique	Acc_{Mn}	Acc_{Fb}	Acc_{Tr}	Acc_{Ps}	$Acc_{Overall}$
ADWPT [8]	89	80	85	97	88
TSA [13]	93.75	90	95	91.25	92.50
Proposed	**93.75**	**90**	**100**	**98.75**	**95.63**

V. DISCUSSION

The meningioma nuclei and their respective skeletons with noteworthy characteristics are expected to offer significant contribution for the classification of meningioma variants. The histology images of meningioma subtypes shown in Fig. 1. have a clear visual representation of nuclei shapes owned by different subtypes. The nuclei for *Mn* subtype are usually round or oval shaped. The nuclei for *Fb* subtype are rod or spindle shaped and appear as thin thread like structures. If the visual structural analysis of *Mn* and *Fb* subtypes is performed on account of nuclei shapes and their respective skeletons, they show quite different nuclei and consequently their skeletons. The *Tr* subtype is also known as a hybrid or mixed subtype having characteristics of both *Mn* and *Fb* subtypes. The nuclei of *Tr* subtype are round, oval, rod-like or spindle shaped. Therefore, the *Tr* nuclei skeletons have a considerable similarity with skeletons of *Mn* or *Fb* nuclei. All the images of *Ps* subtype have a large number of psammoma bodies and relatively a small number of cell nuclei. In most of the cases, the nuclei are very small in size. For images of some *Ps* patients the nuclei look like very thin fibers or thread-like structures, while in some images of other patients, the nuclei are round or oval just like *Mn* nuclei. Again, some images have majority of small sized nuclei showing characteristics of *Tr* subtype. Therefore, the *Ps* nuclei and their skeletons show a mixed pattern of similarity to other subtypes besides some different and true *Ps* representatives. The morphological features of meningioma nuclei and their respective skeletons provides a valid reason for low classification accuracy achieved for *Tr* and *Ps* subtypes.

The images from *Tr* and *Ps* subtypes for test1 database are weakly classified owing to insufficient or small number of true representative nuclei. There are large variations in the nuclei contours appearing in different images of *Tr* and *Ps* subtypes. In case of Ps subtype, insufficient number of nuclei present in most of the segmented images and over-split or irregular-shaped nuclei also provided a reason for misclassification. If a test trial is performed to evaluate a *Ps* patient with images having thread-like nuclei, then the nuclei of test images will show greater similarity to *Fb* train nuclei as compared to *Ps*. In this case, when the class label will be assigned to an individual nucleus based on similarity, there will be great chance of misclassification. Accordingly, when the class label for a test image will be decided based on nuclei voting only, the image will be labeled as *Fb* instead of *Ps*.

Most of the meningioma classification techniques cited in Section II performed the texture analysis at image level for all the subtypes. Two subtypes of meningioma (*Mn* and *Fb*) have considerable structural differences, while the other two subtypes (*Tr* and *Ps*) have noteworthy textural variations. In this paper, the hybrid framework is proposed to capture both types of characteristics (local shape contours and global texture) for improved meningioma classification. The proposed hybrid framework presented the highest classification results in comparison with other meningioma classification techniques. If a histology dataset has some visual differences in nuclei shapes of all the subtypes, then phase-I is expected to present good classification results. If a dataset has subtypes with both types of structural and textural variations as in meningioma dataset, then hybrid framework seems a good option for classification.

VI. CONCLUSION

Meningioma subtype classification is a real-world multi-class classification problem of digital pathology. It is a quite complex pattern classification problem due to heterogeneity issues of tumor texture, low inter-class and high intra-class texture variations of tumor samples, and architectural variations of cellular components. In this paper, a novel hybrid framework based on nuclear level shape and image level texture analysis is proposed for the histology classification of benign meningioma subtypes. The basic aim of the proposed hybrid framework is the achievement of promising classification results for all the subtypes of meningioma while dealing with the inherent complexity and texture variations. The ultimate goal is to mimic the prognosis decision of expert pathologists and assist newer pathologists or others in making the right and quick decisions. The proposed framework comprises two main phases: Shape analysis of nuclei through matching of skeletons and shock graphs and texture analysis through extraction of higher-order texture features from RGB color channels. The proposed hybrid framework efficiently captured shape and texture variations and classified meningioma subtypes with 95.63% accuracy. In the future, other texture measures and methods for optimal feature subset selection may be explored. The alternate methods to improve the quality of segmentation may also be investigated.

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DoS Detection Method based on Artificial Neural Networks

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***Abstract*—DoS attack tools have become increasingly sophisticated challenging the existing detection systems to continually improve their performances. In this paper we present a victim-end DoS detection method based on Artificial Neural Networks (ANN). In the proposed method a Feed-forward Neural Network (FNN) is optimized to accurately detect DoS attack with minimum resources usage. The proposed method consists of the following three major steps: (1) Collection of the incoming network traffic, (2) selection of relevant features for DoS detection using an unsupervised Correlation-based Feature Selection (CFS) method, (3) classification of the incoming network traffic into DoS traffic or normal traffic. Various experiments were conducted to evaluate the performance of the proposed method using two public datasets namely UNSW-NB15 and NSL-KDD. The obtained results are satisfactory when compared to the state-of-the-art DoS detection methods.**

Keywords*—*DoS detection; Artificial Neural Networks; Feed-forward Neural Networks; Network traffic classification; Feature selection

I. Introduction

DoS attack is a rapidly growing problem that continues to threat web services' availability in our days. It aims mainly to deprive legitimate users from Internet services [1]. Despite the important evolution of the information security technologies, the attack continues to challenge the existing defense systems [2]. According to [3] there are four implementation schemes of DoS defense systems: Source-end, intermediate, distributed and victim-end. Considering the difficulties of source-end, intermediate and distributed defense systems discussed in [3], we designed the proposed DoS detection method as a victim-end solution. The victim-end DoS defense systems are deployed in the victim's infrastructure, which allows efficient analysis of the incoming network traffic to the victim. Although, victim-end defense systems are the most practically applicable, they require evolution and application of sophisticated and intelligent techniques. However, the more sophisticated the victim-end defense systems become, the more they consume significant amounts of computational, storage and networking resources of the victims. Therefore, the ideal DoS defense system seem to be a victim-end defense system that can detect the attack accurately, in less period of time and with low computational cost. In this paper we present a DoS detection method based on Artificial Neural Networks (ANN) [4], [5]. The proposed method is a victim-end solution in which a Feed-forward Neural Network (FNN) [6], [7] is used to classify the incoming network traffic into DoS or normal. The simplicity of the proposed method design which consists of three layers (input, hidden and output layers) allows to detect DoS attack with minimum resources usage. The proposed method constitutes of three modules. The network traffic collector module used to collect the incoming network traffic to the victim's routers. The data pre-processing module responsible of normalizing the network traffic data and selecting relevant features. The detection module classifies the incoming network traffic into DoS traffic or normal traffic using an ANN classifier. Several optimizations are applied to the adopted ANN in order to improve the performance of the proposed method. These optimizations include selection of the optimum topology parameters and the optimum training algorithm, weight initialization function and activation function that yield better DoS detection performance. Kim K. J. et al. [8] have presented many optimization techniques that can improve the performance of a neural network for classification tasks. To improve the processing time and detection performance of the proposed method relevant features are selected using a Correlation-based Feature Selection method [9], [10]. The proposed method was evaluated on two datasets namely NSL-KDD [11] and UNSW-NB15 [12], [13]. Compared to the state-of-the-art the obtained results are satisfactory. The contributions of this paper can be summarized by the following points:

- Optimization of a single ANN classifier to accurately detect the DoS traffic in different network protocols, rather than using a specific classifier for each network protocol which is costly in computation and time.
- Adoption of an unsupervised CFS method for selecting relevant features of DoS attack with low computational cost.

The reminder of this paper is organized as follows. Section II highlights state-of-the-art DoS detection methods which are based on machine learning approaches. An overview of the DoS attack is given in section III. Section IV introduces the feature selection method used in this paper. Section V presents a detailed explanation of the proposed DoS detection method. The conducted experiments are given in section VI. The obtained results, the results discussion and the conducted comparisons are detailed in section VII. Finally, section VIII draws the conclusion and outlines future works.

II. Related Works

Several previous methods have been developed to enhance the DoS detection time and accuracy by using Machine Learning approaches. Siaterlis C. et al. [14] have proposed a DoS detection method based on Multi-Layer Perceptron (MLP). The authors use multiple metrics to successfully detect flooding attacks and classify them as incoming or outgoing attacks. The MLP is trained with metrics coming from different types of passive measurements of network which allows to enhance the DoS detection performances. Similarly, Bhupendra Ingre and Anamika Yadav [15] have used an ANN to detect various type of attacks in the NSL-KDD dataset. Satisfactory results are obtained based on several performance metrics. Akilandeswari V. et al. [16] have used a Probabilistic Neural Network to discriminate Flash Crowd Event from DoS attacks. The method achieves high DoS detection accuracy with lower false positives rate. Adel Ammar and Khaled Al-Shalfan [17] have used feature selection method based on HSV to enhance the performance of neural network for intrusion detection. Alan S. et al. [18] have proposed a DoS Detection Mechanism based on ANN (DDMA). The authors used three different topologies of the MLP for detecting three types of DoS attacks based on the background protocol used to perform each attack namely TCP, UDP and ICMP. The mechanism detect accurately known and unknown, zero day, DoS attacks. The main drawbacks of DDMA are its large resource requirement and its limitation on only the TCP, UDP and ICMP protocols. The majority of the DoS defense systems in the literature are hybrid systems and combine two or more ML approaches to detect the attack which often overwhelms resources of the victim. Furthermore, the early detection of DoS attack is the main drawback of the existing DoS detection systems. Therefore, the need of a new DoS detection method that can detect the attack accurately with low computational and time costs.

III. DoS Attack

Flooding the victim with a large number of network packets or repeatedly sending to it corrupted or infected packets are the most common techniques used to perform the DoS attack [3]. There are two categories of DoS attack namely Direct DoS attack and Reflection-based DoS [19]. In the Direct DoS attack the attacker uses the zombie hosts to flood directly the victim host with a large number of network packets. Within a short time interval the victim is crippled causing a deny of services. Figure 1 illustrates the Direct DoS attack. Whereas, in

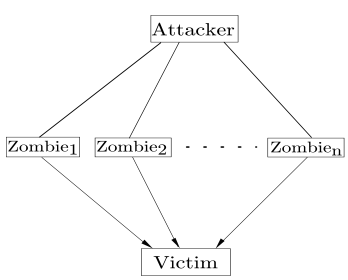


Fig. 1. Direct DoS attack

the Reflection-based DoS attack the attacker uses the zombie hosts to take control over a set of compromised hosts called Reflectors. The latter are used to forward a massive amount of attack traffic to the victim host, as illustrated in figure 2. The principal role of the Reflectors in this attack is to reflect the Botmasters commands and hide his IP address. Understanding

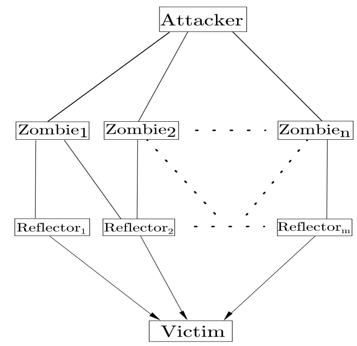


Fig. 2. Reflection-based DoS attack

how DoS attack works is a necessary step towards the design of appropriate DoS attack detection systems. In both types of DoS attack, the computers infected by the same Bot conduct the same behavior. This behavioral similarity leads to a correlation or even a redundancy in the network traffic data of the Reflectors belonging to the same Botnet. On the other hand, the relevant features in the network traffic dataset of Reflectors that belong to the same Botnet have the same variations over the time. Based on this distinction of the DoS traffic and the legitimate traffic, one can easily classify them.

IV. Feature Selection

Feature Selection (FS) is an important issue in machine learning. It aims at selecting optimal subset of relevant features from the original dataset. Removing trivial and redundant features enhances the performances of the learning algorithm and the modeling of the phenomena under analysis. However, FS is usually skipped and the features are selected without a proper justification [20]. There are mainly three categories of feature selection approaches. Wrapper approach [20], [21] uses a predetermined machine learning algorithm to select the new features subset. Where the classification performance is used as the evaluation criterion. Embedded approach performs feature selection in the process of training and are usually specific to the machine learning algorithm [20]. Filter approach [20], [21] depends on the general characteristics of data to select the new set of features. The features are ranked based on certain statistical criteria, where the features with highest ranking values are selected. Filter methods include Consistency-based Feature Selection (CNF) [22] and Correlation-based Feature Selection (CFS) [23]. In the CNF relevant features are selected based on their contribution to enhance the learning algorithm' accuracy. In spite of the important improvement in the accuracy of the classifiers that CNF brings, it consumes important computational resources and the selection takes more time. Whereas, in CFS relevant features are selected based on their correlation to the output class which does not requires high computational and time cost to improve the classifier performances. Hence, it is more appropriate for the DoS attack detection problem. The CFS method used in this paper is based on the Pearson Correlation Coefficient (PCC). A definition of the PCC is given in the following section.

A. Pearson correlation coefficient

The Pearson correlation coefficient (ρ), better known as the correlation coefficient, is a measure of dependence or similarity between two random variables [24]. ρ summarizes the relationship between two variables that have a straight line or linear relationship with each other. The Pearson correlation coefficient ρ can be defined as follows. Suppose that there are two variables X and Y, each having n values x_1 ,$x_2, \ldots, x_n$ and y_1, $y_2, \ldots, y_n$ respectively. The Pearson's coefficient ρ is computed according to the following formula:

$$\rho = \frac{cov(X,Y)}{\sqrt{\sigma^2(X)\sigma^2(Y)}} \tag{1}$$

Where $cov(X,Y)$ is the covariance between X and Y, and σ is the standard deviation. Let the mean of X be $\bar{x_i}$ and the mean of Y be $\bar{y_i}$. The estimation of the Pearson correlation coefficient ρ is given by:

$$\rho = \frac{\sum_i (x_i - \bar{x_i})(y_i - \bar{y_i})}{\sqrt{\sum_i (x_i - \bar{x_i})^2 \sum_j (y_i - \bar{y_i})^2}} \tag{2}$$

The value of ρ lies between -1 and 1. $\rho = -1$ means perfect negative correlation, as one variable increases the other decreases. $\rho = 1$ means perfect positive correlation. $\rho = 0$ means no linear correlation between the two variables. Thus, features redundancy can be detected by correlation analysis. The features which are strongly correlated positively represent a redundant information.

B. CFS method

The CFS method used in this paper constitutes of two main steps. We already know that a feature is highly correlated to to another feature as ρ between them go near to 1.

In the first step, for each pair of features X_i and X_j in the dataset we compute the Pearson's coefficient ρ_{ij} in order to detect redundant features subset. According the formulate (1), ρ_{ij} between X_i and X_j is defined as follows:

$$\rho_{ij} = \frac{cov(X_i, X_j)}{\sqrt{\sigma^2(X_i)\sigma^2(X_j)}} \tag{3}$$

We consider only whether the upper triangular matrix $\rho_{ij(i=1,2,\ldots,j,j+1,\ldots,n)}$,or the lower triangular matrix $\rho_{ij(j=1,2,\ldots,i,i+1,\ldots,n)}$. The features X_i and X_j corresponding to $\rho_{ij} > \delta$ are considered redundant, only one of them is selected to the new dataset of relevant features. Where, δ is the PCC threshold, its optimum value is $\delta = 0.4$ which is determined empirically (see section VII-B).

In the second step, for each feature we create a list of its correlated features. The features correlated with highest number of other features are considered relevant and they are selected first for the new dataset. This because they contain more information about their correlated features. The latter are dropped from the ρ_{ij} matrix. At the end a list of high relevant features is constructed.

C. Dataset

The UNSW-NB15 dataset contains nine types of modern attacks and new patterns of normal traffic. It has 49 features split into five groups namely Flow features, Basic features, Content features, Time features and Additional generated features. This dataset contains a total number of 257,705 records labeled whether by an attack type label or a normal label. A number of 16,353 records correspond to the DDoS attack. For efficient evaluation of the proposed method, normal and DDoS records are filtered from UNSW-NB15. The resulted subset consists of 109,370 records of DDoS and normal traffic. The training and testing sets constitute respectively of 60% and 40% of the subset. Three major reasons motivated us to use the UNSW-NB15 dataset. The dataset contains modern normal and attack traffic, it is well structured and comprehensible and it is more complex than other previous datasets which makes it a good benchmark to evaluate our method. The NSL-KDD dataset contains four types of attacks namely DoS, Probe, R2L and U2R. It has 41 features divided to three groups: Basic features, Traffic features and Content features. This dataset contains a total number of 148,517 records in both training and testing sets. We selected this dataset for two main reasons. First, it is widely used for IDSs' benchmarking in the literature. Also, it overcomes some of the inherent problems of its predecessors KDD Cup'99 and DARPA'98 [11], such as records redundancy and duplication. To use the UNSW-NB15 dataset in the learning of the proposed method, we perform the following preprocessing tasks. First we drop the 14 additional generated features from the dataset. Second, as we previously mentioned in section III, the DoS attack is mainly based on Reflectors. Where a Reflector is a legitimate computer controlled by the attacker, which use his IP address to perform the DoS. Hence, in the DoS attack the IP address do not contain relevant information to classify its traffic. The source and destination IP features are then dropped from the dataset. This allows to generate a reduced dataset of 33 features. Finally, the CFS method is used to select relevant features form the generated dataset. The final dataset is reduced from 33 features to 6 relevant features showed in table 1.

The final dataset constitutes of 31,283 records of DoS and normal traffic. The records are labeled as 1 to designate a DoS record and 0 to designate normal record.

V. ANN-based DoS Detection Method

A. Framework of the detection method

The basic framework of the proposed DoS detection method consists of the following four modules:

Network traffic collector module: is a program implemented in the edge network routers of the victim. This module collects the incoming network packets to the victims routers. For this purpose we use Tshark [25], other sniffer tools can be used such as Tcpdum [26].

Data preprocessing module is responsible of normalizing values of features and selecting relevnt features for DoS detection. Generally, values of attributes in a network traffic dataset are not distributed uniformly. It is important to maintain a uniform distribution of each attribute values before starting the learning process. For this purpose we use the *MinMax* method. In *MinMax* the values of features are scaled to the range [0, 1] as follows:

$$x_i^{new} = \frac{x_i - \min(X)}{\max(X) - \min(X)} \quad (4)$$

Where X is a relevant feature, x_i is a possible value of X within the current time window and x_i^{new} is the normalized value. The module selects relevant features for DoS detection from UNSW-NB15 [12], [13] or NSL-KDD [11] datasets using the method detailed in IV-B.

DoS detection module: responsible of the classification of the incoming network traffic to the victim's routers. This module is based on a three layers ANN, more details about this module are given in V-B6. The proposed DoS detection method follows a specific process that consists of three main steps illustrated in figure 3.

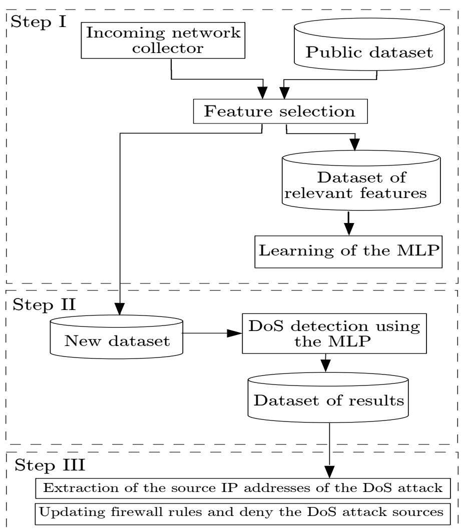


Fig. 3. DoS detection process

B. Network traffic classification

This section introduces the adopted MLP to classify DoS traffic and normal traffic. Moreover, we present here the optimization techniques applied to the adopted MLP in order to improve the DoS detection performances and time of the proposed method. These techniques include the topology of the MLP, the learning algorithm, the weights initialization function, the activation function and the cost function. First let us give an overview of the MLP.

1) Multi-layer perceptron: A Multi-Layer Perceptron (MLP) is a feed-forward neural network which constitutes of one or more hidden layers of neurons, computational units, linked by weighted arcs often called synapses. Consider a MLP in which the activation Z_i of the i^{th} unit is a non-linear function. Each hidden unit of the MLP computes its input data according to the following models [4], [5]:

$$Z_i = f(a_i) \quad (5)$$

$$a_i = \sum_j w_{ij} z_i + b_i \quad (6)$$

Where a_i is given by a weighted linear sum of the outputs of other units, w_{ij} is the synaptic weight from unit i to unit j, and b_i is a bias associated with unit i.

2) Topology of the adopted MLP: The MLP topology used is related to the subset of relevant features of the input dataset. According to the relevant features subsets obtained in the section VI-B, we designed our MLP of 6 input units for the UNSW-NB15 dataset and 5 input units for the NSL-KDD dataset. For both datasets one output unit is used. The discrimination of the DoS traffic from normal traffic does not requires many hidden layers. Therefore, for this purpose we used the single hidden layer MLP. The number of units in the hidden layer is crucial for optimal learning and better performances of the MLP. Large number of hidden units causes the over-fitting problem. Whereas, a small number of the hidden units causes the under-fitting problem [4], [5]. In our case, based on the empirical results in section VII-C, the optimum number of hidden units of the MLP that produces best classification performances in less period of time is 7 for the UNSW-NB15 dataset and 6 for the NSL-KDD dataset.

3) Learning algorithm: Backpropagation is a very popular neural network learning algorithm because it is conceptually simple, computationally efficient, and because it often works [27]. In our case we trained the backpropagation algorithm using the mini-batch stochastic gradient descent (SGD) algorithm, which is much faster and which allows to the learning algorithm to avoid local minimums [26].

4) Weights initialization function: The weights initialization function has a significant effect on the training process of a neural network. Weights should be chosen randomly but in such a way that the activation function is primarily activated in its linear region. Extremely large or small weights causes the saturation of the activation function in small gradients and makes the learning slow. Whereas, intermediate weights produce enough large gradients, hence the learning process proceed quickly [27]. In order to achieve this, we used the LeCun's uniform initialization function [28], in which the weights are drawn from a uniform distribution with mean zero and standard deviation defined as follows:

$$\sigma_m = m^{-1/2} \quad (7)$$

Where m is the number of the connections feeding into the neuron.

5) Activation function: In this paper we used the standard logistic function as the activation function of the adopted MLP [29], [28]. The standard logistic function or softmax is a generalized case of the logistic regression where the labels were binary: $y(i) \in \{0, 1\}$. The Softmax allows us to handle $y(i) \in \{1, \ldots, K\}$, where K is the number of classes. Let $\{(x(1), y(1)), \ldots, (x(m), y(m))\}$ be a training set of m labeled examples. Where $x(i)$ are the input features and $y(i)$ represents the labels. In the logistic regression the labels are binary $y(i) \in \{0, 1\}$. Whereas, in the standard logistic function the labels are multi-class $y(i) \in \{1, 2, \ldots, K\}$. The standard logistic function is defined as follows:

$$h_\theta(x) = \frac{1}{1 + \exp(-\theta^\top x)} \quad (8)$$

Where θ represents the model parameters which are trained to minimize the cost function.

6) Cost function: In [29] Xavier G. and Yoshua B. found that the standard logistic function coupled with the Cross-entropy cost function worked much better for classification problems than the quadratic cost which was traditionally used to train feed-forward neural networks. Hence, we adopted the Cross-entropy as our cost function which is defined as follows:

$$J(\theta) = -\left[\sum_{i=1}^{m} y^{(i)} \log h_\theta(x^{(i)}) + (1 - y^{(i)}) \log\left(1 - h_\theta(x^{(i)})\right)\right] \tag{9}$$

Where θ is the model parameters and $h_\theta()$ represents the activation function.

VI. Experiments

In this section we aim to assess the performances of the proposed DoS detection method and to illustrate the impact of the optimization techniques on the MLP performances. First, let us refer to the proposed method as ANN-based DoS Detection Method (ADDM). The performances of ADDM were compared with an unoptimized MLP (u-MLP) that we developed for this purpose. Both methods ADDM and u-MLP are trained and tested using the dataset of relevant features obtained in section VI-B. Two more experiments were performed in order to find the optimum PCC threshold value and the optimum number of hidden units of the ADDM. Further comparisons of ADDM performances were conducted with the NSL-ANN [15], the HSV-ANN [17], the DDMA [18] and the ANN [13]. The hardware used in our experiments is a core i3 2.4 GH and 6 GB of memory running under Debian 8 x64. ADDM is implemented using two Python frameworks namely Keras [30] and Theano [31].

A. Performance metrics

The main purpose of the ADDM is to classify the captured network flow data as either positive or negative which correspond respectively to DoS traffic and normal traffic. The confusion matrix has four categories: True positives (TP) are examples correctly labeled as positives. False positives (FP) refer to negative examples incorrectly labeled as positive. True negatives (TN) correspond to negatives correctly labeled as negative. Finally, false negatives (FN) refer to positive examples incorrectly labeled as negative. The experimental results of the ADDM are evaluated using the following performance metrics:

Accuracy: percentage of the traffic records that are correctly classified by the ADDM.

$$Accuracy = 100 * \frac{TP + TN}{TP + TN + TN + FN} \tag{10}$$

Sensitivity or True Positive Rate (TPR):

$$Sensitivity = \frac{TP}{TP + FN} \tag{11}$$

Specificity or True Negative Rate (TNR):

$$Specificity = \frac{TN}{FP + TN} \tag{12}$$

False Alarm Rate (FAR): The false alarm rate is the average ratio of the misclassified to classified records either normal or abnormal as denoted in the following equation:

$$FAR = \frac{FPR + FNR}{2} \tag{13}$$

where $FPR = \frac{FP}{FP+TN}$ is the false positive rate and $FNR = \frac{FN}{FN+TP}$ is the false negative rate.

Processing time: DoS detection time depends on two time metrics: training time and testing time.

ROC and AUC curves: Receiver Operator Characteristic (ROC) and Area Under ROC (AUC) curves are commonly used to present results for binary decision problems in machine learning. The ROC curve shows how the number of correctly classified positive examples varies with the number of incorrectly classified negative examples. The AUC value represents the accuracy of the classifier.

B. Data pre-processing

The values of each attributes in the UNSW-NB15 and NSL-KDD datasets are not distributed uniformly. It is important to maintain a uniform distribution of each input attribute in the datasets before starting the training process of the MLP. For this purpose the *MinMax* method, as described in section V-A, is applied to the datasets. Then, the feature selection method presented in section **??** is applied to both the UNSW-NB15 and the NSL-KDD datasets. Table I shows the final subsets of relevant features used in the experiment.

TABLE I. Relevant Features Selected for DDoS Detection

Dataset	CFS subset
UNSW-NB15	F7,F10,F11,F12,F18,F32
NSL-KDD	F6,F11,F19,F23,F26

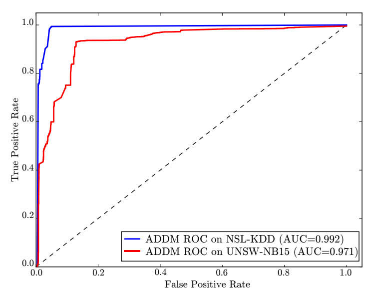
VII. Results and Discussion

A. DoS detection performances

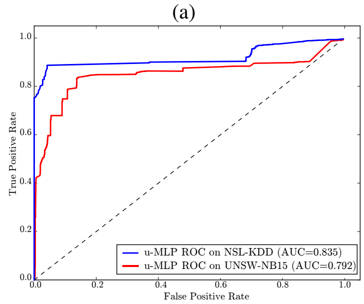
In order to evaluate the performances of the ADDM and u-MLP both datasets UNSW-NB15 and NSL-KDD are used. The obtained testing results are compared with the findings in the related works [15], [17], [18], [13]. Table 2 summarizes the obtained results and the performed comparisons. It is obvious that the ADDM has the highest testing accuracy rates in the shortest period of time: 97.1% on UNSW-NB15 in 0.46s and 99.2% on NSL-KDD in 0.35s. Whereas, the u-MLP achieved 79.2 on UNSW-NB15 in 3.05s and 83.5% on NSL-KDD in 2.16s.The remain DoS detection accuracy rates of DDMA, NSL-ANN, HSV-ANN and ANN are respectively 98%, 81.2%, 92% and 81.34%. The applied optimizations techniques on the ADDM have improved significantly the DoS detection accuracy rate. The shortest DoS detection time intervals are 0.46s and 0.35s which correspond to the ADDM. The feature selection phase has enabled the ADDM to reduce drastically the DoS detection time. Overall, these experimental results agree well with our expectation, i.e., the optimization techniques applied on the ADDM improve the DoS detection

TABLE II. THE TESTING PERFORMANCES OF THE ADDM COMPARED WITH U-MLP, DDMA[18], NSL-ANN[15], HSV-ANN[17] AND ANN[13]

Method	Testing accuracy rate (%)	Testing time (s)	Dataset	Sensitivity (%)	Specificity (%)	FAR (%)
ADDM	97.1 99.2	0.46 0.35	UNSW-NB15 NSL-KDD	97 99	100 100	0.06 0.02
u-MLP	79.2 83.5	3.05 2.16	UNSW-NB15 NSL-KDD	82 90	87 93	0.14 0.11
DDMA	98	NA	Local dataset	96	100	NA
NSL-ANN	81.2	NA	NSL-KDD	0.96	0.70	0.32
HSV-ANN	92	NA	KDDCup 99	NA	NA	0.15
ANN	81.34	NA	UNSW-NB15	NA	NA	21.13



(a)



(b)

Fig. 4. ROC curves summarizing the DoS detection performances of ADDM (a) and u-MLP (b).

performances and the processing time. The ROC curve of the ADDM and the u-MLP are plotted in figures 4(a) and 4(b) respectively. The experimental results obtained in the testing phase are used to plot the ROC curves in order to better understand the trade-of between the TPR and the FPR of the ADDM and the u-MLP. Figures 4(a) and 4(b) depict that the ADDM has high true positive rate with fewer false alarms. Whereas, the u-MLP has lower true positive rate and high false alarm rate that exceeds 15%. The ADDM acquired the highest AUC values.

B. Optimum PCC Threshold Selection

Feature selection aims at selecting a set of relevant features from the original dataset. Eliminating the redundancy allows to reduce the dataset dimension, which improves the ADDM processing time. While, using relevant features improves the ADDM accuracy. The PCC threshold value ρ is used to find high correlated features that contain redundant information. From a set of redundant features only one feature is selected. This implies selection of different distributions of features for each value of δ. In order to determine the preference value of δ which corresponds to the optimum dataset that produces high accuracy rate, for each dataset the ADDM was fitted with the obtained subsets corresponding to each value of δ. The threshold value that corresponds to the highest accuracy rate of ADDM is then selected. Figure 5 summarizes the conducted experiment results to select the optimum value of δ, it shows the ROC curves of the ADDM fitted with different feature subsets for each value of δ. It is obvious that the value $\delta = 0.4$ corresponds to the highest accuracy rate of ADDM. A dataset of relevant features is then selected, as shown in table 1 section VI-B.

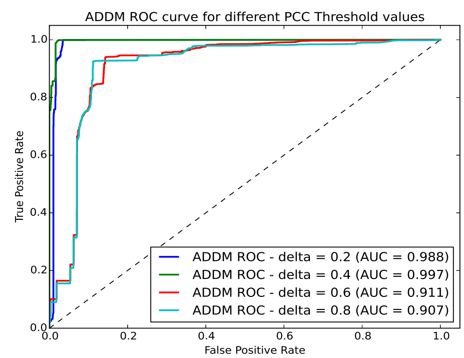


Fig. 5. ADDM ROC curves correspond to different PCC threshold values

C. Finding the optimam number of hidden units

TABLE III. ADDM TRAINING AND TESTING PERFORMANCES AGAINST THE NUMBER OF HIDDEN UNITS OF THE MLP

		Number of hidden units of the MLP							
		3	**4**	**5**	**6**	**7**	**8**	**9**	**10**
UNSW-NB15	**Avg of acc**	0.88	092	0.94	0.95	**0.97**	0.96	0.95	0.95
	Avg of loss	0.058	0.057	0.054	0.051	**0.047**	0.048	0.050	0.052
	Train time(s)	**2.511**	2.855	3.201	3.016	3.128	3.035	3.253	3.647
	Test time(s)	**0.461**	0.479	0.473	0.484	0.466	0.471	0.766	0.798
NSL-KDD	**Avg of acc**	0.92	0.96	0.97	**0.99**	0.98	0.98	0.96	0.95
	Avg of loss	0.034	0.029	0.024	**0.023**	0.25	0.026	0.032	0.045
	Train time(s)	**1.82**	1.91	2.03	2.16	2.25	2.37	2.53	2.72
	Test time(s)	**0.35**	0.38	0.42	0.51	0.56	0.62	0.73	0.88

Here, we aim to explain the process used to find the optimum number of hidden units which produces high performances of the ADDM in less period of time. This is not known in advance, and must be determined by experiment. To tackle this problem for each dataset ADDM was fitted with the subsets of relevant features that corresponds to the PCC threshold $\delta = 0.4$ as mentioned in the previous section. Eight numbers of hidden units are considered to collect the average of accuracy, the average of loss, the training time and the testing time of the ADDM. The numbers of hidden units used are 3, 4, 5, 6, 7, 8, 9, and 10. Table 3 summarizes the obtained results for each number of hidden units. As shown in table 3, the lower periods of training and testing time of the ADDM corresponds to three hidden units. The ADDM training and testing time appear to fluctuate with the increase of the number of the hidden units. Whereas, the highest average of the testing accuracy and the lower average of loss are reached when seven hidden units are used. For these reasons, we used seven units in the hidden layer of the basic MLP of the ADDM. At the end, we concluded that the performances of the ADDM are sensitive to the parameters δ and the number of hidden units.

VIII. Conclusion

In this paper we have presented a detection method of the DoS attack based on ANN, named ADDM. A multi-layer perceptron was optimized to improves the detection accuracy and the detection time of the proposed method.

For the experiments two public datasets are used, the UNSW-NB15 and the NSL-KDD. An unsupervised correlation-based feature selection method is used to select relevant features. Several experiments were conducted to evaluate the impact of the optimization techniques and the feature selection method on the ADDM performances.

ADDM was compared with an unoptimized MLP (u-MLP) and other methods in the literature. The experiment results are in accordance with the hypothesis that application of the optimization techniques improves the learning performances of the basic MLP of ADDM. Furthermore, we notice that the feature selection phase reduces drastically the dataset dimension which improved the training and detection time of the ADDM.

For future works we intend to upgrade the ADDM to detect accurately other network attacks. Also, we are working on integrating the ADDM in a real world implementation.

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DSP Real-Time Implementation of an Audio Compression Algorithm by using the Fast Hartley Transform

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***Abstract*—This paper presents a simulation and hardware implementation of a new audio compression scheme based on the fast Hartley transform in combination with a new modified run length encoding. The proposed algorithm consists of analyzing signals with fast Hartley Transform and then thresholding the obtained coefficients below a given threshold which are then encoded using a new approach of run length encoding. The thresholded coefficients are, finally, quantized and coded into binary stream. The experimental results show the ability of the fast Hartley transform to compress audio signals. Indeed, it concentrates the signal energy in a few coefficients and demonstrates the ability of the new approach of run length encoding to increase the compression factor. The results of the current work are compared with wavelet based compression by using objective assessments namely CR, SNR, PSNR and NRMSE. This study shows that the fast Hartley transform is more appropriate than wavelets one since it offers a higher compression ratio and a better speech quality. In addition, we have tested the audio compression system on DSP processor TMS320C6416.This test shows that our system fits with the real-time requirements and ensures a low complexity. The perceptual quality is evaluated with the Mean Opinion Score (MOS).**

***Keywords*—Speech compression; Fast Hartley transform (FHT); Discrete Wavelet Transform (DWT)**

I. Introduction

The advancement of communication technology and the growth of the Internet have made speech compression a prime concern in the field of digital signal processing. The main motivation behind development of speech compression schemes is to reduce the number of bits required to represent an audio signal in order to minimise memory storage costs and transmission bandwidth requirements. The fundamental way of audio compression is based on removing signal redundancy while preserving the intelligibility of the signal. An audio compressor is characterized by three factors which are reconstructed audio quality, the amount of data compression and the codec complexity. There is always a compromise between increasing the compression ratio, maintaining the quality and intelligibility of the reconstituted voice. Compression methods can be categorized into two basic types lossless or lossy. Lossless compression methods represent the signal with a few bits while providing the same shape as the original speech signal at the decoder end, the run length encoding and the Huffman coding are the most known in this type. Lossy compression methods generate an inaudible distortion in the reconstructed signal. The possible compression ratio using lossy compression is often much higher than by lossless methods [1]. Many standards of compression use both of them in order to increase the compression ratio. For example, the MPEG-Layer3 uses a lossy compression and Huffman coding. There are three key speech compression techniques, namely the waveform coding, parameter extraction and transformation methods. The waveform coding consists of removing correlation between speech samples to reduce the bit rate. It aims to minimize the error between the reconstructed and the original speech signal. Waveform coding schemes almost have low complexity, whereas their compression factors are also low. The simplest form of waveform coding is Pulse Code Modulation (PCM) which is defined in the ITU-T G.711 specification. The parameter extraction method is inspired from speech mechanism. It extracts the features of the signal which are then coded into binary bit stream. Compared to waveform-based codec, parametric-based codec has a high complexity, but can achieve a better compression factor. A typical parametric codec is Linear Prediction Coding (LPC) [2] [3]. The third technique is the transform based compression. It converts the signal from the time domain to another parsimonious domain. Many mathematical transforms have been exploited for audio compression. (E.g., discrete cosine transform, wavelet transform...). Among them, the wavelet transform is the most popular one since it was used in many coders [4] [5] [6] [7] [8]. The basic principle of Discrete Wavelet Transform (DWT) consists in separating the signal into two sets, one representing the general shape of the signal and the other representing its details. The general shape of a signal is represented by its low frequencies and the details are represented by its high frequencies. In order to make the separation between them, a pair of filters is needed: a low-pass filter that extracts the general shape called approximation , and a high-pass filter which estimates its details.The output of the high-pass and low-pass filters are down sampled by a factor of two.

Previous studies have proven that wavelet outperforms the FFT (fast Fourier transforms) , DCT (Discrete Cosine Transform.) [12], and LPC (Linear Predictive Coding) [13].

In recent years many researches in the field of digital signal processing show interests on Discrete Hartley Transform (DHT) [14] [15][16].Computing the DHT directly from its definition is too slow which does not fit with real-time application in which the computational time has a great importance.In above context, we have proposed a real-time speech compression system based on Fast Hartley Transform

(FHT). We have also proposed a modified scheme for Run Length Encoding (RLE) to improve compression factor.

The content of this paper is structured as follows; the next section shows the mathematical formulation for FHT. Section III describes the different stages of the proposed algorithm followed by the evaluation criteria.Section V exposes the simulation results. The real-time implementation is detailed and evaluated in section VI. Finally, we conclude this work in section VII.

II. Algorithm Formulation for FHT

The Fast Hartley Transform uses two properties of DHT to reduce the number of computations.The first property is that the kernel for Hartley Transform is periodic.The second is that temporal shifting correspond to multiplication in the frequency domain.The generalized Discrete Hartley Transform (DHT) is defined for sequence x (n) by the following equation:

$$H\left(k\right)=\sum_{n=0}^{N}x\left(n\right)cas\left(\frac{2\pi kn}{N}\right) \quad (1)$$

And the inverse transformation can be defined as:

$$x\left(n\right)=\frac{1}{N}\sum_{n=0}^{N}H\left(k\right)cas\left(\frac{2\pi kn}{N}\right) \quad (2)$$

Where $cas(x) = \cos(x)+\sin(x)$. From the above equations it can be observed that both forward and inverse transformations can be computed in the same kernel except the constant multiplication. Eqn. (1) can also be decomposed as:

$$H\left(k\right)=\sum_{n=0}^{\left(\frac{N}{2}\right)-1}x\left(n\right)\ \ cas\left(\tfrac{2\pi kn}{N}\right)\ +\sum_{n=N/2}^{N-1}x\left(n\right)\ \ cas\left(\tfrac{2\pi kn}{N}\right) \quad (3)$$

Let n = n + N/2 in the second summation of Eqn. (3).

$$H\left(k\right)=\sum_{n=0}^{\left(\frac{N}{2}\right)-1}\left\{x\left(n\right)\ \ cas\left(\tfrac{2\pi kn}{N}\right)\ +x\left(n+\tfrac{N}{2}\right)cas\left(\tfrac{2\pi k\left[n+\frac{N}{2}\right]}{N}\right)\right\} \quad (4)$$

Separating even and odd part of the input points, and representing $H(2k)$ and $H\left(2k+1\right)$ for even and odd respectively, eqn.4 may be rewritten as:

$$H\left(2k\right)=\sum_{n=0}^{\frac{N}{2}-1}\left[x\left(n\right)+x\left(\tfrac{N}{2}+n\right)\right]\quad cas\left(\frac{4\pi nk}{N}\right) \quad (5)$$

$$H\left(2k+1\right)=\sum_{n=0}^{\frac{N}{2}-1}\left[x\left(n\right)+x\left(\tfrac{N}{2}+n\right)\right]cas\left(\tfrac{2\pi n(2k+1)}{N}\right) \quad (6)$$

A more complete development of the FHT can be found in [13]. The DHT requires N^2 multiplication whereas the FHT requires only $Nlog2\ N$ multiplication.

III. The Proposed Algorithm

The block diagram of the proposed compression system is illustrated in Fig. 1. The different steps of the system are explained in the succeeding paragraphs.

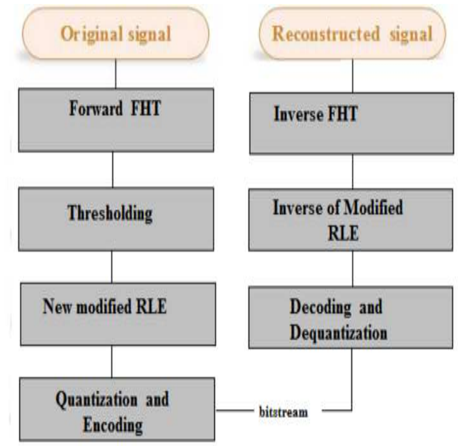

Fig. 1. Block diagram of a the proposed speech

A. Fast Hartley transform

The first step of our approach consists in decomposing the speech signal using FHT. It converts the temporal representation of a signal into a frequency representation. This domain transformation reduces the redundancy and decorrelates the signals samples, so, decreases the bitrates of transmission. The FHT concentrates speech information into a few coefficients as shown in Fig. 2. Therefore, after analyzing the Hartley transform of a signal, many coefficients will either be zero or have negligible magnitudes.

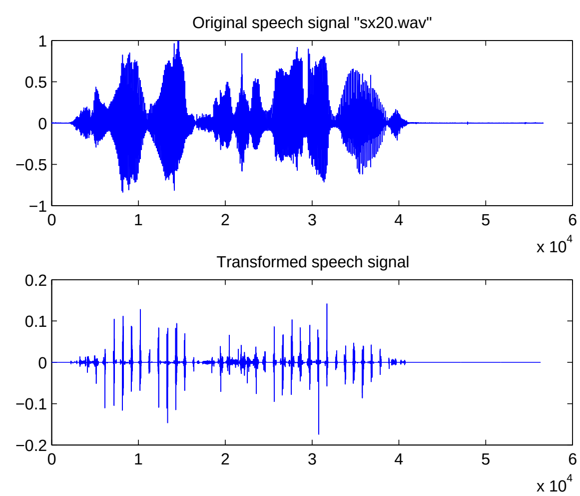

Fig. 2. Normalized hartley coefficients of speech signal(sx20.wav)

B. Thresholding

Thresholding is the most important step in a transform based compression; it consists of rejecting the coefficients of the FHT transform inferior to a given threshold. There are different methods of thresholding, such as the hard and the soft thresholding which are the commonly used methods. In this work we have used the hard thresholding given by this equation:

$$C_{Re}=\begin{cases}C_{Re}\ if\left|C_{Re}\right|\geq T\\ 0\quad otherwise\end{cases} \quad (7)$$

C. Modified Run Length Encoding

The majority techniques based on transform coding use the zero run length encoding (ZRLE). Indeed, the thresholding increases the number of consecutive zeros. ZRLE is a very simple method of data compression in which a run of zeros is encoded using two values. The first value indicates the start of the sequence while the second value indicates the number of zeros in this sequence. For example, the sequence 1,0,0,0,0,0,2,0,0,0,0,0,0 would be encoded as 1, 0, 5, 2, 0, 6. Compression factor (CR) for this example is 2.6.

As we can see from the above example, ZRLE works better with data where there are successive runs of zeros.If the number of zeros in each run is longer than two, compression factor will be greater than or equal to 1. Whereas, many single zeros in data make expansion of data instead of compression.In order to overcome this problem and to increase the compression factor, we have proposed a modified scheme of run length encoding which takes into account that the speech signal is normalized to the range [-1,1] .

It consists first of replacing the samples of amplitude 1 by 0.99 and -1 by -0.99. Then, we code the each run of zeros by a one value which represent at the same time the start of the sequence and the number of zeros. The proposed modified run length encoding overcomes the problems of the classic ZRLE and increases the compression factor. **Example1:**

Input = {0.6, 0.2, 0.8, 0, 0, 0, 0.9, 0}.

Output with MRLE = {0.6, 0.2, 0.8, 4, 0.9, 1}: CR=1.3.

Output with ZRLE = {0.6, 0.2, 0.8, 0, 4, 0.9, 0, 1}: CR=1.

Example2:

Input= {0, 0.2, 0.3, 0, 0.8, 0.3, 0, 0.5, 0}.

Output with MRLE= {1, 0.2, 0.3, 1, 0.8, 0.3, 1, 0.5, 1}: CR=1.

Output with ZRLE= {0, 1, 0.2, 0.3, 0.1, 0.8, 0.3, 0, 1, 0.5, 0, 1}: CR=0.75(expansion).

Exemple3:

Input= {0, 0,0,0,0.2, 0.3, 0, 0, 0, 0}.

Output with MRLE= {4, 0.2, 0.3, 4}: CR=2.5.

Output with RLE= {0, 4, 0.2, 0.3, 0, 4}: CR =1.66. The signal is reconstructed by checking the type of each sample. Thus, the integer type of data informs about the number of zeros whereas the non-integer values present necessarily the samples of the signal.

IV. Evaluation Criteria

The metrics used for the assessment of the quality of reconstructed signal are either objective or subjective. Objective evaluation criteria are based on mathematical parameters which do not require much material and time consumption.The majority of these criteria are defined in the temporal domains. Some frequently used metrics are listed below.

- Compression ratio (CR)

$$C = \frac{length(x(n))}{lenght(c(n))} \tag{8}$$

$c(n)$,is the compressed signal.

- Signal to noise ratio (SNR)

$$SNR = 10\log_{10}(\frac{\delta_x^2}{\delta_e^2}) \tag{9}$$

Where, δ_x^2 is the mean square of the speech signal and δ_e^2 is the mean square difference between the original and reconstructed signals.

- Peak Signal to noise ratio (PSNR)

$$PSNR = 10\log_{10}\frac{NX^2}{|x-r|^2} \tag{10}$$

N,is the length of the reconstructed signal, X, is the maximum absolute square value of the signal and $|x-r|^2$ is the energy of error between the reconstructed and original signal.

- Normalized root mean square error (NRMSE)

$$NRMSE = \sqrt{\frac{(x(n)-r(n))^2}{(x(n)-\mu_x(n))^2}} \tag{11}$$

$x(n)$, is the speech signal, $r(n)$ is the reconstructed signal, and $\mu_x(n))^2$ is the mean of the speech signal.

- Absolute Category Rating

Several methods for subjective assessment are used in literature which are described in ITU-T Recommendation P.830.The most commonly used evaluation method is the absolute category rating (ACR) in which a group of listeners listen to audio sequences and then judge the perceived quality according to a rating scale. The ACR is frequently used in ITU-T applications like G711, G728, G711.The average numeric score over all experiments provides a score called Mean Opinion Score (MOS). We present in the table below the correspondence between the scores and the different quality judgments.

TABLE I. Rating Scale and Descriptions for the Absolute Category-Rating (ACR) Test

Rating	ACR description-MOS
5	Excellent
4	Good
3	Fair
2	poor
1	Bad

V. Test And Results

In this section, a Matlab program has been developed to implement the speech compression codec based on FHT with MRLE. To evaluate the efficiency of the developed algorithm, a comparative study between the wavelet based compression and the proposed system is performed using objective criteria; CR, SNR, PSNR and NRMSE. In all simulations, only source speech signals extracted from the TIMIT database are exploited [14].

Throughout the figures below,it is observed that the proposed system rates are better than those obtained by DWT based compression. Fig.6 reveals the superiority of the proposed algorithm. In fact, it gives the lowest NRMSE. The results of SNR and PSNR show a gain of 2db compared to the wavelet based compression. The compression factor reached by the proposed algorithm is increased from 2.5 to 7. To prove the reliability of the proposed system in preserving the speech quality, we have compared the objective criteria (SNR, PSNR and NRMSE) obtained by applying FHT and the adopted algorithm. So, we have remark that the criteria are maintained the same which demonstrates that the proposed system does not affect the signal quality.

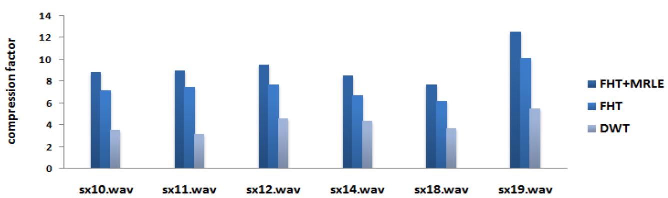

Fig. 3. Compression Ratio (CR) variation using FHT, MFHT and DWT algorithms

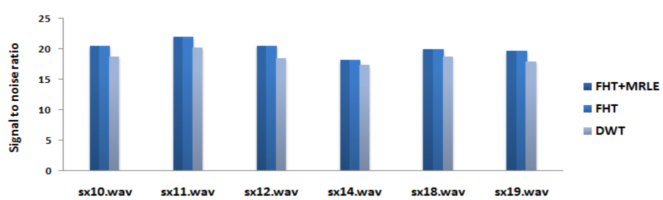

Fig. 4. Signal to noise ratio variation using FHT, MFHT and DWT algorithms

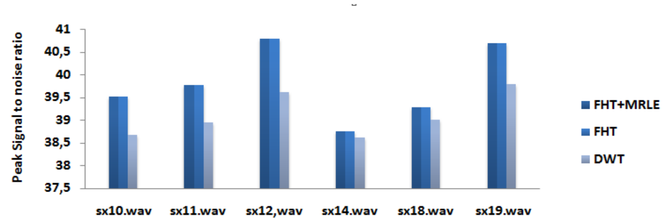

Fig. 5. Peak to noise ratio variation using FHT, MFHT and DWT algorithms

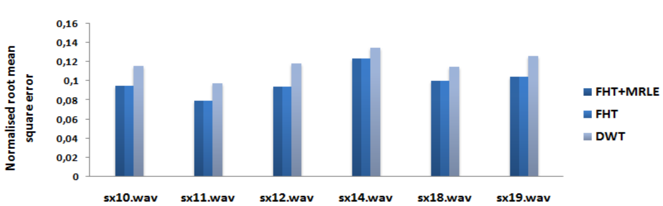

Fig. 6. Normalized mean square error variation using FHT, MFHT and DWT algorithms

VI. Real-Time Implementation based on DSP

Real-time test has a great importance, especially for audio applications which have a strict timing constraints such as audio streaming. In real-time application, the input signal and the generated output can be processed continuously that explains that the mean processing time per sample is lower than the sampling period. So, we have tested our algorithm on a flexible platform which convenient with the particularity of our application. For this purpose we have used a developed starter kit containing a DSK board based on DSP-TMS320C6416 and the software tool (Code Composer studio). We have also used a rapid prototyping tool from Mathworks.

A. DSK C6416 Overview

The DSK C6416 board includes a fixed point digital signal processor TMS320C6416 which operates with a clock frequency of 1GHz. It is also equipped with audio codec TLV320AIC23 (AIC23) that provides analog-to-digital conversion (ADC) and digital-to-analog conversion (DAC) functions with a selecting sampling rate ranged of alternative settings from 8 to 96 kHz. As indicated in the figure bellow the DSK board has four connections which provide analog inputs and outputs: A microphone input port, a line in port, a line out port, and a headphone port. The DSK board includes 16 MB (megabytes) of synchronous dynamic RAM (SDRAM) and 512 kB (kilobytes) of flash memory.The TMS320C6416 is based on the very long instruction word (VLIW) architecture, which is well suited for numerical intensive algorithms. The internal program memory is structured so that a total of eight instructions can be fetched every cycle. For example, with a clock rate of 1 GHz, the C6416 is capable of fetching eight 32 bit instructions every 1/ (1 GHz) or 1.0 ns. Fig. 7 presents an overview of the Spectrum Digital DSK board and the AIC23 Codec.

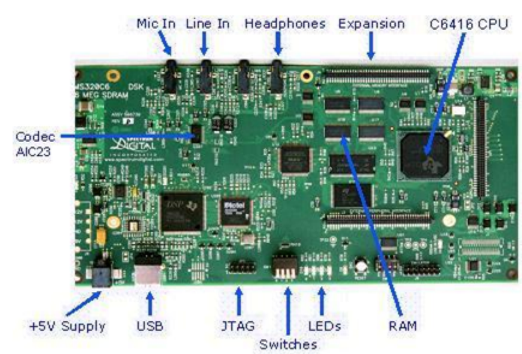

Fig. 7. TMS320C6416 DSK development board from Texas instruments

B. Rapid Prototyping Technology

For a rapid prototyping of real-time applications on DSP processor, we have used the Embedded Target for C6000 DSPs Platform and RTW (Real-time Workshop). They convert the Simulink model into efficient C code specifically for C6000 processors. MATLAB Link for CCS Development Tools interface with TI CCS (code composer studio) to produce an executable that is loaded into the DSK-C6416. Fig. 8 shows the general scheme for communication between Matlab \ Simulink and the embedded DSP target;

Fig.9, shows the designed Simulink model for implementing the audio codec based on FHT and on TMS320C6416.The

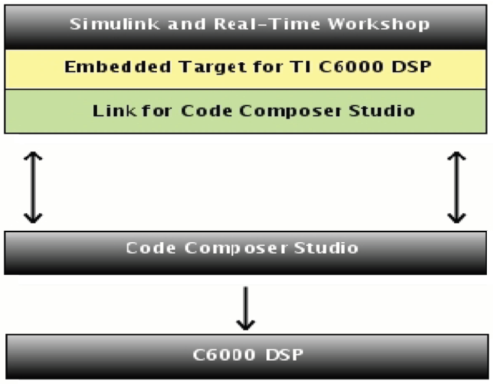

Fig. 8. Flow Diagram connecting Simulink and Real Time Workshop with DSK C6416

DSK-C6416 block has a prime importance. Indeed it provides access to the processor hardware settings. It is extracted from the C6000 Target Preferences library.

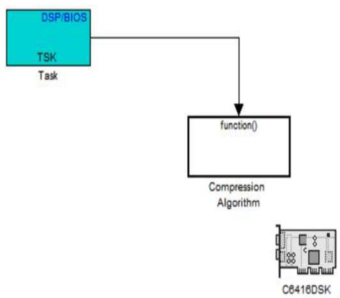

Fig. 9. Simulink model of audio compression system on TMS320C6416

Fig.10 shows the Simulink blocks of FHT, which is executed using a TSK thread of DSP/BIOS. This latter is a scalable real-time kernel designed to be used by applications that require a real-time scheduling and synchronization. It provides preemptive multi-threading, hardware abstraction, real-time analysis, and configuration tools. It is also designed to minimize CPU requirements and memory on the target [15]. The Simulink block "compression algorithm" presents a subsystem that contains the different stages of the compression algorithm.

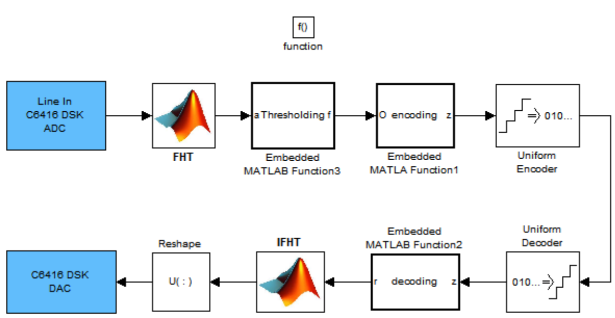

Fig. 10. Simulink model of the proposed audio codec

In order to validate the performances of the proposed speech compression algorithm, we have calculated the number of cycles and the memory consumption. Table II presents the number of cycles in MCPS and the memory consumption in kilobytes (KB) required to running the audio compression system. From the above table, we can remark that total MCPS required for running the FHT code decreases by using DSP/BIOS tool. The CPU speech and the memory consumption meet the real time processing requirements of TMS320C6416 (CPU speed = 1 GHz, 512KB of flash memory and 16MB of SRAM). Compared to the results obtained in [16], which highlights a real-time implementation of speech compression using wavelet, our work brings some improvements in term of complexity. Due to the accuracy of subjective evaluation, we have considered the listening test ACR. 10 volunteers have evaluated the quality of the sentences generated from the headphone connected on the DSP board. The tested sentences are pronounced with different dialects (English, French and Arabic). The mean opinion scores (MOS) resulted from the listening ACR is 4 which is close to the MOS of the pulse code modulation (PCM). From this test we have noticed that the change of dialect does not affect the quality of our algorithm.

TABLE II. Cycle Count and Memory Consumption of the Proposed Speech Compression Algorithm

Algorithm	Total (MCPS)	Memory consumption (Ko)
Compression with DSP /BIOS	5.033	234
Without DSP/BIOS	37.146	200

VII. Conclusion

In this paper, a new speech compression algorithm using fast Hartley transform combined with a modified run length encoding scheme has been presented.The proposed algorithm proves its reliability to improve the speech compression ratio without affecting the signal quality referring to the performance evaluation made using the objective criteria such as: CR,SNR,PSNR and NRMSE. In this context, a comparative study with the wavelet based compression has demonstrated that the application of our algorithm increases the compression factor from 2,5 to 7 without sacrificing neither the speech intelligibility nor the quality. Finally, the real-time test of speech compression codec has been successfully implemented in TMS320C6416 platform and reveals that the proposed algorithm has significantly decreased the system complexity mostly when DSP/BIOS is intervening.

As a future work, we tend to integrate a voice activity detection(VAD) to improve the coder performances.

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Dynamic Programming Inspired Genetic Programming to Solve Regression Problems

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***Abstract*—The candidate solution in traditional Genetic Programing is evolved through prescribed number of generations using fitness measure. It has been observed that, improvement of GP on different problems is insignificant at later generations. Furthermore, GP struggles to evolve on some symbolic regression problems due to high selective pressure, where input range is very small, and few generations are allowed. In such scenarios stagnation of GP occurs and GP cannot evolve a desired solution. Recent works address these issues by using single run to reduce residual error which is based on semantic concept. A new approach is proposed called Dynamic Decomposition of Genetic Programming (DDGP) inspired by dynamic programing. DDGP decomposes a problem into sub problems and initiates sub runs in order to find sub solutions. The algebraic sum of all the sub solutions merge into an overall solution, which provides the desired solution. Experiments conducted on well known benchmarks with varying complexities, validates the proposed approach, as the empirical results of DDGP are far superior to the standard GP. Moreover, statistical analysis has been conducted using T test, which depicted significant difference on eight datasets. Symbolic regression problems where other variants of GP stagnates and cannot evolve the required solution, DDGP is highly recommended for such symbolic regression problems.**

Keywords*—Genetic Programming; Evolutionary Computing; Machine Learning; Fitness Landscape; Semantic GP; Symbolic Regression and Dynamic Decomposition of GP

I. Introduction

Since the inception of Genetic Programming by Koza [1], it is being used in various domains of Medical, Engineering and Computer science. GP is inspired by human biological evolution process. The leverage of Genetic Programming over some other inductive logic programming techniques is as it does not require any human interaction and domain specific knowledge. Comparatively GP is still a young field in research and has attracted substantial research community. Varieties of problems are being solved by genetic programming. For example: designing the robot controllers, discovering new quantum algorithms and continuous optimization problems etc. One of the important strength of Genetic Programming is its ability to find the solution of problem which human would probably never consider. On the other hand GP still persist some problems for instance scalability issues, GP Bloat are the most commonly concerned for research community.

It has been observed that GP struggles to evolve on different symbolic regression problems and stagnation occurs. The reason of stagnation and insignificant improvement is high selective pressure. In some problems where input ranges are very small and fewer generations are allowed the stagnation occurs and GP can not evolve the required solution. The primary goal of this research work is to overcome these aforesaid problems for example GP stagnation etc. This research work also diverts the focus of GP in order to overcome GP struggle and stagnation. Furthermore, it has been also observed when stagnation occurs in GP, the size of tree is continuously increasing with less or no performance improvement with respect to fitness. The same problem associated with GP is also reported by Maarten Keijzer and had mentioned that due to very small range of inputs the traditional GP struggles to evolve or cannot evolve a model for some symbolic regression problems [2]. It has also been reported in literature that the curve of performance improvement of GP is much higher at early generations as compared to later generations. As the number of generation increases there is minor improvement in performance with respect to fitness [3], [4]. The said scenario is termed as GP bloat which is defined as the growth of GP tree increases without improvement in fitness or with insignificant improvement in fitness.

Substantial portion of research has been conducted in Genetic Programming to overcome aforesaid problems like semantic GP by Moraglio [6] and Sequential Symbolic Regression SSR [7]. In order to tackle state of the art problems, a novel approach has been proposed named Dynamic Decomposition of Genetic Programming (DDGP). DDGP has some similarities with SSR and semantic GP. However, in order to find a particular solution, proposed approach decomposes the GP run into number of dynamic runs instead of using single run. The cumulative sum of these sub-runs are then merged to get the final solution of a problem. Keeping in view, the aforesaid problems, proposed approach got an inspiration form dynamic programming. In which previously found sub-solutions helps in finding the final solution. Empirical results mentioned in section V depicted that DDGP is much better than SGP in term of fitness improvement. It is highly recommended to use DDGP in the problems where standard GP struggles to evolve and stagnation occurs. DDGP is the main contribution of this research work, which is comprised of small runs instead of single independent run of GP. In DDGP the succession of these sub-runs participates in finding the final solution. DDGP simply add these sub-runs and reaches upto desired solution. DDGP incorporated the dynamic decomposition with the help of special parameter named error change parameter. The paper is organized as follow: section II comprises of literature review and study of previous approaches to dynamic fitness landscape in GP section III describes Dynamic Decomposition of GP;

; section IV comprises of experimental setup and symbolic regression problems suited for this approach. Section V ; summarizes the results and significance of DDGP; in last, section VI concludes the achievements of DDGP and highlights the future work directions.

II. Literature Review

The first and most popular approach for creating sub modules was coined by Koza named Automatically Defined Function in (1994). Koza proposed ADF for exploring the regularities and modularities of the search space when dealing with complex problems in context of GP. The proposed architecture decomposed the problem into simpler sub problems. Koza has implemented these steps within the run of GP. The architecture proposed by koza exploits the problem regularities through modularization. Problem decomposition is being done manually such as number of ADFs, number of arguments for each ADF. Moreover, interactions of ADFs were restricted by user defined value. In addition to this all these should be specified prior to the run of GP. Another limitation of this approach is that there is single decomposition step. It may be possible more complex problem with respect to GP require many decomposition steps.

Ahmed Kattan and Alexandar et al [5] performed unsupervised problem decomposition using genetic programming at two levels. At top level GP evolves way of splitting the fitness cases in each subset. At lower level GP evolves the program that solves the fitness cases in each subset. The objective of their contribution was to reduce complexity and to discover regularities in problem space. Two main steps of their work was training and testing. In training the system learn to divide the training cases into different group based on similarity. Training is further split into re-sampling and solving phase. Re-sampling tries to discover best decomposition of problem and solving phase tries to solve the problem by solving sub problem independently discovered in re-sampling phase.

Otero and Johnson [9] proposed a sequential covering strategy for problem decomposition specific to Boolean domain. Prior to Otero and Johnson, focus of previous research was on discovery of modules rather than the use of modules in problem decomposition [9]. They had introduced three distinct steps as like ADF. First one is decomposition of the problem, second is searching for a sub problem solution and third one is combination of sub solutions into a complete solution. SCGP is started with an empty solution by considering all the input cases and evolves the partial solution. SCGP add this partial solution to a solution tree. Next step is the removal of input cases for which SCGP predicts accurately and repetition of process until all input cases are removed. The removal of input cases, after each iteration changes the search space effectively for next iteration and allows GP to evolve different parts of the problem. They have used mask selector based on semantic crossover to combine the partial solutions from solution tree to final solution. Experiments were conducted on two Boolean benchmark problems namely even parity and multiplexer. Their work is only limited to Boolean domain and does not deal in real domain. Moreover, they gave no idea of generalization for unseen input cases.

Nabi and et al [8] have proposed automatic problem decomposition for increasingly complex problems called differential grouping. It is based on divide and conquers approach. According to Nabi the growth in dimensions impacted the performance of evolutionary algorithms adversely. The differential grouping uncovers the underlying interaction of decision variable and form subcomponent with minimum number of interdependencies. Nabi highlighted the drawback of previous approaches of unequal distribution of computational budget among subcomponents. They have allocated the computational budget according to the contribution of subcomponents [8]. This work also showed that near optimal decomposition is beneficial and along with contribution based approach can improve the performance in large scale optimization with up to 1000 decision variables. They have used additively separable function [8] for differential grouping based on two stages namely grouping stage and optimization stage. As mentioned earlier in grouping stage the interaction of underlying variable structure is identified and in optimization stage the subcomponent discovered in grouping stage are optimized in round robin fashion. The experiments conducted on IEEE CEC 2010 benchmark and used 20 benchmarks functions in order to evaluate the performance and compared with CCVIL. The results gave 100 percent accuracy on 13 benchmarks out of 20 benchmarks.

Luiz Otavio V.B. Oliveira et al [7] proposed a framework to deal with complex problems using GP named sequential symbolic. Their main contribution was transformation of original problem into potentially simpler problems based on semantic distance and semantic crossover. Luiz Otavio work is inspired from sequential covering strategy SCR, same to one proposed by Otero and Johnson [9]. The difference between SSR and SCR is of transformation and reduction, In SSR the problem is transformed into simpler problem, while in SCR the problem is reduced, after each iteration. In SCR the training cases covered by an iteration are removed which results in reducing the size of problem. Iterative solution in SSR allows GP to focus on different aspect of original problem and combines the individual solution (sub problems) using GSC. After generating a sub optimal function the residual is approximated by another function [7].

The concept of semantic Genetic operator SGP is coined by Moraglio [6]. As Moraglio work combines individual at random therefore, exponential growth is reported in SGP. SSR has overcome this flaw by finding the individual with minimum error on desired output vector. SSR does not need to keep all the solution in memory. Experiments of SSR are conducted using 8 univariate polynomial function of degree 3 to 10 with real valued coefficient [-1,1] same as Moraglio et al [6]. The results of SSR are same as GP but better than SGP along with better generalization than SGP. However, the critical part of SSR is the setting of different parameter and it does not reduce the fitness budget effectively. Moreover, SSR has not been validated in more complex Symbolic regression problems for example the GP benchmarks (white et al, 2013) yet.

Tomasz P. Pawlak and Krzysztof et al [10] proposed semantic backpropagation for designing search operators in Genetic Programming. According to them inversion of program execution can generate the subtasks from the original task. These sub tasks can be solved using exhaustive search in constraint set of programs [10]. For the sake of desired intermediate output, their algorithm can heuristically inversed the execution of evolving program. With the help of inverse operator they can get desired output of any sub sequent node. The proposed algorithm randomly selects any node and gets desired output. After obtaining desired output the algorithm searches for a program with a match or very close match in the repository. Tomasz P et al have introduced two kinds of operators for this purpose namely Random Desired Operator (RDO) and Approximately Geometric Semantic Crossover Operator (AGX). RDO is useful for Boolean and regression problems and for unknown target output due to some confidential reasons, AGX operator is used. The empirical results showed that their works helps the evolution at identifying the desired intermediate states and also improve the search process and make it more efficient [10]. Moreover, they have introduced the program semantic in order to analyze the program behavior. Their results showed that the inversion of program can be a feasible for automatic programming algorithm, including GP, with property of problem decomposition [10].

Amin Lamine et al [11] conducted a study on finding solution to constrained optimization problems (COPs). COPs are generally considered as NP-Hard problems. The proposed technique is S&D (solve and decompose). It uses depth-first iteration technique based on decomposition of problem. The proposed strategy uses the solution of COP which is feasible, that is found by any exact technique, which is further decomposed into smaller sub problems. To strengthen the cost based filtering it uses values of feasible solution as the bound to be added to sub problems. Exploitation of feasible solution (promising region of search tree) is done for finding sub problems that show more promise in finding good solutions. Heuristic is needed that may be adaptive for comparison of two sub problems for finding better one to improve whole solution because, the objective function is linear .Depth first approach is used for their exploration. This whole process is continued in proposed work until some criteria is reached where further decomposition is stopped. After this Branch and Bound type of exact methods are used to solve these sub problems in optimal way. Experiment results for the S&D approach show that improvements in order of three magnitudes were achieved in comparison with Branch and Bound methods, with respect to their runtime.

David Medernach et al [20] proposed a novel approach named Wave GP. Wave is the form of semantic genetic programming which works on periods. Periods are short genetic programing runs. This work shares some similarities with methods such as Sequential Symbolic Regression. The main idea of this work is to run succession GP periods and produce cumulative solution by training on the basis of previous residual errors. The algebraic sum of best evolved period is called final solution. New periods are started when the rate fitness gain slows down. Residual errors are optimized for each successive period on the basis of previous Heterogeneous configuration is applied across the periods, which results in different generation span for different periods on the basis of their progression. Partial population is renewed with 80% new individuals at the beginning of every new successful period. Wave performs equal or better than standard GP with or without linear scaling. It performs significantly better than GSGP.

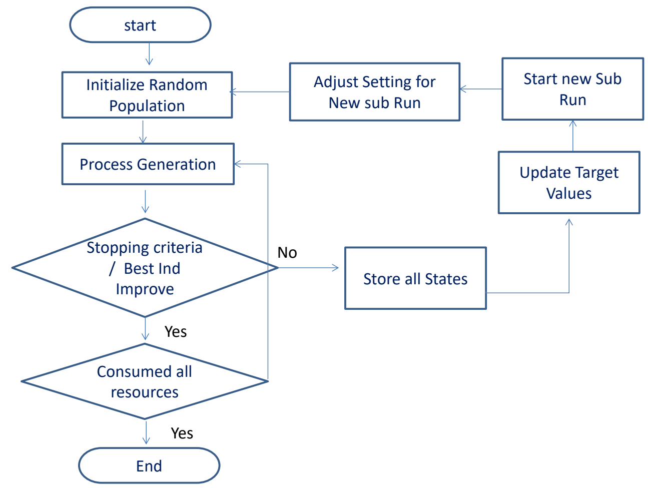


Fig. 1. Flow chart of Proposed Approach DDGP is depicted.

III. Dynamic Decomposition of GP

Dynamic decomposition of genetic programming is an idea inspired from dynamic programming. The symbolic regression problems where standard GP struggles and stagnation occurs, DDGP is quiet successful in such problems. Moreover, DDGP is also beneficial to avoid GP bloat. The DDGP decomposes the original GP run into number of sub-runs (problem dependent) in order to find the final solution, which cannot be found by traditional GP. Proposed approach incorporates divide and conquer strategy, which is quiet helpful in those areas where standard GP struggles. DDGP starts like a traditional GP and tries to find the solution with the help of fitness function. DDGP used a special parameter named error change parameter. The purpose of error change parameter is to monitor the best individual after each generation. If the best individual does not improve in term of fitness for x number of consecutive generations, then decomposition comes into an action. The proposed methodology stores all the states of current run and initiates a new run. The new run requires some parameter adjustments for example modification of target values and number of generations. The recursive process of this mechanism either yields required final solution or end up with termination criteria. At the end of each sub-run, DDGP stores the best individual. On the basis of this, target values are updated which lead to change in fitness landscape. This mechanism changes the target value for the subsequent run. In the end, the final solution is the cumulative sum of all the linear sub runs. The flow chart of proposed DDGP is shown in figure 1.

Pertaining to the proposed idea of DDGP, it is deemed appropriate to mention a mechanism which decides, when decomposition will incorporate. For the sake of this, error change parameter has been used as mentioned above. This special parameter works on the basis of best individual of every generation. For intelligent stopping mechanism the error change parameter monitors the best individual of each generation. If the performance of best individual does not improve or remain same for X number of consecutive generation, then current run is halted and all states are stored.

The argument is supported by stasis introduced by Blackburn (1995). The stasis is the time period in human biological evolution process, when no change occurs for some time period in human biological evolution. Similarly to this when best individual does not improve, current run is halted and incorporates the decomposition by introducing new sub runs. For above mentioned stopping mechanism some threshold could have been used but DDGP did not use this option. After intelligent stopping and saving the states, new run is initiated. The proposed approach repopulates and uses the same desired parameter setting except number of generations. For number of generations, DDGP subtracts the number of generations consumed by previous run from total allocated generations as given below: $M_f = M_1 + M_2$...........M_n

$$G_{M_i} = G_t - G_{M_i-1} \tag{1}$$

Where M_1 to M_n are the number of decomposed models or sub models which are dynamic in DDGP and depends upon the nature of problem while M_f is the final model. G_t is the total number of allocated generations and G_{M_i} is the number of generations for current sub run or sub model and G_{M_i-1} is the number of generations consumed by previous sub run or sub model.

When the best individuals does not improve or remain same for x number of consecutive generations, the intelligent stopping criteria stops the current run and stores all the states. For new sub-run target value is modified by subtracting the obtained output of a previous sub run from the desired target value. This lead to change in fitness landscape for subsequent runs. The procedure for updating the target value is given as under:

$$O_{M_i} = O_t - O_{M_i-1} \tag{2}$$

Where O_{M_i} is the target output for current run and O_t is the desired output against the input cases and O_{M_i-1} is the output model evolved by the previous sub-run. the final solution will be the algebraic sum of all the sub runs or sub models i-e.

$$Final(Solution) = \sum_{i=1}^{n} M_i \tag{3}$$

The proposed ideal help us in finding the target solution using algebraic sum of all the runs. Moreover, it also overcomes the GP stagnation and bloat problem because of the mechanism, which is monitoring the performance of best individual after each generation for fitness improvement. Due to which DDGP eradicates the chance of stagnation and GP bloat. Moreover, DDGP also improves the speed and accuracy of standard GP, the empirical results mentioned in section IV are evidence to this argument.

A. DDGP Algorithm

Algorithm 1 presents the high level pseudo-code fo DDGP. Fitness cases comprised of inputs / outputs usually provided to algorithm 1. It starts with empty solution S and constructs the required solution iteratively just like traditional GP. If the required solution is found at k-th generation, the required solution is added to S. Otherwise proposed approach monitors the best individual after each generation using Error-change($Best_{Individual}, Gen$). If fitness does not improve for

```
Input: fitness cases (T), DDGP Parameters, Stopping
       Criteria
Input ← (t_1, t_2, ...., t_n fort_k ∈ T);
Output ← (O(t_1), O(t_2), ..., O(t_n) forO(t_k) ∈ T);
/* Construction of Required Solution
   Iteratively                                   */
S ← 0;
while While stopping criteria does not reach do
    M_i ← RunGp(input, output);
    if (MSError(M, output) ≤ 0.001) then
        S ← AddSolution(M_i);
    else
        ErrorChange ←
         FitnessImprovement(Best_Individual, Gen);

        Return ErrorChange;
    end
    /* Set Threshold according to
       nature of problem and resources
       */
    ε ← value;
    if ErrorChange ≥ ε then
        StopCurrentRun;
        Run_i ←
         StoreSt(UpTarget(output, Parameters));
        S ← AddPartialSol(Run_i);
        M_i ← RunGp(input, updatedoutput);
        Go to Step 6 and Repeat the process ;
    else
        Go to Step 5;
    end
end
```

Algorithm 1: Algorithm for Dynamic Decomposition of GP

x number of consecutive generations, Algorithm 1 stops the current run and updates the target vector. The partial solution evolved by recently stopped run is subtracted from desired output and new target vector is updated for subsequent run. Moreover, the partially evolved solution is added to S. Now algorithm 1 runs on original inputs and updated target vectors and process is repeated until termination criteria is met. Finally the algebraic sum of all the partially evolve solutions are merged and final solution can be achieved, which was difficult to obtain using single run or using standard GP.

B. Running Example

Lets take a look at example of divide and conquer approach used by DDGP in table I for solving equation 4. The first columns contains the input value shown as x ranging from [-1,1]. The second column contains output value shown as y. It can be seen from the table that the difference between input and desired output values are very large. In these cases where this difference between desired output and input is very large, Standard GP struggles and stagnates. Stagnation can be referred as condition where GP is unable to improve the fitness and gets stuck at some value despite further evolution occur over the generations. In table I third column shows the evolved model M1. It can be seen from table I that GP was suppose to evolve output y of 499 against input value -1 of x, but it was unable to achieve it, instead it stagnated at the output value of 202.1. In standard GP there is no way to overcome stagnation in problems where there is huge difference between input and desired output values along with small generation sizes. In proposed approach when stagnation happens divide and conquer strategy is used. As shown in table I in first row third column M1 is 202.1 this is the evolved model until stagnation happened. At this point in DDGP new desired output y' is evolved by subtracting M1 from original desired output y. Column four show the new desired output value y' of 296.9. DDGP starts the sub run and the new value of y' is evolved as it is still large as compared to input x, it results in stagnation and DDGP stops after evolving M2 model with value of 150.1 . At this stage new desired value output y" is evolved using model M2. Again DDGP is started with input x = -1 and desired output y" value of 146.8. Again same process is repeated and new modal is evolved using divide and conquer strategy until desired outcome or termination criteria is achieved. In table I value of y" is 48.7, and at this stage DDGP evolved model M4 with value 48.69 which is equal to the desired value resulting in termination of DDGP. At this stage all the partially evolved models are combined to form complete solution to the problem. In the example cumulative result is formed by adding partial solutions of M1, M2, M3, M4 as shown in 5 . By using this approach DDGP overcomes the problem of stagnation which standard GP is unable to solve.

$$Y = 500 + x \tag{4}$$

$$Y = M1 + M2 + M3 + M4 \tag{5}$$

TABLE I. EXAMPLE OF DIVIDE AND CONQUER STRATEGY USED IN DDGP

X	Y= f(x)	M1	Y= Y-M1	M2	Y=Y-M2	M3	Y= Y-M3	M4
-1	499	202.1	296.9	150.1	146.8	98.1	48.7	48.69
-0.99	499.1	202	297.1	150.2	146.9	98.2	48.7	48.7
-0.98	499.2	201.9	297.3	150.3	147	98.3	48.7	48.7
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
1	501	201	300	152	148	100	48	48

IV. EXPERIMENTS

A. Dataset

This paper targets the symbolic regression problems to perform variety of experiments. The symbolic regression tasks are of varying difficulties in order to test the proposed GP variant named DDGP and methods over wide range of dataset with varying complexities.

B. Symbolic Regression

An opposed to traditional regression, symbolic regression does not make any assumption regarding underlying relationship between dependent and independent variable [7].Symbolic regression try to find a model which completely satisfy all the inputs and outputs. The model in symbolic regression is composed of mathematical expression which describes the relationship among one dependent and multiple / single interdependent variables. The purpose of traditional regression techniques is to seek optimization of parameters for already specified model. While in symbolic regression goal is to find the model which is a mathematical expression, in short symbolic regression find both model structure and model parameters.

C. Experimental Setup

The experimental setup for DDGP is Symbolic regression problems. Symbolic regression is usually solved by genetic programming and is supervised learning. In GP, the system is presented with data points from which GP construct a mathematical modal which fit all the inputs and outputs points in the dataset. Usually the fitness function use for obtaining this model accurately is Means Squared error [12].

Selection of good set of problems for conducting experiments on symbolic regression is difficult task. Because no well-formed established benchmarks has been formulated. This paper takes most of the problems from past papers that perform improvement on symbolic regression. Keeping in view the stagnation problem associated with GP, following symbolic regression are used for experimental setup. First three symbolic regressions problems are chosen from Maarten Keijzer's benchmark and other 8 symbolic regression are comprises of 8 univariate polynomial function of degree 2 to 9 .

$$f(x) = 0.3xsin(2x) \tag{6}$$

$$f(x) = x^3exp - xcos(x)sin(x)(sin2(x)cos(x)1) \tag{7}$$

$$f(x) = Sqrt(x) \tag{8}$$

$$f(x) = x^2 + 500 \tag{9}$$

$$f(x) = 200 + x^2 \tag{10}$$

$$f(x) = x^4 + 4x + 700 \tag{11}$$

$$f(x) = f(x) = x^5 + x^2 + sin(x) + 400 \tag{12}$$

$$f(x) = x^6 + 7x^3 + 2x^2 + cos(x) + 300 \tag{13}$$

$$f(x) = x^7 + 5x^4 + 3x^3 + cos(x) + 600 \tag{14}$$

$$f(x) = x^8 + 3x^6 + 2x^4 + sin(x) + 900 \tag{15}$$

$$f(x) = x^9 + 9x^7 + 5x^5 + cos(x^3) + 450 \tag{16}$$

The common parameter setting for experimental setup involves the population size which is set to 5000 for all symbolic regression problems in suited experiment setup for DDGP. Different generation size is set for different problems as specified in Maarten keijzer paper for fair comparative analysis. The input range of all problems is from [-1,1] to support keijzer argument. According to keijzer when input range is very small and few generations are allowed, selection pressure for selecting the right range is so high on GP. Due to this GP spends most of the time for finding the particular value and if found in some cases, the diversity has dropped substantially. The functional set comprises of arithmetic and logarithmic functions. Crossover probability is set to 0.7, mutation is set to 0.2 and 0.1 is set for reproduction. Minimum depth of tree allowed is 2 and maximum allowed depth is set to 16. According to DDGP the error change parameter is set to five for intelligent stopping criteria, which means if the best individual does not improve or remain same for five consecutive generations. The algorithm stops the current run and initiates a new run. The question is how much runs would be there for any problems? In case of DDGP it is dynamic; depend upon the nature of problem and termination criteria. The detailed configuration for all the symbolic regression problems suited for DDGP's experimental setup is given in table II.

GP System used for this research work is LIL GP developed by Dr Bill punch and Douglas Zongker at Michigan State University. It is written in C language for the sake of high execution speed, modularity, ease of use and support number of other options. Lil GP code is modified according to proposed methodology. Necessary changes and modifications are made in standard LIL GP code in order to examine DDGP. The naming convention used in this paper are given as; the "Pop" means the population size; "Gen No" means the total number of generations allowed for a problem at start of run. Input ranges are used from [-1,1] and two hundred fitness cases have been used for testing each regression problem. ECP stands for error change parameter which is used to monitor the stopping criteria of intermediate run as stated above.

TABLE II. GP: PARAMETER SETTINGS

Problem Name	Pop Size	Gen No's	ECP	Range	Fitness cases
Equation No 6	5000	30	5	[-1,1]	200
Equation No 7	5000	30	5	[-1,1]	200
Equation No 8	5000	25	5	[-1,1]	200
Equation No 9	5000	50	5	[-1,1]	200
Equation No 7	5000	30	5	[-1,1]	200
Equation No 11	5000	30	5	[-1,1]	200
Equation No 12	5000	35	5	[-1,1]	200
Equation No 13	5000	35	5	[-1,1]	200
Equation No 14	5000	35	5	[-1,1]	200
Equation No 15	5000	35	5	[-1,1]	200
Equation No 16	5000	35	5	[-1,1]	200

V. RESULTS AND DISCUSSION

In experimental phase, the proposed approach (DDGP) is tested on suited symbolic regression problems from Maarten keijzer benchmarks and on eight univariate polynomials from 2 to 9. It is imperative to mention that both SSR and Moraglio [6] have the same benchmark for their experimental setup (Polynomials from 2 to 9). DDGP is close to the work performed, by Luiz and Otero in SSR. They have performed transformation of original problem into simpler problem, while this paper performed dynamic decomposition. The problem of stagnation and GP struggles on different problems was also highlighted by Maarten Keijzer. However, his work was related to linear scaling. The results of experiments depicted that DDGP outperforms the standard GP.

For monitoring stagnation and incorporating decomposition the value of error change parameter can be x number of generations. In all the experiments, performed on Maartin Keijzer's benchmarks and eight univariate problems the values of x is set to five. However, error change parameters is also tested on the values 3,4,5,6. The behavior of DDGP was relatively better on using x = 5 for error change parameter. Due to this x was set to five during evaluation of DDGP in context of error change parameter.

A. Suited Benchmarks

In experimental setup the first three mathematical equations are taken form keijzer paper. Same parameter settings are used as mentioned by keijzer, for fair and transparent comparative analysis. The mathematical expressions were $f(x) = 0.3xsin(2x)$, $f(x) = x^3exp - xcos(x)sin(x)(sin2(x)cos(x)1)$ and $f(x) = Sqrt(x)$. The input range for all these equations was between [-1, 1] as specified by keijzer. The error change parameter in DDGP was set to five. Two hundred fitness cases are chosen for each equation that are generated at regular intervals between the range [-1,1]. Thirty independent runs of SGP are conducted on 30 different seeds for each equation of keijzer. Same seeds are used for 30 runs of DDGP on above mentioned three problems. The results produced by DDGP were many times better than SGP. The figure 2a showed the average fitness of SGP and DDGP for 30 runs. From the figure 2a it is clearly obvious that DDGP beats the SGP and the average maximum fitness of DDGP was 0.188797 while in case of SGP it was 0.071755133 for equation 6 of Keizjer. Moreover, it can be noted from the figure 2a that in case of SGP after second generation the best individual is no more improving upto 30th generation and stagnation occurred. Due to stagnation The SGP is not able to solve the problem. While DDGP helps to remove the stagnation of GP and it is improving in fitness graph as shown in figure 2a.

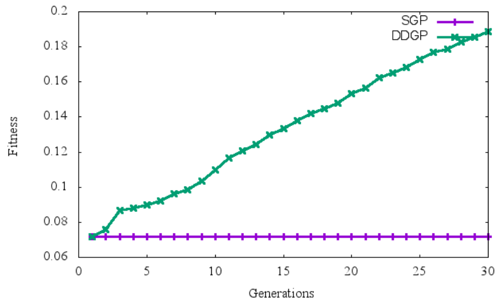
For second and third equations of keijzer the experiment comprises of 30 independent runs for both SGP and DDGP on different seeds as like for equation (6) . The results in a figure 3a and 4a showed that DDGP outperforms the Standard GP. Moreover, the scenarios where the input range is so small and few generations are allowed, the standard GP cannot find the solution due to stagnation and high selective pressure. While in those scenarios the DDGP performs far better than SGP. Furthermore, speed and performance of DDGP is better than standard GP and also overcomes the problem of GP bloat.

B. 8 univariate Polynomials

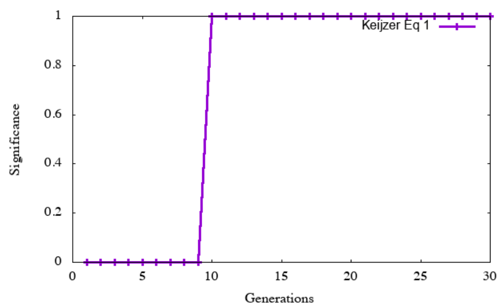
In this phase of experiments evaluation of proposed approach DDGP is done on eight univariate polynomials [7] and Moraglio [6] from degree 2 to 9. Thirty independent runs have been conducted for each polynomial (from 2 to 9) using both Standard GP and DDGP. Each polynomial consists of 200 input fitness cases between the range of [-1, 1]. Other parameter settings are specified in table II. The error change parameter is used to monitor the best individual after each generation and for intelligent stopping of current run, when stagnation occurred. The decompositions of models were dynamic. The results of each polynomial 2 to 9 showed that DDGP performs better than Standard GP. Moreover, using proposed approach GP bloat problem can be minimized and it has been observed from empirical results that, performance in term of fitness and speed of DDGP is much better than Standard GP. The figure 5a, figure 6a, figure 7a, figure 8a, figure 9a, figure 10a, figure 11a and figure 12a are evidence that the performance of DDGP is better than Standard GP.

C. Statistical Analysis

Student T Test has been conducted on all the datasets (polynomial 2 to 9) and (suited Keizjer's benchmark equa-



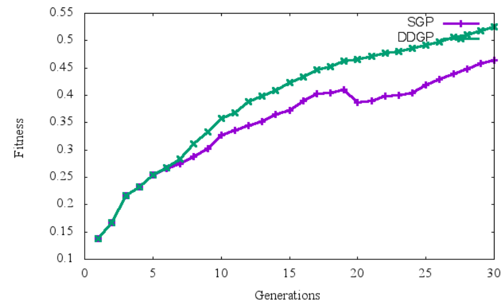
(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = 0.3xsin(2x)$ between range -1 to 1. 1



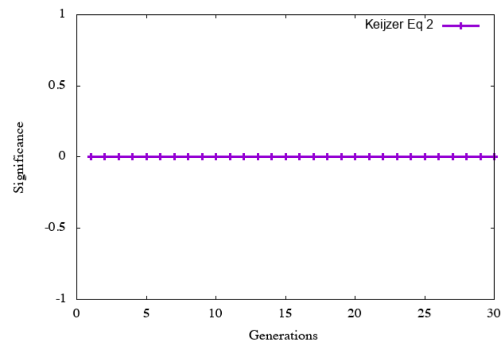
(b) T Test of Keizjer's benchmark equation 1 $f(x) = 0.3xsin(2x)$ after each generation between DDGP and SGP

Fig. 2. DDGP and SSGP Comparison with respect to fitness and T Test for Kezijer's benchmark equation 1

tions). The purpose of student T test is to determine the significant difference between the results obtained by DDGP and SGP. The T test has been performed on the best individual obtained after each generation by DDGP and SGP. As in experimental setup 30 independent runs are conducted for each dataset. The T test examine the significant difference between the best individual obtained through DDGP and SGP after each generations of all 30 runs on all datasets. The T Test shows that the fitness improvement on seven datasets (2b,4b,6b,5b,8b,9b,10b) are significant improvement with 95% confidence and more while, on four datasets (3b,7b,11b,12b) the improvement is not quiet significant. However,results are better than SGP.

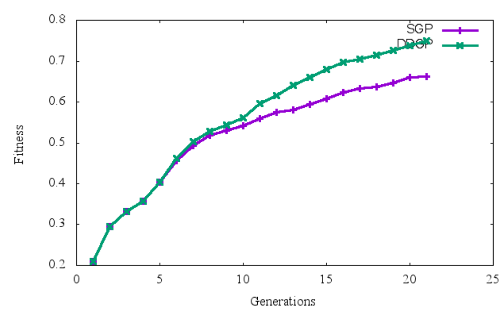


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = x^3expxcos(x)sin(x)(sin2(x)cos(x)1)$ between range -1 to 1 1

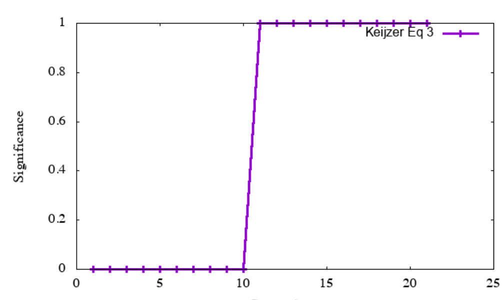


(b) T Test of Keizjer's benchmark equation 2 $f(x) = x^3exp - xcos(x)sin(x)(sin2(x)cos(x) - 1)$ after each generation between DDGP and SGP

Fig. 3. DDGP and SSGP Comparison with respect to fitness and T Test for Kezijer's benchmark equation 2

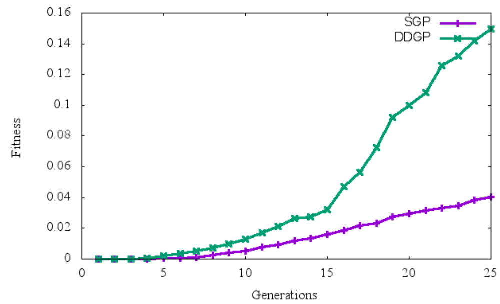


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = Sqrt(x)$ between range -1 to 1

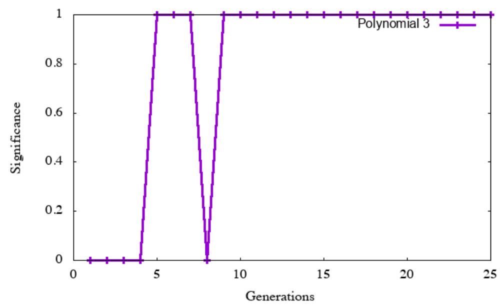


(b) T Test of Keizjer's benchmark equation 3 for dataset $f(x) = Sqrt(x)$ after each generation between DDGP and SGP

Fig. 4. DDGP and SSGP Comparison with respect to fitness and T Test for Kezijer's benchmark equation 3

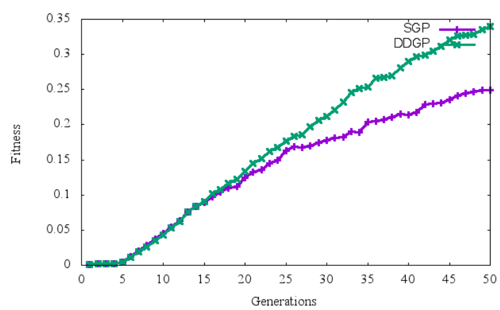


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $Y = x^3 + 500$ between range -1 to 1

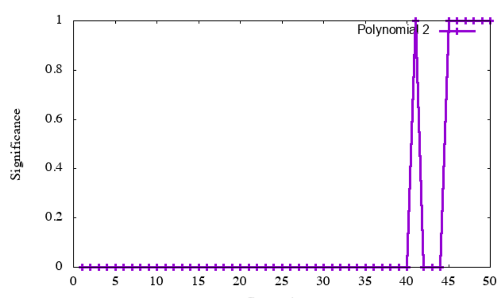


(b) T Test on Polynomial 3 $Y = x^3 + 500$ after each generation between DDGP and SGP

Fig. 5. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 3

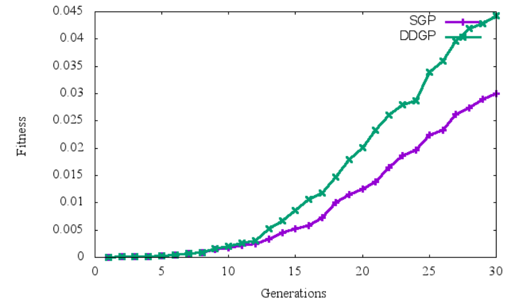


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $Y = x^2 + 200$ between range -1 to 1

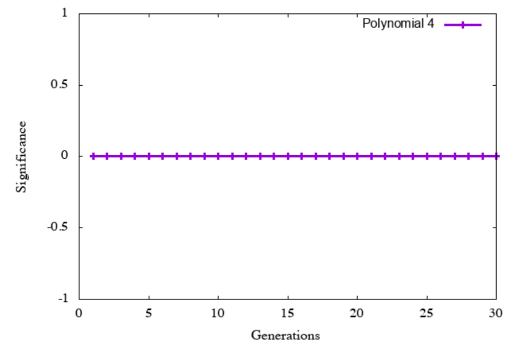


(b) T Test on Polynomial 3 $Y = x^2 + 200$ after each generation between DDGP and SGP

Fig. 6. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 2

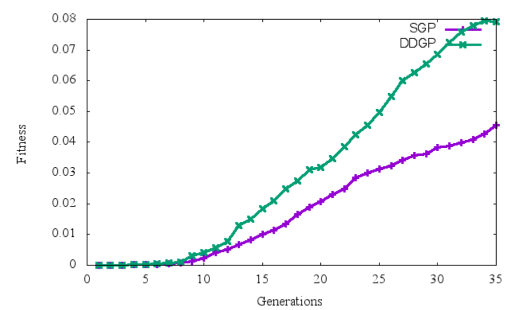


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = x^4 + 4x + 700$ between range -1 to 1

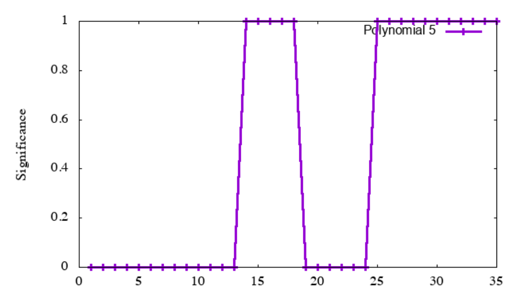


(b) T Test on Polynomial 4 $f(x) = x^4 + 4x + 700$ after each generation between DDGP and SGP

Fig. 7. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 4

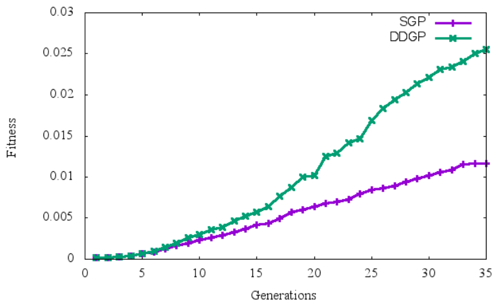


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = x^5 + x^2 + sin(x) + 400$ between range -1 to 1

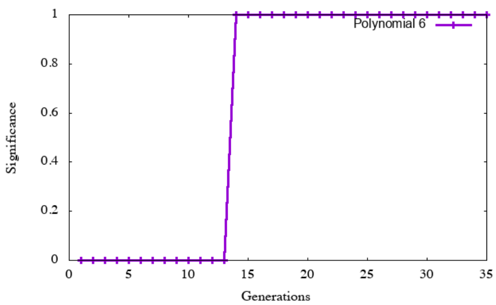


(b) T Test on Polynomial 4 $f(x) = x^5 + x^2 + sin(x) + 400$ after each generation between DDGP and SGP

Fig. 8. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 5

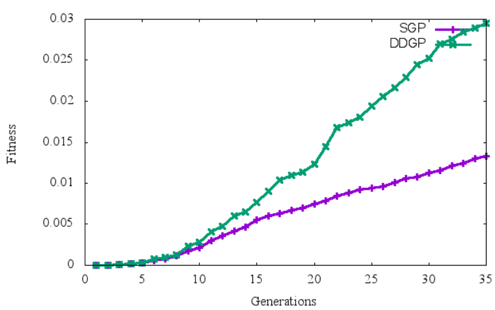


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = x^6 + 7x^3 + 2x^2 + cos(x) + 300$ between range -1 to 1

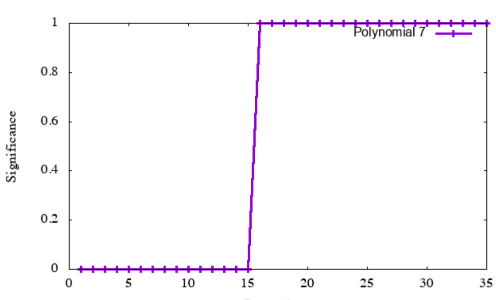


(b) T Test on Polynomial 4 $f(x) = x^6 + 7x^3 + 2x^2 + cos(x) + 300$ after each generation between DDGP and SGP

Fig. 9. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 6

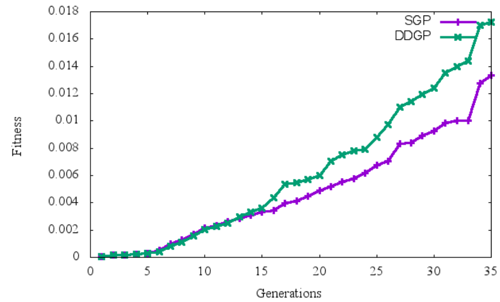


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = x^7 + 5x^4 + 3x^3 + cos(x) + 600$ between range -1 to 1

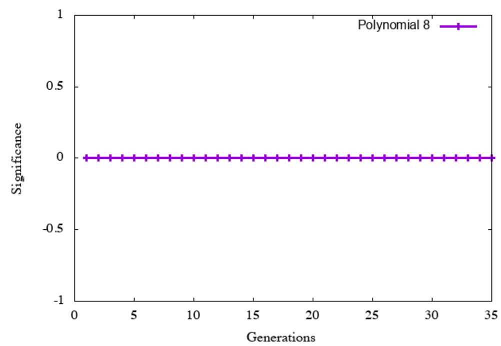


(b) T Test on Polynomial 4 $f(x) = x^7 + 5x^4 + 3x^3 + cos(x) + 600$ after each generation between DDGP and SGP

Fig. 10. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 7

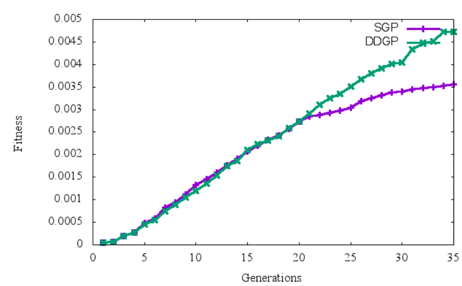


(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = x^8 + 3x^6 + 2x^4 + sin(x) + 900$ between range -1 to 1

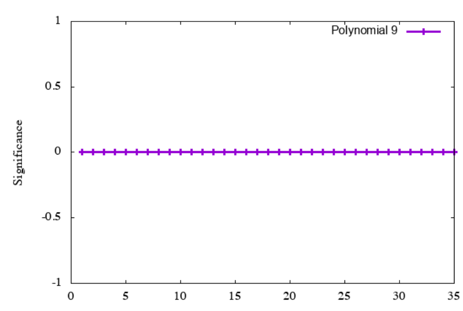


(b) T Test on Polynomial 4 $f(x) = x^8 + 3x^6 + 2x^4 + sin(x) + 900$ after each generation between DDGP and SGP

Fig. 11. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 8



(a) Average fitness of DDGP and SGP over 30 independent runs for dataset $f(x) = x^9 + 9x^7 + 5x^5 + cos(x^3) + 450$ between range -1 to 1



(b) T Test on Polynomial 4 $f(x) = x^9 + 9x^7 + 5x^5 + cos(x^3) + 450$ after each generation between DDGP and SGP

Fig. 12. DDGP and SSGP Comparison with respect to fitness and T Test for Polynomial 9

VI. Conclusion

This paper has proposed a novel approach called Dynamic Decomposition of Genetic Programming DDGP. The inspiration for this idea was dynamic programming. It has been reported several time in literature that prolong evaluation of GP cause the GP bloat or extra growth without significant improvement in fitness. Moreover, it has been also reported, when input ranges are very small and few generations are allowed. Traditional GP cannot evolve the required solution and stagnation occurs. Keeping in view, the aforementioned problems a new system is developed named DDGP to address state of the art problems.

DDGP involves the decomposition of original GP by introducing the special parameter which is known as Error change parameter. This parameter decides the stopping criteria for a sub run or sub model. By using this parameter the fitness of best individual is monitored at each generation. If fitness of best the individual does not change for x number of consecutive generations. DDGP saves all the states of currently halted run and initiate a new run. Before initializing the new run the target values are updated for new run by subtracting the values obtained by currently halted run from the desired target values. In this way, the final solution is the algebraic sum of all the successive runs. Some parameter setting is also performed when new sub runs come into an action. DDGP is tested on Maarten Keijzer's benchmarks (2003) and on eight univariate polynomials 2 to polynomial 9. The empirical results showed that DDGP outperforms the standard GP. Moreover, DDGP helps in reducing the GP bloat problem by introducing the small sub runs as decomposition. The speed and performance of DDGP is much better than standard GP.

A. Future Work and Directions

Although DDGP has been tested on numerous symbolic regression problems and all of these aforesaid problems involve single variable. DDGP has not been tested on multivariate symbolic regression problems. In future DDGP is require to evaluate on multivariate SR problems. Moreover, error change parameter is used as stopping criteria for monitoring the best individual for x consecutive generations. A certain threshold can be used as stopping criteria for instance, if the fitness of an individual is not improving from specified threshold for specific number of generations. This mechanism of using some threshold for stopping criteria is not tested and left for future work. Moreover, how DDGP will behave, when specific threshold will be used as a stopping criteria.

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Identification and Nonlinear PID Control of Hammerstein Model using Polynomial Structures

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***Abstract*—In this paper, a new nonlinear discrete-time PID is proposed to control Hammerstein model. This model is composed by a static nonlinearity gain associated to a linear dynamic sub-system. Nonlinear polynomial structures are used to identify and to control this class of systems. The determination of parameters is based on the use of RLS algorithm. A coupled two-tank process is given to illustrate the effectiveness of the proposed approach.**

***Keywords*—Parametric identification; Hammerstein model; RLS algorithm; Polynomial structure; Nonlinear PID controller**

I. Introduction

There are well-developed theories for the control and identification of linear time invariant (LTI) systems. In modern applications, physical systems are nonlinear. This drives an increasing need for modeling techniques able to adequately describe these systems behavior. Nonlinear system identification is an important tool wish can be used to improve control performance. Indeed, there are serval types models that describe perfectly this process such as Hammerstein model [1], polynomial structures [2] [3], voltera [4], NARMAX [5], *etc*.

Hammerstien model is consisted of a static nonlinearity followed by a linear dynamic system. Many chemical processes have been modeled with it, for examples, pH neutralization processes [6], distillation columns [7] [8], polymerization reactor [9] [10] and dryer process [11].

Polynomial models are possibly the most attractive of all nonlinear representations due to the inherent simplicity of the model structure and because they revealed the dynamical properties of the underlying system is a very straightforward manner [12].

Serval nonlinear predictive control algorithms are existed based on PID [13], neural networks [14], B-spline neural networks [15], Fuzzy logic [16] adaptive predictive control [17] [18]. In most algorithms for nonlinear predictive control, their performance functions are minimized using nonlinear programming techniques to compute the future manipulated variables in on-line optimization. This can make the realization of the algorithms very difficult for real-time control.

An important advantage of block-structured models is that they allow the use of standard linear controller design methods. This is possible because static nonlinearity in the process can be negated by inserting the nonlinear inverse of static nonlinearity at the appropriate place in the loop [19] [20] [21].

For the Hammerstein model, reverse nonlinear tuning must be placed at the output of the controller, wish only sees the linear dynamic part of the process and conventional linear controller methods can be used. Often static nonlinearity may be non-invertible this present a limit for this method.

In this work, a polynomial structure is employed to describe the nonlinear static function of Hammerstein model. Recursive least square RLS algorithm is used to estimate the unknown parameters. A new nonlinear discrete PID is proposed. It is composed by a linear controller associated with the inverse of the nonlinearity wish is obtained by an approximation using polynomial structure.

The remainder of this paper is organized as follows: first, a Parametric identification of the Hammerstein model is defined. Second, a proposed nonlinear polynomial structure of Hammerstein model is described. Third, a method to control the model is presented. After that, the proposed identification and control method are applied to a coupled two-tank system.

II. Parametric Identification of Model Hammerstein

Assume that the Hammerstein model of Fig. 1 is composed of a nonlinear block $f\left(.\right)$ associated with a linear sub-system $\frac{B\left(q^{-1}\right)}{A\left(q^{-1}\right)}$. It is described by:

$$\left\{ \begin{array}{l} y_k = \frac{B\left(q^{-1}\right)}{A\left(q^{-1}\right)} v_k \\ v_k = f\left(u_k\right) \end{array} \right. \tag{1}$$

with:

$$A\left(q^{-1}\right) = 1 + a_1 q^{-1} + \ldots + a_{nA} q^{-n_A}$$

$$B\left(q^{-1}\right) = b_1 q^{-1} + \ldots + b_{nB} q^{-n_B}$$

$$v_k = d_1\, u_k + d_2\, u_k^2 + \ldots + d_N\, u_k^N$$

q^{-1} delay operator, u_k input of the system, y_k output, v_k the unmeasurable internal signal and w_k represents the modeling error, external disturbances, *etc*.

In order to have a unique parameterization of the Hammerstein model structure, the first coefficient of the nonlinear function $f\left(.\right)$ equals to 1, $d_1 = 1$, [22] [23].

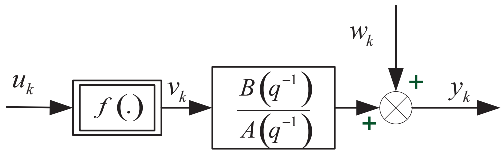

Fig. 1 – Hammerstein model structure.

The output y_k is given by:

$$y_k = -\sum_{i=1}^{n_a} a_i\, y_{k-i} + \sum_{i=1}^{n_b} b_i \left(u_{k-i} + \sum_{p=2}^{N} d_p\, \mathrm{u}^p{}_{k-i} \right) \quad (2)$$

Eq. 2 can be put in the following form:

$$y_k = \Phi_k^T\ \theta_k \quad (3)$$

with:

$$\Phi_k = \begin{pmatrix} Y_k \\ U_k \end{pmatrix},\ \theta_k = \begin{pmatrix} a_k \\ b_k \\ s_k \end{pmatrix},$$

$$Y_k = \begin{pmatrix} -y_{k-1} \\ -y_{k-2} \\ \vdots \\ -y_{k-n_a} \end{pmatrix}, U_k = \begin{pmatrix} U_{1k} \\ U_{2k} \\ \vdots \\ U_{Nk} \end{pmatrix},$$

$$U_{jk} = \begin{pmatrix} u^j{}_{k-1} \\ u^j{}_{k-2} \\ \vdots \\ u^j{}_{k-n_b} \end{pmatrix}, \text{ for } j = 1, 2,\ \ldots,\ N$$

$$a_k = \begin{pmatrix} a_{1k} \\ a_{2k} \\ \vdots \\ a_{nk} \end{pmatrix},\ b_k = \begin{pmatrix} b_{1k} \\ b_{2k} \\ \vdots \\ b_{nk} \end{pmatrix},\ s_k = \begin{pmatrix} d_{2k}b_k \\ d_{3k}b_k \\ \vdots \\ d_{Nk}b_k \end{pmatrix},$$

Φ_k and $\theta_k \in R^{n_R}$ where $n_R = n_a + N\,n_b$, $Y_k \in R^{n_a}$, $U_k \in R^{Nn_b}$, $U_{jk} \in R^{n_b}$, $a_k \in R^{n_a}$, $b_k \in R^{n_b}$ and $s_k \in R^{Nn_b}$.

The parameter vector θ_k can be estimated using the RLS algorithm. It is described by the following equations:

$$\begin{cases} \hat{\theta}_k = \hat{\theta}_{k-1} + P_k\, \Phi_k\, \varepsilon_k \\ P_k = P_{k-1} - \frac{P_{k-1}\,\Phi_k\ \Phi_k^T\ P_{k-1}}{1+\Phi_k^T P_{k-1}\Phi_k} \\ \varepsilon_k = y_k -\ \hat{\theta}_{k-1}^T\ \Phi_k \end{cases} \quad (4)$$

where P_k is the adaptation gain matrix, Φ_k is the observation vector and θ_k is the parameters vector.

III. Proposed Nonlinear Polynomial Structure of the Hammerstein Model

We propose a nonlinear polynomial structure of $f(.)$. It's described by :

$$v_k = f(u_k) = \sum_{i=1}^{r} w_{i,k}\, U_k^{[i]} = \sum_{i=1}^{r} \tilde{w}_{i,k}\, \tilde{U}_k^{[i]} \quad (5)$$

with $w_{i,k}$, $i = 1, 2, \ldots, r \in R^{1\times n_i}$ (resp. $\tilde{w}_{i,k} \in R^{1\times n_i}$) are variable vector and $U_k = (u_k, u_{k-1},\ \ldots,\ u_{k-n_u+1})^T \in R^{n_u}$ where $n_u \leq n_A$.

$U_k^{[i]}$ is the Kronecker power of the vector U_k defined as [12]:

$$\begin{cases} U_k^{[0]} = 1, \\ U_k^{[i]} = U_k^{[i-1]} \otimes U_k = U_k \otimes U_k^{[i-1]}, \ \text{ for } i \geq 1 \end{cases} \quad (6)$$

$\otimes$ designates the symbol of the Kroneker product,

$\tilde{U}_k^{[i]} \in R^{n_i}$, for $i = 1, 2, \ldots, r$ and $n_i = \begin{pmatrix} n+i-1 \\ i \end{pmatrix}$, is the non-redundant. It's defined as:

$$\begin{cases} \tilde{U}_k^{[1]} = U_k^{[1]} = U_k \\ \tilde{U}_k^{[i]} = \begin{pmatrix} u_k^i \\ u_k^{i-1} u_{k-1} \\ \vdots \\ u_k^{i-1} u_{k-n} \\ \vdots \\ u_k^{i-2} u_{k-n}^2 \\ \vdots \\ u_k^{i-3} u_{k-1}^3 \\ \vdots \\ u_{k-n}^i \end{pmatrix}, \text{ for } i \geq 2 \end{cases} \quad (7)$$

when the repeated components of the redundant ($ith-$ power) $U_K^{[i]}$ are omitted and r is the polynomial order.

In this work, we have modeled $v_k = f(u_k)$ by a nonlinear polynomial structure as:

$$v_k = \tilde{w}_{1,k}^1\, U_k + \tilde{w}_{2,k}^1\, \tilde{U}_k^{[2]} + \tilde{w}_{3,k}^1\, \tilde{U}_k^{[3]} + O(U_k^{[4]}) \quad (8)$$

with $U_k = \begin{pmatrix} u_k \\ u_{k-1} \end{pmatrix}$, $\tilde{w}_{1,k}^1 = \begin{pmatrix} 1 & 1 \end{pmatrix}$, $\tilde{w}_{2,k}^1 = \begin{pmatrix} \alpha_{1,k} & \alpha_{2,k} & \alpha_{3,k} \end{pmatrix}$ and $\tilde{w}_{3,k}^1 = \begin{pmatrix} \alpha_{4,k} & \alpha_{5,k} & \alpha_{6,k} & \alpha_{7,k} \end{pmatrix}$

and the linear dynamic system by:

$$y_k = -a_{1,k}\, y_{k-1} - a_{2,k}\, y_{k-2} + b_{1,k}\, v_{k-1} + b_{2,k}\, v_{k-2} \quad (9)$$

Equations 8 and 9 give:

$$y_k = -a_{1,k}\, y_{k-1} - a_{2,k}\, y_{k-2} + \tilde{w}_{1,k}^2\, U_{k-1} + \tilde{w}_{2,k}^2\, \tilde{U}_{k-1}^{[2]} + \tilde{w}_{3,k}^2\, \tilde{U}_{k-1}^{[3]} + O(U_k^{[4]}) \quad (10)$$

with:

$$\begin{cases} \tilde{w}^2_{1,k} = (b_{1,k}\,;\;\; b_{1,k} + b_{2,k})^T \\ \tilde{w}^2_{2,k} = (b_{1,k}\,\alpha_{1,k}\,;\;\; b_{1,k}\,\alpha_{2,k}\,;\;\;\; b_{1,k}\,\alpha_{3,k} + b_{2,k}\;\alpha_{1,k}\,)^T \\ \tilde{w}^2_{3,k} = (b_{1,k}\,\alpha_{4,k}\,;\;\; b_{1,k}\,\alpha_{5,k}\,;\;\; b_{1,k}\,\alpha_{6,k}\,; \\ \qquad\quad b_{1,k}\,\alpha_{7,k} + \;\; b_{2,k}\;\alpha_{4,k})^T \end{cases}$$

Eq. 10 can be written in the form (3) with:

$$\Phi_k = \begin{pmatrix} -y_{k-1} \\ -y_{k-2} \\ U_{k-1} \\ \tilde{U}^{[2]}_{k-1} \\ \tilde{U}^{[3]}_{k-1} \end{pmatrix} \text{ and } \theta_k = \begin{pmatrix} a_{1,k} \\ a_{2,k} \\ \tilde{w}^2_{1,k} \\ \tilde{w}^2_{2,k} \\ \tilde{w}^2_{3,k} \end{pmatrix}$$

The parameters $\alpha_{i,k}$, $\quad i = 1, 2, \ldots, 7$, will be successively estimated by the RLS algorithm.

IV. Nonlinear PID Controller of the Hammerstein Model

In this section, the control of the Hammerstein model with a nonlinear PID will be discussed. Firstly, we presented a nonlinear PID based on the exact inverse of $f\,(.)$. After that, we proposed a method to determine the inverse of the nonlinearity using the polynomial structure wish will be used to control the Hammerstein model.

A. Nonlinear PID controller using the exact inverse

The design strategy discrete-time control is implemented by introducing the inverse function of Hammerstein model [20]. Fig. 2. illustrates the control of Hammerstein model. It is based PID regulator as [24]:

$$u_k = K_p\,\varepsilon_k + K_i\,T_e\,\sum_{j=0}^{k}\varepsilon_j \;+\; K_d\frac{\varepsilon_k - \varepsilon_{k-1}}{T_e} \tag{11}$$

where $\varepsilon_k = y^c_k - y^m_k$ is the error, y^c_k is the set point, y^m_k is the response of the model, T_e is the sampling period and K_p, K_i and K_d are the proportional, integral and derivative controller gains, respectively.

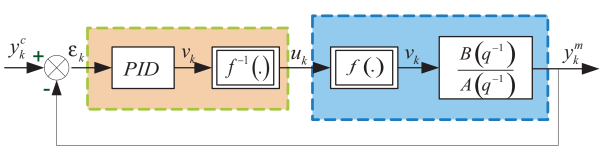

Fig. 2 – Nonlinear PID controller of a Hammerstein model [21].

This technique is valid only if the nonlinear fonction $f\,(.)$ is invertible.

B. Proposed PID controller based-on polynomial structure

The proposed method consisted to approximate the inverse nonlinear gain using the polynomial structure, noted $f^{-1}_{app}\,(.)$. It eliminated the effect of the nonlinear gain in the Hammerstein model. Hence, a new nonlinear PID, noted PID^{NL}, is obtained wish is described as follow:

$$PID^{NL} = PID\;f^{-1}_{app}\,(.) \tag{12}$$

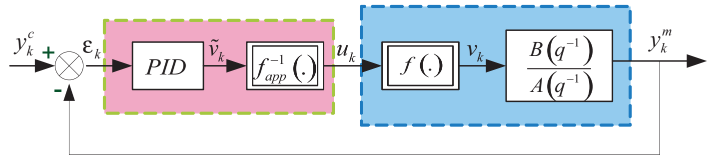

Fig. 3 – Proposed nonlinear PID controller of a Hammerstein model.

Noting that $\tilde{v}(k)$ is an approximate signal of v_k, we have chosen the following structure of $u_k = f^{-1}_{app}\,(\tilde{v}_k)$:

$$u_k = w^3_{1,k}\,V_k + \tilde{w}^3_{2,k}\,\tilde{V}^{[2]}_k + \tilde{w}^3_{3,k}\,\tilde{V}^{[3]}_k + O(V^{[4]}_k) \tag{13}$$

with $V_k = \begin{pmatrix} \tilde{v}_k \\ \tilde{v}_{k-1} \end{pmatrix}$, $w^3_{1,k} = \begin{pmatrix} \beta_{1,k} & \beta_{2,k} \end{pmatrix}$, $\tilde{w}^3_{2,k} = \begin{pmatrix} \beta_{3,k} & \beta_{4,k} & \beta_{5,k} \end{pmatrix}$ and $\tilde{w}^3_{3,k} = \begin{pmatrix} \beta_{6,k} & \beta_{7,k} & \beta_{8,k} & \beta_{9,k} \end{pmatrix}$.

By the identification of equations 8 and 13, we obtain:

$$\begin{aligned} &\beta_{1,k} = 1;\; \beta_{2,k} = -1;\; \beta_{3,k} = -\alpha_{1,k}; \\ &\beta_{4,k} = 2\,\alpha_{1,k} - \alpha_{2,k};\; \beta_{5,k} = \alpha_{2,k} - \alpha_{3,k}; \\ &\beta_{6,k} = 2\,\alpha^2_{1,k} - \alpha_{4,k}; \\ &\beta_{7,k} = 3\,\alpha_{1,k}\,\alpha_{3,k} - 6\,\alpha^2_{1,k} + 3\,\alpha_{4,k} - \alpha_{5,k}; \\ &\beta_{8,k} = -5\,\alpha_{1,k}\,\alpha_{2,k} + 5\,\alpha^2_{1,k} + 2\,\alpha_{1,k}\,\alpha_{2,k} - 3\,\alpha_{4,k} \\ &\qquad - 2\,\alpha_{5,k} - \alpha_{6,k}\,; \\ &\beta_{9,k} = \alpha_{4,k} + 3\,\alpha^2_{1,k} + \alpha_{1,k}\,\alpha_{2,k} + \alpha_{2,k}\,\alpha_{3,k} + 3\,\alpha_{5,k} \\ &\qquad + \alpha_{6,k}. \end{aligned}$$

V. Illustrate Example: Coupled Two-Tank System

A two-tank system is used to illustrate the performance of the proposed polynomial structures of the Hammerstein model and the effectiveness of the proposed control approach.

A. System description

The system setup is a model of a chemical plant fragment. Very often tanks are coupled through pipes and the reactant level and flow has to be controlled. In the proposed work, only pump 1, tank 1, tank 2, and corresponding sensors have been used in SISO configuration, Fig. 4.

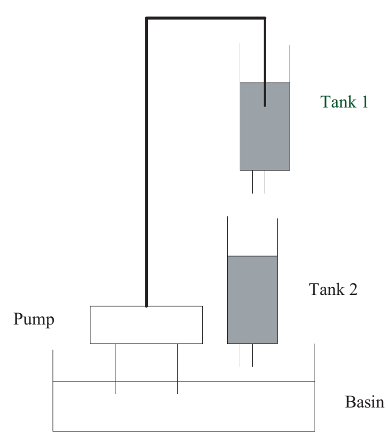

Fig. 4 – Diagram for two-tank system.

B. Mathematical modeling

The coupled tank system is described by the following nonlinear equations:

$$\begin{cases} h_1 = K\ sat\,(h_{11}) \\ \dot{h}_{11} = \eta\, sat\,(u) - \frac{a_1}{A}\sqrt{2\,g\,sat\,(h_{11})} \\ h_2 = K\ sat\,(h_{22}) \\ \dot{h}_{22} = \frac{a_1}{A}\sqrt{2\,g\,sat\,(h_{11})} - \frac{a_2}{A}\sqrt{2\,g\,sat\,(h_{22})} \end{cases} \quad (14)$$

with:

$$sat\,(h_{ii}) = \begin{cases} h_{ii} & \text{if} \quad 0 \le h_{ii} \le 0.3 \\ 0.3 & \text{if} \quad h_{ii} > 0.3 \\ 0 & \text{if} \quad h_{ii} < 0.3 \end{cases} \quad \text{for } i = 1, 2.$$

$$sat\,(u) = \begin{cases} u & \text{if} \quad 0 \le u \le 5 \\ 5 & \text{if} \quad u > 5 \\ 0 & \text{if} \quad u < 0 \end{cases}$$

h_1 and h_2 denote the water level in the corresponding tank and u is voltage applied to the pumps. a_1 and a_2 are the outlet area of the tanks, η constant relating the control voltage with the water flow from the pump, A is the cross-sectional area of the tanks and g is the gravitational constant. The values of the simulink system parameters are shown in the table I.

TABLE I – Parameters of the System [25]

	Value	Unit	Description
u	$0-5$	V	Voltage level of pump
A	0.01389	m^2	Cross-sectional area
a_i	$50.265\ 10^{-6}$	m^2	Outlet area of tank i
η	$2.4\ 10^{-3}$	$\frac{m^3}{V.s}$	Water level of tank i
g	9.81	m^{-2}	Gravitational constant
K	100	$--$	constant

C. Parametric estimation and control result using the exact inverse function of $f\,(.)$

The input of the system is shown in Fig. 5. The signal is set to $[0 \ldots +5V]$. It's a pseudo-random binary sequence SBPA. The value of the sampling period is $T_e = 1s$.

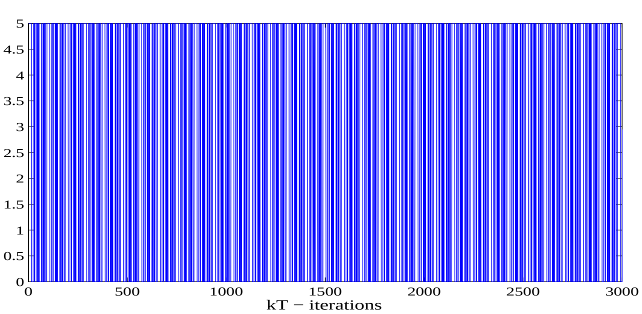

Fig. 5 – SBPA signal u_k.

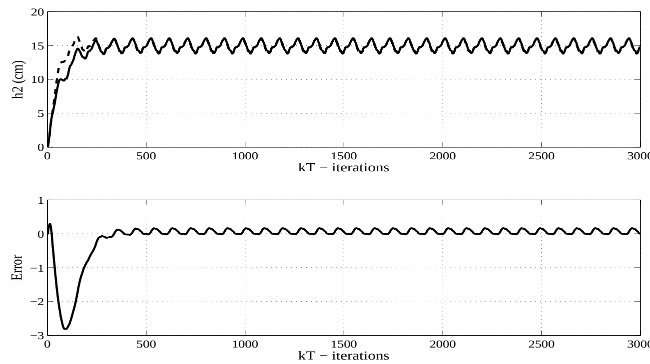

Fig. 6 – Responses of the real (*solid line*) and estimated (*dotted line*) output h_2.

Fig. 6. shows the responses of estimated and real output. Simulation results demonstrated that the error between the real system and the identified structures is negligible.
The estimated model is described by:

$$\begin{cases} y_k = \frac{B(q^{-1})}{A(q^{-1})}\, v_k = 10^{-3}\,\frac{3.7633\,q^{-1} + 3.7748\,q^{-2}}{1 - 1.9518\,q^{-1} + 0.9527\,q^{-2}}\, v_k \\ v_k = f\,(u_k) = u_k + 5\,u_k^2 \end{cases} \quad (15)$$

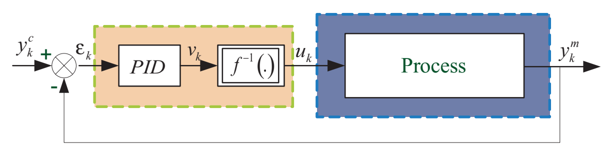

Fig. 7 – Nonlinear PID controller of a two-tank system.

Fig. 7 illustrates the diagram block of the nonlinear PID controller of a two-tank system. It consists of:

- the inverse of the nonlinearity:
  $u_k = f^{-1}\,(v_k) = 0.1\,\left(\sqrt{1 + 20\,v_k} - 1\right)$, for $v_k > -0.05$
- the PID regulator:
  $$(K_p,\ K_i,\ K_d\,) = (4.5,\ 1,\ 0)$$

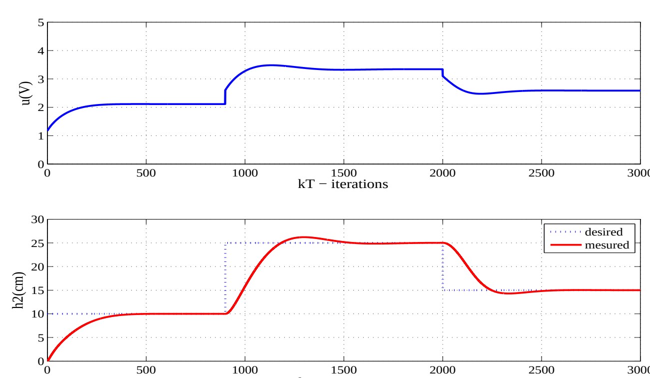

Fig. 8 – Responses of u and h_2 of identified model.

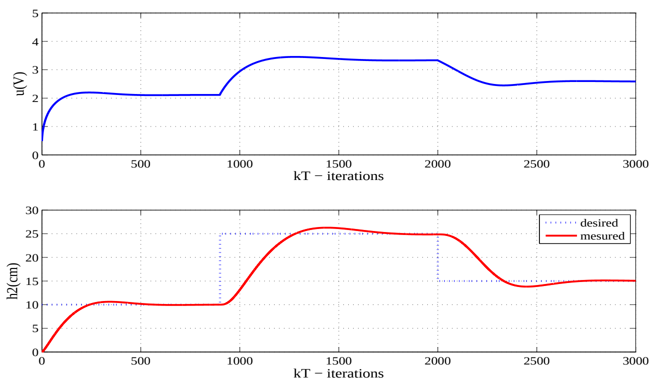

Fig. 9 – Responses of u and h_2 of system.

Figures 8 and 9 show the control signals and the responses respectively of the mathematical model and the simulink system using the first method. Simulation results show that both follow the desired reference. To improve the results, we can increase the order of the polynomial $v_k = f(u_k)$. The problem is the no-existence of the inverse of the nonlinear function or the complexity of the computation of the inverse $f^{-1}(v_k)$.

D. Parametric estimation and control result using polynomial structures

We used the signal shown in Fig. 5 as input to estimate the model described by:

$$\begin{cases} y_k = \frac{B(q^{-1})}{A(q^{-1})}\, v_k = 10^{-3}\, \frac{3.7657\, q^{-1} + 5.1097\, q^{-2}}{1 - 1.9518\, q^{-1} + 0.9527\, q^{-2}}\, v_k \\ v_k = \tilde{w}^1_{1,k}\, U_k + \tilde{w}^1_{2,k}\, \tilde{U}^{[2]}_k + \tilde{w}^1_{3,k}\, \tilde{U}^{[3]}_k + O(U^{[4]}_k) \end{cases} \tag{16}$$

with:

$$\tilde{w}^1_{2,k} = (\ 5 \quad -0.0571 \quad 5\ )$$

$$\tilde{w}^1_{3,k} = (\ 25 \quad -0.2856 \quad -0.2856 \quad 525\ )$$

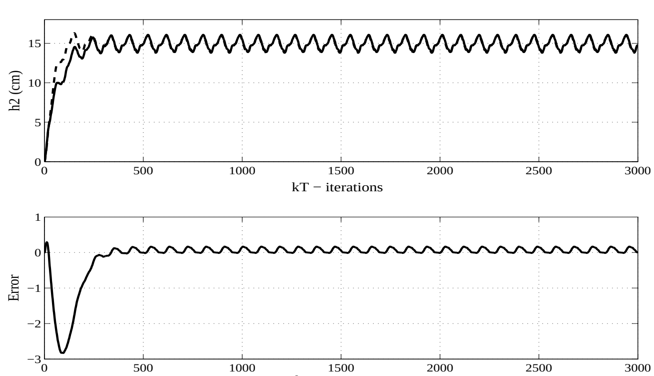

Fig. 10 – Responses of the real (*solid line*) and estimated (*dotted line*) output h_2 using the proposed approach.

Fig. 10 presents the responses of estimated and real output h_2. Simulation results demonstrate that the proposed structure describe very well the system behavior.

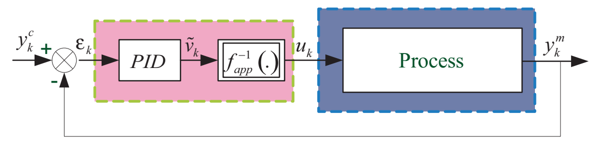

Fig. 11 – Proposed nonlinear PID controller of a two-tank system.

Fig. 11 shows the diagram block of the proposed nonlinear PID controller of a two-tank system. It is consists of:

- the inverse of the nonlinearity $f^{-1}_{app}(\tilde{v}_k)$:

$$u_k = w^3_{1,k}\, V_k + \tilde{w}^3_{2,k}\, \tilde{V}^{[2]}_k + \tilde{w}^3_{3,k}\, \tilde{V}^{[3]}_k + O(V^{[4]}_k)$$

with:

$$w^3_{1,k} = (\ 1 \quad -1\ )$$

$$\tilde{w}^3_{2,k} = (\ -5 \quad 10 \quad -5\ )$$

$$\tilde{w}^3_{3,k} = (\ 25 \quad 75 \quad 76 \quad 25\ )$$

- the PID regulator:

$$(K_p,\ K_i,\ K_d) = (0.45,\ 0.7,\ 0)$$

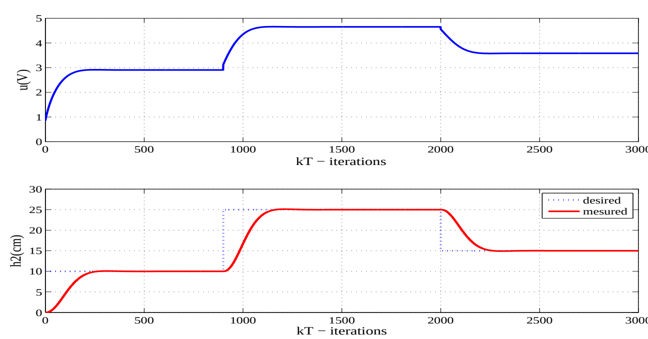

Fig. 12 – Responses of u and h_2 using the proposed method of identified model.

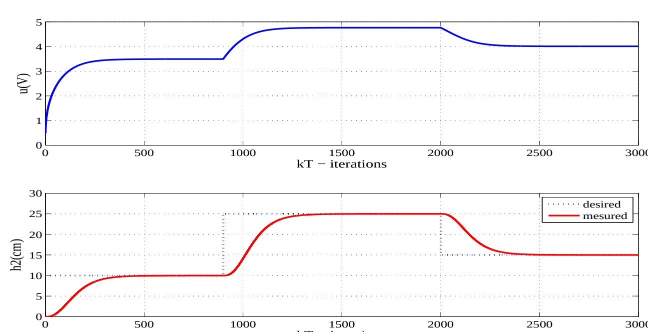

Fig. 13 – Responses of u and h_2 using the proposed method of system.

The control signals and the results of the regulator are presented in figures 12 and 13. They proved that the PID^{NL} had achieved a satisfactory performance in tracking the reference signal.

VI. Conclusion

In this paper, a new strategy to identify Hammerstein model has been proposed. A polynomial structure is used to model the nonlinear static function. This structure provide a good identification results. It has the advantage to approximate the inverse of the nonlinear part of Hammerstein model. A new design of PID^{NL} controller is successfully elaborated. It is composed by a PID associated with the inverted of the identified nonlinearity. A two-tank system is presented to illustrate the effectiveness of the proposed approach.

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Large Scale Graph Matching(LSGM): Techniques, Tools, Applications and Challenges

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***Abstract*—Large Scale Graph Matching (LSGM) is one of the fundamental problems in Graph theory and it has applications in many areas such as Computer Vision, Machine Learning, Pattern Recognition and Big Data Analytics (Data Science). Matching belongs to the combinatorial class of problems which refers to finding correspondence between the nodes of a graph or among set of graphs (subgraphs) either precisely or approximately. Precise Matching is also known as Exact Matching such as (sub)Graph Isomorphism and Approximate Matching is called Inexact Matching in which matching activity concerns with conceptual/semantic matching rather than focusing on structural details of graphs. In this article, a review of matching problem is presented i.e. Semantic Matching (conceptual), Syntactic Matching (structural) and Schematic Matching (Schema based). The aim is to present the current state of the art in Large Scale Graph Matching (LSGM), a systematic review of algorithms, tools and techniques along with the existing challenges of LSGM. Moreover, the potential application domains and related research activities are provided.**

***Keywords*—Big Data; Graph Matching; Graph Isomorphism; Graph Analytics; Data Models; Large Scale Graphs**

I. Introduction

In this era of big data, graphs are considered as data representation tool that is capable for holding large scale attributed data and the relationships among data entities. It has been proven that graphs can represent structural information in the form of attributed objects (vertices) and their relationships (edges) in an efficient manner. The ubiquitous nature of graph structure provides better modeling approach for representation of relationships among almost anything (any kind of entities). Some examples from real world where graphs are playing an important role are: Social Networks[1], World Wide Web[2], Flight Route Graphs[3], Communication Networks[4] and Biological/ Chemical Networks[5] etc.

According to literature of graph processing, the problem sizes (benchmarked data sets) are getting large such as Social Network Graph has reached the limit of trillions of edges. Other examples are the Twitter graph which is one of the largest graphs that have 1.5 Billion edges and graph for Yahoo (The Altavista graph) contains 6.6 Billion edges [6], [7]. All the real world graphs with billions or trillions of vertices and edges are challenging to store, process and analyze.

There are various domains like Distributed Systems, Image Processing, Bio/Cheminformatics, Computer Vision and Pattern Matching in which characteristics of graphs are exploited . It is required in many applications to find similarity among objects/graphs. The problem of finding similarity among (sub) graphs is known as (sub) Graph Pattern Matching. Graph simulation[8], Graph isomorphism[9] and Attributed matching[10] are widely studied problems in graph matching. Isomorphism belongs to the NP-complete class of problems and is used for strictest matching of graphs which is conceptually applicable but could not scale well for large graphs[8]. On contrary, graph simulation is considered as an alternative to isomorphism with the relaxation in matching constraints and practically possible in polynomial time[11].

The outline followed in this paper is as: in section 2 it is discussed, how a data model can be represented as a graph model. Section 3 describes the graph matching problems grouped in three categories: semantic, syntactic and schematic matching. Further in section 4, graph matching measures are discussed. In section 5, a systematic review of existing algorithms, tools and techniques related to graph matching along with their potential applications is presented. In section 6, open challenges for both academia and industry are discussed. Related work is presented in section 7, followed by the conclusion in section 8.

II. Data Models as Graphs

The matching problem for graph-oriented data is challenging. Big data and IoT has made World Wide Web (WWW) a major source of data. In many diverse application domains, graphs are one of the important data structures to represent variety of data (Unstructured, Semi-structured, and Structured). Graphs are dominant among data models because of their expressive nature and power to model highly connected and attributed data[9]. Data models such as relational, object-oriented, XML, ontologies, RDF and hierarchies can be represented as graph-oriented data model. In this paper, data models are presented which can map structural data into graph data.

Relational data model is one of the basic and traditional data models which implements first order predicate logic for data management. Data entities have attributes and relationships. Key constraints (such as primary and foreign keys) or referential constraints are applied to attributes and possibly some attributes have data instances as well. The question arises about the data mapping from one model to another model. How can the relational data be represented as the graph data? How can nodes and edges of a graph represent entities, attributes, relationships, key-constraints and data instances of relational data? There are many possible ways for such kind of data mappings.

Generally, graphs represent data as nodes and edges. In the case of relational databases, database name becomes root node and schema is partitioned into tables at level-1 where edges between level-0 (Root Node) and level-1 (Table Nodes) represent relationships. At level-2, nodes can be specified as columns and edges can be considered as attributes. Further, leaf nodes specify data instances or can be referred as tuples. We present a general mapping tree of height 3 (see 1), considering the fact that tree is a specialized form of graph and it is possible to map data from one model to another.

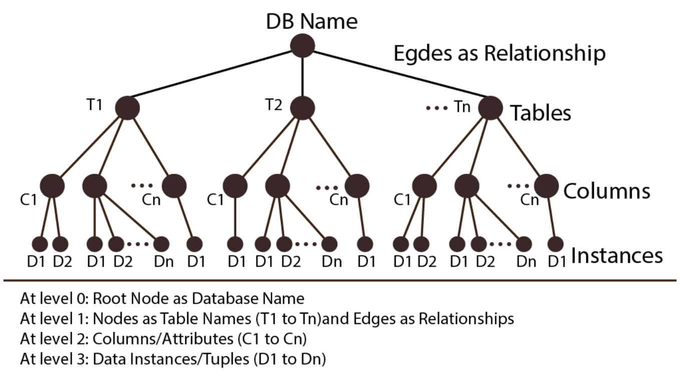

Fig. 1. Data Mapping from Relational Data Model to Graph Data Model

XML data model is capable to model big data like it can capture features of data which is semi-structured and unstructured in nature. DAGs (Directed Acyclic Graphs) are used to represent XML data. Data instances in XML model can either be elements or attributes. Relationships among data entities can be referred as IS-A property. The mechanism of obtaining DAG from XML data is known as ID/IDREF. As XML data possess irregular structure, duplication, missing values and loose constraints, the mechanism of ID/IDREF causes removal of duplicated data and makes it sure that one object has one or more than one instances. The resultant data will be a graph with Parent-Child hierarchy (DAG). Therefore, matching problems related to data source can be resolved by mapping data from one model to another model. Similarly, conceptual hierarchies, ontologies, RDFs and object oriented data models can also be transformed into graph model[12]. The scope of this work is graph or subgraph matching problem. Data models (Relational model for structured data and XML model for semi-structured/Unstructured data) are discussed in which input data could be available for matching problems and it have to be transformed into graph data model.

III. Graph Matching

In Graph theory, Computer Scientists and Mathematicians have done variety of significant work. Graph Matching is one of the graph-based techniques which is briefly discussed in this paper. As Graph matching problems belong to the class of combinatorial problems so it can be practically (computationally) expensive. Graph algorithms which usually take labeled and attributed graphs as an input are good candidates for solving matching problems. From 1976 onward, there has been an increase of algorithms and techniques on graph matching. Representative example of matching algorithms is Ullmans matching algorithm[9]. Other tools and techniques are presented in section 5. In graph matching, categories can be made between matching techniques based on three classifications.

First, does the matching require on structural (topology) level between vertices of one graph or among transactions (set of graphs)? Matching of graph structure is often called as Exact matching or Precise matching or Syntactic Matching. Syntactic matching refers to the techniques in which input is interpreted as a function of structural information which follows formal definition of an algorithm. It was proposed by Bernstein and Cupid [13] system was used for its implementation. There are several graph matching approaches that work on structure-based matching[14], [15]. Conceptual similarity matching is usually insufficient in syntactic matching.

The second category in matching techniques for graphs is based on finding conceptual correspondence between graphs and it is also called semantic matching or approximate matching. Semantic matching refers to the techniques in which input is interpreted as model-theoretic/formal semantics and valid justifications of results are provided[8].

The final distinction in graph matching can be made by matching graphs on the basis of schema and it is also referred as schema-based matching or Schematic Matching. Graph mining is another interesting problem that exploits the similar concepts as graph matching. Graph mining[16] is also known as structural motif finding and it is aimed to find common and interesting patterns in single graph or in transactions (set of small graphs)[17], [4]. In this work, different aspects of graph matching problems and techniques are focused. Several aspects of Graph mining are discussed in surveys which provides a thorough understanding about this technique [18], [19].

IV. Graph Matching Measures

Graph matching measures are well-known concepts that are also known as graph similarity measures such as Graph edit distance, Median Graph, Maximum Common Subgraph, Minimum Common SuperGraph, Graph Isomorphism and Subgraph Isomorphism. Graph isomorphism is used to check whether graphs have structural similarity or not. Subgraph Isomorphism is used to find if a graph is a subgraph(part of a graph) of another.

A. *Graph Edit Distance(GED):*

The GED (Graph Edit Distance) of data graphs is determined by the number of edit operations needed to transform one graph into another. Thus, smaller the edit distance of two graphs, the more similarity will exist between graphs. Among the graph similarity measures, GED (Graph Edit Distance) is most commonly used to find similarities between pair of graphs or subgraphs.It is also referred as error-tolerant graph isomorphism. Many applications need to manipulate graph-oriented data with less distortion in order to transform a graph into a similar structured graph[20]. Like SED (String Edit distance), GED performs a set of basic graph edit operations for manipulation such as vertex/edge insertion, vertex/edge deletion and vertex/edge substitution. It has numerous applications in the fields of Computer Vision, Pattern Recognition, Machine Learning, Handwriting Recognition and Cheminformatics.

B. *Median Graph:*

The concept of median graph is used for representation of graphs. It can be exploited to extract significant structural patterns from graphs on the basis of similarity or dissimilarity. The resultant graph that contains important information can be obtained by the procedure of graph matching[21]. Graphs for big data are usually stored in clusters. Median graph is a potential candidate for better partitioning of graphs in clustered environment. Web Mining, Shape Matching and Image Retrieval are some of the dominant applications of median graph.

C. *Maximum Common Subgraph(MCS)*

The similarity of the objects can be measured by Maximum Common Subgraph (MCS) if no isomorphism exists between graphs. Graph matching can be accomplished by MCS between a set of (sub) graphs[22]. For example in Cheminformatics and Bioinformatics, MCS plays an important role in several aspects like Molecular Spectra Interpretation, Biochemical Activity Prediction, Reaction Modeling and many others. There are many research fields other than Chem/Bioinformatics as well, in which MCS is playing a significant role such as Image Recognition, Computer Vision, Mathematics and Pattern Matching etc.The minimum common supergraph of corresponding graphs can be thought of as either the concept of smallest super trees between corresponding trees or the shortest common supersequence among collection of strings.

V. Potential Application Domains, Algorithms, Tools and Techniques for LSGM

There are many emerging applications where semantic matching is applicable such as schema emergence, event processing, data migration/integration, management of knowledge diversity, query translation and resource discovery etc[41].

In Health Sciences, Subgraph Matching has applications for example biological graphs [42], alignment of metabolic and protein networks [43], [44], inference of brain connectivity on MRI(Magnetic Resonance Imaging) data[45] and biological network analysis[5]. Network monitoring[2], schema matching [46], information fusion and control[47], product assembling and design [48], process management[49], document classification [50] and anomaly detection[51] are among real use cases of Graph Matching.

Schema based matching is used to operate traditional applications such as data warehousing , information integration and distributed query processing as well as emergent applications like service integration on WWW, peer to peer database management and agent communication etc. Generally, such applications exploit structural data or typically conceptual models.

Computer Vision and Image processing have various potential applications where GM is intensively used for example, similar image detection[52], Person or Object identification and retrieval[53] , 3D perspective reconstruction[54], image extrapolation[55], satellite imagery [56] etc.

Table I presents the systematic review of surveyed Graph Matching tools, techniques and algorithms. DualIso[40] is an algorithm that performs exact matching for subgraph isomorphism problem by exploiting pruning algorithm which makes it conceptually simple and memory efficient. TuboIso[39] is another robust and efficient solution for Isomorphic subgraph search for large scale graphs which is exploiting two novel concepts: COMP/PREM (Combine and Permute strategy) and the Candidate Region Exploration. STwig[12] is the first system that can perform online graph matching and exploration on large scale graphs. For graph exploration, graph data is deployed on memory cloud which exploits commodity hardware (machines) for clusters. Spidermine[38] is suitable to obtain top-K results for graph pattern matching from input graphs. SIGMA (A SET-COVER-BASED INEXACT GRAPH MATCHING ALGORITHM)[37] provides efficient inexact graph matching featured by filtering algorithms.

Catalog integration is one of the prominent applications of web service integration. Conceptual hierarchies can be represented as trees with attributed nodes and edges. In applications like catalog integration, catalogs/service dictionaries can be represented as conceptual hierarchies. eBay and Amazon catalogs are typical examples of such catalogs to quote. Catalog Matching Problem and mapping techniques are discussed in [57]. Web services are applications that provide web interface for users so that they can interact and utilize web services[58]. On the other hand, semantic web exploits the concepts of ontologies and knowledge representation in order to deliver better services. In [59], the process of integration and discovery of web services is presented.

VI. Existing Challenges for Large Scale Graph Matching

With the advent of cutting edge technologies, data is getting huge and traditional approaches are not sufficient to grasp the meaningful hidden insights from data. There are many significant open challenges that are posed by the scale of graphs ranging from storage infrastructures to processing paradigms. General purpose systems for graph processing are not available yet because it is critical to develop such platforms. Graph analytics are of two types that is real-time/online graph analytics and batch/offline graph processing. Distributed systems are considered as feasible platform for both kind of processing for graphs that contain hundreds of billions of nodes. Dataset of graph can be a single large graph or a set of small graphs that are often known as transactions.

Graph partitioning belongs to the class of problems which are NP-complete. Parallel and distributed tools and techniques are upsurging to analyze graph data efficiently. Since the graph of big data is difficult to process at once so it has to be partitioned into set of small graphs while preserving the connectedness of graph and balancing the load on clusters. Therefore, in distributed environments it is challenging to apply state-of-the-art graph algorithms and analytics techniques. A well discussed problem of graph processing is to find good and balanced partitions of large graphs so they could evenly distribute the computational load across clusters[60]. The prominent methods for graph partitioning are edge-cut partitioning and vertex-cut partitioning. Communication overheads can be reduced by exploiting edge-cut partitioning also it can balance the number of nodes (vertices) for each partition [1]. On contrary, vertex-cut partitioning technique can be used to partition Power-Law graphs that contain real-world data such as Collaboration Network or Social Networks.

Graph comparison can be performed by matching graphs or subgraphs. Generally, graph matching problem is to find

TABLE I. ALGORITHMS, TOOLS AND TECHNIQUES FOR LSGM

Algorithms,tools and Techniques		Indexing Scheme	Matching Scheme	Locality	Spatial Complexity	Temporal Complexity
Ullman[15]	1976	No-Indexing	Exact	In-Memory	$O(N^3)$	$O(N!N^2)$
SubDue[23]	1994	Frequent Subgraph	Inexact	Out-of -core	-	Exponential
GraphGrep[24]	2002	Frequent Subgraph	Both	In-Memory	$O(l_p.n_p.l_i)^{l_p}$	$O(n_q + e_q)$
gIndex[25]	2004	Inverted Indexing	Both	Out-of-core	-	$\theta(\frac{1}{max_l})^2$
CTree[26]	2006	Frequent Subgraph	Both	In-Memory	$O(n^2)$	$O(n.d^2 logn)$
FG-Index[27]	2007	Edge indexing	Exact	Out-of-core	$O(F_d)$	$O(T)$
Tree+Delta[28]	2007	Tree-based indexing	Exact	In-Memory	$O(C_q)$	Ploynomial
TALE[29]	2008	NH-Indexing	Inexact	Out-of-core	$O(S_{bit}.log(d))$	$O(S_{bit})$
GraphQL[30]	2008	Frequent Subgraph	Both	In-Memory	$O(k.n)$	$O(n^k)$
RJOIN[31]	2008	Frequent Subgraph	Both	In-Memory	$O(n.5^n)$	$O(mn5^n)$
QuickSi[32]	2008	Swift Indexing	Exact	In-Memory	$O(SEQ_q + g)$	Polynomial
GADDI[33]	2009	NH-Indexing	Exact	In-Memory	$O(n^2)$	$O(n^3)$
DistanceJoin[34]	2009	Frequent Subgraph	Inexact	In-Memory	$O(n)$	$O(n)$
BitMat[35]	2010	Edge indexing	Exact	In-Memory	$O(m)$	$O(m)$
Rdf-3x[36]	2010	Edge indexing	Inexact	Out-of-core	$O(m)$	$O(m)$
SIGMA[37]	2010	Frequent Subgraph	Inexact	On-cloud	-	-
SpiderMine[38]	2011	Frequent Subgraph	Exact	Out-of-core	-	Exponential
STwig[12]	2012	No-Indexing	Both	On-Cloud	$O(n)$	$O(n)$
TurboIso[39]	2013	No-Indexing	Exact	In-Memory	Polynomial	$O(G^2)$
DualIso[40]	2014	Vertex Indexing	Exact	In-Memory	$O(E)$	$O(E)$

the similarity (or dissimilarity) between model graph and input graph. Graph matching can be exact that is exploiting graphs by using their syntactical description or inexact which means comparison between graphs can be performed on the basis of semantics of graphs. There are different approaches used to achieve exact matching for example Isomorphism, monomorphism and subgraph isomorphism.

During last few decades, it has been an open challenge to design well suited algorithms with low complexity for matching large scale graphs. There are many different invariant of graph properties such as scaling and rotation etc. Usually, a good structural correspondence between graphs can be achieved by Graph Isomorphism [61]. Graph isomorphism has applications like Bio/Cheminformatics, Automation of Electronic Circuits and Exact Pattern Recognition[62].

VII. RELATED WORK

In case of big data, graph-oriented data is too large to be queried in an easy and efficient manner. Graph pattern matching queries can be large,take exponential time and return number of matches from a graph[63]. Among classes of queries, TWIG queries are grabbing attention of users from both academia and industry. Many important queries like RDF queries and XQuery/ XPath queries which are XML queries can be treated as TWIG queries[64].

Experiments can be performed on real datasets as well as on synthetic datasets. Examples of existing real datasets are US Patents and WordNet which represents relationships between US referenced patents and English words, respectively. First mentioned graph contains 133,455 edges and 82,670 vertices [65]while second graph has 16,533,438,8 edges and 3,774,768 vertices[66]. Additionally, R-MAT[67] can be used to generate synthetic datasets. The problem of matching graphs for big data is challenging due to the concern of size of graph. Some existing approaches for matching graphs are: Indices method[68] and pruning methods [69]. Distributed and parallel approaches are also used for processing large graphs for example MST (Minimal spanning tree), SPP (Shortest path problem) and connected component are algorithmic strategies that can be used for computation[3].

Matching operations can be classified in various dimensions such as on the basis of input/output of algorithms or on the basis of characteristics of an entire matching process[10]. As first dimension, data/conceptual model representation (either schema or ontology) can be considered as an input for algorithm. For example OWL and RDF models are supported by QOM[70], Relational and XML models are supported by Cupid[13] and Object Oriented and Relational models are supported by Artemis[63]. As a second possibility, algorithms can exploit the characteristic of data (what is the kind of input data?) that is either the input provides instance level information, the schema level information or both. For example COMA[71]and Cupid[13] rely on schema level information, GLUE[36] rely on Instance level information while QOM[70] rely on both. In matching process, algorithms can be classified as semantic, syntactic and schematic nature of computation. Algorithms are used analyze the patterns of data exactly or approximately.

Recently proposed Matching Systems based on schema level matching are Artemis (Analysis of Requirements: Tool Environment for Multiple Information Systems), Similarity Flooding (SF), QOM (Quick Ontology Mapping), OLA (OWL Lite Aligner), COMA (Combination of Matching Algorithms), Cupid, NOM (Naive Ontology Mapping) and Anchor Prompt [72], [70], [71], [13]. There also exist some infrastructures that use matching as integration such as Protoplasm, OntoMerge, MAFRA and Chimaera [73].

VIII. CONCLUSION

We are living in the age of Big Data and graphs are the most suitable choice for representing large scale multi-modal data as they can effectively represent the relationships of different data. Large scale graphs have been used for analysis of complex data sets like social networks, bioinformatics, health informatics, social security, web and scientific applications that produce large amount of data. To fully utilize the information represented by graphs, efficient matching algorithms, tools and techniques are required. In this paper, a review of state of the art Large Scale Graph Matching (LSGM) algorithms, techniques and tools has been presented. Matching problem is described according to various types of graph matching.

Moreover, potential applications and research activities has been presented. This article will be helpful for the researchers to get firsthand knowledge of existing LSGM algorithms and techniques and to plan for future research.

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Medical Image Retrieval based on the Parallelization of the Cluster Sampling Algorithm

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***Abstract*—Cluster sampling algorithm is a scheme for sequential data assimilation developed to handle general non-Gaussian and nonlinear settings. The cluster sampling algorithm can be used to solve a wide spectrum of problems that requires data inversion such as image retrieval, tomography, weather prediction amongst others. This paper develops parallel cluster sampling algorithms, and show that a multi-chain version is embarrassingly parallel, and can be used efficiently for medical image retrieval amongst other applications. Moreover, it presents a detailed complexity analysis of the proposed parallel cluster samplings scheme and discuss their limitations. Numerical experiments are carried out using a synthetic one dimensional example, and a medical image retrieval problem. The experimental results show the accuracy of the cluster sampling algorithm to retrieve the original image from noisy measurements, and uncertain priors. Specifically, the proposed parallel algorithm increases the acceptance rate of the sampler from 45% to 81% with Gaussian proposal kernel, and achieves an improvement of 29% over the optimally-tuned Tikhonov-based solution for image retrieval. The parallel nature of the proposed algorithm makes the it a strong candidate for practical and large scale applications.**

***Keywords*—Bayes' theorem; Hamiltonian Monte-Carlo; Inverse problems; Markov chain Monte-Carlo; Medical image reconstruction; Parallel programming**

I. INTRODUCTION

Signal retrieval from noisy measurements (observations) involves solving an inverse problem. Inverse problems are essential in many fields such as image reconstruction or retrieval, tomography, weather prediction, and other predictions based on space-time models. The solution of inverse problems usually employs a data assimilation (DA) methodology [2], [5], [6], [10] [13], [16]. DA refers to the process of fusing information about a physical system obtained from different sources in order to produces more accurate conclusions about the physical system of concern. Two approaches are widely employed to solve an inverse problem. The first approach is a variational approach that involves solving an optimization problem with a regularized solution. The second approach is the statistical formulation of the DA problem which incorporates a prior distribution that encapsulates the knowledge about the system produced by the model, prior to the incorporation of any other source of information. Given the prior information, a likelihood function, the posterior is formulated as best estimate of the truth. Markov Chain Monte-Carlo (MCMC) is one of the most powerful simulation techniques for sampling a high-dimensional probability distribution, given only it's shape function, without the intrinsic need to the associated scaling factor. HMC sampling filter [3] is an accelerated Markov chain Monte-Carlo (MCMC) algorithm for solving the non-Gaussian sequential DA "filtering problem". This algorithm works by sampling the posterior distribution to produce description of the system state along with associated uncertainty. Specifically, these algorithms follow a Hamiltonian Monte-Carlo (HMC) approach to sample the posterior.

Cluster sampling filters ($\mathcal{C}\ell$HMC, and MC-$\mathcal{C}\ell$HMC) [1] are developed as extension of the Hamiltonian Monte-Carlo (HMC) sampling filter presented in [3] where the true (unknown) prior distribution is approximate using a Gaussian mixture model (GMM). Given the current computational power, it is natural to try to run Monte-Carlo simulations in parallel. However, Markov chains in general have to satisfy the so-called the "*Markovian*" property which makes the chain generation an inherently sequential problem. This restriction is mainly posed by the transition density function used to generate a proposal state given the current state of the chain. Two approaches have gained wide popularity to parallelize MCMC samplers. The parallel-chain approach proceeds by running several chains in parallel from different initial states. The main disadvantage of this approach is that the burn-in stage has to be carried out by all chains independently, which limits the efficiency gained by running the chains on different processors. Another difficulty with this approach is the aggregation of samples generated on different processors such that the combined ensemble correctly represents the mass of the target distribution. The second approach is to parallelize a single chain. The parallel chain approach turns out to be surprisingly effective in practice. Moreover, if sufficient information about the geometry of the target distribution is available, the parallel chains can be guided to sample effectively from the target distribution. The accuracy of $\mathcal{C}\ell$HMC filters to handle nonlinearity in both model dynamics, and observational mapping operator, puts it on the right direction of applicability to practical problems. The cost of serial $\mathcal{C}\ell$HMC is nearly similar to the cost of the original HMC sampling filter, however the MC-$\mathcal{C}\ell$HMC algorithm is naturally parallel. Following a Bayesian approach, $\mathcal{C}\ell$HMC algorithm can be easily modified and applied for image retrieval given noisy image and a probabilistic representation of prior knowledge [8], [16]. This can be very useful in settings where several medical snapshots are collected for the same object, e.g. a tumor, of different resolution or uncertainty levels. Mathematical regularization is amongst the most popular methods for image reconstruction from noisy sources [7], [12], [17]. Among the regularization methods, the Tikhonov scheme is most popular due to the Gaussianity assumption about data noise, and the easiness to incorporate prior information. Despite simplicity, the performance of this approach is highly influenced by the choice of the regularization parameter. Widely used methodologies for solving the Bayesian image retrieval problem include the algorithms discussed in [9], [15]. In [9], the authors investigate statistical image reconstruction (SIR) with regularization based on the Markov random field (MRF) model. While, regularization approach is popular, it is sensitive to the choice of the regularization parameter.

The main interest here is to develop highly accurate parallel Bayesian sampling algorithms that can be efficiently used for solving large-scale inverse problems, and show that they are suitable for a wide spectrum of applications including medical image retrieval. This work develops parallel cluster sampling algorithms, and shows that a multi-chain version is embarrassingly parallel, and can be used efficiently for medical image retrieval amongst other applications. The approach discussed in this work does not require regularization, and is designed to work in both Gaussian, and non-Gaussian case, where the computational expense is minimized via parallelization. Specifically, this paper focuses on describing the complexity analysis of a specific scenario where the MC-$\mathcal{C}\ell$HMC is parallelized by running several chains in parallel to sample the posterior distribution. The algorithm proceeds by running several Markov chains in parallel such that the number of chains is specified by the the number of components in the mixture model. This paper will focus on the case where an ensemble of states, generated from an unknown prior distribution is available, and the likelihood function relating observations to target states is either a linear or a nonlinear map. The prior distribution is approximated using a Gaussian mixture distribution which parameters are approximated based on the given prior ensemble by running an expectation maximization (EM) algorithm.

Section II reviews the general iterative and Bayesian frameworks for inverse problems and image reconstruction. Section III formulates the problem, and reviews the $\mathcal{C}\ell$HMC filter formulation. Section IV discusses opportunities for parallelization of $\mathcal{C}\ell$HMC. Section V presents a detailed complexity analysis of the proposed parallel version of $\mathcal{C}\ell$HMC filter. Numerical results are presented in Section VI. Conclusions and future works are drawn in Section VII

II. Iterative and Bayesian Image Reconstruction

As mentioned in Section I, one of the most popular iterative reconstruction algorithms is Regularization-based algorithms. For the sake of completeness, This paper reviews the Tikhonov regularization approach [14], [17], then it presents the Bayesian formulation. The Tikhonov regularization approach involves solving the following optimization problem:

$$\mathbf{x}^{\mathrm{a}} = \min_{\mathbf{x}} T(\mathbf{x}) = \|\mathcal{H}(\mathbf{x}) - \mathbf{y}\|^2_{R^{-1}} + \alpha \|\mathbf{x}\|^2_{\mathbf{C}}, \tag{1}$$

where α is the regularization parameter, and $\mathbf{C}$ is the regularization matrix and it can be chosen in many clever ways. Here $\mathcal{H}$ is an observation operator that maps the model space to the observation space. If the target state is directly observed then $\mathcal{H} = \mathbf{I}$, where $\mathbf{I}$ is the identity operator. The weighted norm in Equation (1) is described as follows:

$$\|\mathbf{c} - \mathbf{d}\|^2_M = (\mathbf{c} - \mathbf{d})^{\mathbf{T}} \mathbf{M} (\mathbf{c} - \mathbf{d}) \tag{2}$$

The traditional approach to regularization is the variational formulation in which equation (1) is minimized w.r.t $\mathbf{x}$. Usually, derivative-based iterative minimization algorithms are employed to solve the problem described by (1). The derivative of the objective function $T(\mathcal{H}(\mathbf{x}))$ w.r.t the parameter $]x$ is given by:

$$\nabla_{\mathbf{x}} T(\mathcal{H}\mathbf{x}) = [\partial \mathcal{H}(\mathbf{x})]^* \, \mathbf{R}^{-1} (\mathcal{H}(\mathbf{x}) - \mathbf{y}) + \alpha \mathbf{C} \mathbf{x}, \tag{3}$$

where $[\partial \mathcal{H}]^*$ is the adjoint of the derivative, e.g. the Jacobian-transpose, of the observation operator $\mathcal{H}$. In the case of a linear observation operator this is simply the transpose of the observation operator.

In the statistical approach the underlying state $\mathbf{x}$ based on a formulation constructed using Bayesian theory is inferred, where the goal is to represent the state as a random variable which distribution is of interest. Assume $\mathcal{P}^{\mathrm{b}}(\mathbf{x})$ is a prior probability density function (PDF) representing prior knowledge about the state $\mathbf{x}$. Assume also that $\mathcal{P}(\mathbf{y}|\mathbf{x})$ is the data likelihood function that describes the observational error distribution. Using Bayes' theorem, the probability of the state $\mathbf{x}$ given the collected measurements is characterized by the posterior distribution:

$$\mathcal{P}(\mathbf{x}|\mathbf{y}) \propto \mathcal{P}(\mathbf{y}|\mathbf{x}) \mathcal{P}(\mathbf{x}) \, . \tag{4}$$

A common practice is to assume that the prior distribution is, generally speaking, a multivariate normal (Gaussian) distribution centered around a a first-guess state, e.g. a fore-casted state $\mathbf{x}^{\mathrm{b}}$, and have a predefined covariance structure $\mathbf{C}$, i.e. $\mathbf{x} \sim \mathcal{N}(\mathbf{x}^{\mathrm{b}}, C)$.

For Gaussian priors and consequently Gaussian posteriors, the variational approach corresponds to finding the maximum a posteriori probability (MAP) estimate of the posterior PDF. The MAP is the maximizer of the posterior PDF, or equivalently, the minimizer of its negative logarithm $-\log\left(\mathcal{P}(\mathbf{x}|\mathbf{y})\right)$. Following Tikhonov regularization approach (1), and assuming Gaussian noise, the likelihood function reads:

$$\mathcal{P}(\mathbf{y}|\mathbf{x}) \propto \exp\left(-\frac{1}{2} \|\mathcal{H}(\mathbf{x}) - \mathbf{y}\|^2_{\mathbf{R}^{-1}}\right). \tag{5}$$

Without loss of generality, assuming $\mathbf{x} \sim \mathbf{N}(0, \mathbf{C})$, the prior would be on the form

$$\mathcal{P}(\mathbf{x}) \propto \exp\left(-\frac{1}{2} \|\mathbf{x}\|^2_{\mathbf{B}}\right), \tag{6}$$

where $\mathbf{B}$ is the precision matrix, i.e. the inverse of the covariance $\mathbf{B} = \mathbf{C}^{-1}$. The MAP estimator in this formulation is the minimizer of

$$-\log \mathcal{P}(\mathbf{x}|\mathbf{y}) \propto \frac{1}{2} \|\mathcal{H}(\mathbf{x}) - \mathbf{y}\|^2_{\mathbf{R}^{-1}} + \frac{1}{2} \|\mathbf{x}\|^2_{\mathbf{B}} \, . \tag{7}$$

This shows the equivalence between Tikhonov regularization approach with the Bayesian formulation in the Gaussian linear settings.

In the Bayesian approach, once the posterior is constructed, a sampling mechanism is usually employed to estimate all the desired statistics of the posterior PDF, such as the posterior mean $\mathbb{E}(\mathbf{x}|\mathbf{y})$ that can be used as a reliable estimate of the state given the data. Moreover, the generated ensemble can be used to estimate the posterior covariance that can be used as a proxy prior error covariance for future applications of the inverse problem. Sampling the posterior PDF is usually carried out following a Monte-Carlo approach. The most powerful Monte-Carlo sampling methodology is the general family Markov-Chain Monte Carlo (MCMC) samplers. Sampling high dimensional distribution however is a very expensive process, and requires parallel efficient implementation to be considered practical. As explained in the next Section, MCMC is not limited to Gaussian or linear settings, and can be very efficient if implemented in parallel.

III. Cluster Sampling Filter

Let $\mathbf{x} \in \mathbb{R}^{\mathrm{N_{var}}}$ is a discretized approximation of the true state of the model, for example the intensities of an image pixels.

The prior distribution $\mathcal{P}^{\mathrm{b}}(\mathbf{x})$ encapsulates the knowledge about the system state before additional information is incorporated. The likelihood function $\mathcal{P}(\mathbf{y}|\mathbf{x})$ quantifies the deviation of the prediction of model observations from the collected measurements $\mathbf{y} \in \mathbb{R}^{\mathrm{N_{obs}}}$, where $\mathrm{N_{obs}} \leq \mathrm{N_{var}}$.

From Bayes' theorem, the posterior distribution $\mathcal{P}^{\mathrm{a}}(\mathbf{x})$ reads:

$$\mathcal{P}^{\mathrm{a}}(\mathbf{x}) = \mathcal{P}(\mathbf{x}|\mathbf{y}) = \tfrac{\mathcal{P}(\mathbf{y}|\mathbf{x})\mathcal{P}^{\mathrm{b}}(\mathbf{x})}{\mathcal{P}(\mathbf{y})} \propto \mathcal{P}(\mathbf{y}|\mathbf{x})\mathcal{P}^{\mathrm{b}}(\mathbf{x})\,, \tag{8}$$

where $\mathcal{P}^{\mathrm{b}}(\mathbf{x})$ is the prior distribution, $\mathcal{P}(\mathbf{y}|\mathbf{x})$ is the likelihood function. $\mathcal{P}(\mathbf{y})$ acts as a scaling factor and is ignored in in the MCMC context.

Assuming the prior distribution is approximated by a Gaussian Mixture distribution, the prior takes the form:

$$\begin{aligned}\mathcal{P}^{\mathrm{b}}(\mathbf{x}) &= \sum_{i=1}^{\mathrm{N_c}} \tau_i\, \mathcal{N}(\mu_i,\, \Sigma_i) \\ &= \sum_{i=1}^{\mathrm{N_c}} \tau_i\, \frac{(2\pi)^{-\frac{\mathrm{N_{var}}}{2}}}{\sqrt{|\Sigma_i|}}\, \exp\left(-\frac{1}{2}\|\mathbf{x}-\mu_i\|^2_{\Sigma_{\mathbf{i}}^{-1}}\right),\end{aligned} \tag{9}$$

where the weight τ_i quantifies the probability that an ensemble member $\mathbf{x}[e]$ belongs to the i^{th} component, and $(\mu_i,\, \Sigma_i)$ are the mean and the covariance matrix associated with the i^{th} component of the mixture model. Here $\mathbf{x} \in \mathtt{R}^{\mathrm{N_{var}}}$, where $\mathrm{N_{var}}$ the dimension of the target state space.

Assuming the observation errors are characterized by a Gaussian distribution $\mathcal{N}(0, \mathbf{R})$, the likelihood reads:

$$\mathcal{P}(\mathbf{y}|\mathbf{x}) = \frac{(2\pi)^{-\frac{\mathrm{m}}{2}}}{\sqrt{|\mathbf{R}|}}\, \exp\left(-\frac{1}{2}\|\mathcal{H}(\mathbf{x})-\mathbf{y}\|^2_{\mathbf{R}^{-1}}\right), \tag{10}$$

where $\mathbf{R} \in \mathtt{R}^{\mathrm{m}\times\mathrm{m}}$ is the observation error covariance matrix, and $\mathcal{H} : \mathtt{R}^{\mathrm{N_{var}}} \to \mathtt{R}^{\mathrm{m}}$ is the observation operator that maps the state space to the observation space. Here $\mathbf{y} \in \mathtt{R}^{\mathrm{m}}$ is the observation vector.

From Equations (8), (9), (10), the posterior takes the form:

$$\begin{aligned}\mathcal{P}^{\mathrm{a}}(\mathbf{x}) \propto \exp&\left(-\frac{1}{2}\|\mathcal{H}(\mathbf{x})-\mathbf{y}\|^2_{\mathbf{R}^{-1}}\right) \\ &\sum_{i=1}^{\mathrm{N_c}} \frac{\tau_i}{\sqrt{|\Sigma_i|}}\, \exp\left(-\frac{1}{2}\|\mathbf{x}-\mu_i\|^2_{\Sigma_{\mathbf{i}}^{-1}}\right)\end{aligned} \tag{11}$$

This mixture distribution may not correspond to a Gaussian mixture in general if the observation operator is a nonlinear map.

The negative-logarithm (negative-log) of the posterior distribution kernel (11) is required by the HMC sampling algorithm. Specifically, the posterior negative-log is viewed as the potential energy function in the extended Hamiltonian phase space. The posterior negative-log is given by:

$$\begin{aligned}\mathcal{J}(\mathbf{x}) &= \frac{1}{2}\|\mathcal{H}(\mathbf{x})-\mathbf{y}\|^2_{\mathbf{R}^{-1}} \\ &\quad -\log\left(\sum_{i=1}^{\mathrm{N_c}} \frac{\tau_i}{\sqrt{|\Sigma_i|}}\, \exp\left(-\frac{1}{2}\|\mathbf{x}-\mu_i\|^2_{\Sigma_{\mathbf{i}}^{-1}}\right)\right)\end{aligned} \tag{12}$$

The derivative of the posterior negative-log reads:

$$\begin{aligned}\nabla_{\mathbf{x}}\mathcal{J}(\mathbf{x}) &= \mathbf{H}^T\mathbf{R}^{-1}(\mathcal{H}(\mathbf{x})-\mathbf{y}) \\ &+ \frac{\sum_{i=1}^{\mathrm{N_c}} \frac{\tau_i}{\sqrt{|\Sigma_i|}} \left(\exp\left(-\frac{1}{2}\|\mathbf{x}-\mu_i\|^2_{\Sigma_{\mathbf{i}}^{-1}}\right)\right) \Sigma_{\mathbf{i}}{}^{-1}(\mathbf{x}-\mu_i)}{\sum_{i=1}^{\mathrm{N_c}} \frac{\tau_i}{\sqrt{|\Sigma_i|}}\, \exp\left(-\frac{1}{2}\|\mathbf{x}-\mu_i\|^2_{\Sigma_{\mathbf{i}}^{-1}}\right)}\end{aligned} \tag{13}$$

In this work, the posterior is sampled distribution (11) following a parallel chains approach given only ensemble of states generated from the prior distribution.

IV. Parallelization of $\mathcal{C}\ell$HMC Filter

In this section, a brief review of the MCMC sampling algorithm is presented, and discuss opportunities of running $\mathcal{C}\ell$HMC filter on parallel architecture. The parallelism of $\mathcal{C}\ell$HMC filter even if the Hamiltonian system is replaced with a Gaussian proposal kernel build around the forecast also discussed.

A. Markov Chain Monte-Carlo (MCMC)

MCMC is a sampling scheme capable of producing ensembles from an arbitrary distribution given it's shape function, without the need for the associated scaling factor. The choice of the proposal kernel has the greatest influence on the performance of the sampler. Here, two proposal kernels are chosen; a) a Gaussian density function centered around the current state of the chain, b) Hamiltonian Monte Carlo (HMC). The standard MCMC sampler is described in Algorithm 1.

The standard MCMC algorithm1 generally suffers from random walk behavior, slow convergence to the target density, low acceptance rate, and slow space exploration. Moreover, the generated samples are highly correlated when the vanilla MCMC algorithm is used. Many of these problems can be addressed by using Hybrid Monte Carlo (HMC). HMC uses a Hamiltonian system which plays the role of the proposal density.

Algorithm 1 MCMC algorithm to sample from $\pi(\mathbf{x})$.

Input: An initial state for the chain ($\mathbf{x}^0$), and the proposal kernel q
Input: An ensemble of states from the posterior distribution $\propto \pi(\mathbf{x})$
while No sufficient samples collected **do**
  Given current state $\mathbf{x}^k$, use q to propose x'
  Calculate the acceptance probability (MH): $a^k = \min\left(1\,,\ \frac{\pi(x')q(x',x^k)}{\pi(x^k)q(x^k,x')}\right)$
  Sample a uniform r.v. $u^k \sim \mathcal{U}(0,1)$
  if $a^k > u^k$ **then**
    Accept the proposal: $x^{k+1} = x'$
  else
    Reject the proposal: $x^{k+1} = x^k$

B. The multi-chain MCMC algorithm (MC-MCMC)

Although the traditional MCMC algorithm is inherently serial, there are several modifications that can be made to allow for parallelization. In the proposed approach, instead of constructing a single long Markov chain to produces $\mathrm{N_{ens}}$ samples, generate several shorter Markov chains are generated and divide the ensemble size $\mathrm{N_{ens}}$ over these chains. The constructed chains can run in parallel to sample different regions of the target distribution independently. The parallel (MC-MCMC) sampler starts by running an Expectation Maximization step to build a Gaussian Mixture Model (GMM) approximation of the prior distribution. Once the GMM is constructed on the root processor, the GMM information is broadcasted to all the working nodes. Of course, if the number of processors is exactly the same as the number of components, each node is assigned one chain. If the number of processors is less than the number of components/chains, several chains can be assigned to each processor, e.g. based on the local ensemble sizes or simply in a round-robin fashion. Caution has to be exercised to maintain a balanced load. Once all chains have generated their assigned local samples, the ensembles are gathered to the root processor and returned as output. Of course parallel output can be considered to reduce the communication overhead. The steps of the proposed MC-MCMC scheme is detailed in Algorithm 2.

By running a Markov chain starting at each component of the mixture distribution, the proposed algorithm navigates all modes of the posterior distribution, and covers all regions of high probability.

While parallelization of HMC itself can be considered for further increase in the performance, it has been avoided for clarity and to simplify the idea. The Master-Slave parallel pattern is elected to be used, where a master core sends the information required for creating the individual chains.

V. Complexity Analysis

This section provides a detailed theoretical discussion of the computational cost of the proposed parallel algorithm.

A. Cost of sampling a Gaussian $\mathcal{N}(\mu,\,\Sigma)$

A scalar normal distribution can be sampled using many accurate algorithms such as the Mersenne Twister, Box-Muller transform, Marsaglia polar method, and Ziggurat algorithm. The least expensive is Ziggurat algorithm, where a typical value produced only requires the generation of one random floating-point value and one random table index, followed by one table lookup, one multiply operation and one comparison. The cost of generating an $\mathrm{N_{var}}-$dimensional standard normal random vector $\mathbf{x} \in \mathbb{R}^{\mathrm{N_{var}}}$ is $O(\mathrm{N_{var}})$. To generate a multivariate normal (MVN) random vector *Ziggurat algorithm* from a general Gaussian distribution $\mathcal{N}(\mu,\,\Sigma)$ the following steps are required:

1) Factorization of the covariance matrix Σ, to generate $\Sigma^{\frac{1}{2}}$, e.g. using Cholesky decomposition
2) Draw a standard normal random vector $\mathbf{y} \in \mathcal{N}(\mathbf{0}\,\mathbf{I})$,
3) Scaling: $\mathbf{x} = \Sigma^{\frac{1}{2}}\mathbf{y} + \mu$

If the covariance matrix Σ is diagonal, the factorization costs $O(\mathrm{N_{var}})$, while the cost of Cholesky decomposition in general is $O(\mathrm{N_{var}^3})$. If the covariance matrix Σ is diagonal, the cost of the scaling step is $O(\mathrm{N_{var}})$, otherwise the scaling cost is $O(\mathrm{N_{var}^2})$.

Algorithm 2 MC-MCMC parallel sampling algorithm.

Input: Ensemble of prior states.
Output: An ensemble of states from the posterior Mixture distribution (11).
Run an EM algorithm (possibly in parallel) to build a GMM approximation of the prior distribution the given ensemble
if EM is run in parallel **then**
  GatherAll GMM information to all processors
else
  Broadcast GMM information to all processors
$\mathrm{N_c}$ chains are assigned to the available processors
The local ensemble size (sample size per chain) can be specified for example based on the weight of the prior weight of the corresponding component, multiplied by the likelihood of the mean of that component
Every chain is initialized to the mean of the corresponding component in the prior distribution
The parameters of the proposal kernel, e.g. covariance of the Gaussian kernel, or the mass matrix associated with HMC sampler, are set locally based on the statistics obtained from the prior ensemble under the corresponding component in the prior mixture.
After each chain collects it's assigned sample size, Gather the ensembles generated by all nodes, and possibly weight them according to the importance of each component

B. Cost of MCMC with a Gaussian proposal density

Assuming independent observations, evaluating the posterior PDF at a given state requires the evaluation of $\mathrm{N_c}+1$ matrix-vector products. The cost of evaluating the posterior PDF is $O\left((\mathrm{N_c}+1)\,\mathrm{N_{var}}\right) = O(\mathrm{N_{var}})$ if the covariance matrices of the components the GMM prior are diagonal, otherwise, the cost is $O(\mathrm{N_{var}^2})$.

a) Cost of one MCMC step:: In the presence of a Gaussian kernel, each step of the chain construction requires the following:

1) One MVN random vector drawn from the Gaussian kernel,
2) Two function (posterior PDF) evaluations,
3) One draw from a uniform random distribution $\mathcal{U}(0,1)$,
4) One scalar comparison in the Metropolis-Hastings step.

The cost of one MCMC step can be summarized as follows:

$$\begin{cases} O(\mathrm{N}_{\mathrm{var}}^2) + O(\mathrm{N}_{\mathrm{var}}^2) + O(1) = O(\mathrm{N}_{\mathrm{var}}^2) & \text{full GMM covariances, and full Gaussian kernel} \\ O(\mathrm{N}_{\mathrm{var}}^2) + O(\mathrm{N}_{\mathrm{var}}) + O(1) = O(\mathrm{N}_{\mathrm{var}}^2) & \text{full GMM covariances, and diagonal Gaussian kernel} \\ O(\mathrm{N}_{\mathrm{var}}) + O(\mathrm{N}_{\mathrm{var}}^2) + O(1) = O(\mathrm{N}_{\mathrm{var}}^2) & \text{diagonal GMM covariances, and full Gaussian kernel} \\ O(\mathrm{N}_{\mathrm{var}}) + O(\mathrm{N}_{\mathrm{var}}) + O(1) = O(\mathrm{N}_{\mathrm{var}}) & \text{diagonal GMM covariances, and diagonal Gaussian kernel} \end{cases}$$

To find the total cost of MCMC sampling algorithm, it is needed to evaluate the total number of steps in the Markov chain. If the ensemble size is $\mathrm{N}_{\mathrm{ens}}$, it is needed to construct a chain of length $b_s + m_s \times \mathrm{N}_{\mathrm{ens}}$, where b_s are burn-in steps carried out to achieve convergence to the stationary distribution, and m_s are mixing steps introduced to improve the sampler mixing and reduce the correlation between selected ensembles

b) Total cost of MCMC sampling:: The total cost of a serial MCMC with with a Gaussian proposal density reads:

$$T_s = \begin{cases} O\Big((b_s + m_s\, \mathrm{N}_{\mathrm{ens}})\, \mathrm{N}_{\mathrm{var}} \Big) & \text{diagonal prior covariances, and diagonal Gaussian kernel} \\ O\Big((b_s + m_s\, \mathrm{N}_{\mathrm{ens}})\, \mathrm{N}_{\mathrm{var}}^2 \Big) & \text{otherwise} \end{cases}$$

C. Cost of HMC

The HMC sampler requires the evaluation of the gradient of the negative-log of the target distribution.

a) Cost of one HMC step:: In the case of HMC, each step of the chain construction requires the following:

1) One draw of a momentum $\mathbf{p} \sim \mathcal{N}(0, \mathbf{M})$ costs $O(\mathrm{N}_{\mathrm{var}})$ with diagonal M.
2) Forward propagation of the pair $(\mathbf{p}, \mathbf{x})$.

The cost of the second step is dominated by the cost of evaluating a Jacobian-vector product $O(\mathrm{N}_{\mathrm{var}}^2)$. With step parameters $T = m \times h$, the cost is $O(m\,\mathrm{N}_{\mathrm{var}}^2)$, where m is the number of steps in the Hamiltonian trajectory. Evaluating loss of energy requires evaluating the negative-log of the posterior shape function. Again, the cost of evaluating the posterior PDF is $O\left((\mathrm{N}_{\mathrm{c}} + 1)\, \mathrm{N}_{\mathrm{var}}\right) = O(\mathrm{N}_{\mathrm{var}})$ if the covariance matrices of the components the GMM prior are diagonal, otherwise, the cost is $O(\mathrm{N}_{\mathrm{var}}^2)$.

For Hamiltonian Monte Carlo (HMC), Assuming a diagonal mass matrix $\mathbf{M}$ the cost of one step of the chain is

$$\begin{cases} O(\mathrm{N}_{\mathrm{var}}) + O(m\,\mathrm{N}_{\mathrm{var}}^2) + O(\mathrm{N}_{\mathrm{var}}) + O(1) = O(m\,\mathrm{N}_{\mathrm{var}}^2) & \text{diagonal prior covariances} \\ O(\mathrm{N}_{\mathrm{var}}) + O(m\,\mathrm{N}_{\mathrm{var}}^2) + O(\mathrm{N}_{\mathrm{var}}^2) + O(1) = O(m\,\mathrm{N}_{\mathrm{var}}^2) & \text{non-diagonal prior covariances} \end{cases} \tag{14}$$

b) Total cost of HMC sampling:: Following the discussion above, the cost of serial HMC sampler is $T_s = O\Big((b_s + m_s\, \mathrm{N}_{\mathrm{ens}})\; m\, \mathrm{N}_{\mathrm{var}}^2 \Big)$.

D. Cost of MC-MCMC sampling

The serial complexity T_s of MC-MCMC is summarized as follows:

$$T_s = \begin{cases} \left.\begin{matrix} O\left((b_s + m_s\, \mathrm{N}_{\mathrm{ens}})\, \mathrm{N}_{\mathrm{var}}\right)\ ; & \text{diagonal or spherical covariances of GMM, and proposal density} \\ O\left((b_s + m_s\, \mathrm{N}_{\mathrm{ens}})\, \mathrm{N}_{\mathrm{var}}^2\right)\ ; & \text{otherwise} \end{matrix}\right\} \text{Gaussian proposal} \\ O\left((b_s + m_s\, \mathrm{N}_{\mathrm{ens}})\; m\, \mathrm{N}_{\mathrm{var}}^2\right) \quad \} \text{ Hybrid Monte Carlo} \end{cases} \tag{15}$$

a) Parallel cost:: The parallel complexity can be studied clearly under a simplified (ideal) assumption, where each chain is to sample $\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}$ ensemble points. In this case, since there are N_{c} chains the parallel cost (discarding the communication cost) of MC-MCMC is given by:

$$T_p = \begin{cases} \left.\begin{matrix} O\left(\frac{\mathrm{N}_{\mathrm{c}}}{p}\left(b_s + m_s\,\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)\mathrm{N}_{\mathrm{var}}\right)\ ; & \text{diagonal, or spherical covariances of GMM, and proposal density} \\ O\left(\frac{\mathrm{N}_{\mathrm{c}}}{p}\left(b_s + m_s\,\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)\mathrm{N}_{\mathrm{var}}^2\right)\ ; & \text{otherwise} \end{matrix}\right\} \text{Gaussian proposal} \\ O\left(\frac{\mathrm{N}_{\mathrm{c}}}{p}\left(b_s + m_s\,\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right) m\,\mathrm{N}_{\mathrm{var}}^2\right) \quad \} \text{ Hybrid Monte Carlo} \end{cases} \tag{16}$$

b) Speedup:: The speedup of MC-MCMC is given by:

$$S = \frac{T_s}{T_p} = \frac{(b_s + m_s\,\mathrm{N}_{\mathrm{ens}})}{\frac{\mathrm{N}_{\mathrm{c}}}{p}\left(b_s + m_s\,\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)} = \frac{p\,(b_s + m_s\,\mathrm{N}_{\mathrm{ens}})}{\mathrm{N}_{\mathrm{c}}\left(b_s + m_s\,\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)} \tag{17}$$

c) Parallel efficiency:: The parallel efficiency of MC-MCMC is given by:

$$E = \frac{S}{p} = \frac{(b_s + m_s\,\mathrm{N}_{\mathrm{ens}})}{\mathrm{N}_{\mathrm{c}}\left(b_s + m_s\,\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)} \tag{18}$$

If the burn-in stage is discard , i.e. set $b_s = 0$, the speedup, and the parallel efficiency simplify to:

$$S = \begin{cases} \mathbf{p} & ; \quad p \leq \mathrm{N}_{\mathrm{c}} \\ \mathrm{N}_{\mathrm{c}} & ; \quad p > \mathrm{N}_{\mathrm{c}} \end{cases}, \text{and,} \qquad E = \frac{S}{p} = \begin{cases} 1 & ; \quad p \leq \mathrm{N}_{\mathrm{c}} \\ \frac{nc}{p} & ; \quad p > \mathrm{N}_{\mathrm{c}} \end{cases}.$$

It follows that both speedup, and parallel efficiency are independent from the state space dimension $\mathrm{N}_{\mathrm{var}}$.

d) Communication overhead:: Assuming serial GMM run on the root node, the cost of broadcasting GMM information to all nodes is the cost of broadcasting, the means, the covariance and/or precision matrices, and the weights.

Assuming a linear communication model [11], and assuming that t_s, and t_w are the startup, and the per-word transfer times respectively, the cost of broadcasting GMM information to p nodes is given by:

$$\begin{cases} \Big(t_s + t_w\left((2\mathrm{N}_{\mathrm{var}} + 1)\,\mathrm{N}_{\mathrm{c}}\right)\Big)\log(p)\,; & \text{diagonal, or spherical GMM covariances} \\ \Big(t_s + t_w\Big(\big(\frac{\mathrm{N}_{\mathrm{var}}^2}{\mathrm{N}_{\mathrm{c}}} + \mathrm{N}_{\mathrm{var}} + 1\big)\,\mathrm{N}_{\mathrm{c}}\Big)\Big)\log(p)\,; & \text{tied GMM covariances} \\ \Big(t_s + t_w\left((\mathrm{N}_{\mathrm{var}}^2 + \mathrm{N}_{\mathrm{var}} + 1)\,\mathrm{N}_{\mathrm{c}}\right)\Big)\log(p)\,; & \text{full GMM covariances} \end{cases} \tag{19}$$

After sampling in parallel, the collected ensembles are gathered on the root node, at a cost $\left(t_s + t_w\left(\mathrm{N}_{\mathrm{ens}} \times \mathrm{N}_{\mathrm{var}}\right)\right)\log(p)$. Consequently, the total communication cost reads:

$$\begin{cases} \Big(2t_s + t_w\Big[\Big(\Big(\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}} + 2\Big)\,\mathrm{N}_{\mathrm{var}} + 1\Big)\;\mathrm{N}_{\mathrm{c}}\Big]\Big)\log(p)\,; & \text{diagonal, or spherical GMM covariances} \\ \Big(2t_s + t_w\Big[\Big(\Big(\frac{\mathrm{N}_{\mathrm{ens}} + \mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}} + 1\Big)\,\mathrm{N}_{\mathrm{var}} + 1\Big)\;\mathrm{N}_{\mathrm{c}}\Big]\Big)\log(p)\,; & \text{tied GMM covariances} \\ \Big(2t_s + t_w\Big[\big(\frac{\mathrm{N}_{\mathrm{ens}} \times \mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}} + \mathrm{N}_{\mathrm{var}}^2 + \mathrm{N}_{\mathrm{var}} + 1\big)\,\mathrm{N}_{\mathrm{c}}\Big]\Big)\log(p)\,; & \text{full GMM covariances} \end{cases} \tag{20}$$

e) Total parallel cost:: It follows immediately from the discussion above, that the total parallel cost of MC-MCMC sampling algorithm simplifies to:

$$pT_p = \begin{cases} \left.\begin{cases} \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}+2\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p) + O\left(\mathrm{N}_{\mathrm{c}}\left(b_s + m_s\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)\mathrm{N}_{\mathrm{var}}\right); & \text{diagonal, or spherical covariances of GMM, and proposal density} \\ \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}+\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+1\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p) + O\left(\mathrm{N}_{\mathrm{c}}\left(b_s + m_s\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)\mathrm{N}_{\mathrm{var}}^2\right); & \text{tied covariances of GMM} \\ \left(2t_s + t_w\left[\left(\frac{\mathrm{N}_{\mathrm{ens}}\times\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+\mathrm{N}_{\mathrm{var}}^2+\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p) + O\left(\mathrm{N}_{\mathrm{c}}\left(b_s + m_s\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)\mathrm{N}_{\mathrm{var}}^2\right); & \text{otherwise} \end{cases}\right\} \text{Gaussian proposal} \\ O\left(\mathrm{N}_{\mathrm{c}}\left(b_s + m_s\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}\right)m\,\mathrm{N}_{\mathrm{var}}^2\right) + \left.\begin{cases} \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}+2\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p); & \text{diagonal, or spherical GMM covariances} \\ \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}+\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+1\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p); & \text{tied GMM covariances} \\ \left(2t_s + t_w\left[\left(\frac{\mathrm{N}_{\mathrm{ens}}\times\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+\mathrm{N}_{\mathrm{var}}^2+\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p); & \text{full GMM covariances} \end{cases}\right\} \text{HMC} \end{cases} \tag{21}$$

f) Total overhead:: The total overhead function ($T_o = PT_p - T_s$) of MC-MCMC reads:

$$T_o = \begin{cases} \left.\begin{cases} \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}+2\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p) + O\left((\mathrm{N}_{\mathrm{c}}-1)\,b_s\,\mathrm{N}_{\mathrm{var}}\right); & \text{diagonal, or spherical covariances of GMM, and proposal density} \\ \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}+\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+1\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p) + O\left((\mathrm{N}_{\mathrm{c}}-1)\,b_s\,\mathrm{N}_{\mathrm{var}}^2\right); & \text{tied covariances of GMM} \\ \left(2t_s + t_w\left[\left(\frac{\mathrm{N}_{\mathrm{ens}}\times\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+\mathrm{N}_{\mathrm{var}}^2+\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p) + O\left((\mathrm{N}_{\mathrm{c}}-1)\,b_s\,\mathrm{N}_{\mathrm{var}}^2\right); & \text{otherwise} \end{cases}\right\} \text{Gaussian proposal} \\ O\left((\mathrm{N}_{\mathrm{c}}-1)\,b_s\,m\,\mathrm{N}_{\mathrm{var}}^2\right) + \left.\begin{cases} \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}}{\mathrm{N}_{\mathrm{c}}}+2\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p); & \text{diagonal, or spherical GMM covariances} \\ \left(2t_s + t_w\left[\left(\left(\frac{\mathrm{N}_{\mathrm{ens}}+\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+1\right)\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p); & \text{tied GMM covariances} \\ \left(2t_s + t_w\left[\left(\frac{\mathrm{N}_{\mathrm{ens}}\times\mathrm{N}_{\mathrm{var}}}{\mathrm{N}_{\mathrm{c}}}+\mathrm{N}_{\mathrm{var}}^2+\mathrm{N}_{\mathrm{var}}+1\right)\mathrm{N}_{\mathrm{c}}\right]\right)p\log(p); & \text{full GMM covariances} \end{cases}\right\} \text{HMC} \end{cases} \tag{22}$$

g) Isoefficiency:: Assuming the burn-in stage is discarded, i.e. set $b_s = 0$. With $\mathrm{N}_{\mathrm{ens}} \geq 2\mathrm{N}_{\mathrm{c}}$, the isoefficiency function $W(p) = \frac{E}{1-E}T_o = kT_o$ simplifies to (the dominant terms):

$$W(W,p) = \begin{cases} k\,t_w\,\mathrm{N}_{\mathrm{ens}}\,\mathrm{N}_{\mathrm{var}}\,p\,\log(p); & \text{diagonal, or spherical GMM covariances, and HMC, or Gaussian proposal with diagonal covariance} \\ k\,t_w\,(\mathrm{N}_{\mathrm{ens}}+\mathrm{N}_{\mathrm{var}})\,\mathrm{N}_{\mathrm{var}}\,p\,\log(p); & \text{tied covariances of GMM, and HMC, or Gaussian proposal} \\ k\,t_w\,(\mathrm{N}_{\mathrm{ens}}+\mathrm{N}_{\mathrm{var}}\,\mathrm{N}_{\mathrm{c}})\,\mathrm{N}_{\mathrm{var}}\,p\,\log(p); & \text{full covariances of GMM, and HMC, or Gaussian proposal} \end{cases} \tag{23}$$

VI. NUMERICAL EXPERIMENTS AND PERFORMANCE ANALYSIS

This section presents numerical experiments to assess the complexity analysis provided in Section V. As mentioned above, the speedup, and parallel efficiency are independent of problem dimensionality. The computational cost and the performance are discussed using one dimensional examples. The GMM distribution is fitted to the ensemble using Python code borrowed from the PYTHON DA testing suite DATeS [4].

To execute the Markov chains in parallel, the MPI4PY package is used, which provides bindings of the Message Passing Interface (MPI) standard for the PYTHON programming language, allowing any PYTHON program to exploit multiple processors.

Numerical experiments are presented to assess the complexity analysis provided in Section V. Specifically, numerical results are shown for the parallel $\mathcal{C}\ell$HMC flavors discussed in this paper using one dimensional synthetic example, and a two dimensional image retrieval experiment.

A. One-dimensional example:

Following the strategy described in [1], starting with a synthetic prior ensemble generated from a GMM with $\mathrm{N}_{\mathrm{c}} = 5$. A GMM approximation of the true prior probability distribution is constructed using the EM algorithm. The model selection criterion used here is AIC. The parameters of the true GMM prior are:

$$\begin{aligned} &\{(\tau_i;\, \mu_i, \sigma_i^2)\}_{i=1,\dots,5} = \{(0.09;\, -6.0, 0.20), \\ &(0.19;\, -2.5, 0.28),\, (0.09;\, 0.0, 0.08), \\ &(0.28;\, 2, 5, 0.24),\, (0.15;\, 6.0, 0.28), \\ &(0.15;\, 6.5, 0.08),\, (0.03;\, 7.5, 0.12), \\ &(0.02;\, 8.0, 0.04)\}\,. \end{aligned} \tag{24}$$

Assume the observation errors follow Gaussian distribution with zero mean, and variance 2.2. Assuming a synthetic observation $\mathbf{y} = -1.0$, the observation likelihood function given by:

$$\mathcal{P}(\mathbf{y}|\mathbf{x}) = \frac{1}{\sqrt{2.2}\,\sqrt{2\pi}}\ \exp\left(-\frac{1}{2}\,\frac{(\mathbf{x}-\mathbf{y})^2}{2.2}\right). \tag{25}$$

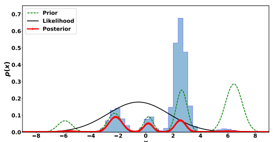
The generated GMM approximation of the prior has $\mathrm{N}_{\mathrm{c}} = 7$ and the following parameters:

$$\begin{aligned} &\{(\tau_i;\, \mu_i, \sigma_i^2)\}_{i=1,\dots,7} = \{(0.111;\, -5.78, 0.123), \\ &\quad (0.177;\, -2.49, 0.223),\, (0.045;\, -1.49, 0.001), \\ &\quad (0.065;\, 0.12, 0.061),\, (0.146;\, 2.05, 0.032), \\ &\quad (0.225;\, 2.78, 0.148),\, (0.231;\, 6.12, 0.164)\}\,. \end{aligned} \tag{26}$$

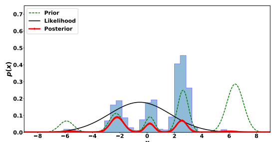
Figure 1 shows the results of sampling a one dimensional posterior (11) with seven components. Since this paper is mainly interested in asymptotic behavior of the sampler, and to avoid the effect of sampling error, the ensemble size here is set to 1000. Despite the good mass distribution resulting from the use of a Gaussian density with the serial MCMC sampler 1a, the acceptance rate is $\approx 45\%$ resulting in a large amount of wasted calculations. On the other hand, the parallel MC-MCMC with Gaussian proposal kernel 1b improves the acceptance rate to $\approx 81\%$. The acceptance rate is increased due to the local adjustment of the sampler hyper-parameters based on the local ensemble under the corresponding prior component in the mixture.

While the Gaussian-based MCMC sampler represents an acceptable mass distribution, it suffers from random walk behavior leading to the demonstrated low acceptance rate. One the other hand HMC sampling results in general in high acceptance rate. Unfortunately, as explained by the results in Figure 1c is unable to sample all probability modes. The acceptance rate in the serial $\mathcal{C}\ell$HMC sampler here is 96%. By running $\mathcal{C}\ell$HMC sampling methodology in parallel, the acceptance rate drops to 81% (which is still very high). However, the mass distribution is much better than the serial case. This is supported by results in Figure 1d compared to Figure 1c.

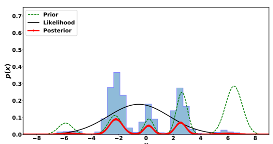
Figure 2 shows the CPU time and speedup results of the clustering sampling algorithms with Gaussian and HMC proposal mechanisms. As suggested by the analysis in Section V, the CPU time becomes flat once the number of processors reaches 7, the number of components in the mixture.



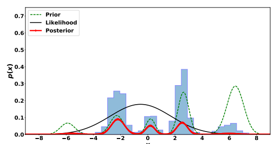
(a) Gaussian Proposal, Serial MCMC



(b) Gaussian Proposal, Parallel MCMC



(c) HMC Proposal, Serial MCMC



(d) HMC Proposal, Parallel MCMC

Figure 1. Sampling results of a one dimensional posterior with seven components. The results of the serial MCMC and MC-MCMC with two proposal mechanisms are shown. The mode (serial vs. parallel) and the proposals are shown under each panel. The ensemble size here is 1000

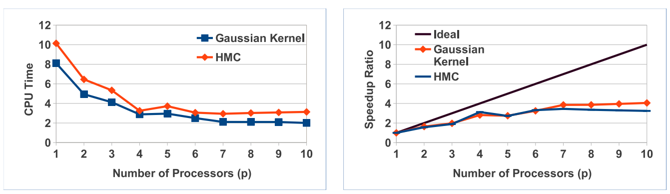


Figure 2. Sampling results of a one dimensional posterior with four components. The CPU time, and speedup results of MC-MCMC with two proposal mechanisms are plotted. The ensemble size here is 1000

The parallel efficiency results are shown in Figure 3. The numerical results shown here suggest that, running the clustering filters in parallel not only results in computational saving, but also can potentially increase the sampling accuracy. While the discussed parallelization of the sampler reduces the computational time, the numerical results suggest that more parallelization effort is needed in order to achieve higher efficiency. In the current settings, the chains are assigned to processes in a round-robin fashion. The performance of the sampler can be greatly enhanced if the a smart scheduler is used such that the parallel chains are assigned to processors based on the sample size per chain.

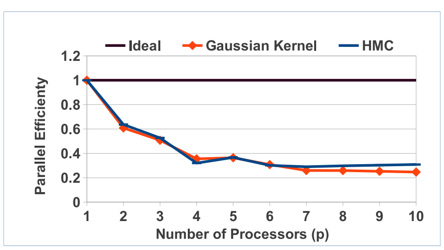


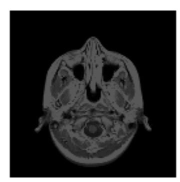
Figure 3. Sampling results of a one dimensional posterior with four components. The parallel efficiency results of MC-MCMC with two proposal mechanisms are plotted. The ensemble size here is 1000

B. Two-dimensional example

The parallel $\mathcal{C}\ell$HMC sampling algorithm as a tool for statistical medical image retrieval is tested here and employing a non-linear Gaussian convolution filter as a forward operator $\mathcal{H}$. The convolution filter is applied to a two-dimensional image resulting in a blurred image, then Gaussian noise is added to collect synthetic measured/observed image. Here, the vector $\mathbf{x}$ represents intensities of the image pixels arranged in a column vector. The observation noise level is set to be 9% of the average intensity of the original image. This formulation clearly results in a nonlinear inverse problem that can be challenging for traditional approaches such as Tikhonov regularization. For , the Jacobian of the convoluted image with respect to the intensities of the image pixels is found to be a Toeplitz matrix.

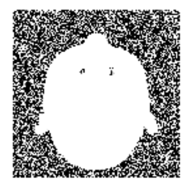
The goal here is to retrieve the original image given the noisy measurement, and a sample drawn from the probability distribution from which the blurred image is drawn. This is is a relevant problem description in many cases, where several low resolution or blurred images are taken along with the collected measurement.

Figure 4 shows the original (true) image, the blurred image constructed by the convolution filter, and the noisy image, i.e. the blurred image with additive noise.



(a) Original Image.

(b) Blurred Image.



(c) Data: Blurred Image with added noise.

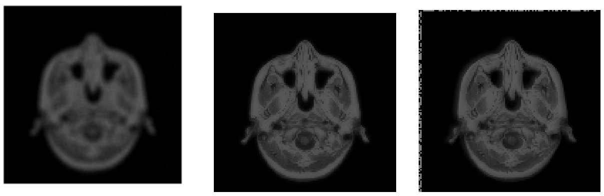
Figure 4. Inputs to the sampling filter. Original image $\mathbf{x}$, blurred image $\mathcal{H}(\mathbf{x})$, and noisy image $\mathbf{y}$.

To create a synthetic non-Gaussian sample, 50 images was sampled from a Gaussian distribution centered around the blurred image with variances equal to 8% of the average intensity of the original image. To create a synthetic prior sample, $\mathrm{N_{ens}} = 30$ uniformly random distributed images have been selected from the generated Gaussian sample. This procedure is guaranteed to result in a non-Gaussian prior, and is powerful to test the GMM prior assumption.

The $\mathcal{C}\ell$HMC sampling algorithm with both Gaussian and Hamiltonian kernels performed similarly. The acceptance rates however were quite different. Specifically, the rejection rate in the case of Gaussian proposal was 56% resulting in wasted computations, while HMC rejection rate was 7%.

The initial state of each chain is chosen as the mean of the corresponding component in the prior mixture, and the parameters of the Hamiltonian system are tuned empirically to give acceptable acceptance rate. 30 sample members are collected from the posterior distribution.

The mean and median of posterior samples collected using the parallel $\mathcal{C}\ell$HMC sampling algorithm are shown in Figure 5 (panels 5b, and 5c). For the sake of comparison to one of the most popular and widely used approaches, the results obtained using Tikhonov regularization approach with regularization parameter are shown as they optimally tuned following an L-curve approach. The Tikhonov-regularized solution is shown in panel 5a of Figure 5.



(a) Tihonov regularized solution (b) $\mathcal{C}\ell$HMC: sample mean (c) $\mathcal{C}\ell$HMC: sample mean

Figure 5. Inverse problem solution using Tihonov regularization and the parallel $\mathcal{C}\ell$HMC posterior sample. Mean and Median, of the collected 30 sample members using parallel $\mathcal{C}\ell$HMC. The method and statistic used are shown under each panel.

By comparing results in Figure 5, to the blurred (prior) image 4b and the noisy image 4c, one can see that the posterior samples produce statistics those are closer to the original image. Moreover, the retrieved results using the non-Gaussian $\mathcal{C}\ell$HMC (serial or parallel) algorithm is much better than the solution obtained by the traditional Tikhonov regularization approach. The relative error of the mean obtained using the parallel $\mathcal{C}\ell$HMC sampling algorithm is 0.01663, while the relative error of the regularized solution is 0.021447. The relative error is defined as $\frac{\|\mathbf{x}-\mathbf{x}^{\mathrm{true}}\|}{\|\mathbf{x}^{\mathrm{true}}\|}$, where $\mathbf{x}$ is the retrieved image, and $\mathbf{x}^{\mathrm{true}}$ is the true image. The proposed parallel algorithms achieve an improvement of 29% over the optimally tuned Tikhonov-based solution. These results show the capability and accuracy of the $\mathcal{C}\ell$HMC sampling algorithm in non-Gaussian settings.

While the blurred image has been shown in Figure 4, it is of utmost importance to highlight the fact that the formulation and the sampler is unaware of this blurred image. This is mainly due to the fact that that has uniformly sampled the Gaussian sample centered around this blurred image.

VII. Conclusions and Future Work

This work developed parallel cluster sampling algorithms for solving Bayesian inverse problems. Specifically, a set of parallel sampling algorithms, based on the non-Gaussian cluster non-Gaussian sampling filter ($\mathcal{C}\ell$HMC), have been proposed. The presented methodologies can be efficiently used for solving various large-scale inverse problems including medical image retrieval from noisy observations. Detailed complexity analysis of the proposed algorithms (MC-$\mathcal{C}\ell$HMC) with mixture model representation of the prior information has been introduced. Generally speaking, aside from parallelization, the parallel versions of the algorithm result in higher acceptance rates. Specifically, the parallel $\mathcal{C}\ell$HMC increased the acceptance rate of the sampler from 45% to 81% with Gaussian proposal kernel, leading to massive saving of computations. The proposed sampling algorithms have also achieved an improvement of approximately 29% over the optimally-tuned Tikhonov-based solution for image retrieval. The algorithm can run significantly faster than the serial sampler in ideal settings, where the load is equally distributed among all working nodes. In future work, we will investigate the possibility of parallelizing other components of the sampling algorithm such as the likelihood function and the proposal mechanisms. For example a parallel version of EM can be considered to construct the GMM approximation to the prior distribution. In the case of HMC, the symplectic integrator can also be parallelized. Methods for parallelizing a single chain can be considered for an additional level of parallelization.

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Online Reputation Model Using Moving Window

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***Abstract*— Users are increasingly dependent on decision tools to facilitate their transactions on the internet. Reputation models offer a solution to the users in supporting their purchase decisions. The reputation model takes product ratings as input and produces product quality as score. Most existing reputation models use naïve average method or weighted average method to aggregate ratings. Naïve average method is unstable when there exist a clear trend in the ratings sequence. Also, the weighted methods are influenced by unfair and malicious ratings. This paper introduces a new simple reputation model that aggregates ratings based on the concept of moving window. This approach enables us to study variability of ratings over time which allows us to investigate the trend of ratings and account for sudden changes in ratings trend. The window size can be defined by either number of ratings or duration. The proposed model has been validated against stat-of-art reputation models using Mean Absolute Error and Kendall tau correlation.**

Keywords*— Reputation Model, Moving Window, Ratings Aggregation Method, E-Commerce.

I. Introduction

E-commerce and mobile commerce systems are increasingly growing in the last two decades which resulted in emergence of new technologies and services [1][6][10]. Therefore, the internet turns into the most common workspace for performing our transactions such as selling and purchasing goods. When users usually want to buy goods on the internet they encounter many similar products, which make the selection process among them is relatively difficult. Accordingly, the users are looking for effective methods that facilitates their decisions. Therefore an accurate and reliable reputation system has moved from novelty and convince to necessity. Almost all B2C and C2C websites ask users to provide ratings and reviews after any successful transaction [1]. For example, eBay users can rate each other, while other review websites, user can rate other reviews as helpful or not. These ratings can serve as decision support tool for other people. It is widely acknowledged that the virtual trust can be achieved when sufficient number of similar ratings are received for a specific product [7]. But in fact, online ratings suffer from many challenges such as unfair ratings, malicious ratings and biased ratings.

Ratings aggregation method is the key part of reputation model which is responsible for calculating the product quality. Many online rating systems use today the simplest method for aggregating rating which is the naïve average method. This method is straightforward, but it cannot discover the trends emerging from recent ratings [10]. To illustrate that, let us have a look at Figure 1 which illustrates that there is a clear trend in ratings where recent ratings are lower than old ratings. So there is no doubt that using naïve average method will fail to inform users with such clear trend. Figure 2 illustrates a different scenario where there is no clear trend in the ratings and there are many sudden changes. In this case, such product should not be given high score. Other studies focused on using rating aging functions to discount old rating [12]. While this approach is theoretically realistic, it might ignore some important hidden knowledge in old ratings, and cannot ensure that the most recent ratings are more informative. Other studies investigated the effect of unfair and malicious ratings on the aggregation process [4][9][11]. They use weighted average method to calculate the product score, where weight can be often the user reputation [2][11]. These approaches have been widely investigated, but most of them focus on one aspect of user reputation, whereas some of them are not working efficient with sparse datasets (i.e. products with few ratings).

None of the previous studies attempted to investigate the variability of ratings over time (i.e. following chronological order of ratings). As explained early, product ratings usually have unclear trend and there are frequently sudden changes in ratings sequence. That is, there is desperate need to involve the variability of ratings in computing product score. This paper uses the concept of moving window to analyze the variability of ratings at specified intervals and then reflect that during aggregation of ratings. The window can be imagine as subset of ratings with a predefined size. The window size is defined by either fixed number of ratings or duration. The big issue is to ensure that there is enough number of ratings for the products with few ratings. The procedure of moving window technique works as follows: Each time the window is shifted one step forward, the variability of window is measured by using statistical variance. This step allows us to see the effect of sudden changes from neighbor's window and detect the ratings that makes sudden changes, these ratings are called unfair ratings.

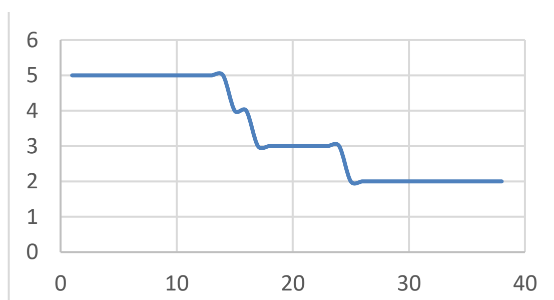

Figure 1. Clear ratings trend over time.

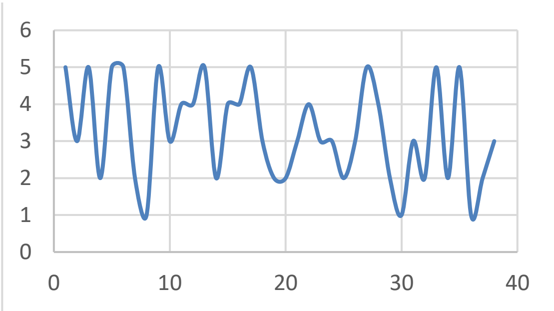

Figure 2. Unclear ratings trend over time.

This paper is structured as follows: section two presents the related works. Section three introduces idea of moving window. Section four presents the proposed model. Section five discusses the datasets. Section six presents evaluation measures. Section seven discusses the results. Section eight contains the conclusions.

II. Related Work

Naïve averaging method is the common method used for aggregating ratings on electronic social and commerce systems [10]. This method is not informative as it cannot discover recent trend in ratings and easily influenced by unfair ratings [10]. In turns, the weighted average method seems more effective as it can take into consideration the quality of users who made ratings. Many studies confirmed that all received ratings for a product are not equal because of many factors such as ratings age, and user credibility, reliability and confidence [4][11]. Therefore many reputation systems attempt to involve one or more factors in computing weight for potential users. Josang et al. [6][7] stated that the ratings age is a good indicator of the importance of ratings. They showed that both linear and nonlinear aging discount function can be used through weighted average method. However, this approach requires determination of decay function parameter such as age unite (i.e. day, week, month and year), which it needs professional experts. On the other hand, another study suggested using the number of past transaction instead of ratings age [12]. Leberknight et al. [10] reveled that recent ratings should have higher weight than old ratings, and the reputation model should take that as discounting factor during ratings aggregation process. They proposed a model that divides rating into number of non-overlapping equal subsets, and then investigate the volatility in each subset with respect to the near subset. Finally the variabilities in all subsets are fused together through discounting function that is used later to compute product score.

Apart of ratings age, other studies investigate the user data in order to discover some important factors such as user reliability, credibility and confidence. In this regard, Riggs et al. [13] suggest including user reliability as weight during rating aggregation process. User reliability means that his provided ratings are very close to the global agreement for all products he rated. Likewise, Lauw et al. [9] studied the leniency ad strictness of users in providing ratings. Lenient user are those who frequently provide positive ratings regardless the actual product quality. Strict users are those who frequently provide negative ratings regardless the actual product quality. Computing leniency of users are quite similar to computing reliability, but the difference is in computing final product score. Jøsang et al. [7] introduced a reputation model based on multinomial Dirichlet probability distribution. Bharadwaj et al. [3] developed some new metrics based on work of Jøsang et al. [7] and using fuzzy logic to compute trust and reputation of product. Cho et al. [4] proposed three factors that assess the user reliability. These factors are user expertise in a specific category, user trustworthiness, and co-orientation. These factors are fused together using either arithmetic mean, harmonic mean, or multiplication. In the same direction, Liu et al. [11] proposed three factors to address the problem of unfair ratings. These factors are fused together using fuzzy logic. The model has been validated using single and multiple attacks procedures.

III. Moving Window

As explained in the introduction section, when the ratings trend is clear the naïve average method cannot discover recent trend in the ratings, analyzing the variability in ratings becomes a must. Moving window is a mechanism similar to moving average method that is used with time series to analyze and find trends in the data. The basic idea of moving window is to analyze the variability of ratings by creating series of variability scores for different windows. The conventional way to measure the variability of ratings inside a window is to use statistical variance method. However, other statistical methods can be also applied. An important question is how to find the appropriate size of window. In practice, there are two approaches to specify the window size, the first approach is to use fixed size window, while another approach is based on duration. The first approach ensures that window size does not change while the window is moving and guarantee the availability of ratings in each window. In contrast, the second approach does not guarantee that all windows have equal number of ratings, but it can provide meaningful interruption for discounting function. Furthermore, this approach does not guarantee that there exist enough number of ratings in each window. In this case the windows without ratings are ignored. In summary, the moving window works as follows: given a series of ratings, the moving window starts with subset of rating, then in each round the window is shifted forward by excluding the first element in the window and added the next rating to the window.

IV. The Prposed Model

In this section the proposed model is described, first, how to measure the variability for each window is described. Then how to reflect the obtained variances on the ratings as discounting factor. Finally the aggregation method is described. Rating variability is calculated based on finding the statistical variance among the ratings in each window. The window size can be determined based on either fixed number of ratings, or duration. In case of duration, one might decide to use week unite as window size, while others might use different time unite based on the timespan of ratings. It is important to note here that window size should not be empty or having small number of rating as it affects the accuracy of computing ratings variance. In case of fixed number, the chosen size should be reasonable to correctly find variance in ratings. Actually 10 ratings in each window have been chosen. The reason behind this selection is because most online portals displays the most five recent ratings for their visitors.

To illustrate how the moving window works, consider a product has the following ratings sequence ordered chronologically based on the receiving time: $R = \{4,3,5,4,4,5,5,3,4,5\}$ and consider window size is 4. The first window will include {4, 3, 5, 4}, the second window will include {3, 5, 4, 4} and so forth. The last window will include {5, 3, 4, 5}. According to this scenario there will 7 possible windows. The corresponding variance for possible windows are: 0.6667, 0.6667, 0.3333, 0.3333, 0.9167, 0.9167, and 0.9167 respectively. It is clear from the values that there is high variance at the beginning of ratings then that variance began to decrease by time then suddenly rise up to confirm that there is a trouble at latent ratings. Therefore the ratings with large variances should be discounted as it affects the product reputation score. In this example, the ratings in the second and third window should be given greater weight than others.

To reflect the fluctuation of variances as rating weight, a function that maps the obtained variance for each window to a discounting factor is used. The hypothesis of our discounting function is that the window with small variance is given greater weight than other windows of higher variance. In other words, if the variance of the window is very small then greater weight is given to that window. In contrast, if the variance is high then little weight is given to that window. Finally, since each rating may belong to more than window the final discount rate is the average of all discounting rates obtained. The discounting function used in this paper that satisfy our hypothesis is sigmoid function as shown in Equation 1 and Figure 3.

$$f = \frac{1}{1 + e^{-\alpha(var-\lambda)}} \quad (1)$$

Where λ is the variance of the whole product ratings. var is the variance of a particular window. α is a scaling constant to make f is close to 1 when $var \simeq 0$, and can be used to control the sensitivity of the discounting function to the rating fluctuation.

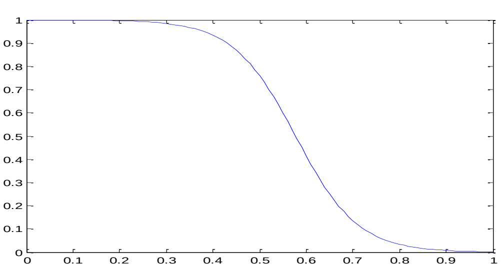

Figure 3. Sigmoid discounting function with $\lambda = 0.57$ and $\alpha = 15$

The aggregation function use weighted average method, where weights are computed from the discounting factor. For each possible window the discount factor is computed. Some ratings receive one discounting value, while other may receive more than one discounting value based on the windows that they belong. In this case the average of these discounting ratios is taken. Finally the obtained ratios are normalized to work as weight for the ratings during aggregation process. Equation 2 shows the weight normalization process. In case of the number of ratings was quite small (i.e. less than or equal to windows size) then only the naïve average of those ratings is considered.

$$w_i = \frac{f_i}{\sum_i^n f_i} \quad (2)$$

$$q = \sum_{i=}^{n} w_i \times r_i \quad (3)$$

Where q is the generated score for a product.

V. Datasets

Three benchmark datasets that come from one source are used to validate the proposed reputation model. These datasets come from MovieLens data repository [5]. The first dataset called 100K which contains 943 users with 1682 movies and total of 100,000 ratings. The second dataset called 1M which contains 6040 users and 3706 Movies and total of 1,000,209 ratings. The last dataset called 10M which contains 72,000 users and 10,000 movies with total of 1,000,000 ratings. These datasets have been chosen because they are widely used for validating reputation models and publically available so it facilitates replication studies.

Table 1. Datasets characteristics

Dataset	Users Count	Movies Count	Ratings Count
100K	943	1682	100,000
1M	6040	3706	1,000,209
10M	72,000	10,000	10,000,000

VI. Evaluation Measuers

Evaluation measures are good indicators for the accuracy of the reputation models. Unfortunately, there is no accuracy measures that have been agreed among researchers for evaluating the reputation models, however, the most common measures which are Mean Absolute Error (MAE) and Kendall Similarity [1][3] are used. MAE is an indication to the similarity of the product reputation score to the actual ratings of product as shown in Equation 4. Accurate reputation score is the one with very small MAE, close to zero. Kendall similarity measures the correlation between rankings of two lists. It enables us to check if there is agreement between two rankings. The similarity degree falls between -1 (typical disagreement) and +1 (typical agreement). In our case, the good results are achieved when two list have different rankings which confirms that both reputation models are different.

$$MAE = \frac{1}{m}\sum_{j=1}^{m}\frac{\sum_{i=1}^{n}(r_{ji} - q_j)}{n} \qquad (4)$$

Where q_j is the generated score for item *j*. *m* is the number of items in the testing data. *n* is the number of ratings for j^{th} item in the testing data.

VII. Results

In practice, the accuracy of any reputation model is usually measured by how helpful were the generated scores to the users in taking right decisions. Unfortunately, this measure is difficult to be obtained because most users do not leave their feedbacks and degree of satisfaction from the given ratings. To avoid this pitfall, it has been suggested to compare between our model and some common reputation models using MAE and Kendall similarity. To successfully perform the comparison among models 10-Fold cross validation is used where the dataset is divided into 10 different training and testing datasets. The training dataset is used to train the model and the testing dataset is used to validate the model. It is important to mention that the original dataset is divided based on the users Ids. In each iteration the MAE is calculated, and the overall MAE is averaged at the end. The reputation models that have been used for comparison purposes are: Naïve average, LQ [9], Dirichlet [7], and Fuzzy model [3]. As discussed in literature, there are two approaches to find the appropriate size of the window: fixed size and duration. In terms of duration it has been preferred to use one month as window size because the online products are not often changed monthly. For fixed window size the 10 ratings have been chosen because most online stores display recent 10 ratings on their websites. The results of comparisons as shown in Table 3. It can be noticed that the moving average in general produces better results over all small and large datasets. Although the difference is not so significant, but it can confirm that our moving window model has the capability to deal with dense and few ratings. Particularly, when comparing between Moving window with fixed size and duration, it can be noticed that using fixed size is slightly better because this approach ensures at least there are sufficient ratings for each window. In practice, some products are not popular so they are not rated regularly, thus it is very hard to ensure that there exist sufficient number of rating in each window.

Table 2. Mean Absolute Error Results

Dataset	Moving Window (fixed size)	Moving Window (duration)	Average	LQ	Dirichlet	Fuzzy
100K	0.7971	0.8106	0.905	1.02	0.898	0.916
1M	0.7891	0.7969	0.841	0.96	0.841	0.848
10M	0.7269	0.7350	0.791	0.92	0.776	0.795

Furthermore, the Kendall similarity between two ranked lists are computed for all comparisons between Moving window (with fixed window size) and each reputation model. To investigate the sensitivity of this analysis, the similarity is computed over a specified percentage of the top ranked products. 10%, 20%....100% have been chosen as threshold points. The main objective of this analysis is that the users are usually concerned about top products, and to confirm that our model produces relatively different list of ranked products from other models. Figures 4, 5 and 6 show the trend for Kendall similarity between our moving window model and each reputation model over each dataset individually. The general trends confirm that our model produce likely different list of ranked product than other models, then this trend decline towards nearly no similarity between them after using 10% top products. This fact suggests that our model and other models generating different lists of top ranked products. Figure 3 shows that that there is slight positive agreement between Moving window and Dirichlet at top 1%, then this degree began to drop when more top products are added to the comparison. Figure 4 shows relatively similar trend to Figure 3, but this time the average method has positive agreement with our moving window model until 10% then began to drop. Figure 5 has quite similar trend to Figure 3. In conclusion, it can be noticed that our model generates different list of top products which confirms our model is different than previous models and show better accuracy as confirmed by MAE.

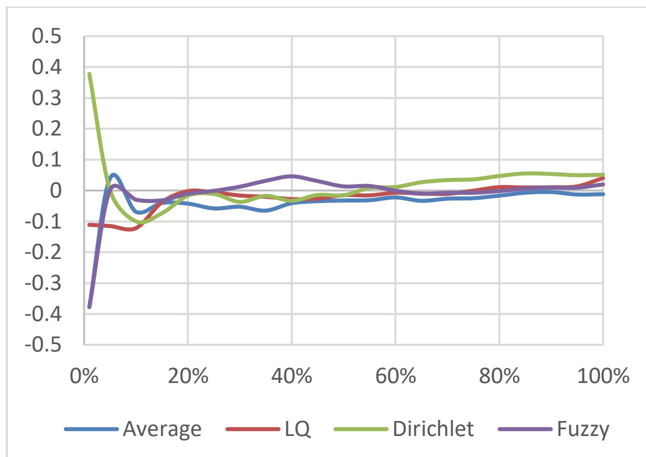

Figure 4. Kendall similarity between Moving window and each compared method over 100K dataset

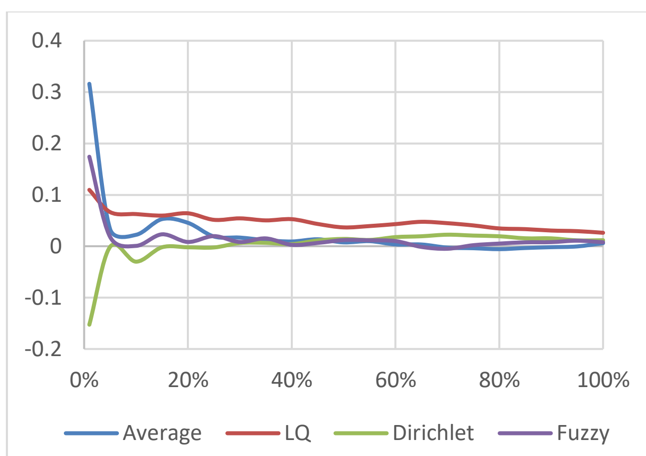

Figure 5. Kendall similarity between Moving window and each

compared method over 1M dataset

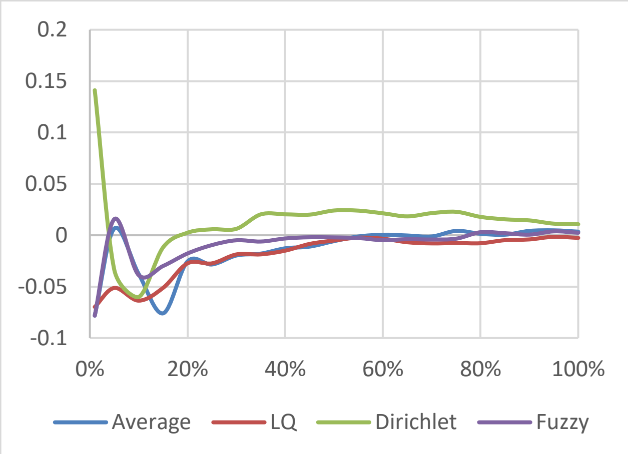

Figure 6. Kendall similarity between Moving window and each compared method over 10M dataset

VIII. CONCLUSIONS

Understanding the variability in the ratings over time is an important step towards improving ratings aggregation procedures. When ratings have clear trends, the naïve methods are unstable and cannot discover that trend. But, in reality, product quality are changing over time so the ratings received for that product are likely to change accordingly. Therefore, in this paper a model that can capture the variability in the ratings over time is proposed which can reflect that on the ratings aggregation procedure. The validations over dense and sparse datasets showed that our model produces relatively better accuracy than other previous reputation models. Also, our model generates different list of top ranked products than other models which confirms that our model is significantly different.

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PaMSA: A Parallel Algorithm for the Global Alignment of Multiple Protein Sequences

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***Abstract*—Multiple sequence alignment (MSA) is a well-known problem in bioinformatics whose main goal is the identification of evolutionary, structural or functional similarities in a set of three or more related genes or proteins. We present a parallel approach for the global alignment of multiple protein sequences that combines dynamic programming, heuristics, and parallel programming techniques in an iterative process. In the proposed algorithm, the longest common subsequence technique is used to generate a first MSA by aligning identical residues. An iterative process improves the MSA by applying a number of operators that were defined in the present work, in order to produce more accurate alignments. The accuracy of the alignment was evaluated through the application of optimization functions. In the proposed algorithm, a number of processes work independently at the same time searching for the best MSA of a set of sequences. There exists a process that acts as a coordinator, whereas the rest of the processes are considered slave processes. The resulting algorithm was called PaMSA, which stands for Parallel MSA. The MSA accuracy and response time of PaMSA were compared against those of Clustal W, T-Coffee, MUSCLE, and Parallel T-Coffee on 40 datasets of protein sequences. When run as a sequential application, PaMSA turned out to be the second fastest when compared against the nonparallel MSA methods tested (Clustal W, T-Coffee, and MUSCLE). However, PaMSA was designed to be executed in parallel. When run as a parallel application, PaMSA presented better response times than Parallel T-Cofffee under the conditions tested. Furthermore, the sum-of-pairs scores achieved by PaMSA when aligning groups of sequences with an identity percentage score from approximately 70% to 100%, were the highest in all cases. PaMSA was implemented on a cluster platform using the C++ language through the application of the standard Message Passing Interface (MPI) library.**

***Keywords*—Multiple Sequence Alignment; parallel programming; Message Passing Interface**

I. Introduction

A fundamental research subarea of bioinformatics is biological sequence alignment and analysis, which focuses on developing algorithms and tools for comparing and finding similarities in nucleic acid (DNA and RNA), and amino acid (protein) sequences [1]. The sequence similarities found are used for identifying evolutionary, structural or functional similarities among sequences in a set of related genes or proteins [2]. The set of sequences to be aligned are assumed to have an evolutionary relationship. Sequence alignment plays a central role in several areas of biology, such as phylogenetics, structural biology, and molecular biology.

Multiple sequence alignment (MSA) can be defined as the problem of comparing and finding which parts of the sequences are similar and which parts are different in a set of three or more biological sequences. The resulting alignment can be used to infer sequence homology. Homologous sequences are sequences that share a common ancestor and usually also share common functions.

Multiple sequence alignment is a well-known problem in computer science. A number of strategies have been applied to obtain MSAs, such as progressive alignment methods [3][4], iterative methods [5][6], dynamic programming [7], genetic algorithms [8], greedy algorithms [9], Markov chain processes [10], and even simulated annealing methods [11]. Currently, MSAs are obtained via two main approaches. The most popular alternative is the progressive multiple sequence alignment method. The main drawback with progressive alignments is that errors in the initial alignments of the most closely related sequences are propagated to the final multiple sequence alignment. The second most common approach to accomplish MSAs is the use of heuristic methods, which are more efficient than dynamic programming, but that do not guarantee finding an optimal alignment.

The main contribution of the present work is the development of a parallel algorithm—PaMSA, which stands for Parallel MSA—for the global alignment of multiple protein sequences. The strategies applied in PaMSA to obtain an MSA of a set of sequences differ from those of other currently used MSA algorithms in several ways. The PaMSA algorithm is not a progressive-alignment approach, as all sequences are aligned simultaneously. In contrast to existing heuristic alignment methods, which start from completely unaligned sequences, the PaMSA algorithm generates an initial MSA of the sequences based on a Longest Common Subsequence (LCS) of the set of sequences to be aligned. In addition, in the PaMSA algorithm several processes work independently at the same time searching for the best MSA of a set of sequences. Thus, the PaMSA algorithm combines a number of strategies to produce the sequence alignment.

The PaMSA algorithm was implemented as a parallel program that runs on a cluster platform; however it is not necessary to have a cluster environment to execute the application, as it can run even on a single processor. Currently, only protein sequences are aligned by PaMSA, but it is possible to adapt the implementation to align nucleic acid sequences as well.

Our implementation of PaMSA was compared against the currently used MSA algorithms Clustal W [3], T-Coffee [4], MUSCLE [5], and Parallel T-Coffee [12]. The comparison against the first three methods was done using a sequential version of PaMSA, as these methods are non-parallel implementations of the respective algorithms. The comparison in all cases was through the application of the sum-of-pairs function [13]. PaMSA was faster than Parallel T-Coffee, whereas the sequential version of PaMSA was the second fastest when compared against the nonparallel methods.

The remainder of this article is organized as follows. Section II describes the PaMSA algorithm and the metrics used to evaluate the alignments, whereas Section III specifies the protein sets and the conditions for the runs. Results are presented in Section IV with a discussion of their relevance. Finally, Section V presents the conclusions and future work.

II. The PaMSA Algorithm

Our parallel approach for the global alignment of multiple protein sequences, PaMSA [14], combines dynamic programming, heuristics, and parallel programming techniques in an iterative process. Dynamic programming techniques are applied for setting up an initial alignment. The algorithm improves the initial MSA in an iterative manner by applying a number of operators that move, delete or realign gaps. The algorithm ends when the termination criteria are reached.

The PaMSA algorithm was implemented on a cluster platform. Hence, in this approach a number of processes work in parallel for the search of the best MSA of a set of sequences. If np is the number of processes used by the algorithm, the number of possible different MSA solutions is equal to np. For example, if $np = 2$, there will be 2 independent processes searching for the best alignment. As the number of processes increases, the number of solutions increases as well. A consecutive integer $0, 1, 2, \ldots, np - 1$ is assigned to each process, which acts as an identification number (id) for the process. There exists a process that acts as a coordinator, whereas the rest of the processes are considered slave processes. The id for the coordinator process is always equal to zero. Slave processes have a consecutive integer id, which goes from 1 to the total number of processes minus one. The algorithm was implemented to be run on a cluster, however it works also on a nonparallel environment. In order to evaluate the quality of the MSA, a number of objective functions were implemented.

A. General structure

As mentioned above, the PaMSA algorithm is not a progressive-alignment approach, as all sequences are aligned simultaneously. In contrast to existing heuristic alignment methods, which start from completely unaligned sequences, PaMSA generates an initial MSA of the sequences based on a Longest Common Subsequence (LCS) of the set of sequences. The proposed algorithm follows a strategy analogous to a parallel genetic algorithm. The main steps in the general structure of a simple genetic algorithm (GA) are followed in the basic PaMSA algorithm procedure (Fig. 1). In PaMSA there is a population of initial MSAs, whereas in a GA there is a population of random initial solutions. In PaMSA, alignments are given a score, whereas in a GA, individual solutions are evaluated by an optimization function. An alignment is improved by applying operators in PaMSA, whereas individuals in a population evolve by applying operators in a GA. Finally,

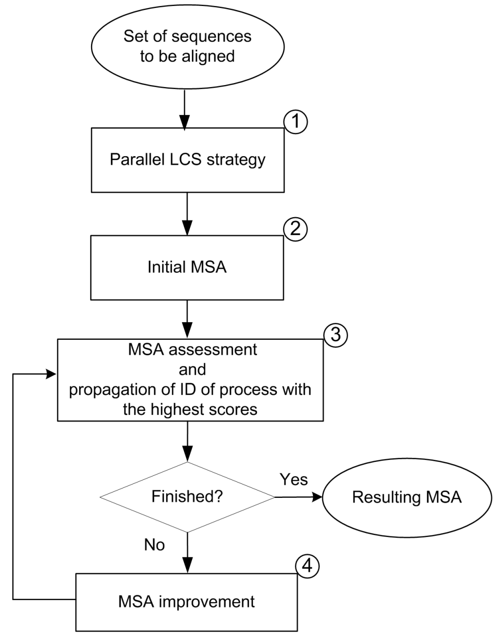

Fig. 1. The basic PaMSA algorithm procedure.

in both algorithms, operators are applied in an iterative process until a predefined condition is satisfied.

PaMSA combines a number of strategies to produce the sequence alignment, which are briefly described next and explained in more detail in the following sections. First, a well-known LCS technique for two sequences that uses dynamic programming was adapted and implemented to obtain an LCS of more than two sequences. In this approach, a number of processes work in parallel, so that each process calculates an LCS of the sequences. Even though all processes apply the same algorithm to the same set of sequences, the resulting LCSs are possibly different, because the calculations are based on a different order of sequences and there exists the possibility of having more than one LCS for the same sequences. Second, an algorithm is applied to the set of sequences in order to generate a first MSA by aligning identical residues, as well as similar residues, as much as possible. This algorithm uses the LCS generated at each process, which can be different from the LCSs in the other processes. This approach allows various potential solutions to be running in separate processes. Third, after the first MSA is generated in each process, the quality of the MSA is evaluated using a set of objective functions (OFs). Each process evaluates its MSA, and the slave processes send the scores of four of the OFs to the coordinator—the ID, the SY, the SP, and the PWS scores, described below—, which receives the scores and determines what process has the best MSA for all four OFs. The coordinator then propagates the id of the process with the best scores to all the slave processes. If the alignment has not shown improvement in all processes in two consecutive iterations, or if a predefined number of iterations is reached, the algorithm ends and the process with the best alignment of the sequences provides the resulting MSA. Otherwise the alignment is improved at each process by iteratively applying a number of operators that move, delete or realign gaps in the sequences following specific rules. These proposed operators perform a search along the length of the sequences with the aim of finding an opportunity to improve the alignment. The search is focused on the detection of gaps in order to minimize their number. The operators accept a certain number of parameters. Therefore, the operators can act differently in the sequences of the separate processes in order to have a variety of potential solutions. After each iteration, the resulting MSA is evaluated in all processes. This procedure is repeated until the termination criteria mentioned above are met.

B. The LCS technique

Given a sequence $S_i = s_{i1}s_{i2}\dots s_{im}$, a subsequence of S_i is a sequence $S' = s'_1s'_2\dots s'_p$, defined by $s'_k = s_{ir_k}$, where m is the length of sequence S_i, $r_1 < r_2 < r_p$, p is the number of selected items from sequence S_i, $1 \leq k \leq p$, and $p \leq m$; i.e. S' can be obtained by deleting $m - p$ (not necessarily contiguous) symbols from S_i without changing its order.

Let $S_1 = s_{11}s_{12}\dots s_{1m}$ and $S_2 = s_{21}s_{22}\dots s_{2n}$ be two sequences of length m and n, respectively. The sequence $S' = s'_1s'_2\dots s'_p$ is a common subsequence of S_1 and S_2, if S' is a subsequence of both sequences. The LCS of S_1 and S_2 is the longest sequence S' that is a subsequence of both S_1 and S_2. In general, the LCS problem consists of finding the maximal-length subsequence—i.e. there exists no other subsequence that has greater length—that is a common subsequence of the sequences.

Let S_1 and S_2 be the above defined sequences of length m and n, respectively. The algorithm implemented to obtain the LCS of two sequences [15] uses dynamic programming and requires calculating the LCS table (LCST) as

$$LCST(i,j) = \begin{cases} 0 & \text{if } j=0 \quad \text{or} \quad i=0 \\ LCST(i-1,j-1)+1 & \text{if } i>0, j>0 \; and \; s_{1i} = s_{2j} \\ max(LCST(i,j-1), LCST(i-1,j)) & \text{if } i>0, j>0 \; and \; s_{1i} \neq s_{2j} \end{cases},$$

where $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$. The number of rows and columns in LCST are $m+1$ and $n+1$, respectively, whereas the cell $LCST(i,j)$ is the element in the LCS table at row i and column j. The LCS table stores numbers which correspond to the actual length of the LCS. After filling the LCS table, the lower right cell in the table contains the length of the LCS. The longest common subsequence can be found by tracing back from the cell at $LCST(m,n)$. Each time a match is found, it is appended to the longest common subsequence and a movement is made to cell $LCST(i-1, j-1)$. When the symbols do not match, a movement is made to the cell with $max(LCST(i-1,j), LCST(i,j-1))$ in order to find the next match. In general, there may be several such paths, because the LCS is not necessarily unique, i.e. it is possible to have more than one LCS. For example, let S_1="MFVFS" and S_2="MVFVS". After application of the previous rules, the subsequence "MFVS' is the LCS of the sequences. However, if we placed the sequences in the inverted order, the subsequence "MVFS" would be the LCS of the sequences.

C. Parallel LCS strategy

Let $S = \{S_1, S_2, \dots, S_n\}$ be a set of n protein sequences, where $S_i = s_{i1}, s_{i2}, \dots, s_{im_i}$, m_i is the length of S_i for $i = 1, 2, \dots, n$, and s_{ik} is the k^{th} residue in the sequence S_i. Let np be the number of processes used by the algorithm. In this step, each process calculates an LCS of the set S. First, sequences are read and saved into an array. The procedure in this step is as follows: the i^{th} process applies the LCS algorithm to all possible pairs of sequences $LCS(S_i, S_j)$ in the set S that result from the combination of sequence S_i for $i = 1, 2, \dots, n$ with the rest of the sequences S_j, for $j = 1, 2, \dots, n$ and $i \neq j$. Even though all processes apply the same algorithm to the same set of sequences, the resulting LCSs are possibly different, because the calculations are based on a different order of sequences and there exists the possibility of having more than one LCS for the same sequences, as previously noted. For example, in the first iteration of this step, *Process 1* applies the algorithm to the following pairs of sequences:

$$LCS(S_1, S_2), LCS(S_1, S_3), \dots, LCS(S_1, S_n).$$

In the same manner, *Process 2* will apply the algorithm to the following pairs of sequences:

$$LCS(S_2, S_1), LCS(S_2, S_3), \dots, LCS(S_2, S_n),$$

and a similar strategy is applied for the rest of the np processes.

The results obtained from this first iteration are saved in order to create a new set of sequences. Thus, this new set of sequences contains the LCSs of the pairs of sequences in the original set S and its size will be $n - 1$. Next, the process repeats this iterative procedure with the obtained LCSs until there remains only one LCS. When this happens, it means that the LCS of the sequences in the set S has been found.

D. Setting up an initial MSA

After the LCS is obtained, an algorithm is applied to the set of sequences in order to generate a first MSA. This algorithm aligns identical residues of the sequences by using the resulting LCS. In general, the algorithm aligns identical residues, as well as similar residues, as much as possible.

Let A be an array of strings, with the sequences to be aligned, and n the number of rows (sequences) in array A, with $A_i = a_{i1}, a_{i2}, \dots, a_{im_i}$ the i^{th} row in array A, m_i the length of sequence in A_i, for $i = 1, 2, \dots, n$, and a_{ij} the j^{th} element (residue) in row A_i (sequence i), for $j = 1, 2, \dots, m_i$. Moreover, let $R = r_1r_2\dots r_p$ be a string with the LCS of the sequences in array A, with p the length of string R. The algorithm initiates with $j = 1$ (pointing to the first column in array A) and $k = 1$ (pointing to the first element in string R). The element r_k in string R is compared with all elements a_{ij} in A for $i = 1, 2, \dots, n$. The resulting comparison can fall into one of the following three cases:

Case A. All elements a_{ij} in A match the element r_k in R. No gap is inserted in the sequences of array A, so identical residues are aligned, and k is increased for $k = 1, 2, \dots, p$, in order to point to the next element r_{k+1} in string R.

Case B. None of the elements a_{ij} in A match the element r_k in R. No gap is inserted in the sequences of array A, so residues at this position are aligned, and k is increased for

$k = 1, 2, \ldots p$ in order to point to the next element r_{k+1} in string R.

Case C. Only some elements a_{ij} in A match the element r_k in R. An iterative procedure introduces a gap in the sequences of array A at position a_{ij}, if $a_{ij} = r_k$ for $i = 1, 2, \ldots, n$.

In all the previous cases, j is increased in order to point to the next residue of sequences in array A, for $j = 1, 2, \ldots, m$. The iterative procedure is repeated until the last element r_p in string R is processed. The maximum length of sequences in array A is calculated, and this length is established as the length of the initial MSA. Finally, gaps are inserted if needed at the end of sequences having a smaller length than the maximum length calculated, so that all sequences have the same length. As a result of the previous calculations, a matrix is created containing an initial MSA.

The procedure described above uses the LCS generated at each process, which could be different from the LCSs in the other processes. This approach allows various potential solutions to be running in separate processes.

E. MSA assessment

The accuracy of PaMSA—i.e. the quality of the alignment—is evaluated using the following five optimization functions (OFs):

$$OFs = \begin{cases} ID(MSA) \\ SY(MSA) \\ SP(MSA) \\ PWS(MSA) \\ NG(MSA) \end{cases},$$

where ID measures the identity percentage score, SY evaluates the similarity percentage score, SP calculates the sum-of-pairs score, PWS obtains a pairwise score of the sequences compared with the first sequence in the alignment, and NG counts the number of gaps in the alignment.

1) Identity percentage (ID): In our implementation, the identity percentage score among the sequences being aligned is calculated as

$$ID(A) = \left(\left(\sum_{j=1}^{r} \sum_{i=1}^{n} a_{ij} \right) * 100 \right) / r \,, \tag{1}$$

where A is the array with the MSA as previously defined, r is the length of the aligned sequences in A, n is the number of sequences aligned, and $\sum_{i=1}^{n} a_{ij}$ is counted only if all the a_{ij} are identical for $i = 1, 2, \ldots, n$ in the j^{th} column of the MSA for $j = 1, 2, \ldots, r$. In general, the higher the identity percentage score, there better the alignment.

2) Similarity percentage (SY): The similarity percentage score is calculated using the same formula used to calculate the identity percentage score. However, the sum $\sum_{i=1}^{n} a_{ij}$ is counted only if all the a_{ij} in the j^{th} column of the MSA are similar—i.e. not necessary identical but imperatively different from a gap. In general, the higher the similarity percentage score, the better the alignment.

3) Sum of pairs (SP): The sum-of-pairs score is a metric for measuring MSA accuracy, based on the number of correctly aligned residue pairs, where the score of all pairs of sequences in the multiple alignment is added to the overall score. The SP score is calculated as

$$SP(A) = \sum_{i=1}^{r} sp(a_i) \,, \tag{2}$$

$$sp(a_i) = \sum_{1 \leq k < l \leq n} s(a_{ki}, a_{li}) \,, \tag{3}$$

where A is the array with the MSA as previously defined, r is the length of the aligned sequences in A, n is the number of rows (sequences) in array A, and $s(a_{ki}, a_{li})$ is the score obtained by comparing the k^{th} row in the i^{th} column of the MSA with the l^{th} row in the same i^{th} column of the MSA for $k = 1, 2, \ldots, n-1$ and for $l = 2, 3, \ldots, n$. This score is calculated using the following general formula:

$$s(a_{ki}, a_{li}) = \begin{cases} 1 & \text{if } a_{ki} = a_{li} \\ -1 & \text{if } a_{ki} \neq a_{li} \\ -2 & \text{if } a_{ki} = gap\ XOR\ a_{li} = gap \\ 0 & \text{if } a_{ki} = gap\ AND\ a_{li} = gap \end{cases}.$$

The value of the sum-of-pairs score depends on the number of sequences aligned, the length of the sequences aligned, and the similarity among the sequences aligned. Therefore, there is not a pre-established range of values for this score. The higher the sum-of-pairs score of a particular set of sequences, the better its alignment. It is possible to use a substitution matrix to compare the residues among sequences in order to obtain better alignments. The BLOSUM62 matrix is provided in our implementation as it is the *de facto* standard in protein database searches and sequence alignments [16].

4) Pairwise score (PWS): The pairwise score of sequences was included in the evaluation of our algorithm. In our implementation, this pairwise score obtained among all pairs of sequences is calculated as

$$PWS(A) = \sum_{i=1}^{r} \sum_{j=2}^{n} s(a_{1i}, a_{ji}) \,, \tag{4}$$

where A is the array with the MSA as previously defined, r is the length of the aligned sequences in A, n the number of rows (sequences) in array A, and $s(a_{1i}, a_{ji})$ is the score obtained by comparing the $first$ row in the i^{th} column of the MSA with the j^{th} row in the same i^{th} column of A. The same comparison evaluation criteria as in *SP* are used. The value of the pairwise score depends on the number of sequences aligned, the length of the sequences aligned, the similarity among the sequences aligned, and the first sequence in the alignment. Hence, there is not a pre-established range of values for this score. In general, the higher the sum-of-pairs score of a particular set of sequences, the better the alignment.

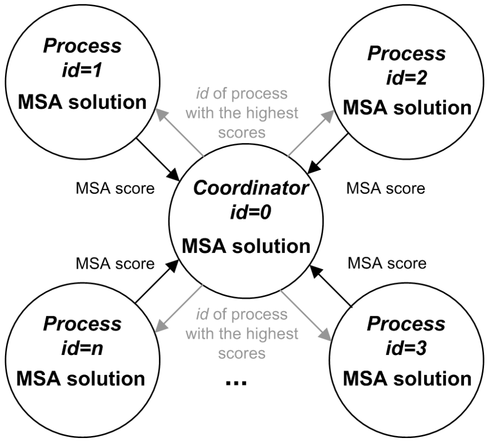

Fig. 2. Communication topology used among processes.

5) Number of gaps (NG): The number of gaps is an additional score, which is calculated using the formula

$$NG(A) = \sum_{j=1}^{r} \sum_{i=1}^{n} a_{ij} \, , \tag{5}$$

where A is the array with the MSA as previously defined, r is the length of the aligned sequences in A, n is the number of rows (sequences) in array A, and a_{ij} is counted only if it is a gap. The value of the number of gaps depends on the number of sequences aligned, the length of the sequences aligned, and mainly on the similarity among the sequences aligned. Therefore, there is not a pre-established range of values for this score. The fewer the number of gaps of a particular set of sequences, the better the alignment.

After the first MSA is generated in each process, the alignment is evaluated using the implemented OFs. Each slave process evaluates its MSA and sends the scores of four of the OFs to the coordinator—the ID, the SY, the SP and the PWS scores—, which receives the scores and determines which process has the best MSA for all four OFs (Fig. 2). The Number of Gaps (NP) score is calculated and displayed in the screen output, but it was left out of the selection criterion, as preliminary results suggested that the other four OFs were sufficient to evaluate the alignment.

After the coordinator process receives the OFs scores from the slave processes, it propagates the id of the process with the best scores to all the slave processes. If the scores of all four OFs of the MSA have not shown improvement in two consecutive iterations or if a predefined number of iterations is reached, the algorithm ends and the process with the best alignment of the sequences provides the resulting MSA. Otherwise the alignment is improved by iteratively applying a number of operators that move, delete or realign gaps in the sequences following specific rules.

F. Improvement of the MSA

In order to improve the MSA, sixteen operators were defined in the present work. In the current version of PaMSA, there exist two main groups of operators: the basic operators, and the refinement operators, both shown in Table I. The main differences between the two groups of operators are that refinement operators can be applied even when only one sequence of the two sequences has the gaps, and that some of them are applied only in the last iteration of the algorithm—i.e. when the number of generations was reached or if there was no improvement in the alignment after two consecutive iterations—, in contrast to basic operators which are applied only when both sequences have gaps. The proposed operators perform an exhaustive search along the total length of all sequences with the aim of finding an opportunity to improve the alignment. The search is focused on the detection of gaps and identical or similar residues that are not totally aligned.

TABLE I. ALIGNMENT IMPROVEMENT OPERATORS

Operator	Function	Type
mGapRF_3	Moves three gaps in 1st sequence to the right	BS
mGapRS_3	Moves three gaps in 2nd sequence to the right	BS
mGapRF_2	Moves two gaps in 1st sequence to the right	BS
mGapRS_2	Moves two gaps in 2nd sequence to the right	BS
mGapRF_1	Moves a gap in 1st sequence to the right	BS
mGapRS_1	Moves a gap in 2nd sequence to the right	BS
mGapRF_G	Moves a gap in 1st sequence to the right	BS
mGapRS_G	Moves a gap in 2nd sequence to the right	BS
rGaps	Removes an MSA column if all elements are gaps	BS
mGapRF_3S	Realigns three gaps in 1st sequence to the right	RF
mGapRS_3S	Realigns three gaps in 2nd sequence to the right	RF
mGapRF_2S	Realigns two gaps in 1st sequence to the right	RF
mGapRS_2S	Realigns two gaps in 2nd sequence to the right	RF
mGapLF_1S	Realigns a gap in 1st sequence to the right	RF
mGapLS_1S	Realigns a gap in 2nd sequence to the right	RF
mGapn	Moves a residue in 2nd sequence *n* columns	RF

Type: BS = Basic, RF = Refinement.

The operators are always applied to pairs of sequences. At every iteration, operators are applied—when necessary—to each of the potential solutions running in the independent processes. An assessment method marks columns of sequences in the MSA when their elements are totally aligned, so that the algorithm will not apply the operators to those columns in future iterations. This strategy improves the performance of the algorithm.

1) Basic operators: There are nine basic operators (Table I), which mainly move gaps trying to minimize their number by eliminating columns that only contain gaps. The $mGapRF\_3$ operator moves three gaps to the right in the first sequence of a pair of sequences being compared in the alignment. This operator is applied in order to align identical residues. The $mGapRS\_3$ operator acts in a similar way as the $mGapRF\_3$ operator, but in this case the operator is applied to the second sequence of the pair of sequences being compared. In the same manner, the $mGapRF\_2$ and the $mGapRS\_2$ operators move two gaps to the right in the first and second sequence, respectively. These operators are also applied in order to align identical residues. Similarly, the $mGapRF\_1$ operator moves a gap to the right in the first sequence of a pair of sequences with the aim of aligning identical residues. The $mGapRS\_1$ operator moves a gap to the right in the second sequence of the pair of sequences being compared in order to align identical residues.

The $mGapRF\_G$ and the $mGapRS\_G$ operators move a gap to the right in the first or second sequence, respectively, of a pair of sequences. These operators are applied in order to reduce the number of gaps by aligning similar—i.e. non-identical—residues.

The *rGaps* operator is used to remove a column from the alignment when all the residues in the column are gaps. This operator is applied after the application of any of the other operators. Once the *rGaps* operator has been applied, a new assessment of the MSA is made in order to update the MSA scores.

2) Refinement operators: As can be seen in Table I, there are seven refinement operators. The $mGapRF\_3S$ and $mGapRS\_3S$ operators move three gaps to the right in the first and the second sequence, respectively, of a pair of sequences being compared. These operators are applied in order to align identical residues. Unlike the $mGapRF\_3$ and $mGapRS\_3$ operators, these refinement operators are applied even when only one of the sequences has the gaps. The $mGapRF\_2S$ and $mGapRS\_2S$ operators act similarly as the $mGapRF\_3S$ and the $mGapRS\_3S$ operators, but in this case the refinement operators realign only two gaps to the right.

The three remaining refinement operators, $mGapLF\_1$, $mGapLS\_1$, and $mGapn$, move a gap to the left in order to align identical residues in the alignment. Because these operators are the only ones that move gaps to the left, they are applied at the last iteration of the algorithm.

III. Method

The implementation of the PaMSA algorithm was developed on a computer cluster provided by Intel Corporation, which contained 10 nodes, each node with two Intel Xeon 5670 6-core 2.93 GHz CPUs, 24 GB of 1066 MHz DR3 RAM, and two 274 GB 15K RPM hard drives. The operating system used was Red Hat Enterprise Linux 5 Update 4 with Perceus 1.5 Clustering Software and Server 5.3 running Intel MPI 3.2. An implementation of PaMSA can be downloaded from http://www.bioinformatics.org/pamsa.

The Message Passing Interface (MPI) library was used in our implementation of the algorithm. MPI defines the syntax and semantics of a set of functions in a library designed to exploit the existence of multiple processors, and it provides the synchronization and communication needed among processes. Synchronous communication operations were used in this work to handle communication and synchronization among tasks. When a synchronous operation is invoked, a process sends a message and then waits for a response before proceeding with the process flow. Object-oriented and structured programming paradigms were applied using C++ as the programming language. The PaMSA algorithm was implemented on a cluster platform using the Linux operating system; however, PaMSA can be run on a nonparallel environment.

Results presented in this work were obtained from alignments performed on the Hybrid Cluster Supercomputer *Xiuhcoatl* of the General Coordination of Information and Communications Technologies (CGSTIC) at CINVESTAV, in Mexico City. This cluster contained 88 nodes, each node with 1056 Intel X5675 CPUs, 2112 GB of RAM, and 22000 GB in local hard disk drives.

Table II presents the 40 datasets of protein sequences that were used in the present work in order to analyze the performance of PaMSA and the other MSA methods tested. Each protein dataset was chosen according to its number of sequences, identity percentage, and length average. Datasets were organized in eight groups of five sequence clusters each, named from A to H (i.e. Group A, Group B, and so on). The groups of sequences were obtained from the UniProt Reference Clusters (UniRef) contained in the UniProKB protein database. At this site, sequences are classified in groups—called clusters—according to their identity percentage; thus, similar sequences can be obtained through a database query. Sequences that belong to a specific cluster are called cluster members.

TABLE II. Cluster Groups used for the Alignments

Group	Dataset	Cluster name	Number of sequences	Average length	Minimum identity (%)
A	1	C1CIT9	10	100	100.0
	2	P15020	52	100	100.0
	3	E5G6P9	98	100	100.0
	4	Q8XA92	129	100	100.0
	5	A7X428	177	100	100.0
B	6	B5Y0W9	40	80	100.0
	7	B5XNF9	40	127	100.0
	8	Q5HNW5	40	210	100.0
	9	B5XZH9	40	309	100.0
	10	Q5HPT8	40	467	100.0
C	11	Q5HP42	37	468	100.0
	12	C1HFG3	45	597	100.0
	13	A0A1X4	50	757	100.0
	14	B3BQU1	83	843	100.0
	15	Q5HG69	114	914	100.0
D	16	O53454	48	369	98.9
	17	Q833H5	66	228	98.2
	18	Q6GIG7	37	354	97.4
	19	A7WZ82	128	100	91.0
	20	P10321	18	355	90.7
E	21	Q2YIT5	55	231	87.3
	22	A0A084	14	326	85.8
	23	A0B0S7	13	407	83.5
	24	Q9KTA3	72	303	81.8
	25	K0HNA3	77	193	79.8
F	26	A0AZ41	25	169	76.6
	27	A0A2S1	20	129	78.2
	28	A0A125	14	47	75.5
	29	A0A0A7	10	147	75.9
	30	A0A1U6	9	124	70.0
G	31	A0A0X0	7	374	69.9
	32	A0B092	21	264	68.2
	33	Q3SZ22	5	279	66.3
	34	A0AZ19	23	116	65.7
	35	A0B0W2	13	174	61.6
H	36	A0A092	19	294	60.6
	37	A0A0T0	25	228	53.7
	38	A0A9I3	31	308	52.1
	39	A0A132	20	50	52.3
	40	A0A194	48	119	50.4

The Identity score shown is the minimum of all methods tested for each cluster. These protein datasets can be found at http://www.uniprot.org/uniref/.

The number of iterations of the PaMSA algorithm can be modified by the user as a parameter, the default value being five. A file with the resulting MSA was created with sequences in *clustal* format. The MSA output file has the same name as the input file but with the *pamsa* extension. Basic validations are implemented, such as verification of the existence of the input file with the sequences to be aligned, the creation of the output file, the correct introduction of the parameters given, and the verification of the FASTA format of the sequences to be aligned. PaMSA was compared against the following versions of the MSA programs: MUSCLE v3.7, Clustal W v2.0.10, T-Coffee v9.03r1318, and Parallel T-Coffee v1.913, all of them running in Linux.

IV. Results and Discussion

In this section we present results obtained from alignments using PaMSA, as well as comparisons made against several methods commonly used for MSA, namely MUSCLE, Clustal

W, T-Coffee, and Parallel T-Coffee—a parallel implementation of T-Coffee. Of particular note is the Parallel T-Coffee method, which runs on a cluster platform and uses the MPI library, just as our implementation of the PaMSA algorithm. The variables used for evaluating the performance of the methods tested were the MSA accuracy (quality of the alignment), and the response time.

A. MSA accuracy results

The sum-of-pairs score was used in the present work for evaluating the quality of the alignments, as it is a simple and sensitive measure for assessing the accuracy of alignments and has been widely used [17]. The greater the sum-of-pairs score, the better the alignment obtained; thus, the alignment with the highest sum-of-pairs score is considered the most accurate (the best) MSA of all the alignments obtained. The sum-of-pairs scores for all dataset groups and MSA methods are presented in Table III.

TABLE III. SUM-OF-PAIRS SCORES OF RESULTING MSAS

Group	Dataset	MUSCLE	Clustal W	T-Coffee	PaMSA	Parallel T-Coffee
A	1	4500*	4500*	4500*	4500*	4500*
	2	132600*	132600*	132600*	132600*	132600*
	3	475300*	475300*	475300*	475300*	475300*
	4	825600*	825600*	825600*	825600*	825600*
	5	1557600*	1557600*	1557600*	1557600*	1557600*
B	6	62400*	62400*	62400*	62400*	62400*
	7	99060*	99060*	99060*	99060*	99060*
	8	163800*	163800*	163800*	163800*	163800*
	9	241020*	241020*	241020*	241020*	241020*
	10	364260*	364260*	364260*	364260*	364260*
C	11	311688*	311688*	311688*	311688*	311688*
	12	591030*	591030*	591030*	591030*	591030*
	13	927325*	927325*	927325*	927325*	927325*
	14	2868730*	2868730*	2868730*	2868730*	2868730*
	15	5803340*	5803340*	5803340*	5803340*	5803340*
D	16	413408*	413408*	413408*	413408*	413408*
	17	481125*	481125*	481125*	481125*	481125*
	18	233649*	233649*	233649*	233649*	233649*
	19	803395*	803395*	803395*	803395*	803395*
	20	50301*	50301*	44567	50301*	50301*
E	21	305824	305824	305894*	305894*	305894*
	22	25766*	25766*	22003	25766*	25766*
	23	27094	27094	23018	27100*	22765
	24	721444*	721444*	721444*	721444*	721444*
	25	493975*	493975*	493975*	493975*	493975*
F	26	43936	42690	44148*	44148*	40559
	27	21960*	21960*	21960*	21960*	21960*
	28	3291*	3291*	2758	3291*	2980
	29	4637*	4637*	3769	4637*	4637*
	30	3467*	3467*	3467*	3467*	3467*
G	31	5951*	5951*	4093	5951*	5951*
	32	47610*	47434	43219	47144	45592
	33	1742*	1734	1062	1727	1046
	34	23312	23312	23312	23314*	23314*
	35	9934*	9934*	8804	8610	8659
H	36	30864*	30864*	27440	30639	27168
	37	50765*	50765*	46414	45218	46442
	38	137083*	137083*	127785	136413	127467
	39	5598*	5598*	4856	5598*	4975
	40	119868*	119868*	119868*	119868*	119868*

* = Best alignment obtained.

As can be seen, all algorithms achieved the optimal MSA—the alignment with the highest sum-of-pairs score—and 100% of identity percentage, when datasets of protein sequences from Groups A, B, and C were used (Table III). The datasets from these groups had originally 100% of identity percentage among them; thus, the LCS found by the PaMSA algorithm corresponded exactly to the sequences to be aligned, making it simple in this case to find the MSA with a perfect identity percentage.

In the MSA accuracy results obtained from alignments using datasets of protein sequences from Group D (clusters with an identity percentage score within the range from 90% to 99%), the T-Coffee method achieved the best MSA in 4 out of 5 cases tested (Table III). The PaMSA, MUSCLE, Clustal W and Parallel T-Coffee methods obtained the best alignment in all datasets of this group, based on the sum-of-pairs scores.

Clusters of sequences with an identity percentage score approximately within the range from 80% to 89% were used in alignments with sequences from Group E. Datasets from this group have slightly dissimilar sequences. The sum-of-pairs scores obtained using the PaMSA algorithm were the highest in all cases tested (Table III), i.e. the PaMSA algorithm obtained the best alignment in this group of alignments. The MUSCLE, Clustal W and T-Coffee methods obtained the best MSA in 3 out of 5 cases tested, whereas Parallel T-Coffee achieved the best MSA in 4 out of 5 cases.

The MSA accuracy results obtained in alignments using Group F (with an identity percentage score approximately within the range from 70% to 79%) were similar to the results obtained with Group E—the PaMSA algorithm also obtained the best alignment in all the cases tested. Datasets from this group have more variable sequences than the previous groups. The T-Coffee and Parallel T-Coffee methods achieved the best MSA in 3 out of 5 cases. The MUSCLE and Clustal W methods obtained the best MSA in 4 out of 5 cases tested.

The PaMSA algorithm obtained less accurate alignments, according to the sum-of-pairs score, than the MUSCLE and Clustal W methods in at least four cases tested from Group G (clusters with an identity percentage approximately within the range from 60% to 69%) and Group H (clusters with an identity percentage approximately within the range from 50% to 59%). However, the MSA accuracy results obtained by the PaMSA algorithm were equal or better than those obtained by the T-Coffee and Parallel T-Coffee methods using these groups of sequences.

In general, results show that the MUSCLE method had the best MSA accuracy of the methods tested, as it obtained the best alignments (according to the sum-of-pairs score) in all but four of the 40 cases tested. The Clustal W method and the PaMSA algorithm were a close second place in accuracy, achieving the best alignment in 34 out of 40 cases tested. The Parallel T-Coffee method obtained the best alignment in 30 of the cases tested, against the 26 achieved by the T-Coffee method.

With the exception of MUSCLE, PaMSA and the other tested MSA methods had trouble finding accurate alignments when using datasets with an identity percentage lower than 70%. Nevertheless, even in this case PaMSA was able to find the best alignment in 4 out of 10 datasets.

B. Response time results of nonparallel methods

This section presents the execution time results obtained from alignments using PaMSA and three common nonparallel methods for MSA: MUSCLE, Clustal W and T-Coffee. For these alignments, PaMSA and the other three methods were executed in a nonparallel environment. It should be mentioned that the results shown are the best execution times achieved from a set of five runs. Alignments were made under the same conditions for all the methods compared—i.e. computer, environment, operating system, and timer.

Table IV presents the execution time results in seconds obtained from alignments for all dataset groups. As can be seen, in Group A the MUSCLE method achieved the best response times, whereas the PaMSA algorithm had better response times than the Clustal W and T-Coffee applications for all datasets in this group. The performance results obtained using Group B were similar to the results from alignments using Group A, i.e. the MUSCLE method achieved the best response times and the PaMSA algorithm was the second best. The performance results obtained using Group C were similar to the results from the previous group, with the MUSCLE and the PaMSA methods in first and second place, respectively.

TABLE IV. SINGLE-PROCESSOR EXECUTION TIME RESULTS IN SECONDS

Group	Dataset	MUSCLE	PaMSA	Clustal W	T-Coffee
	1	0.033*	0.034	0.053	0.398
	2	0.184*	0.445	0.532	2.208
A	3	0.446*	1.521	1.709	7.094
	4	0.686*	2.614	2.903	12.615
	5	1.139*	4.934	5.446	25.833
	6	0.107*	0.188	0.235	1.280
	7	0.173*	0.389	0.502	1.691
B	8	0.311*	0.908	1.249	2.637
	9	0.533*	1.813	2.565	4.009
	10	0.968*	3.920	5.675	6.583
	11	0.891*	3.358	5.089	5.531
	12	1.633*	7.886	11.427	11.365
C	13	2.715*	15.422	22.097	22.451
	14	5.944*	52.515	71.605	65.168
	15	9.954*	113.462	149.945	154.006
	16	0.859*	3.628	5.050	7.196
	17	0.655*	2.856	3.638	7.389
D	18	0.595*	2.024	2.968	4.084
	19	0.679*	2.604	2.843	12.483
	20	0.411*	0.477	0.817	1.282
	21	0.626*	1.958	2.574	5.403
	22	0.295	0.282*	0.468	0.884
E	23	0.227*	0.320	0.630	0.976
	24	1.089*	4.869	7.433	12.050
	25	0.769*	3.015	3.397	7.984
	26	0.176*	0.252	0.366	1.038
	27	0.095*	0.102	0.164	0.646
F	28	0.026*	0.026*	0.042	0.448
	29	0.049*	0.049*	0.077	0.465
	30	0.041	0.032*	0.063	0.401
	31	0.104	0.094*	0.211	0.512
	32	0.268*	0.388	0.612	1.132
G	33	0.110*	0.134	0.168	0.800
	34	0.058	0.036*	0.086	0.372
	35	0.097	0.094*	0.145	0.514
	36	0.374	0.342*	0.631	1.151
	37	0.288*	0.359	0.619	1.336
H	38	0.811*	0.945	2.363	3.021
	39	0.035*	0.039	0.048	0.533
	40	0.214*	0.500	0.611	2.200

* = Best execution time.

From the execution time results obtained using Group D, there are no differences with previous results regarding the order of the best two methods, i.e. the MUSCLE method also achieved the best response times, whereas the PaMSA algorithm had better response times than the Clustal W and T-Coffee applications. The performance results obtained using Group E were similar to those of the previous alignments, with the exception of Dataset 22, with which PaMSA achieved the best response time. In the rest of the datasets from this group, the MUSCLE method achieved the best response times. The PaMSA algorithm showed once again with this group better response times than the Clustal W and T-Coffee methods. The performance results obtained using Group F were different from those of the previous alignments; in alignments using this group, PaMSA achieved the best response time when using

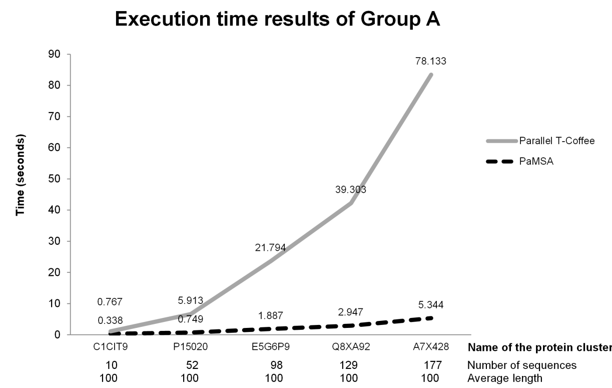

Fig. 3. Parallel execution times of PaMSA and Parallel T-Coffee using datasets from Group A. The times shown are the best of five runs for each dataset.

Dataset 30, whereas this algorithm and MUSCLE method reached a tie in best execution time in two instances. The PaMSA algorithm was again superior to the Clustal W and T-Coffee methods when testing this group of sequences. The response times obtained by the PaMSA algorithm using Group G were superior to those of the other methods tested in three out of five alignments, whereas the MUSCLE algorithm achieved the best response time in the other two cases. Finally, using Group H, the MUSCLE method obtained the best response time in all but one of the cases tested in this group of alignments, whereas the PaMSA algorithm was again superior to the Clustal W and T-Coffee programs.

As can be seen, in most of the MSAs with the datasets presented in Table II, the MUSCLE method achieved the best execution time results. However, the PaMSA algorithm was superior or equal to the MUSCLE method in some cases. On the other hand, the execution times achieved by the PaMSA algorithm were better (i.e. lower) than the results obtained using the Clustal W and T-Coffee programs in all the cases tested.

C. Response time results of parallel methods

In this section we present the execution time results achieved by comparing the PaMSA algorithm against Parallel T-Coffee—a parallel version of the T-Coffee method. Alignments using these two methods were executed in a cluster environment under the same conditions (cluster type, number of processes, MPI library, operating system, and timer). Table V shows the execution times in seconds of Parallel T-Coffee and PaMSA. The times shown are the best of five runs for each dataset.

Fig. 3 graphically shows the execution time results achieved by the PaMSA algorithm and the Parallel T-Coffee method when using datasets of protein sequences from Group A; similar results were found for the rest of the groups. In all the cases tested, execution times achieved by PaMSA were superior to the results obtained with the parallel version of T-Coffee.

In order to confirm the superiority in performance of the PaMSA algorithm over the Parallel T-Coffee method, the

TABLE V. EXECUTION TIME RESULTS OF PARALLEL T-COFFEE AND PAMSA IN SECONDS

Group	Dataset	Parallel T-Coffee time (s)	PaMSA time (s)	Speedup
A	1	0.767	0.338	2.3
	2	5.913	0.749	7.9
	3	21.794	1.887	11.5
	4	39.303	2.947	13.3
	5	78.133	5.344	14.6
B	6	2.658	0.515	5.2
	7	5.555	0.715	7.8
	8	14.774	1.247	11.8
	9	30.149	2.152	14.0
	10	72.149	4.253	17.0
C	11	60.319	3.745	16.1
	12	148.757	8.304	17.9
	13	304.629	16.065	19.0
	14	1113.234	53.668	20.7
	15	2510.508	116.098	21.6
D	16	53.413	4.397	12.1
	17	57.237	3.577	16.0
	18	40.496	2.493	16.2
	19	38.118	3.316	11.5
	20	10.586	0.848	12.5
E	21	37.36	2.429	15.4
	22	4.452	0.585	7.6
	23	4.713	0.671	7.0
	24	151.67	5.627	27.0
	25	44.113	3.785	11.7
F	26	3.144	0.617	5.1
	27	1.628	0.413	3.9
	28	0.643	0.332	1.9
	29	0.919	0.367	2.5
	30	0.748	0.359	2.1
G	31	1.481	0.413	3.6
	32	4.643	0.75	6.2
	33	1.11	0.353	3.1
	34	1.516	0.466	3.3
	35	1.371	0.419	3.3
H	36	6.641	0.671	9.9
	37	4.346	0.721	6.0
	38	17.966	1.484	12.1
	39	0.733	0.359	2.0
	40	6.833	0.886	7.7

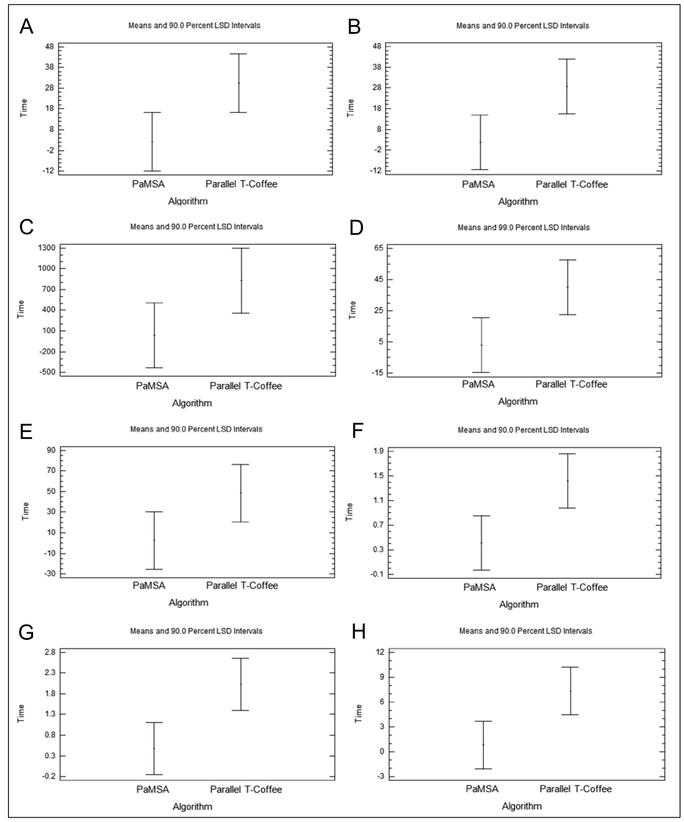

Fig. 4. Multi-factor ANOVA plot of means by group. The panel letters correspond to the protein sequence group being analyzed. Group B used the algorithm and the average length of sequences as factors, whereas the rest of groups considered the algorithm and the number of the sequences as factors.

speedup for all datasets in all groups was computed by dividing the execution time of the Parallel T-Coffee method by the execution time of the PaMSA algorithm. Results showed that the PaMSA algorithm had better response time than Parallel T-Coffee in all the cases tested, as seen in Table V. The PaMSA algorithm was at least 1.9 and up to 27 times faster than Parallel T-Coffee, depending on the number and length of the sequences to be aligned.

A multi-factor ANOVA was done by group in order to statistically compare the execution times of the PaMSA and Parallel T-Coffee algorithms. Two factors were considered for the eight groups. Seven of the eight groups considered the algorithm and the number of the sequences as factors, whereas in Group B the algorithm and the average length of sequences were considered as factors. Table VI shows the p-valued obtained for each group.

TABLE VI. ANOVA p-VALUES BY CLUSTER GROUP

Group	p-value
A	0.998
B	0.0933
C	0.1473
D	0.0084
E	0.1547
F	0.0733
G	0.0589
H	0.0745

Based on their p-values, Table VI shows that in five of the eight groups (A, B, F, G, and H) there was a statistically significant difference between the execution time for the two algorithms at 90% of confidence, and in one of them (Group D) at 99% of confidence. In order to analytically discern which algorithm had better response time, a plot of means by group was performed. Fig. 4 graphically shows the plot of means by group. Insets 4A, 4B, 4D, 4F, 4G, and 4H show that PaMSA was statistically better than the Parallel T-Coffee algorithm in the corresponding groups, whereas Insets 4C and 4E show that PaMSA was statistically equal to Parallel T-Coffee in Groups C and E. Thus, statistically PaMSA was as fast or faster than the Parallel T-Coffee algorithm for all eight groups tested when the mentioned factors were considered.

V. CONCLUSION

The focus of this research project was to propose a parallel solution for the global multiple alignment problem of protein sequences by combining dynamic programming, heuristics, and parallel programming techniques in an iterative process. The resulting algorithm was named PaMSA, which stands for Parallel MSA. Execution time results obtained using the PaMSA algorithm compared against those of the Parallel T-Coffee method indicated that the PaMSA algorithm had equal or better performance in all the cases tested. Accordingly, a multi-factor ANOVA analysis was performed in order to confirm this tendency. Results of the statistical analysis indicate that PaMSA is as fast or faster than Parallel T-Coffee when considering the algorithm, and either the number of sequences or the average length of sequences (in Group B) as factors. It can be concluded that the PaMSA algorithm achieved in general better execution time results than the Parallel T-Coffee method under the conditions tested.

As for the comparison of execution times of the PaMSA algorithm against the sequential MSA methods tested, PaMSA was run as a one-processor application in a nonparallel environment and the results were compared against those of MUSCLE, T-Coffee and Clustal W. In 80% of the tested cases the MUSCLE method achieved shorter response times. However, the PaMSA algorithm was faster than the MUSCLE method in 15% of the cases. On the other hand, the execution times achieved by the PaMSA algorithm were better than the results obtained by Clustal W and T-Coffee in all the cases tested. It can be concluded that the PaMSA algorithm was the second faster of the methods under the nonparallel conditions tested.

As for the accuracy of the alignments, results achieved with the PaMSA algorithm in clusters of very similar protein sequences (within a range from 90% to 100% of identity percentage score, approximately) were at least as accurate as the alignments obtained with the other methods tested. It can be concluded that the PaMSA algorithm, along with the MUSCLE, Clustal W, and Parallel T-Coffee methods, achieved the best overall MSA accuracy results when using these groups of sequences. In general, when aligning closely related sequences, all the tested methods obtained the best—or close to the best—alignment. When using clusters of sequences with an identity percentage score of approximately 70% to 89%, PaMSA found the best alignment in all cases—according to the sum-of-pairs score—, whereas MUSCLE, Clustal W, T-Coffee, and Parallel T-Coffee could not find the best MSA in at least three cases. It can be concluded that the results achieved by the PaMSA algorithm were better than the other methods tested with these groups of sequences. It is possible to assume that when aligning more dissimilar sequences, not all methods can obtain the best alignment. Finally, when using clusters with approximately 50% to 69% of identity percentage score, the PaMSA algorithm achieved less accurate alignments than the MUSCLE and Clustal W methods in 6 out of 10 datasets in both cases. However, the alignments obtained by the PaMSA algorithm were equal or even better than the alignments obtained by the T-Coffee and Parallel T-Coffee methods in 8 out of 10 cases tested in these groups of sequences. According to our results, no single MSA method can always obtain the best alignment for all sets of sequences.

Future work will focus on further improvement of accuracy of the alignments obtained by PaMSA using benchmark protein databases, such as BAliBASE, PREFAB and SABmark. Additional MSA methods, such as MaFFT, will also be considered for comparison. As for improvement in performance, more work remains to be done by studying and applying other parallel optimization techniques in order to obtain better response times. One of the main problems in the evaluation of MSA methods is that it is possible to obtain different MSAs having the same assessment score, making it difficult to discern which of them is the best, especially when aligning very dissimilar sequences. In this case, it is necessary to conduct a thorough analysis to achieve the best results in terms of accuracy. The long-term goal of the present work is to provide researchers with state-of-the-art algorithms and software tools that can help them advance in their field in a more efficient manner.

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Performance Evaluation of Anti-Collision Algorithms for RFID System with Different Delay Requirements

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***Abstract*—The main purpose of Radio-frequency identification (RFID) implementation is to keep track of the tagged items. The basic components of an RFID system include tags and readers. Tags communicate with the reader through a shared wireless channel. Tag collision problem occurs when more than one tag attempts to communicate with the reader simultaneously. Therefore, the second-generation UHF Electronic Product Code (EPC Gen 2) standard uses Q algorithm to deal with the collision problem. In this paper, we introduce three new anti-collision algorithms to handle multiple priority classes of tags, namely, DC, DQ and DCQ algorithms. The goal is to achieve high system performance and enable each priority class to meet its delay requirement. The simulation results reveal that DCQ algorithm is more effective than the DC and DQ algorithms as it is designed to flexibly control and adjust system parameters to obtain the desired delay differentiation level. Finally, it can conclude that the proposed DCQ algorithm can control the delay differentiation level and yet maintain high system performance.**

***Keywords*—RFID; Anti-collision; Q algorithm; Priority**

I. Introduction

Radio-frequency identification (RFID) uses radio-frequency electromagnetic fields to identify and track the objects [1]. The RFID system consists of tags and readers. The tags connect with the readers through a communication channel. During the identification process, each tag sends its identification (ID) code with a probability specified by a system to RFID reader. The EPC Gen 2 air-interface protocol [2-3] employs an anti-collision protocol called Q algorithm [4-7]. In the Q algorithm, each tag randomly selects an integer from the specified range [0, 2^Q -1]. Fig.1 demonstrates the flow chart of the Q algorithm. This algorithm defines a floating-point representation of Q, Q_{fp}, and a fixed step size, C. The RFID reader adjusts the Q_{fp} parameter based on the current slot state and then Q_{fp} is rounded to the nearest integer value, Q. When the collision [8] happens in the current slot, Q_{fp} increases by C. On the contrary, Q_{fp} decreases by C when the current slot is idle. The value of Q_{fp} remains unchanged when only one tag accesses the current slot. Nevertheless, the standard Q algorithm is not designed to support the RFID system with different delay requirements. Example of RFID system with different delay requirements is Automatic Vehicle Identification (AVI) system [9-14]. In the Automatic Vehicle Identification system, the tags that are attached to the emergency vehicles such as ambulances and fire trucks [15-19] needed to be identified before the other vehicles.

Therefore, the new anti-collision algorithms, DC, DQ and DCQ, which are suitable for the RFID system with different classes of tags, are developed. The purpose of these algorithms is to prioritize delay sensitive tags over the less sensitive tags while maintaining high system performance.

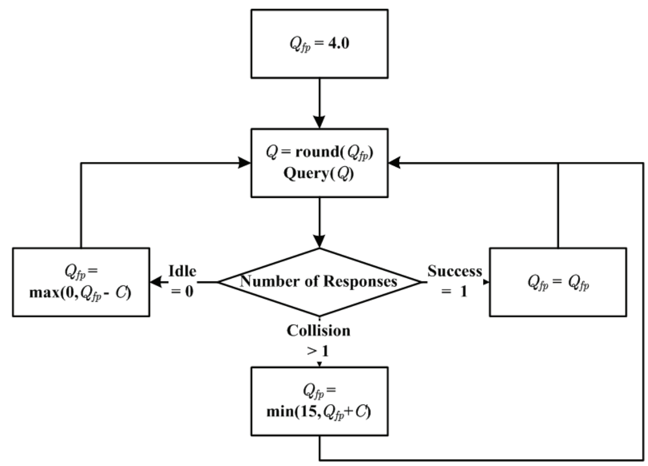


Fig. 1. Approach for the Q algorithm to adjust the parameter Q_{fp}.

The paper is structured as follows. In section II, we shall describe the details of DC, DQ and DCQ algorithms. The results and discussion are presented in Section III. Finally, the conclusion is given in Section IV.

II. Proposed Anti-Collision Algorithms

In this paper, we modified the Q algorithm to the anti-collision algorithms that are capable of handling multiple priority classes, namely, DC, DQ and DCQ algorithms.

Let we first define the following parameters which are used in the detailed description of the algorithms:

C_1 = the step size for priority class 1 tags.

C_2 = the step size for priority class 2 tags.

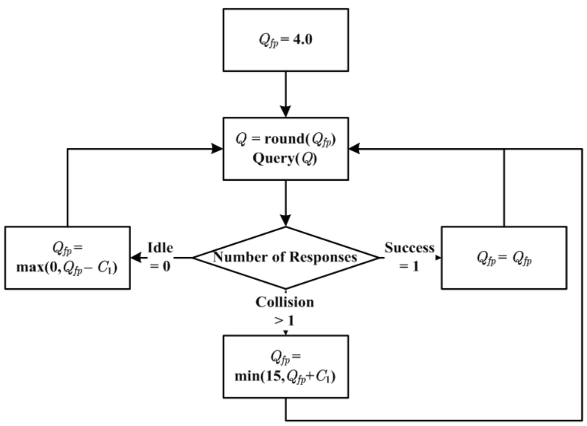
Q_1 = the initial value of Q_{fp} for priority class 1 tags.

Q_2 = the initial value of Q_{fp} for priority class 2 tags.

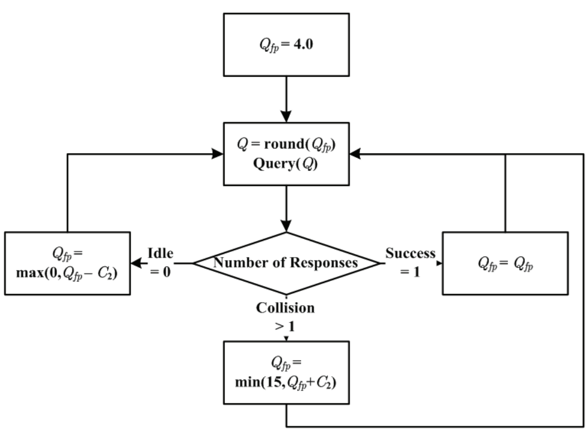
A. DC algorithm

This algorithm is further developed from the Q algorithm to handle multiple priority classes. In the Q algorithm, a predefined step size C is set equally for all tags. Therefore, if the system supports tags with different priority classes, it is more suitable to set different predefined step sizes to different priority classes. This anti-collision algorithm is referred to as Different values of C (DC) algorithm. The order of Q parameter update operations of this algorithm is the same as the Q algorithm, except that the step size values for priority classes 1 and 2 are equal to C_1 and C_2, respectively.

Fig. 2 illustrates the flow chart of DC algorithm. In this flow chart, when the collision happens, Q_{fp} of the priority class 1 tags increases by C_1 whereas Q_{fp} of the priority class 2 tags increases by C_2. When the current slot is idle, the values of Q_{fp} for the priority class 1 and 2 tags decrease by C_1 and C_2, respectively.



(a)



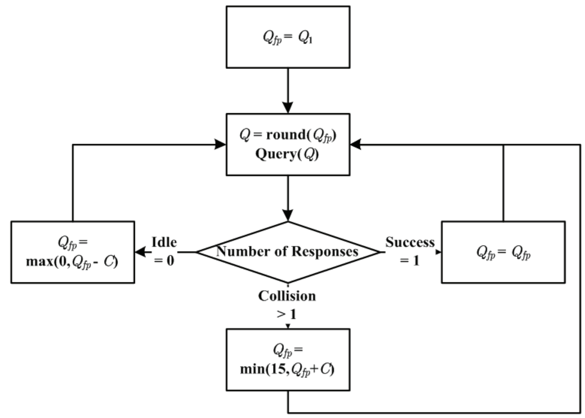
(b)

Fig. 2. Approaches for the DC algorithm to adjust the Q_{fp} values for different priority classes : (a) priority class 1 tags (b) priority class 2 tags.

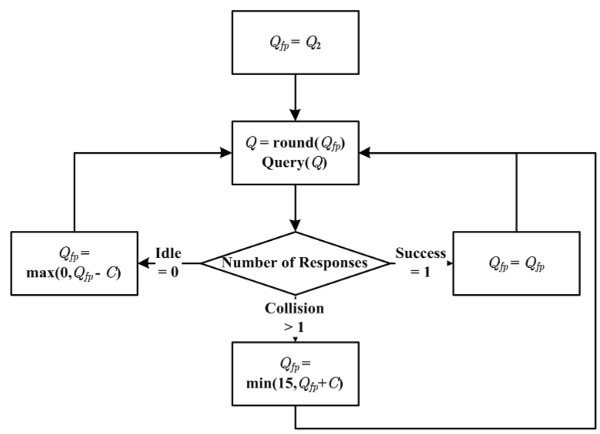
B. DQ algorithm

This algorithm is modified from the Q algorithm. In the Q algorithm, the initial value of Q_{fp} is equal to 4.0 and the value of C is equal to 0.1 [20]. This algorithm allows the tags with different priority classes to employ different initial values of Q_{fp}. Therefore, this anti-collision algorithm is referred to as Different initial values of Q_{fp} (DQ) algorithm.

Fig. 3 demonstrates the approaches for the DQ algorithm to adjust the Q_{fp} values for different priority classes. The DQ algorithm follows the same steps as the Q algorithm, except that the initial values of Q_{fp} for priority classes 1 and 2 are equal to Q_1 and Q_2, respectively. This means that the initial frame lengths for priority classes 1 and 2 are equal to 2^{Q_1} and 2^{Q_2}, respectively.



(a)



(b)

Fig. 3. Approaches for the DQ algorithm to adjust the Q_{fp} values for different priority classes : (a) class 1 tags (b) class 2 tags.

C. DCQ algorithm

This algorithm is obtained by combining the DC and DQ algorithms. In this algorithm, the system performance is achieved by assigning different values of C_1, C_2, Q_1 and Q_2 according to its delay requirement. This more flexible algorithm will be referred to as Different values of C and initial Q_{fp} (DCQ) algorithm.

The procedure of adjusting the values of Q_{fp} can be seen in Fig. 4. The Q parameter update operations of DCQ algorithm are the same as the Q algorithm, except that the step sizes for priority classes 1 and 2 are equal to C_1 and C_2, respectively and the initial values of Q_{fp} for priority classes 1 and 2 are equal to Q_1 and Q_2, respectively.

III. Results and Discussion

For convenience, these notations will be used in the following discussion.

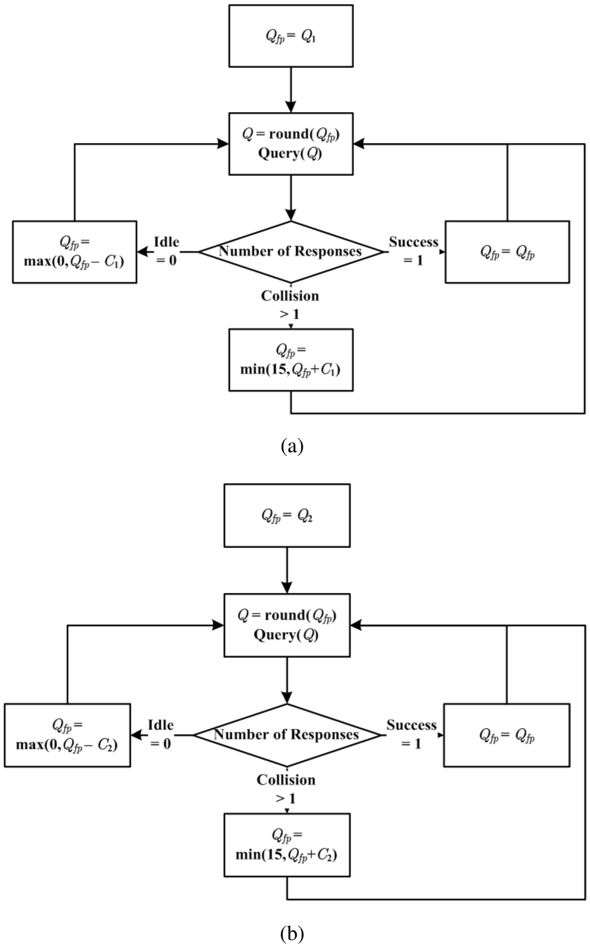


Fig. 4. Approaches for the DCQ algorithm to adjust the Q_{fp} values for different priority classes : (a) class1 tags (b) class2 tags.

N_1 = the number of priority class 1 tags.

N_2 = the number of priority class 2 tags.

R_{21} = the ratio between the average identification time of priority classes 2 and 1.

P_c = the probability of collision.

P_i = the probability of idle.

P_c and P_i can be calculated from all iterations as follows:

$$P_c = \frac{N_c}{N_s + N_c + N_i} \quad (1)$$

$$P_i = \frac{N_i}{N_s + N_c + N_i} \quad (2)$$

where N_s, N_c and N_i are number of success slots, number of collision slots and number of idle slots, respectively. Note that we define the priority class 1 tags to have higher priority than the priority class 2 tags and the total number of tags is fixed at 16 for all results.

A. Performance of DC algorithm

We will now discuss the performance of DC algorithm. Fig. 5 demonstrates the average identification time for all tags under different combinations of N_1 and N_2. In the figure, the values of C_1 and C_2 vary from 0.1 to 0.5. It can be seen that the average identification time for all tags tends to increase with the values of C_1 and C_2. The performance degradation is due to an excessive number of collisions, as evident in Fig. 6. Furthermore, we found that the values of C_1 and C_2 should be small in order to achieve better delay performance.

Fig. 6 illustrates the relationship between the probability of collision and the values of C_1 and C_2. It can be noticed that the probability of collision rises as C_1 and C_2 increase. In case of $N_2 > N_1$, the increment of C_2 can cause more drastic effect on the probability of collision compared to the increment of C_1. In contrast, in case of $N_1 > N_2$, the increase of the value of C_1 has more of an impact on the probability of collision than the increment of C_2.

Fig. 7 shows the probability of idle as a function of C_1 and C_2. It can be seen that the probability of idle tends to decrease with the values of C_1 and C_2. In case of $N_2 > N_1$, the increment of C_2 can cause more effect on the probability of idle compared to the increment of C_1. On the other hand, in case of $N_1 > N_2$, the rise of C_1 has more impact on the probability of idle compared to the increase of C_2.

Figs. 8 and 9 illustrates the average identification time for priority class 1 and 2, respectively under different combinations of N_1 and N_2. It can be noticed that the average identification time for priority class 1 tends to increase with the values of C_2, whereas the average identification time for priority class 2 tends to increase with the values of C_1.

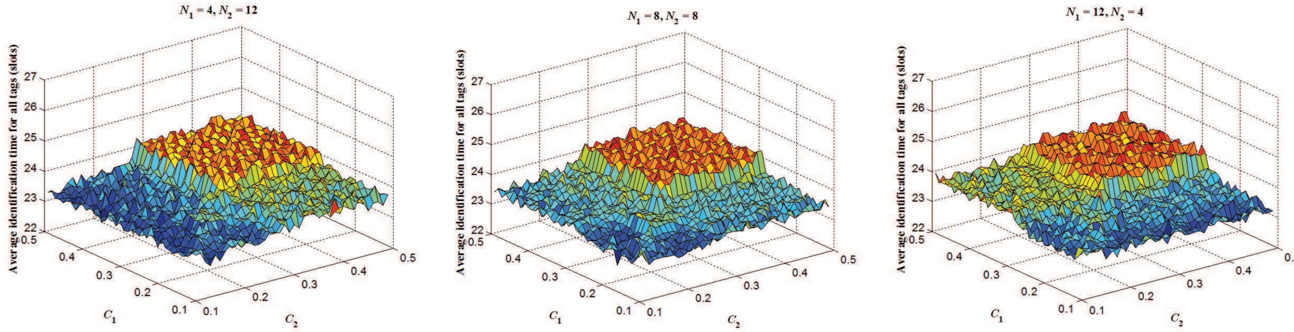
When the ratios of N_1 and N_2 increase, similar results to that of N_1=4 and N_2 =12 are observed. However, the ranges of the average identification time for priority class 1 become narrower than the previous case with N_1=4 and N_2 =12. On the other hand, the ranges of the average identification time for priority class 2 become wider than the previous case with N_1=4 and N_2 =12.

Fig. 10 displays the average identification time ratio between priority classes 2 and 1 (R_{21}) as a function of C_1 and C_2. The results for the average identification time ratio between priority classes 2 and 1 are similar to those of the average identification time for priority class 2. However, when the ratios of N_1 and N_2 are increased, no significant changes are observed in the average identification time ratio between priority classes 2 and 1.

Fig. 11 shows the relationship between the average identification time for all tags and R_{21}. We can see from the results that the DC algorithm has weakness in controlling R_{21}, as there are a limited number of feasible values of R_{21}. In case of N_1=4, N_2=12, the values of R_{21} lie between 0.8 and 1.4. Consider Fig. 11(b) where N_1=8, N_2=8, it can be seen that the values of R_{21} are limited to the range between 0.76 and 1.32. Fig. 11(c) reveals that when N_1=12, N_2=4, the values of R_{21} vary between 0.7 and 1.26.

B. Performance of DQ algorithm

Fig. 12 shows the average identification time for all tags as a function of Q_1 and Q_2 under different combinations of N_1 and N_2 as the values of Q_1 and Q_2 vary from 1 to 15. It can be seen that the average identification time for all tags tends



(a) (b) (c)

Fig. 5. Average identification time for all tags for the DC algorithm as a function of C_1 and C_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

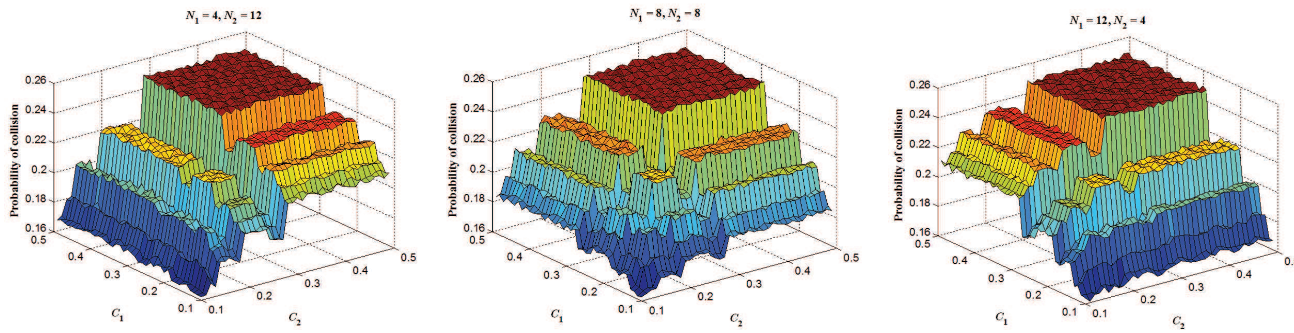


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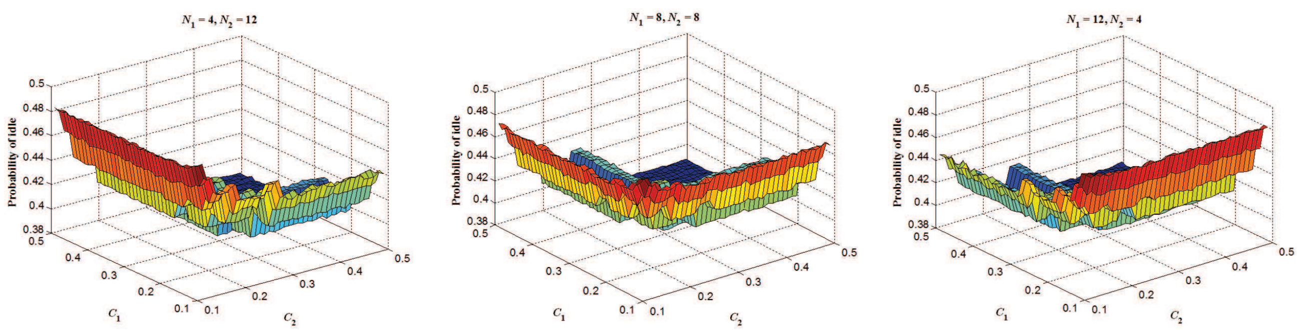
Fig. 6. Probability of collision for the DC algorithm as a function of C_1 and C_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.



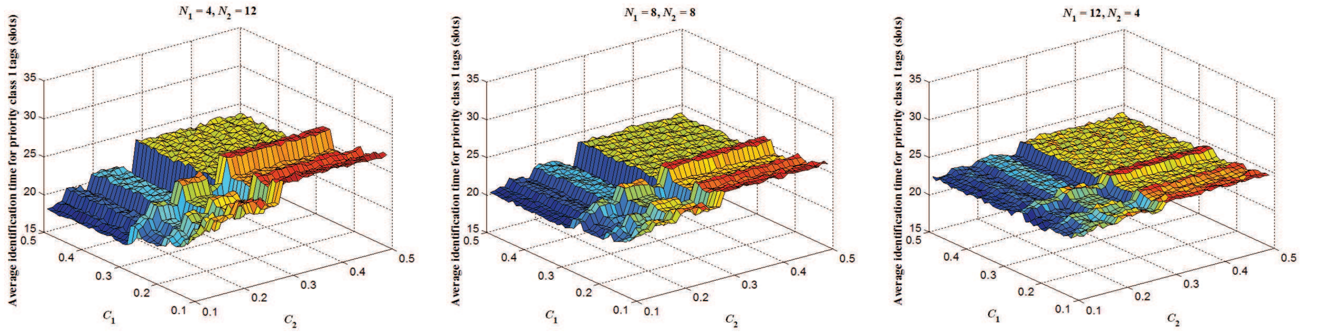
(a) (b) (c)

Fig. 7. Probability of idle for the DC algorithm as a function of C_1 and C_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

to increase with the increment of Q_1 and Q_2. When both Q_1 and Q_2 increase up to 15, the maximum average identification time for all tags is reached. The performance degradation is due to an excessive number of idle slots, as evident in Fig. 14.

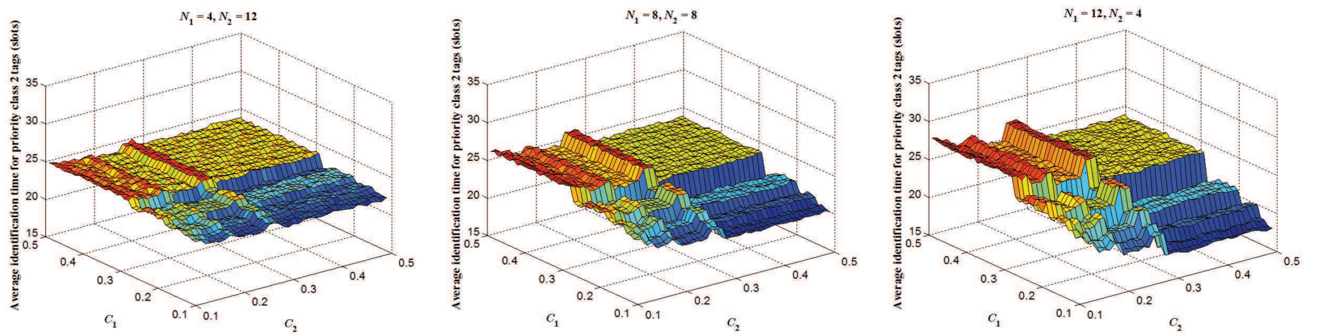
Moreover, it is found that, at small values of Q_1 and Q_2 the average identification time for all tags decreases with the values of Q_1 and Q_2. This is simply because when the values of Q_1 and Q_2 are small, the number of all tags is relatively much higher than the number of available slots. In this scenario, collision will most likely be difficult to avoid. Therefore, an increase in the values of Q_1 and Q_2 can help reduce the number of collision slots and thus improving the system performance. When Q_1 and Q_2 increase up to a certain value, the minimum average identification time for all tags is attained and the values of Q_1 and Q_2 at this point will be referred to as the appropriate values of Q_1 and Q_2. When Q_1 and Q_2 further increases, the average identification time for all tags begins to increase and eventually reaches the maximum average identification time for all tags when Q_1 and Q_2 = 15. Table 1 summarizes the appropriate values of Q_1 and Q_2 for various combinations of N_1 and N_2. It is very interesting to see that the appropriate values of Q_1 and Q_2 for all different combinations of N_1 and N_2 are equal to 4 and 4, respectively.

Fig. 13 demonstrates the probability of collision as a function of Q_1 and Q_2. The probability of collision tends to decrease with the increment of Q_1 and Q_2. This is as expected



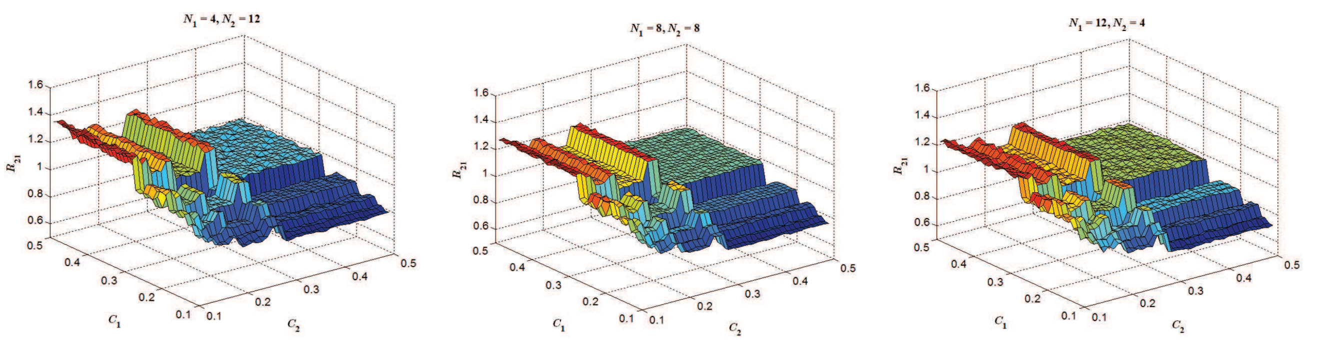
(a) (b) (c)

Fig. 8. Average identification time of priority class 1 for the DC algorithm as a function of C_1 and C_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.



(a) (b) (c)

Fig. 9. Average identification time of priority class 2 for the DC algorithm as a function of C_1 and C_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.



(a) (b) (c)

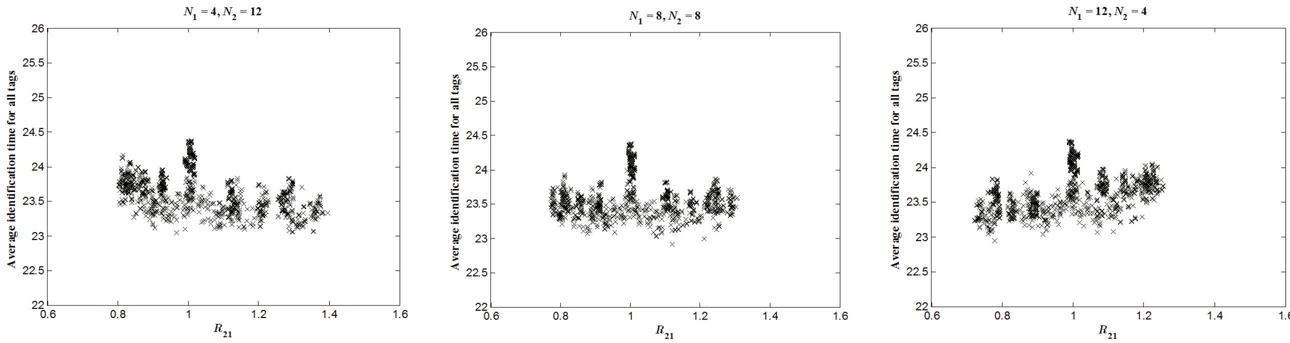
Fig. 10. Average identification time ratio between priority classes 2 and 1 for the DC algorithm as a function of C_1 and C_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

TABLE I. APPROPRIATE VALUES OF Q_1 AND Q_2.

N_1 **and** N_2	**App.** Q_1	**App.** Q_2
N_1=4, N_2=12	4	4
N_1=8, N_2=8	4	4
N_1=12, N_2=4	4	4

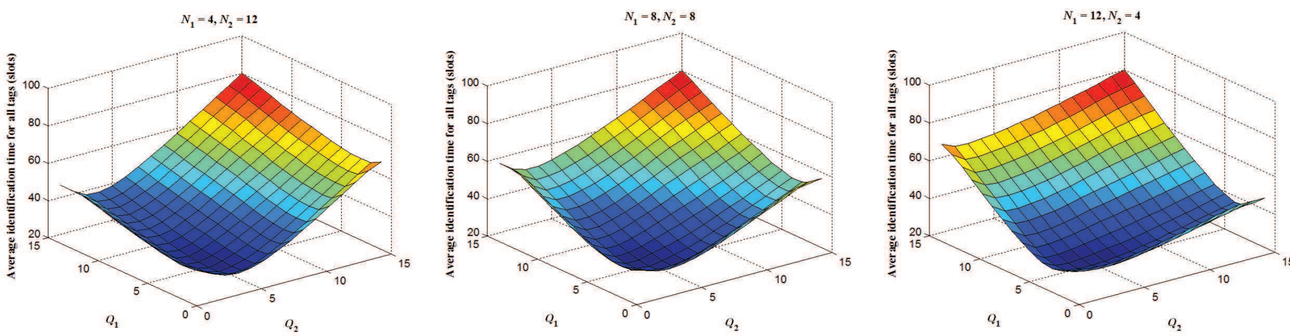
because when the initial frame lengths for priority classes 1 and 2 increase, a lot of time the slots are idle. This results in the reduction of the probability of collision. Moreover, the maximum probability of collision is obtained when the value of Q_1 and Q_2 are both equal to 1. This is not surprising because when Q_1 and Q_2 are both equal to 1, the initial frame lengths for priority classes 1 and 2 are both equal to 2. In this scenario, collisions are difficult to avoid because the number of priority class 1 and 2 tags are relatively much higher than the initial frame lengths.

Fig. 14 shows the relationship between the probability of idle and the values of Q_1 and Q_2. It can be noticed that the minimum probability of idle is reached when the values of Q_1 and Q_2 are both equal to 1. This is as expected because when the initial frame lengths for priority classes 1 and 2



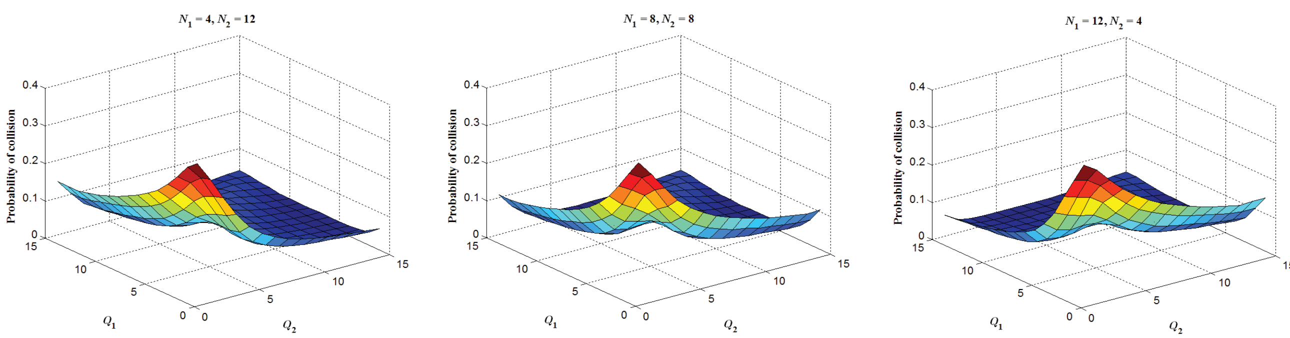
(a) (b) (c)

Fig. 11. Average identification time for all tags vs R_{21} for the DC algorithm : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.



(a) (b) (c)

Fig. 12. Average identification time for all tags for the DQ algorithm as a function of Q_1 and Q_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.



(a) (b) (c)

Fig. 13. Probability of collision for the DQ algorithm as a function of Q_1 and Q_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

are both equal to 2, all tags contend against each other in the contention slots and suffer from collisions. Furthermore, it can be seen that the probability of idle tends to increase as Q_1 and Q_2 increase. This is because when the initial frame lengths for priority classes 1 and 2 are large, the tags do not access the slots often enough and results in the increment of the probability of idle.

Fig. 15 displays the average identification time for priority class 1 under different combinations of N_1 and N_2. It can be noticed that the average identification time of priority class 1 increases with the value of Q_1. This is because the increment of the initial frame lengths for priority class 1 will increase the number of idle slots and result in the increase of the average identification time for priority class 1 tags.

In addition, the average identification time of priority class 1 decreases with the value of Q_2. This is because the increment of the value of Q_2 will reduce the number of accesses from priority class 2 tags in the early slots and results in the increase of the probability of success of priority class 1. Similar results are shown in Fig. 16. In this figure, the average identification time of priority class 2 increases with the value of Q_2 and decreases with the value of Q_1.

Consider Fig. 17 that shows the average identification time ratio between priority classes 2 and 1 using different values of Q_1 and Q_2. As we can see, the average identification time ratio

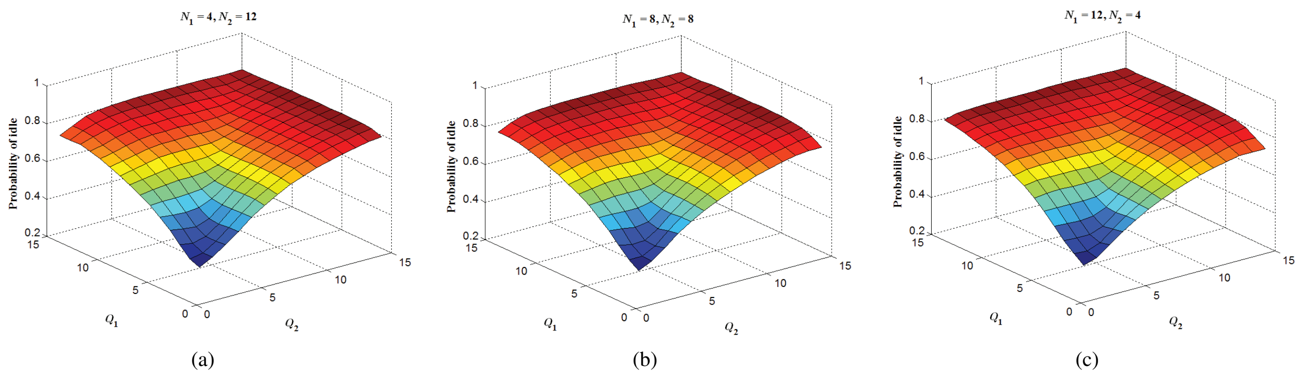


Fig. 14. Probability of idle for the DQ algorithm as a function of Q_1 and Q_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

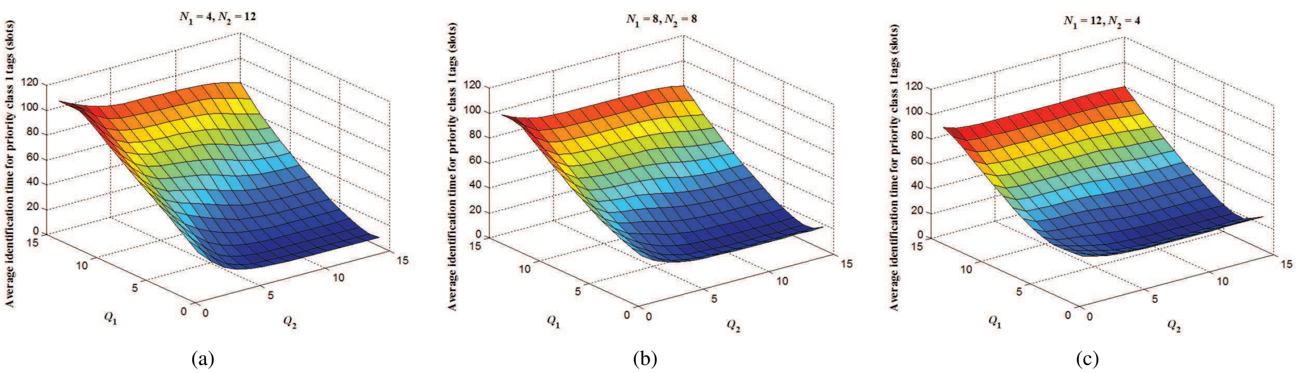


Fig. 15. Average identification time of priority class 1 for the DQ algorithm as a function of Q_1 and Q_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

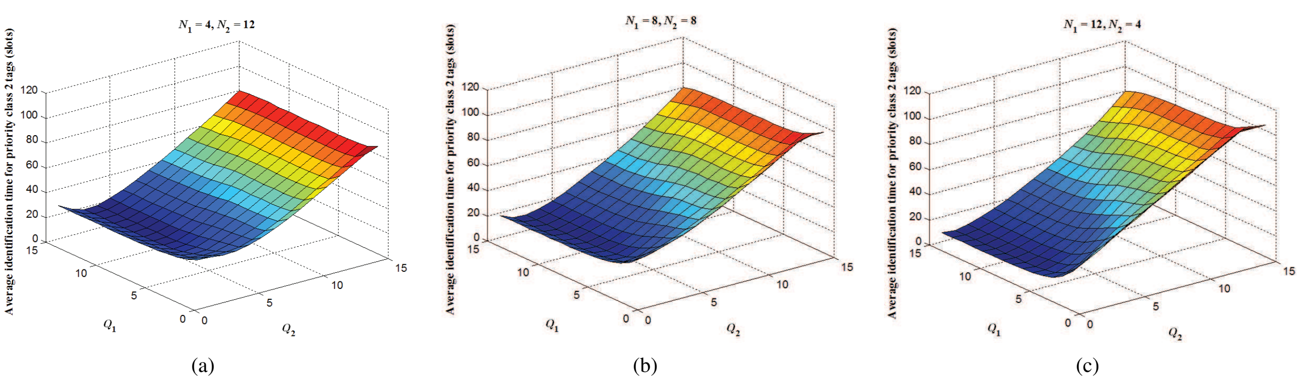
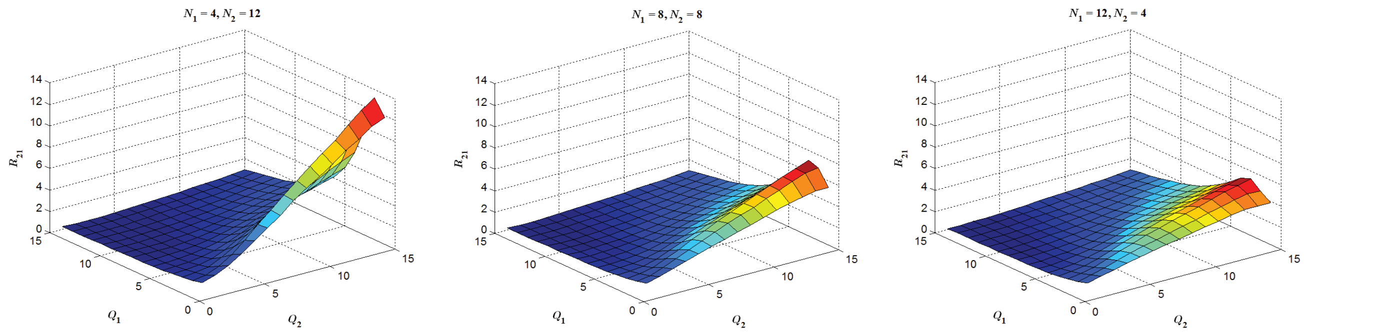


Fig. 16. Average identification time of priority class 2 for the DQ algorithm as a function of Q_1 and Q_2 : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

between priority classes 2 and 1 increases with the value of Q_2. This is because when Q_2 is large, the priority class 2 tags do not access the slots frequently enough in the early slots. This results in the increment of the average identification time of priority class 2 and the decrement of the average identification time of priority class 1. In case of N_1=4, N_2=12, the maximum average identification time ratio between priority classes 2 and 1 is reached with Q_1 = 2 and Q_2 = 15. When the combinations of N_1 and N_2 are equal to N_1=8, N_2=8 and N_1=12, N_2=4, the maximum average identification time ratios between priority classes 2 and 1 are reached with Q_1 = 3 and Q_2 = 15. In addition, the ranges of the average identification time ratio between priority classes 2 and 1 become narrower than the previous case with N_1=4 and N_2 =12.

Fig. 18 shows the relationship between the average identification time for all tags and R_{21}. We can see from the results that there are many different possible values of R_{21}. However, DQ algorithm cannot control the values of R_{21} to obtain the desired integer values. Furthermore, it can be noticed that the values of Q_1 and Q_2 are important parameters affecting the system performance. Therefore, care must be taken in choosing the values of Q_1 and Q_2.



(a) (b) (c)

Fig. 17. Average identification time ratio between priority classes 2 and 1 for the DQ algorithm as a function of Q_1 and Q_2: (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

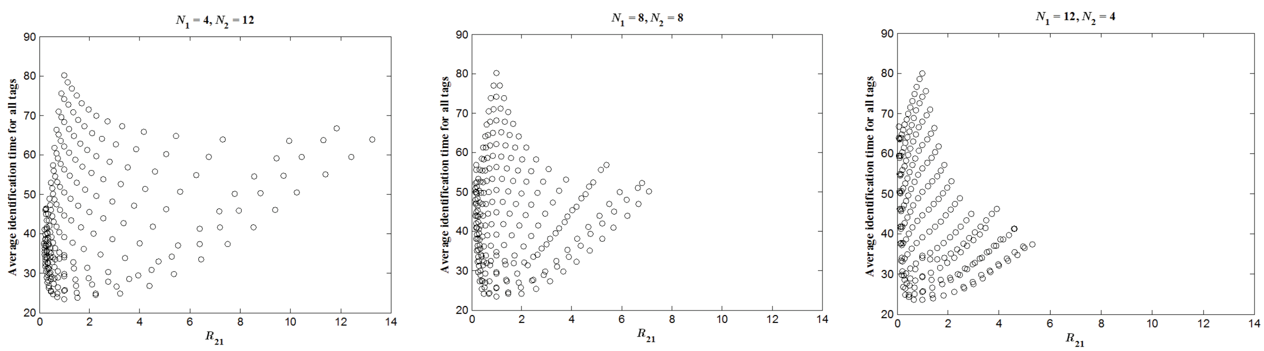


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Fig. 18. Average identification time for all tags vs R_{21} for the DQ algorithm : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

C. Performance of DCQ algorithm

In the DCQ algorithm, the values of C_1, C_2, Q_1 and Q_2 can be adjusted simultaneously in order to achieve the desired R_{21} while maintaining low delay. Fig. 19 displays the relationship between the average identification time for all tags and R_{21}. Note that in this figure, only the limited number of feasible integer values of R_{21} are plotted. These feasible integer values are obtained by using the appropriate values of C_1, C_2, Q_1 and Q_2 in order to achieve the desired integer values of R_{21} while maintaining low delay. The appropriate values of C_1, C_2, Q_1 and Q_2 for DCQ algorithm are illustrated in Figs. 20 and 21, respectively.

As can be seen from Fig. 19, the average identification time for all tags tends to rise as R_{21} increases. This can be explained as follows. In order to achieve high R_{21}, the system has to increase the average identification time of priority class 2 tags. This results in high average identification time for all tags. Moreover, it can be observed that when the ratios of N_1 and N_2 increase, the ranges of R_{21} become narrower than the case with N_1=4 and N_2 =12.

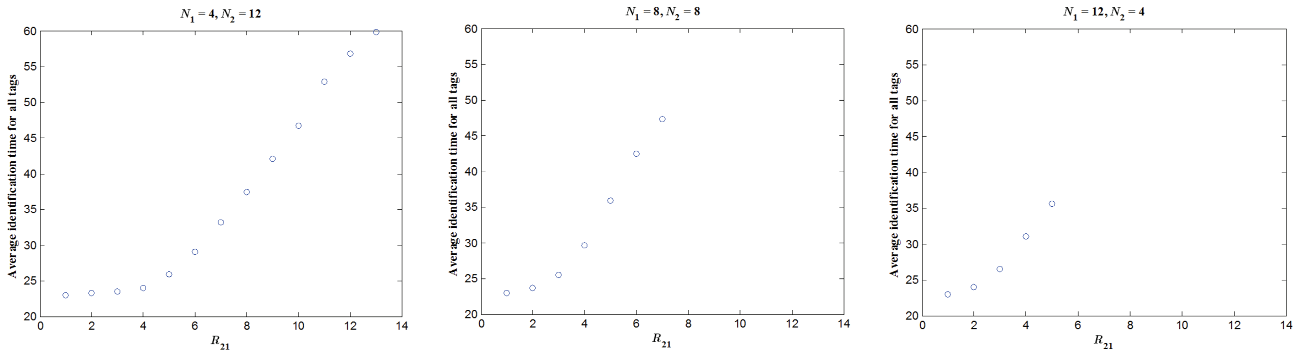
D. Performance comparison of the proposed algorithms and the existing known algorithm

In this section, we compare the performance of all proposed algorithms and the existing known algorithm namely Q algorithm, as illustrated in Fig. 22. In the Q algorithm, all tags have the same priority and the system parameter settings of the Q algorithm are given in the Table 2. Note that the results of the DCQ algorithm are obtained by using the appropriate system parameters. As we can see, at R_{21} = 1, no difference between two classes, the DC, DQ and DCQ algorithms give the same result as the Q algorithm and the minimum average identification time for all tags of 23.73 can be reached. However, when $R_{21} > 1$, it can be observed that the identification time for all tags increases as R_{21} increases. This is because the system has to limit the success rate of service class 2 tags in order to obtain the desired high R_{21} and results in overall performance degradation. It is important to note that we are not interested in the case when $R_{21} <$ 1 because we have defined the priority class 1 tags to have higher priority than the priority class 2 tags.

TABLE II. SYSTEM PARAMETER SETTINGS OF Q ALGORITHM

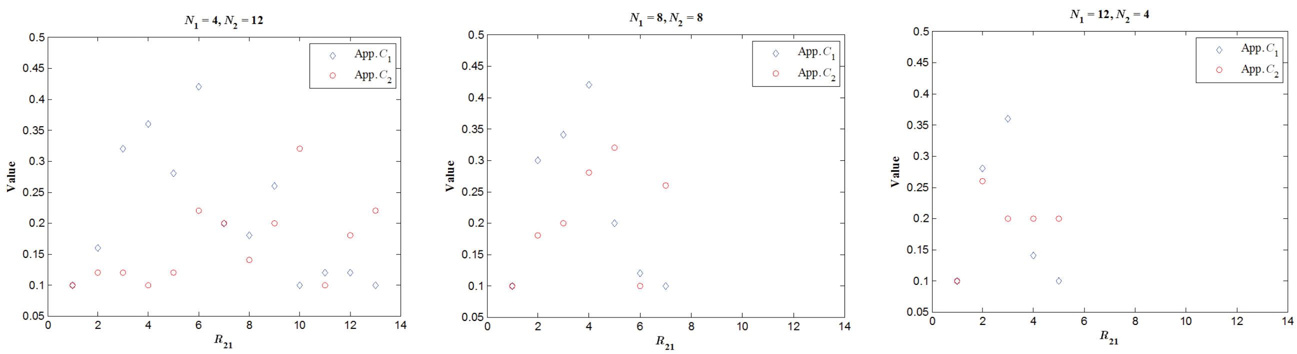
Parameter	Value
C_1	0.1
C_2	0.1
Initial Q_{fp}	4.0
Minimum Q_{fp}	0.0
Maximum Q_{fp}	15.0

In addition, it can be noticed that the DCQ algorithm offers relatively superior performance. This is because in the DCQ algorithm, it is possible to adjust the values of C_1, C_2, Q_1 and Q_2 simultaneously. On the contrary, in the DC algorithm, we



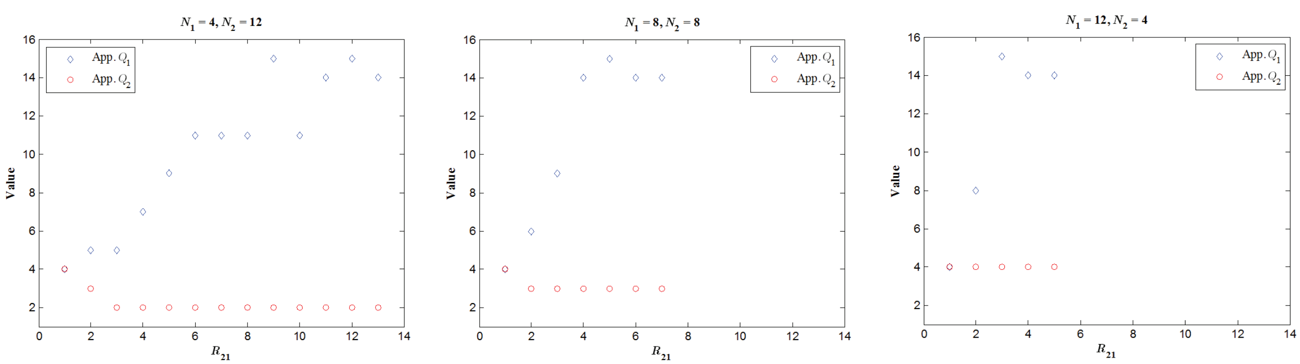
(a) (b) (c)

Fig. 19. Average identification time for all tags vs R_{21} for the DCQ algorithm : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.



(a) (b) (c)

Fig. 20. The appropriate values of C_1 and C_2 vs R_{21} for the DCQ algorithm : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.



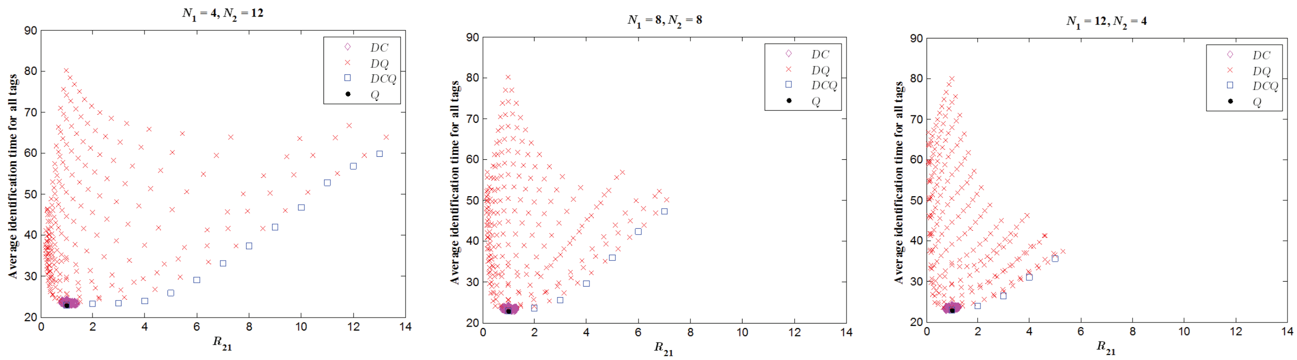
(a) (b) (c)

Fig. 21. The appropriate values of Q_1 and Q_2 vs R_{21} for the DCQ algorithm : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

can adjust only the values of C_1 and C_2 whereas in the DQ algorithm, only Q_1 and Q_2 can be adjusted. For these reasons, the DCQ algorithm is more flexible and hence potentially leading to more effective. However, when the ratios of N_1 and N_2 are increased, the ranges of R_{21} become narrower than the case with N_1=4 and N_2 =12.

IV. Conclusion

In this paper, we have presented three new anti-collision algorithms for RFID system with different delay requirements. Through the simulation results, we found that the minimum average identification time for all tags can be reached when there is no difference between two priority classes. In this case, the DC, DQ and DCQ algorithms become the Q algorithm. Moreover, we can conclude that the values of C_1, C_2, Q_1 and Q_2 are the important parameters that must be set appropriately for different system loads, so that the system can control the delay differentiation level and yet maintain high system performance. When comparing between all proposed algorithms, we found that the DCQ algorithm is more effective and flexible in adjusting the system parameters to meet the delay requirement than the DC and DQ algorithms. This is an essential step toward the design of anti-collision algorithms that support the



(a) (b) (c)

Fig. 22. Performance comparison of DC, DQ, DCQ and Q algorithms : (a) N_1=4, N_2=12 (b) N_1=8, N_2=8 (c) N_1=12, N_2=4.

RFID system with different delay requirements.

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Privacy and Security Mechanisms for eHealth Monitoring Systems

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***Abstract*—The rapid scientific and technological merging between Internet of Things (IoT), cloud computing and wireless body area networks (WBANs) have significantly contributed to the advent of e-healthcare. Due to this the quality of medicinal care has also been improved. Specifically, patient-centric health care monitoring plays important role in e-healthcare facilities by providing important assistance in different areas, including medical data collection and aggregation, data transmission, data processing, data query, and so on. This paper proposed an architectural framework to describe complete monitoring life cycle and indicates the important service modules. More meticulous discussions are then devoted to data gathering at patient side, which definitely serves as essential basis in achieving efficient, vigorous and protected patient health monitoring. Different design challenges are also analyzed to develop a high quality and protected patient-centric monitoring systems along with their possible potential solutions.**

Keywords*—*Wireless body area network; e-healthcare; mobile crowd sensing

I. Introduction

Cloud computing offers number of opportunities to the users and services providers includes providing facility for online computation and/or Google cloud storage outsourcing. Resulting of such technological merging, medical health care systems has benefited from these development. In particular the continuous miniaturization of devices has enabled the improvement of e-health monitoring systems. A number of cost effective sensors are now equipped in cellular phones, wearable devices around patient bodies. They work as important elements of WBAN [1]. Despite the recent technological advancements of WBANs, as well as their great potential to improve the quality of health monitoring, the performance with respect to energy efficiency, privacy and security is not sufficiently guaranteed.

Recent years comprehensive advancement in the smart phones sensors, wireless communications and body sensors have been observed. They are now commonly using with health monitoring systems and are provide efficient results. The health care monitoring tasks are now become persistent user friendly environment compared to the past traditional clinical environment. The variety of monitoring focuses significantly enlarged, varying from the patents at critical care, such as a patient in ambulance or the one with chronic diseases. In precise the body sensors installed around the patients body as well as the context-aware sensors those equipped in smart phones can also be used to measure the patients vital signs or vital health parameters such as temperature, heart rate, blood pressure etc.

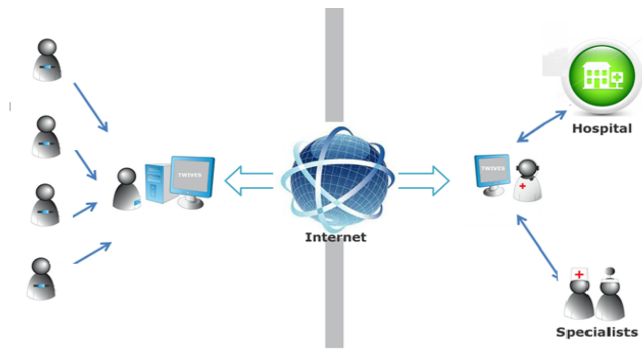

Figure 1: Health Monitoring System Architecture.

To describe explicitly an e-healthcare system, the proposed e-healthcare monitoring framework is shown in Figure 1. The figure 1, explains the following service components,

- *WBANs sensors*: ranging from IoT sensors to wearable sensors used to collect patients (required) data and transmit them to the computer, servers or gateways;
- *Relay communications networks*: ranging from short range wireless communications, cellular networks to wireline networks;
- *Data processing servers*: the data is processed and stored on cloud data centers, allowing clinic stuff or physicians to query in need.

It's clear that the quality of e_health care services depend on on the seamlessly integration of the following three essential components includes;

- *Wireless communications technologies*
- *Energy efficiency*
- *Patient privacy*

Each of these is attract great efforts from both industry and academia and also considered the top concerns of e-health care services. For example, WBAN IEEE standard has become available in 2012 [25]. This paper focuses to investigate the key challenges for succeeding efficient, secure and reliable data collection of the patients that require more efforts. In the proposed framework, a variety of solutions tackling those recognized challenges and eventually proposes the potential amalgamations of multidisciplinary approaches for developing a holistic e-health care oriented, cyber-physical system (CPS), patient-centric framework.

In particular, from the patient-centric perspective, the patients can be either individual or collective, depending on the scenarios. For example, WBANs could be more widely used for individual patient monitoring.

II. Security Requirements in eHealth Monitoring Systems

This section describe the security requirements of the proposed ehealth monitoring system .

1) Trusted Authority: It is assume that this service component is associated with the cloud service provider. It generates public and secret key parameters for the proposed ehealth monitoring system. It is further assume that trusted authority is responsible for the issuing keys, updating them and revoking them. It also grants differential access rights to the individual users based on their attributes and roles.

2) Cloud service provider: Besides providing secure communication mechanism, cloud service provider felicitates with data storage, data processing and secure retrieval of the data based on the access privileges of the data access requesters..

3) Registered User: Patient who is registered to the trusted authority is considered as registered user. A registered user is responsible for defining attribute based access policy. Registered user defines who has to access his/her data.

This entity of the health monitoring system is registered with complete physical address (GPS location), telephone numbers and availability of the doctors and it will periodically update the information about doctors availability and their duty timings as well as number of stand by doctors.

4) Data access requester: Data access requester can be a doctor, a pharmacist, a researcher and hospital. Their access rights and mechanism is defined by the patient (generally) and whole mechanism is provided by the security provider, cloud service provider is that entity in our proposed scheme.

III. Possible Security and Privacy Preservation Solutions

Our proposed multidisciplinary approach contains integration of WBANs, IoT and VSN (one sensor for multiple application and software sensor which is installed in smartphones) is designed to ensure efficient data delivery maintaining security and preserving privacy of all stakeholders. Since, this framework is designed to ensure pervasive, real time and secure data query in networks of medical sensors. Our extensive survey will felicitate to explore promising solutions related to the security, privacy preserving and energy efficient data transmission.

Emergence of the internet of the things have made systems more vulnerable. Privacy and the security of the systems have become pre-requisite for every service. There are a few already proposed solutions which ensure privacy and the security of the system. Secure authentication and access control surely improve the privacy and the security of the any system which has connection with internet. In this section, limited discussion of already suggested solutions for privacy preservation and access control is given i.e., hardware device authentication based physical unclonable functions and role based access control schemes respectively.

A. Physical Unclonable Functions (PUFs)

Despite of the advancements in the technology, authenticity of the requester, sender or receiver of the data has consistently raised various issues. Most of the authentication mechanism is worked on the basis of the unique ID and various secret key protocols in the healthcare systems. Therefore, it is most important concern to store and preserve such secret keys and unique IDs of the all stakeholders and their devices. Moreover, their transportation among the all involved must also be efficient and more secure, so that malicious attackers could not any access to that data. Classical approaches of the storing secret keys and IDs include storing on the volatile storage of the chips or in the fusesor EEPROMS

The integrity of authentication schemes and encryption algorithms lies in a unique ID or a secret key. Hence it is imperative that these secret keys are generated and stored in a secure manner, protecting them from malicious attackers. Conventional approaches rely on storing the secret key in non volatile storage on chip, either in fuses or EEPROMs [10]. However, these approaches are vulnerable to the various types of the attacks because secret keys are permanently stored in the digital form which is definitely risky in the long term. Various methods like reverse engineering, optical and chemical methods can give access to the keys which are permanently stored in the forms of the already mentioned classical methods of the storage and preservation of the secret keys. Therefore, it is need of the time to prevent such attacks which can easily get access to the secret keys and IDs which are the basis of the whole security mechanism.

One of the potential authentication mechanism which can prove more secure in the ehealth monitoring systems is Physical Unclonable Functions (PUFs). It is assumed that all the devices used by medical staff and patients are working under mechanism of PUFs which is more secure alternative to digital keys. Each device used in our proposed system model is bound to a unique random unclonable function that serves as its identity. Physical Unclonable Functions can be enabled into smart cards of medical staff and patients personal servers (PDA/Smatphones) for secure and efficient authentication. A PUF is a physical pseudo-random function which is derived from the small variances in the wire and gate delays. These delays are unique for every hardware. Therefore, these are impossible to create duplication [11].

Mostly, information and the data of the patients is accessed either by the medical or clinical staff or researchers and sometimes government health ministry. Therefore, we assume that service cards of the all involved people who want to access the data are unclonable like VISA bank cards. Operational mechanism of PUF based authentication can be as follows: All smart cards have microchip with a PUF on it. Manufacturing of such cards creates a large set of challenges and their responses in the form of the challenge-response pairs for the future authentication. These pairs are stored in the very secure place. Each time, any one who is interested to access the sensitive data of the patients must use that particular card, the card reader queries the card for the responses to a small set of challenges in the stored database. If that card gives proper response of the challenges means the authentication is granted and user is allowed to access the data. Hence, authentication of the requester or sender is verified.

B. Proposed access control in health monitoring system

Medical data of the patients is more sensitive which needs strong security and tough authentication process in order to avoid any security breach in the data. Proposed design may include one of these two access control schemes, (1) Role Based Access Control and (2) Attribute Based Access control scheme. Here, a brief description of the both schemes is given and discuss which could be appropriate for our proposed health monitoring system.

1) Role Based Access Control Scheme: We assume that our security scheme is working on the mechanism of role based access control schemes. All stakeholders at clinical side are assigned roles to access patients data. For example, every patient has a particular doctor/specialist, he/she can access the sensitive data of the patient. Following is the brief description of the primary roles for the role based access control scheme (RBAC):

1) Role assignment: We assume that assignment of the role to the clinical staff is processed by the security providers (security system) which can be any server some where in the cloud
2) Role authorization: A clinical staff's active role (function) must be authorized for the clinical usage. With above role assignement, this rule ensures that individual who want to access data can take on only roles (functions) for which he/she is authorized.
3) Permission authorization: A clinical staff can exercise a permission only if the permission is authorized for the clinical staff's active role. With the previous two points (role assignment and role authorization), this role ensures that person who want to access the data can exercise only permissions for which he/she is authorized.

We further assume that one staff member can have various responsibilities (functions), similarly one function can be assigned to the multiple clinical staff members. In different situations, when a patient wants to encrypt his/her sensitive data, it is imperative that he/she must define and establish a specific access control policy which clearly and efficiently defines that who can decrypt his/her particular data. For example, patient is admitted in public hospital in Paris wants to send his/her confidential report to concerned doctor. The patient may want to encrypt a sensitive report so that only personnel that have certain roles or functions can access it. For instance, the patient may specify the following access structure for accessing this medical sensitive data: ((Public Hospital AND (Paris)) OR (Specialist Doctor) OR Name: Dr Johns). By this, the patient could mean that the report should only be seen by desired doctor named Dr Johns, who works at the public hospital Paris.

2) Attribute Based Access Control Scheme: The health related data is the most sensitive data of individuals which needs more secure and reliable access control mechanism to ensure maximum privacy. Usually, access to the data is patient centric means patients have the privileges to define access structure (who can access his/her data).

Sometimes, patients give access to their sensitive data to get assistance in the critical conditions. For example, they can disclose their location in order to get health care service at their desired location. Therefore, patients can define access tree depending on the different situations.

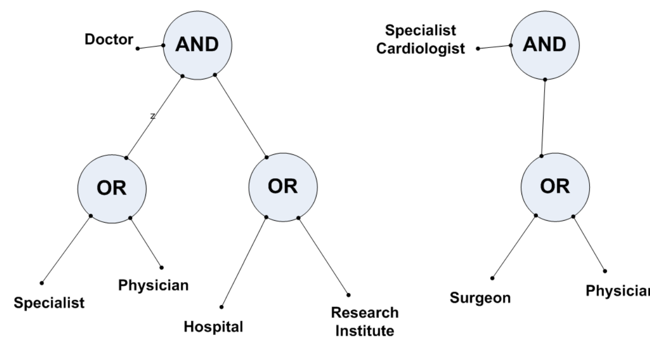

Figure 2: Example of data access control structure

We assume that there are three domains in this access control scheme: a central attribute authority, the patients and the doctors (physicians/specialists). Each doctor has particular privileges or rights to access patient data after proving their authenticity. Each doctor owns a set of privileges associated to his position such as position=specialist or physician, affiliation=Hospital or Research institute. Since, specialization can be of various types depends on the diseases of the patients. That can be cardiology, hypertension, diabetic etc. Specialist doctors and their attributes (functions) are assigned according to the diseases and condition of the patients. For example, personal and medical data of patients suffering from heart diseases is assigned to the specialists satisfying specialist=Cardiology and expertise=Surgeon or Physician can decipher the personal health information and verify his authentic identity. Figure illustrates the access structure in our proposed ehealth monitoring system. Since, The authority is responsible of issuing private keys corresponding to each attribute the doctors possess.

Secure Communication Mechanism:

WBAN sensors have low computational capability, storage and battery power. Traditional protocols like RSA are not suitable for such resource constraints networks. Moreover, various certificates like X.509 are also not suitable during TLS handshake due to their inappropriate size which proof expensive to transmit.

C. Identity-Based Cryptography

For the security of the our proposed ehealth monitoring system, reliable security can be achieved through the formulation of the Identity Based Cryptography. Following is the brief definition of the IBC which can be taken into secure scenario of the ehealth monitoring systems. This scheme can be called light weight it avoids using certificates which reduces the number of the messages to be exchanged during key exchange. Certificates are usually quite large which definitely put burden on the memory and the bandwidth. In IBC there is a Private Key Generator (PKG) which has replaced traditional Certification Authority (CA) used in Certificate-based cryptography [19]. It generates a secret key for each node based on its unique identity. All the nodes must contain these secret keys before their deployment in the netwok. It is generally assumed that PKG is a trusted party which is hard to be compromised. To ensure, proper security mechanism, IBC scheme is used for the proposed system architecture.

D. Eliptic Curve Diffie-Helmann

The main security of the system relies on the secure and efficient transfer of the shared key before exchange of the messages between the sensor nodes and controller or between controller and server. This protocol is generally used between two stakeholders of the healtcare system (wireless body area network in our case). This key exchange protocol allows controller of the wireless body area network and server to agree on a shared key over an unsecure communication channel. More detailed description can be found in RFC 2631 [8]. This protocol is the alteration of eliptic curve public and private key pairs. Here, basic concept of exchange between the controller of the WBAN and the server is given, which goes as follows: Both stakeholders must have the same eliptic curve, eliptic curve is a generator, represented it by P which is a point on the curve. Moreover, each party should also have public and private key pairs denoted as dA and dB for the private part and QA and QB for the public part respectively. More concretly d is a randomly selected value and Q is calculated as $Q = d * P$. After the transmission of public keys between both parties (controller and the server) then they can calculate the shared key x as $xA = dA * QB$ and $xB = dB * QA$ respectively. It holds x=x=x because $dA * QB = dAdB * P = dB * dA * P = dB * QA$. After that some form of hash function is used on x to get the shared key [8]. This is mechanism which is followed for secure transmission of the shared key between two ends of the network.

E. Eliptic Curves

Eliptic Curves are also used for the efficient and secure key exchange. Ecliptic curve can also ensure maximum secure of the key exchange in health monitoring systems. Eliptic Curves key exchange mechanism is considered as one of the small key exchange protocols. It is considered as efficient and light weight mechanism with respect to the RSA. It can provide same level of security with 128 bit, where as RSA achieve that level of security with 1024 bit. Eliptic Curves are the algebric concepts described by the equation: $y^2 = x^3 + ax + b$ and the points on the curves. It is generally believed that as long as discrete algorithm problem is still expensive and difficult to solve, eliptic curve cryptography can be considered as secure [16].

F. Bilinear Pairing

Bilinear Pairing is also previously widely used mechanism for secure communication between two ends. This is also one the proposed security approach in our ehealth monitoring system. We give general and most classified definition of the Bilinear Pairing which is as follows: In simple words, Bilinear Pairing can be described as the agreement of two parties on a shared key without exchanging messages. Mathematically: Let G1 denoted a cyclic additive group of some large prime order q and G2 a cyclic multiplicative group of the same order. A pairing is a map $e : G1 \times G2 \rightarrow G2$ and has property of bilinearity, if *P,Q,R* $\in$ *G1* and a $\in$ Z_d^* [...] $e(aP, Q) = e(P, aQ) = e(P, Q)^a$ [19].

IV. Conclusion

In this paper, a comprehensive framework for advanced E-health system is presented by describing, in detail, the entire remote health monitoring life cycle. It is also highlighted the essential service components, with particular focus on data collection at patient side. The proposed multi-disciplinary approaches are expected to be more robust, efficient, and secure for health monitoring, compared to the existing health care systems. To ensure high efficiency of the proposed framework, the key challenges that need to be solved in order to develop efficient and secure patient-centric monitoring system are presented and analyzed. Moreover, some potential solutions to overcome the above challenges are discussed. Finally, this concise survey paper serves as the blueprint for the future work that aims to propose original and effective solutions in the E-health monitoring field.

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SVM based Emotional Speaker Recognition using MFCC-SDC Features

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***Abstract*—Enhancing the performance of emotional speaker recognition process has witnessed an increasing interest in the last years. This paper highlights a methodology for speaker recognition under different emotional states based on the multiclass Support Vector Machine (SVM) classifier. We compare two feature extraction methods which are used to represent emotional speech utterances in order to obtain best accuracies. The first method known as traditional Mel-Frequency Cepstral Coefficients (MFCC) and the second one is MFCC combined with Shifted-Delta-Cepstra (MFCC-SDC). Experimentations are conducted on IEMOCAP database using two multiclass SVM approaches: One-Against-One (OAO) and One Against-All (OAA). Obtained results show that MFCC-SDC features outperform the conventional MFCC.**

Keywords*—Emotion; Speaker recognition; Mel Frequency Cepstral Coefficients (MFCC); Shifted-Delta-Cepstral (SDC); SVM

I. Introduction

Emotional speaker recognition is one of research fields in Human-Computer Interaction (HCI) or affective computing [1]. The main motivation comes from the want to develop a human machine interface that's more intelligent, adaptive and credible. This may gives computers the ability to know person in such context for many real applications .Speaker recognition in emotional context can be used in criminal or forensic investigation to identify the suspected person who produces the emotional utterances. It can also be used in telecommunication to ameliorate the telephone based speech recognition performance,etc...

Emotional speaker recognition systems are composed of two mains components which are feature extraction and classification [2]. In littrature, different classifiers have been used to model speakers under emotional states. I.Shahin [3] has used Hidden Markov Model(HMM) and suprasegmental hidden Markov models (SPHMMs) to identify speaker using emotional cues. In the same context, Yingchun Yang et al. citeyang have used GMM-UBM classifier. Support Vector Machines (SVM) are used [5] to show the important influence of the emotional state upon text independent speaker identification.

In general, human emotions are complicated phenomenon. Thus, choosing a most suitable features that represent emotional utterances has been an important step in emotional speaker recognition process. Researches have demonstrated that features derived from the speech spectrum usually give best performances for the automatic recognition system. Indeed, the spectrum reflects the geometry of the system that generates the speech signal. Therefore, spectral features are widely developed for the speaker recognition such as Mel Frequency Cepstral Coefficients (MFCC) and Linear Predictive Cepstral Coefficients(LPCC) in addition to the other acoustic features [6].

Many features have been used to ameliorate the performance of speaker recognition system in emotional context [7]. MFCC features are the most common used features in speaker recognition in emotional context [8] [9]. Linear Predictive Cepstral Coefficients(LPCC) have also been used frequently in this context [10] .

MFCC coefficients are based on human auditory system [11]. However, these coefficients will be more efficient, if speech is of short duration. For long-term speech signals, Shifted Delta Coefficients (SDC) features are more appropriated, since they identify the dynamic behavior of the speaker along the prosodic features of speech signal. Kshirod Sarmah et al. [12] have employed MFCC-SDC features to identify language. N. Murali Krishna et al. [13] have used MFCC-SDC to recognize different human emotional states. Fred Richardso et al. [14] have introduced SDC features for speaker and language recognition. However, this method has not been used in emotional speaker recognition applications.

In this work, we propose to investigate MFCC-SDC features to improve the performances of the speaker recognition system in emotional talking environment. Hence in order to evaluate the proposed recognition system, it is advantageous to use two multiclass SVM approaches : One Against One (OAO) and One Against All (OAA) in classification step. We are also interested to compare obtained results from diffrent feature extraction methods.

This paper is organized as follows: Section II present the proposed emotional speaker recognition system . Section III presents the process of MFCC and MFCC-SDC features extraction and Section IV deals with multiclass Support Vector Machines approaches. Results and experiments are given in Section V. Finally, conclusion is given in Section VI.

II. System design

The proposed emotional speaker recognition system is displayed in figure 1. It can be divided into two main components: feature extraction and speaker classification. Firstly,

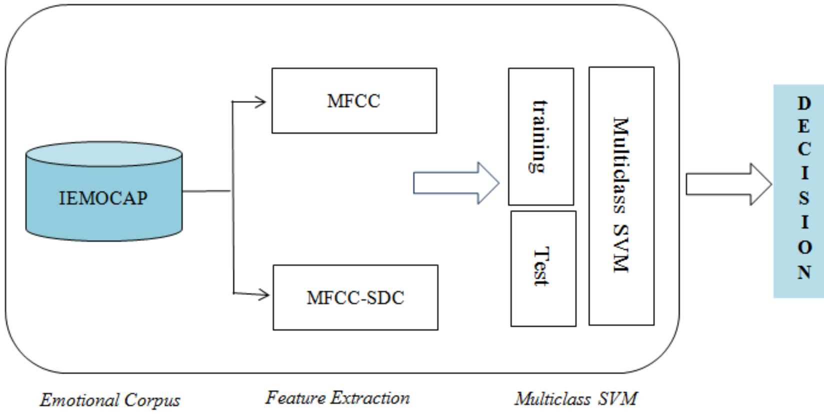


Fig. 1: System description

improvised emotional utterances of IEMOCAP database are considered to evaluate this system. We extract MFCCs and MFCC-SDC from the emotional speech signals. These obtained feature vectors are then divided into training and test sets. Then, classification is done using two well known multiclass SVM approaches which are One-Against-All(OAA), and One-Against-One(OAO). Finally, the decision of the recognition system is specified with accuracy rate using the test set.

III. Feature Extraction

Feature extraction is a critical step in emotional speaker recognition system. In fact, choosing a suitable features which represent useful information increase precision of recognition system. In this section, we describe the procedure of MFCC feature extraction and we introduce Shifted-Delta-Cepstra (SDC) technique in order to compare both the traditional MFCC coefficients and MFCC-SDC features.

A. Mel Frequency Cepstral Coefficients

Mel Frequency Cepstral Coefficients (MFCC) is one of the commonly used technique of feature extraction in emotional speaker recognition. MFCC coefficients are based on human hearing perceptions which cannot perceive frequencies over 1Khz. After frame blocking and windowing step, the FFT is computed and the power coefficients are filtered by a triangular band pass filter bank also known as Mel-scale. They have been used to capture the phonetically important characteristics of speech signal. MFCC has two kind of filters which are filters spaced linearly at low frequency below $1000Hz$ and filters logarithmic spacing above $1000Hz$ [15] . Therefore, the following approximate formula can be used to compute the Mels for a given linear frequency f :

$$Mel(f) = 2595 \times \log_{10}(1 + \frac{f}{700}). \quad (1)$$

The full extraction procedure of a Melfrequency cepstral coefficient is described in figure 2.

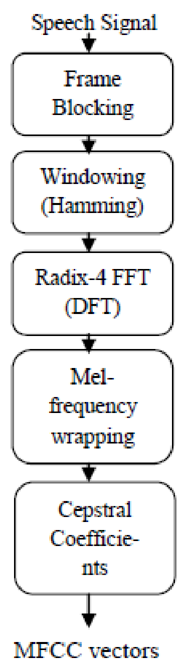


Fig. 2: Pipeline of MFCC extraction.

B. Shifted Delta Cepstra features

SDC features are widely used in language identification and speech recognition fields [12]. SDC feature vectors are an extension of delta-cepstra coefficients. Figure 3 describe the extraction procedure of SDC feature vectors. In fact, these vectors are obtained by stacking delta-cepstra computed across multiple speech frames. SDC coefficients depend on four parameters typically named as $N - d - P - k$. The parameter N represents the number of cepstral coefficients used to compute MFCC at each frame. So each frame is presented by a coefficient vector given as:

$$c(t) = [c_0 c_1 ... c_i ... c_{N-1}]. \quad (2)$$

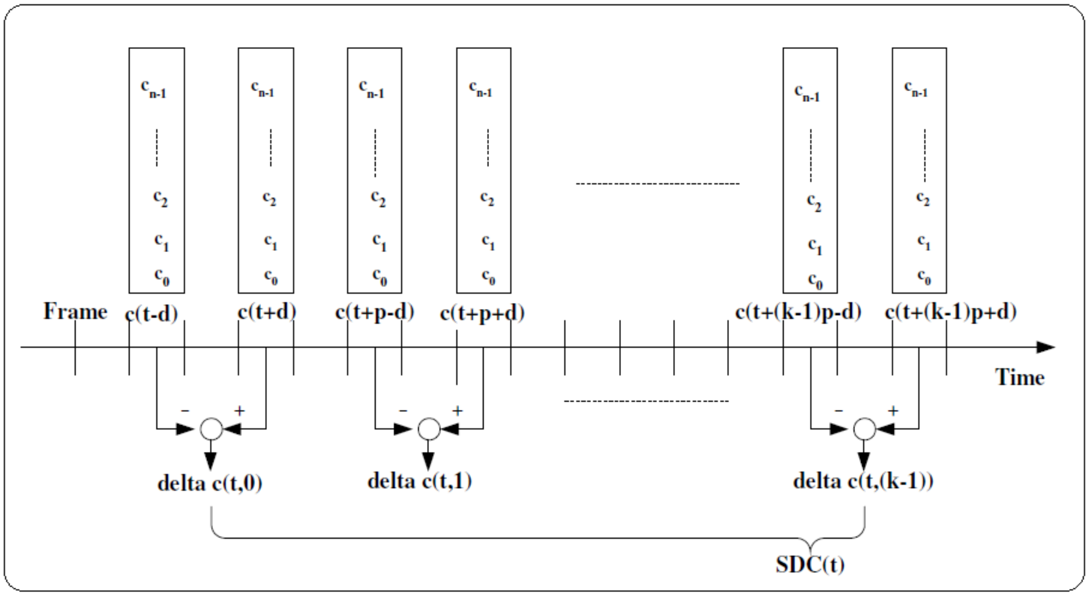


Fig. 3: Extraction procedure of SDC coefficients.

Where c_i are the MFCC coefficients and t is the coefficient index. The parameter d presents the spread over which delta are computed. The gaps between different delta computations is given by the parameter P. Parameter k determines the number of blocks whose delta coefficients are concatenated to obtain the final form of feature vector. For given time t, an intermediate calculation is done to obtain these k coefficients :

$$\Delta\mathbf{c}(t,i) = \mathbf{c}(t + i \times P + d) - \mathbf{c}(t + i \times P - d). \quad (3)$$

Finally, the SDC coefficient vector of k dimension is obtained as:

$$\mathbf{SDC}(t) = [\Delta c(t,0)\Delta c(t,1)...\Delta c(t,k-1)]. \quad (4)$$

Hence, SDC coefficients expressed in 4 are the stracked version of MFCC coefficents given in 1, and $k \times N$ parameters are then used for each SDC feature vector.

The SDC coefficients are able to interpret signal and capture features from the long duration speech samples or dynamically changing samples. Thus, it solves limitations of the traditional short time derivation of the cepstra features. This technique is widely successful in language identification system (LID) using GMM with high order (512-1024-2048) mixture models [16].

IV. Classification

In literature, various classification approches have been used to recognize speaker from his emotional speech such Gaussian Mixture Models [18], Hidden Markov Model [17], and Support Vector Machines [5].

Support vector machines (SVM) were well used for pattern recognition . It is a simple and efficient classifier which transforms the original input set into a higher dimensional space using kernel mapping functions. Its main goal is to find the optimal separating hyperplane using the maximized margin criteria to distinguish between classes. The most frequently employed kernel functions named standard kernels are linear, polynomial and Gaussian)kernels.

SVM are firstly introduced by Vapinik for binary classification [11]. Then, they are extended to solve multiclass problem using different approches. There are two main strategies for extending the binary SVM classifier to multiclass classifier: either by decomposing multiclass problem to a set of binary classifiers and combining it or by taking all the classes at once and considering the others instances in one optimization formulation [19]. In this work, we are interested to the first strategy and we are tested two most popular SVM methods which are One-Against-All (OAA) and One-Against-One (OAO) [20].

The OAA approach is the earliest and simplest one [21]. It builds kSVM binary classifiers in which k is the number of classes. The principle of OAA method is training the i^{th} binary SVM with all the positive labels examples in this class to separate it to the other classes. This j^{th} class is considered as positive class and all other examples are negative samples. Finally, the winner class corresponds to the highest output of SVM. This methods is considered fast, only k binary SVM classifiers are trained. However, OAA is an asymmetric method due to the small ratio of positive examples if compared with the negatives ones in every training hyperplane. Thus, many indecision regions may be created which degraded the performance of the classifier.

The OAO is symmetric method which involves $k(k-1)/2$ SVM binary classifiers [20]. Each SVM binary classifier is trained to distinguish between each pair of classes. Then, these classifiers will be combined using majority voting strategy. The decision of classification obtained by the maximal vote-number class. The training process of this method is long in terms of times.

V. Experiments

A. Emotional Database

The quality of the database plays an important role in performance of emotional speaker recognition. The emotional speech corpus selected for this study is the Interactive Emotional Dyadic Motion Capture (IEMOCAP) [22]. It consists of audio, video and motion-capture recordings of dyadic mixed-gender pairs of actors. It includes five sessions, in each session actors play improvisation of scripts or hypothetical scenarios. Each improvisation conveys a general emotional theme. The main goal is to have an expression that mostly resembles to natural emotion expression. Then, these expressions have been divided into utterances which were manually annotated in categorical labels: {angry, happy, sad, neutral, frustrated, excited, fearful, surprised, disgusted...} and in terms of three dimensional axes :valence, activation, and dominance.

In our study, we used only the speech utterances recorded under four emotional states which are:anger, happiness, sadness and neutrality. In our analysis, emotional speech of 10 speakers are considered that to say that 2218 utterances distributed over four emotions.

B. Experimental setup

In current experiments, IEMOCAP emotional database is used to evaluate the performance of SVM based speaker recognition in emotional context. The MFCCs and MFCC-SDC features are extracted from emotional utterances which represent four emotions: neutral, happy, angry and sad expressed by ten speakers (five male and five female): {SP1, SP2, SP3, SP4, SP5, SP6, SP7, SP8, SP9, SP10}.

All audio recording were sampled at a rate of 16 KHz. Speech samples were segmented into frames of $50ms$ length with 50% overlap between frames. The 70% of data set was used for training phase and 30% of this data formed the testing set.

The feature vector MFCC consists of 13 coefficients stacked with the set of shifted delta cepstra (SDC)features. We have tested some SDC schemes founded in literature [23], 12-1-3-3 SDC scheme was given the best results. The Shifted-Delta-Cepstra coefficients are extracted from MFCC coefficients.

Two multiclass SVM approaches including OAA and OAO were used in order to evaluate the proposed emotional speaker recognition. The multiclass SVMs methods were performed using the SVM-KM toolbox for Matlab [24]. Two kernel functions are used which are polynomial and gaussian kernels with both OAA and OAO strategies. Each kernel is characterized by paire of parameters typically written (C, σ) which C presents the regularization parameter parameter and σ is the gaussian width . To select suitable parameters (C, σ), a cross validation algorithm is employed by varying the C and σ in $[2^{-15}, 2^{-14}, ..., 2^{14}, 2^{15}]$ [25].

C. Results

In this study, a speaker recognition system in emotional context is implemented using MFCCs and MFCC-SDC features. Speakers are recognized under four different emotional states using two multiclass SVM approaches which are OAA and OAO tested with polynomial and gaussian kernels.

We evaluate MFCC and MFCC-SDC features using OAA SVM multiclass method. Different results are detailed in I.We remak firstly that the gaussian kernel gives best classification accuracies using both MFCC and MFCC-SDC features. Comparing the classification rates obtained with traditional MFCCs coefficients to those obtained with the MFCC-SDC features , we remark that the classification accuracies are improved ranging from 86.55% to 88.23% using polynomial kernel and 89.33% to 91.31% using gaussian kernel. With a 95% confidence interval in the range of $[78.33\%, 95.71\%]$, MFCC-SDC presents promising results with polynomial kernel (CI +/- 4%). A best speaker recognition rate obtained with the application of MFCC-SDC features and gaussian kernel by an average of 91.34% (CI +/- 2%).

The same experiment was conducted with the OAO multiclass SVM method. Results of classification accuracies are illustrated in table II. Similar to OAA approach, gaussian kernel gives best results with an average of 88% using MFCC coefficients and 90.90% using MFCC-SDC features. However, we can notice that the MFCC-SDC features have given an improvement with the gaussian kernel while they weren't successful with the polynomial kernel.In fact, with a 95% confidence interval, MFCC-SDC features give classification results with the polynomial kernel in the range of $[53.55\%, 70.80\%]$ (CI +/- 3%) and with the gaussian kernel in the range of $[83.33\%, 96\%]$(CI +/- 2%)

In general, classification rates of speaker recognition in emotional context have been improved using MFCC-SDC features except for polynomial kernel in OAO approach. The best results are obtained when we use the gaussian kernel associated to MFCC-SDC computed with OAA and OAO multiclass SVM startegies.

For a better presentation of results of the table I and the tzble II, rates were shown in figures .These graphs illustrate a comparative analysis between different used features and different multiclass SVM approaches. Indeed, MFCC-SDC features extracted from the traditional MFCC improve the performances of the emotional speaker recognition system using both OAA and OAO multiclass SVM methods. Moreover, the best classification accuracies are often obtained with the use of the gaussian kernel and OAA SVM multiclass method with an avreage of 91.31% (CI +/-2%).

VI. Conclusion

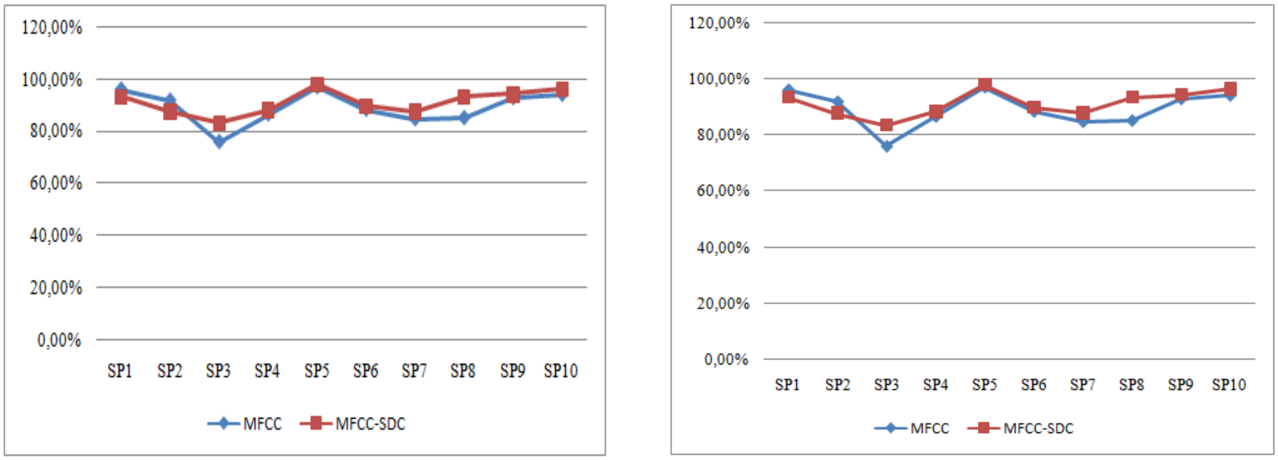
In this paper, it has been observed that the performance of speaker recognition system in emotional context has been improved applying MFCC-SDC as a feature extraction method and SVM as a classifier. The evaluation of emotional speaker recognition system is carried out on IEMOCAP emotional database using two multiclass SVM approaches which are OAA and OAO methods. The experimental results reveal that there is an improvement in the performances of the proposed emotional speaker recognition in improvised context using MFCC-SDC features extracted from the conventional MFCC coefficients and they outperform the baseline systems that using MFCC features.

TABLE I: Classification Results using OAA/SVM

Speakers	Features	Polynomial (%)	Gaussian(%)
SP1	MFCC	95.25	96.10
	MFCC-SDC	94.80	93.50
SP2	MFCC	80.72	91.89
	MFCC-SDC	87.83	87.83
SP3	MFCC	82	86.66
	MFCC-SDC	79.10	83.58
SP4	MFCC	83.11	97
	MFCC-SDC	78.33	88.33
SP5	MFCC	88	88.46
	MFCC-SDC	97	98
SP6	MFCC	84.34	84.84
	MFCC-SDC	82.05	90
SP7	MFCC	83.93	85.24
	MFCC-SDC	84.84	87.87
SP8	MFCC	94.28	92.85
	MFCC-SDC	88.52	93.44
SP9	MFCC	87	94.11
	MFCC-SDC	95.71	94.28
SP10	MFCC	86.85	98.79
	MFCC-SDC	94.11	96.50
AVERAGE	MFCC	86.55	89.33
	MFCC-SDC	88.23	91.34
Confidence Interval	MFCC	+/-0.03	+/-0.03
	MFCC-SDC	+/-0.04	+/-0.02

TABLE II: Classification Results using OAO/SVM

Speakers	Features	Polynomial (%)	Gaussian(%)
SP1	MFCC	96	96.10
	MFCC-SDC	70.80	92.20
SP2	MFCC	83.12	91.89
	MFCC-SDC	56.50	91.90
SP3	MFCC	82.40	82.08
	MFCC-SDC	53.55	89.55
SP4	MFCC	82	80
	MFCC-SDC	57.80	88.33
SP5	MFCC	88.45	91
	MFCC-SDC	55.10	96
SP6	MFCC	85.50	84.61
	MFCC-SDC	59.28	83.33
SP7	MFCC	84	86.36
	MFCC-SDC	61.11	90.91
SP8	MFCC	95	83.60
	MFCC-SDC	58.62	86.88
SP9	MFCC	87.35	91.42
	MFCC-SDC	65 .88	95.71
SP10	MFCC	88.36	92.94
	MFCC-SDC	68.50	94.11
AVERAGE AVERAGE	MFCC	87.22	88
	MFCC-SDC	60.74	90.90
Confidence Interval	MFCC	+/-0.03	+/-0.03
	MFCC-SDC	+/-0.03	+/-0.02



(a) (b)

Fig. 4: Emotional speaker recognition using SVM classifier with MFCC and MFCC-SDC features:(a): OAA multiclass approach,(b): OAO multiclass approach.

For future work, MFCC-SDC features can be tested with other classifiers such as Deep Neural Network (DNN). Moreover, we can combined these features with other cepstral parameters to enhance performance of speaker recognition under different emotional states.

ACKNOWLEDGMENT

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Improving Routing Performances to Provide Internet Connectivity in VANETs over IEEE 802.11p

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***Abstract*—In the intelligent transportation systems, many applications and services could be offered in the road via Internet. Providing these applications over vehicular ad hoc network (VANETs) technology may require good performances in routing. The channel fading and quality of received signal are the two main factors which affect the Mobile ad hoc network performances as well as mobility of vehicles, in terms of throughput and delay packets that are relevant to the performance evaluation of the routing protocols. In this paper, we propose an efficient relay selection scheme based on Contention Based Forwarding (CBF) and Fuzzy Logic System (FLS) that considers two important Quality of Service parameters such as link stability, and quality of received signal to select a potential relay vehicle, in order to improve the routing performances in the network. The simulation results show that the proposed relay selection scheme enhances throughput, and decreases packet delay and overhead comparing it with an existing link stability based routing protocol(MBRP) and M-AODV+.**

Keywords*—*VANET; routing; link stability; fading; RSS; mobility

I. Introduction

Several wireless networking technologies such as WiMAX [1], 3G/4G/5G cellular networks [2], Long Term Evolution [3], [4], IEEE 802.11-based vehicular ad hoc networks (VANETs) named IEEE 802.11p, are available actually to achieve Internet connectivity for VANETs. IEEE 802.11p [5], also known as Wireless Access in Vehicular Environment (WAVE) protocol is an enhancement to the 802.11 physical layer (PHY) and medium access control (MAC) to support high vehicular mobility and faster topological changes. This standard is used as groundwork for Dedicated Short Range Communication (DSRC). It operates in the 5.9 GHz band and supports both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. The maximum data rate supported by this standard is 27 Mbps. The mobility supported is up to 200kmph, making this suitable for VANETs applications involving highway scenario. IEEE 802.11p provides a short-range radio communication of approximately 300 m.

Vehicular ad hoc networks (VANETs) are characterized by frequent and fast topology changes, which are introduced by vehicles mobility as well as by channel fading. Link stability is often measured using mobility parameters (position, speed, direction, etc) and the impact of fading channel on is disregarded. In this paper, we have combined the impact of vehicles mobility and fading channel statistics on link stability. Moreover, we have improved relay selection scheme by considering the link stability and quality of received signal, in order to make vehicles able to select the most stable with the minimum fading, and the strongest received signal route from them to the road side units (RSUs) which are part of wired network (Internet). Hop count-based routing protocols; select the shortest path length in term of a number of hops. However, these protocols do not typically select a route with sufficient lifetime to maintain the longest possible duration of communication with RSUs, which make existing routing protocols basically designed for MANETs not suitable for VANETs. For example M-AODV+ [6] which is an extension version of AODV+ [6] proposed to support the reliability of V2V communication in VANETs by enabling V2I and I2I communications as alternative communication links among vehicles when single hop or multi-hop communication in the network is not possible. In contrast, many routing protocols in the literature such as [7], [8], [9], are proposed to utilize a metric characterizing link stability to choose the most stable route in the network.

Communications in vehicular networks are carried out in an unfavorable external environment for the establishment of radio links, because of the multitude of obstacles (forests, mountains, buildings ...), especially in urban areas. These obstacles cause a severe degradation in the quality of the signals transmission. In the one side, Multipath fading introduced will have an impact on the stability of link as well as mobility of nodes and consequently on the network performances. On the other side, received signal fluctuations will certainly increase the route failures and dropped packets in the network.

In this paper, we have modified relay selection scheme proposed in [10] which base on the contention-based forwarding scheme, to take into account to channel fading and the quality of received signal of a link. We have integrated into the relay selection scheme, two important features: link stability and link quality in term of received signal. Link stability is measured in function of mobility parameters and fading statistics. However, quality of link received signal is measured using a fuzzy logic system between received signal strength (RSS) and mobility.

The layout of this paper is as follows. In Section II, we present the related work. Our proposed work is detailed in Section III. The performance of our protocol is discussed in Section IV. Finally, we give the conclusion and future work directions in Section V.

II. Related Work

In the paper [11], the other has proposed an efficient relay selection mechanism which considers the link stability as the main routing metric to select a potential relay. The link stability is measured not only in function of the mobility parameters such as geographic location, direction, and speed of vehicles but also in function of channel fading statistics. In congested scenarios, basing only on this feature of stability, one vehicle may be selected as a relay for multiple vehicles and if the number of relay requests exceeds the service capacity of this vehicle, it might get overloaded. Thus, the dropping packets and large contention delay in the MAC layer may be happening in the network. As the solution, the authors proposed a new mechanism to adapt the waiting time of each node according to its channel access availability and its queue occupancy using the fuzzy logic system. In this work, the quality of received signal is not taking into consideration which may degrade the network performances especially in the more realistic environment.

MBRP (Mobility Based Routing Protocol) [10] is an efficient routing protocol for connecting vehicular networks to the Internet which uses the characteristics of vehicle movements to predict the future behavior of vehicles, and to select a route with the longest lifetime. The proposed protocol aims to broadcast the advertisement messages through multi-hops in the predefined geographic zone and uses a distributed manner to select relay for a re-broadcasting message, this approach will connect VANETs to Internet on minimizing overhead without flooding network through most stable route. MBRP does not consider the fading feature of wireless channels and the received signal quality.

In this work [12], the authors proposed a multilayer cooperation framework to offer passengers in vehicle continuous and best available access to the Internet with a controlled Quality of Service (QoS). This approach exploits the presence of Road Side Unite installed along the route acting as a gateway to the wired network (Internet), some vehicles acting as a mobile gateway for other vehicles with just a short-range radio interface. This framework consists of estimating in the MAC layer some parameters (expected delay and available throughput) and using them in the network layer, in order to select the route with the minimum bit rate requirement and the residual delay allowed to be spent from the gateway to the destination. At the PHY layer, each node in VANET measures periodically, the received signal strength indicator (RSSI) on each active link to their neighbors, in order, to select the most stable route from vehicle to the gateway. In this framework, vehicles base on the reactive approach to building QoS network paths to the gateway, the disadvantages is that reactive route discovery increase end to end delay. The centralized method (where nodes broadcast periodically hello message) which used to measure RSSI in order to estimate link lifetime, is not suitable for VANET because it causes flooding and broadcast storms in the network which will increase a bandwidth consummation and decrease data throughput.

III. Proposed Work

A. Channel Model of Vehicular Ad hoc Network

Nakagami-m distribution seems to be most suitable to modeled communication in VANET networks in the absence of interferences [13], [14]. In this paper, we assume that the communication between nodes in VANETs is doing over Nakagami fading channel and we aim to select a most stable path with minimum fading. The wireless channel model includes the effects of small-scale fading and large-scale path loss. Here we assume that every node has the same transmission power and that the transmission power is constant. For a transmission over a distance d, in the presence of Nakagami-m fading, instantaneous received signal power p is Gamma distributed. According to [13], in the fast fading (m=3), the probability that a packet is successfully received in the absence of interference, is deduced from the probability that the packet's received signal is stronger than the reception threshold , which represents the minimum acceptable value of received power, that is,

$$\Psi = P_r(p \geq R_{th}) = \exp\left(-3.\frac{R_{th}}{p}\right).\left(1+3.\frac{R_{th}}{p}+\frac{9}{2}.\left(\frac{R_{th}}{p}\right)^2\right) \quad (1)$$

B. Mobility and Fading based Link Stability Metric Estimation

In this paper, the link stability is estimated using a routing metric called Effective Link Operation Duration (ELOD) proposed in [15]. The authors defined it as the duration within the link lifetime in which the received signal power above an acceptable threshold R_{th}. To estimate the ELOD first, the author [15] used mobility parameters to predict the link lifetime and then combine the link lifetime with the fading channel statistics. Noted that the authors [15] have used the Rayleigh distribution as propagation model to model the fading. However, the fading with Rayleigh model is not more satiable in VANET environment, because, it assumes that all the transmitted signals arriving at the receiver are allocated in the same power.

The effective link operation duration between two vehicles i and j noted $ELOD_{ij}$ can be estimated as in [15] as follow:

$$ELOD_{ij} = Let_{ij} \times E[\Psi] \quad (2)$$

where Let_{ij} is a lifetime of link formed between vehicles i and j which are positioned at locations (x_i, y_i), (x_j, y_j), and move in direction θ_i, θ_j with speed v_i, v_j respectively. Assuming that all vehicles have the same transmission range R, the link expiration time noted Let_{ij} can be estimated according to [10] using mobility parameters as follows,

$$Let_{ij} = \frac{\sqrt{(a^2+c^2)R^2-(ad-bc)^2}-(ab+cd)}{a^2+c^2} \quad (3)$$

where,
$a = v_i \cos\theta_i - v_j \cos\theta_j$
$b = x_i - x_j$
$c = v_i \sin\theta_i - v_j \sin\theta_j$
$d = y_i - y_j$.

and Ψ represents the probability of a link between vehicle i and vehicle j which are in connection within link lifetime in

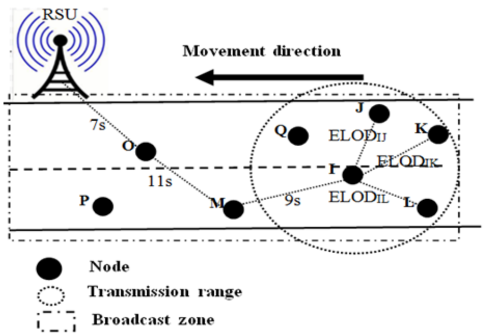

Fig. 1. Route selection based on EROD illustration

which the received signal power is above a certain predefined threshold. $E[\Psi]$ is the expected value of probability Ψ.
Now, let R_{N-1} the route from the RSU to the source vehicle, and in each route there are $N-1$ links between N vehicles. The effective route operation duration noted $EROD_{N-1}$ is defined to be the shortest lifetime along the route R_{N-1}.

$$EROD_{N-1} = Min_{i=1,j=i+1}^{N} ELOD_{ij} \tag{4}$$

As illustrated in Fig. 1, the vehicles O and M are selected as relays to form the route from RSU to vehicle I. The ELOD of each link is written over the link. EROD is its effective route operation duration which equals 7s in this case. The vehicle I in this example is selected as a next relay and will rebroadcast the message to its neighbors such as J, K and L. Noted that the message is disseminated in the opposite direction of vehicles movement, and all vehicles move in the same direction.

The model in [13] neglects large scale fading (shadowing) and considers a quadratic path-loss according to the Friis model (n=2) [16]. Therefore, in the absence of interferences, the average reception power p at a distance d, and the reception threshold R_{th} are :

$$p \propto d^{-2} \tag{5}$$

and

$$R_{th} \propto R^{-2} \tag{6}$$

The model calculates the expected probability of successfully receiving a message at distance d given transmission range R in the absence of simultaneous transmissions. The packet reception probability formula (1) is reformed as follows:

$$\Psi = \exp\left(-3.\left(\frac{d}{R}\right)^2\right).\left(1+3.\left(\frac{d}{R}\right)^2+\frac{9}{2}.\left(\frac{d}{R}\right)^4\right) \tag{7}$$

Due to the mobility of nodes, the relative distance d varies at the times, consequently, the probability Ψ varies with node movement. To account for this random variation, we replace d in (7) with a continuous random variable Z, which represents the distance between the sender and the receiver. As mentioned previously, using the probability that a link is not in a fade, we can estimate the link operation duration. According to [15], the expected value of the probability Ψ can be determined as follow:

$$E[\Psi] = \int_{d_{min}}^{R} \Psi(z) f_Z(z) dz \tag{8}$$

where $f_Z(z)$ is the probability density function (pdf). According to the expression of the function f_Z defined in [15], we distinguished tree cases of expected value $E[\Psi]$:

- Case 1 : If the relative distance between vehicles i and j remains constant during their movement, the average $E[\Psi]$ for the link during the prediction period is

$$E[\psi] = \exp\left(-3.\left(\frac{d_{ij}}{R}\right)^2\right).\left(1+3.\left(\frac{d_{ij}}{R}\right)^2+\frac{9}{2}.\left(\frac{d_{ij}}{R}\right)^4\right) \tag{9}$$

- Case 2: If the two vehicles only move away from each other during the prediction period, the pdf of Z is

$$f_Z(z) = \begin{cases} 0 & if \;\; z < d_{ij} \\ \frac{1}{R-d_{ij}} & if \;\; d_{ij} \le z \le R \\ 0 & if \;\; z > R \end{cases} \tag{10}$$

The expression of expected value $E[\Psi]$ is :

$$\begin{aligned} E[\Psi] = & \tfrac{1}{R-d_{ij}} \int_{d_{ij}}^{R} \exp\left(-3.\left(\tfrac{z}{R}\right)^2\right). \\ & \left(1+3.\left(\tfrac{z}{R}\right)^2+\tfrac{9}{2}.\left(\tfrac{z}{R}\right)^4\right) dz \end{aligned} \tag{11}$$

- Case 3: If the two vehicles first move toward each other, then apart some time later, the pdf of Z is

$$f_Z(z) = \begin{cases} \frac{2}{R+d_{ij}} & if \;\; z < d_{ij} \\ \frac{1}{R+d_{ij}} & if \;\; d_{ij} \le z \le R \\ 0 & if \;\; z > R \end{cases} \tag{12}$$

The expression of expected value $E[\Psi]$ is :

$$E[\Psi] = \begin{aligned} & \tfrac{2}{R+d_{ij}} \int_0^{d_{ij}} \exp\left(-3.\left(\tfrac{z}{R}\right)^2\right).(1+3.\left(\tfrac{z}{R}\right)^2 + \\ & \tfrac{9}{2}.\left(\tfrac{z}{R}\right)^4)dz + \tfrac{1}{R+d_{ij}} \int_{d_{ij}}^{R} \exp\left(-3.\left(\tfrac{z}{R}\right)^2\right). \\ & (1+3.\left(\tfrac{z}{R}\right)^2+\tfrac{9}{2}.\left(\tfrac{z}{R}\right)^4)dz \end{aligned} \tag{13}$$

where $d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$.

C. Design of Fuzzy Inference based Mobility and RSS

As it is explained previously, our relay selection mechanism aims to improve relay selection by considering received signal strength (RSS). The reason behind choosing RSS is to ensure that the packets will be received with enough reception power strength, reduce selecting failures routes and increase the reliability of them. The relative speed between sender and receiver is a metric among others which has a good consistency with RSS. The faster source vehicle moves towards to receiver, the faster will be the increase in the link RSS. Similarly, the faster the source vehicle moves away from the receiver, the faster will be the decline in the link RSS. For this purpose, we take advantage of the fuzzy logic system (FLS) which received signal strength and mobility speed factors are the fuzzy inputs and quality of link received signal (QLRS) is fuzzy output. More details of FLS are given to papers [17], [18].

Upon reception of advertisement message from previous relay (RSU or relay vehicle), each vehicle measures RSS of packet and calculates RSS factor (RSSF) and mobility factor (MF) as shown in the following formulas:

$$RSSF = 1 - \frac{RSS_{thresh}}{RSS} \tag{14}$$

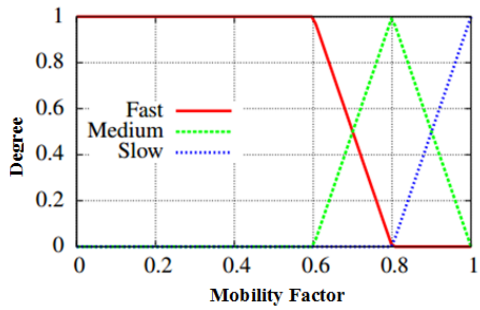

Fig. 2. Mobility membership function

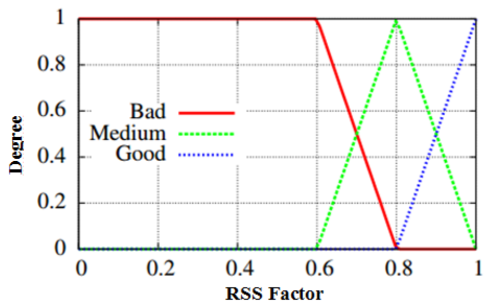

Fig. 3. RSS membership function

$$MF = 1 - \frac{|V_r - V_s|}{V_{max}} \tag{15}$$

where RSS_{thresh} is the received signal strength threshold, V_r and V_s are the receiver and source speeds respectively and V_{max} is the maximum speed in the network. We assume that vehicles are all equipped with GPS devices and keep their speed during prediction link lifetime. The input fuzzy variables of $RSSF$ and MF are classified into three levels. This grouping strategy gives more clues on the weakness and strength of input variables and helps to generate more accurate output data.

Upon reception of advertisement message, each vehicle uses the fuzzy system to calculate the value of the received signal quality of link formed with the sender, based on mobility, moving direction (the sender and the receiver moving direction is towards or away) and the RSS. For each receiver vehicle in competition to be relay, the steps for calculating the numerical value of QLRS are as follows:

- Fuzzification
  Fuzzification is the process of converting a numeric value to a fuzzy value by using a predefined membership function. The predefined linguistic variables and membership functions are used to convert the mobility factor and the RSS factor (taking into account the moving direction) of corresponding fuzzy values. The linguistic variables defined for mobility are Slow, Medium, Fast, and for RSS are Good, Medium, Bad. Fig. 2 and Fig. 3 show the membership function of mobility factor and RSS factor respectively.

- Rules base
  This step consists of mapping the fuzzy values to the predefined IF/THEN rules and then combining them to get the fuzzy value of the quality of link received signal (QLRS) as the output value. Based on the fuzzy values of mobility factor and the RSS factor, the receiver uses the IF/ THEN rules defined in Tables I to calculate linguistic values of QLRS. The linguistic values of the QLRS are Very good, Good, Medium, Bad, Very Bad, Not acceptable.

- Defuzzification
  Defuzzification is the process of converting the output fuzzy value to numerical value based on output membership function and corresponding membership degrees. The fuzzy membership function of QLRS is defined in Fig. 4.

There are various methods used for defuzzifying the fuzzy result. In this work, we have used a weighted average method to calculate the numerical value of $QLRS$ noted $NQLRS$ as follows:

$$NQLRS = \frac{\sum x.\mu_{QLRSF}}{\sum \mu_{QLRSF}} \tag{16}$$

where μ_{QLRSF} is a degree corresponding to membership function. represents the corresponding percentage of each value obtained of fuzzy output variable QLRS. The vehicle having a maximum value of NQLRS will have a better chance to be relay.

TABLE I. FUZZY RULES

	IF			THEN
Rules	Mobility	RSS	Moving direction	QLRS
R1	Slow	Good	Towards	Very good
R2	Medium	Good	Towards	Good
R3	Fast	Good	Towards	Medium
R4	Slow	Medium	Towards	Good
R5	Medium	Medium	Towards	Medium
R6	Fast	Medium	Towards	Low
R7	Slow	Bad	Towards	Low
R8	Medium	Bad	Towards	Very Low
R9	Fast	Bad	Towards	Not acceptable
R10	Slow	Good	Away	Good
R11	Medium	Good	Away	Medium
R12	Fast	Good	Away	Low
R13	Slow	Medium	Away	Medium
R14	Medium	Medium	Away	Low
R15	Fast	Medium	Away	Very low
R16	Slow	Bad	Away	Very Low
R17	Medium	Bad	Away	Not acceptable
R18	Fast	Bad	Away	Not acceptable

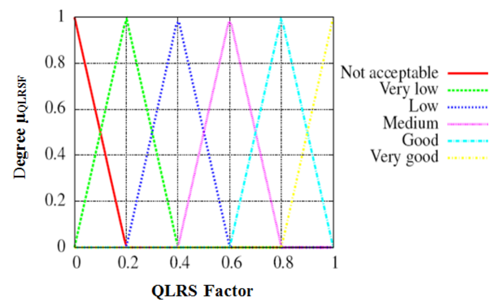

Fig. 4. Quality of link received signal membership function

D. Relay Selection Scheme

There are three main types of VANET routing protocols: topology-based routing, position-based forwarding, and contention-based forwarding [10], [19]. Many recent works [20], [21], [22] demonstrate that contention-based forwarding (CBF) approach is preferable in highly dynamic vehicular environments. In this paper, the selection of next hop is performed by means of contention, by improving the CBF approach.

Our relay selection scheme is an enhancement of modified contention-based forwarding approach in [10], the relay should be the node that has the most stable and the lowest fading link with the source of the message (RSU or previous relay). Furthermore, we are also interested in the received signal strength of message which lies in its better consistency compared to the relative speed between source vehicle and receiver.

Note Ls the link stability function which depends to effective link operation duration ELOD according to the expression :

$$Ls = 1 - exp\left(\frac{-ELOD}{\lambda}\right) \tag{17}$$

where λ is a constant that defines the rate at which the function is rising.

In the equation 17 proposed in [10], we have replaced link expiration time (Let) with ELOD in order to take into consideration the impact of mobility and fading on the link stability. The result of this function Ls is used to fixed the waiting time of each vehicle contending to be relay.

Considering ELOD as a routing parameter, the multi-hop communication will be performed through the most stable route. Consequently, the network performances will be enhanced. However, routing data packets via a route which contains an important number of hops in the ad hoc network may experience large medium access contention, interference, congestion, and packet collisions, because of shared channel among neighboring nodes. Therefore, it will be important to add another metric alongside link stability in the relay selection, in order to select the most stable route with the minimum number of hops. For this purpose, we have combined the link stability function Ls with another metric proposed in [10], named Progress feature (Pf) which allows according to the authors to select the shortest path in term of hops. The expression of PF is :

$$PF = \frac{\cos(\theta_i - \theta_j) \times d_{ij}}{R} \tag{18}$$

where d_{ij} is the distance between vehicle i (sender), and vehicle j (current receiver), and R is the transmission range of vehicles. θ_i and θ_j are respectively the direction angles of vehicles. North axis is used by vehicles as the reference for the direction angle.

The two relay selection metrics are combined in the global function F using weighted mean. The function F is defined as follows :

$$F = k \times Ls + (1-k) \times PF \tag{19}$$

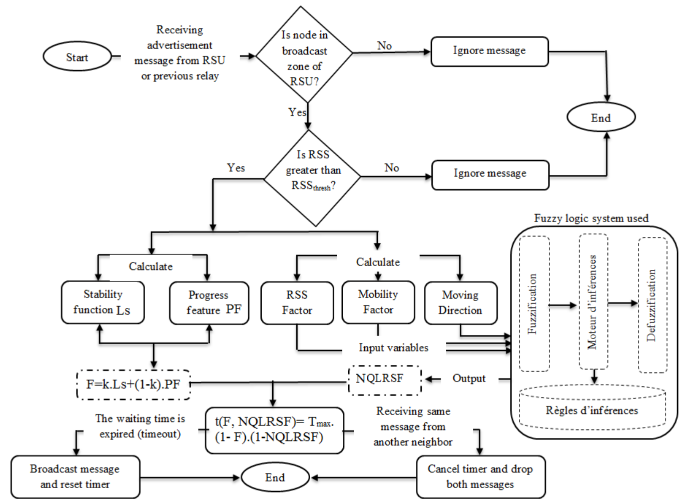

Fig. 5. Flowchart of proposed relay selection scheme

where k may be selected in $\left[\frac{1}{2}, 1\right]$ to give more weight for Ls than PF. That means the forwarding metric with higher weighting factor which is link stability has more impact on the contention based forwarding process. For the contention over link stability and furthest neighbor,the waiting timer is:

$$t(F) = T_{max} \times (1 - F) \tag{20}$$

where T_{max} is a maximum forwarding time.

Another parameter which is not less important than the first is taken into account in our relay selection scheme, it is the factor of the quality of link received signal calculated according to the mobility and RSS using the fuzzy system (see the previous section). In order to consider the quality of link received signal in the relay selection, we reform our definition of equation 20 as follows:

$$t(F, NQLRS) = T_{max} \times (1 - F) \times (1 - NQLRS) \tag{21}$$

where $NQLRS$ is a numerical value of $QLRS$ calculated using fuzzy system, and T_{max} is the maximum time that the contending node waits before rebroadcasting.

The Fig. 5 presents a flowchart of a proposed relay selection scheme based on CBF and FLS.

E. Route to RSU Descovery

The process of route discovery is similar to that proposed in [11]. In this work, we have adopted a hybrid approach which combines the proactive and reactive approaches, in order to profit the advantages of each one of them. During the discovery, the proactive approach reduces the delay and increases the overhead due to the periodic broadcasting of control message; however, the reactive approach generates more delay and minimizes the overhead because the route discovery is executed only on demand. The illustration of the used hybrid approach is given to Fig. 6.

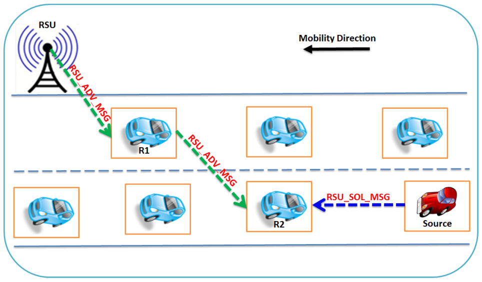

Fig. 6. Hybrid Route Discovery Approach

F. Handover Process

Handover is the process required to transfer the network connectivity of a vehicle from one RSU to another. Due to the high speed of vehicles, frequent disconnections in the network may happen. Connections should be seamlessly handed over to the next RSU before the current connection terminates. The more stables routes are always selected by vehicles to establish the connection over. In order to keep the connection, when the critical time is reached, vehicles must look up the routing table, to find the most stable route available to the next RSU, and start to transfer connection to that. The critical time (T_c), means at what time vehicles decide that the current route is about to expire and the time has come to start the process of handover. It is defined as the effective route operation duration subtracted by the delay T_d experienced by the last packet which has arrived along the route [10]. The expression of critical time is as follows :

$$T_c = EROD - T_d \tag{22}$$

Here we have replaced route expiration time (RET) used in [9] with $EROD$. By using the latest arrived packet to calculate T_c, the scheme is adaptive to changing network conditions and the vehicle will correctly take action in a timely manner.

IV. Simulation and Results

In this section, we discussed the performances of our proposed approach. To validate the proposed approach, we have simulated it and compare it with two approaches developed recently, in [10] MBRP (Mobility Based Routing Protocol), which based only on mobility vehicles parameters to measure link stability and M-AODV+ [6]. The proposed approach is noted MFBRP (Mobility and Fading Based Routing Protocol). We have performed some simulations in order to evaluate our proposed approach in term of throughput, the end to end packet delay and overhead by varying the maximum speed of vehicles and the number of vehicles on the road.

A. Simulation Parameters

In the current paper, we have based on the same simulation environment in the paper [11]. As illustrated in Fig. 7, our scenario is a highway of 8Km with two lanes, using simulators NS2 [24], MOVE [25], and SUMO [26]. All vehicles move from the one end of the highway to other end in the same direction and 10 vehicles are selected randomly to send CBR data at rate 20 packets/s to a node that is part of the wired network and is connected to all the base stations which are

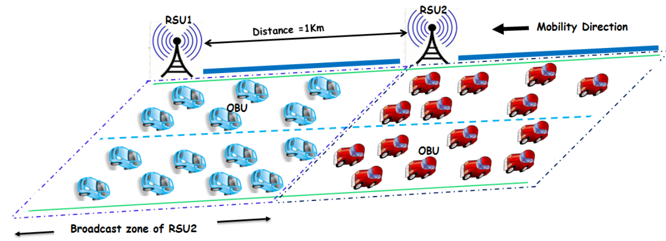

Fig. 7. Sample of our VANET scenario

TABLE II. Network and Mobility Parameters in the Simulation[11]

Paramtre	Value
Mobility model	Highway
Highway length	8km
Number of lanes	2
Maximum speed	10, 20, 30, 40 m/s
Number of vehicles	100, 150, 200, 250
Number of RSUs	8
Distance between RSUs	1000m
Simulation time	460s
Pause time	100s
Channel	Channel/WirelessChannel
Propagation model	Nagakami (m=3)
Network Interface	Phy/WirelessPhyExt
MAC	Mac802_11Ext
Interface queue	QueueDropTailPriQueue
Antenna Type	AntennaOmniAntenna
Interface queue	20
Transmission range	300 m
Routing protocols	M-AODV+ [6], MBRP [?] and MFBRP
Addressing type	Hierarchical
Traffic type	CBR
Packet sending interval	0.05 s
Packet size	512 bytes
New parameters	$k = 0.8$, $\lambda = EROD/2$ [27]
T_{max}	0,00375s [27]

connected to the wired network. To simulate protocols we have scheduled RSU to broadcast the advertisement message every 5s in the predefined broadcast geographic zone which has been considered to be a circle with a radius of 1000m, and the message is broadcasted in the opposite movement of nodes. The TABLES II gives a summary of all simulation environment parameters.

M-AODV+ [6] is used in hybrid gateway discovery, its advertisement interval is fixed to 5s and its advertisement zone is set to 3 hops, this means that an advertisement message will be only broadcast 3 times in the network, and nodes located further than 3 hops from a specific node have to send a route request message in order to find a route to that specific node.

B. Simulation Result

In this section, we present the analyses of the performance of our approach $MBFRP$ in its both case (with and without RSS) in contrast with routing protocol proposed in [9] $MBRP$ and $M-AODV+$.

1) Varying number of vehicles in the network: First, we compare the performance of the routing protocols by changing

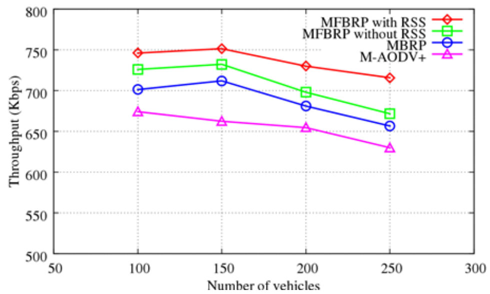

Fig. 8. Throughput comparison under different number of vehicles

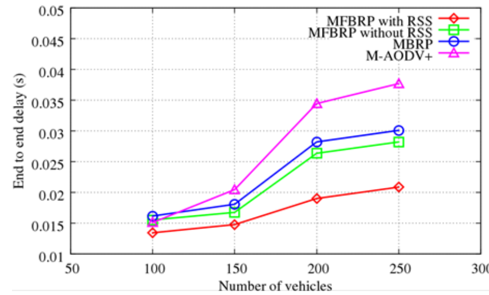

Fig. 9. Average end to end delay comparison under different number of vehicles

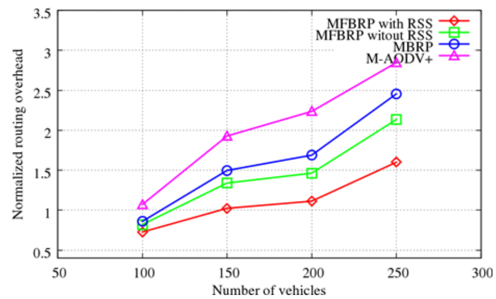

Fig. 10. Normalized overhead routing comparison under different number of vehicles

the number of nodes in the network. The maximum speed of vehicles is fixed to 30m/s and the number of vehicular sources is fixed to 10 vehicles.

The simulation results for network throughput, average end-to-end delay and normalized routing control overhead, are shown in Fig. 8, Fig. 9 and Fig. 10 respectively. From the figures, it can be seen that while the network performance for all routing protocols decreased with the increased number of vehicles on the road. The performance degradation is due to the increased interference and congestion when the number of vehicles increases. As it is shown in the figures, the protocol MBRP outperforms M-AODV+. The reason behind this is that the former uses stability metric to select the most stable route, however, the later bases exclusively on the number of hops to choose a route and due to a large number of vehicles, the alternative wired communication overloads wired links between RSUs. We can see also, that our enhanced approach MFBRP has better performances in terms of throughput, average end-to-end delay and control overhead in the contrast of protocol MBRP. This is due to the considering the impact of fading statistics on the link stability because the fading channel introduces fast topology changes as well as mobility. ELOD and progress feature metrics using in MFBRP, makes the routing protocol to choose most stable and shortest route, to reduce network failure, increase network throughput and decrease end-to-end delay. As shown in the figures, MFBRP with RSS improves significantly network performance in contrast with MFBRP without RSS, this is because the former improves relay selection by considering the quality of received signal which is an important metric of quality of services. This metric leads the protocol to make able vehicles choose strongest routes, thus the packets will be arrived at the destination with enough reception power in order to be decodable. Consequently, the network performances, especially in term of packet loss, have been enhanced.

2) Varying maximum speed: We fixed the number of nodes at 200 vehicles and the number of vehicular sources at 10 sources, to evaluate the performance of the routing protocols with increasing maximum speed.

Fig. 11 illustrates the network throughput, while Fig. 12 shows the average end-to-end delay for the routing protocols and Fig. 13 depicts the normalized overhead routing with varying maximum speed. For all of the routing protocols, performances decrease with increasing vehicle mobility. The MFBRP always outperforms routing protocol MBRP and M-AODV+. The routing protocol M-AODV+ has the worst performance, although the changes that have been to support communication in VANETs. This is because M-AODV+ considers only hop count metric as main route selection parameters. The routing protocol MBRP has the good performance in contrast of M-AODV+. However, it is less efficient than MFBRP, which is because MBRP selects paths composed of links with longer lifetimes, but the paths might include more fading. The fading increases packets loss in the network and causes frequent topology change which will increase the cost in term of packet loss and control overhead routing, consequently, this will affect the network performances. As shown in the figures, the MFBRP with RSS has significant improvement of network performance in contrast with MFBRP without RSS. This is due that both approaches take account of link reliability and hop-count, but in addition to these both metrics, MFBRP with RSS incorporates an important route selection parameter of Quality of Service in mobile ad hoc network which is the quality of received signal. The reason behind this enhancement is because of the selective processing of signals. Only received signals which have RSS values exceed fixed thresholds, will be treated at the routing layer, this improves significantly the network performance especially in term of throughput and end to end delay. Note in our approach, we assume that the vehicles do not move during the interval in which the channel statistics are predicted, which might introduce some prediction errors and reduce the network performance, especially when the vehicle movement is high.

V. Conclusion and Future Works

VANET networks will play an important role in the future, and communication with road infrastructure needs to be covered to provide specific services such as Internet access. In this paper, we proposed an improving relay selection mechanism by considering two main metrics of quality of service which are link stability and quality of received signal in order to

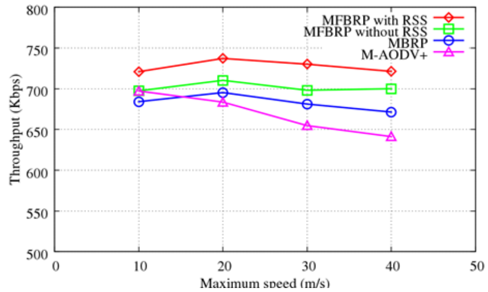

Fig. 11. Throughput comparison under different maximum speed

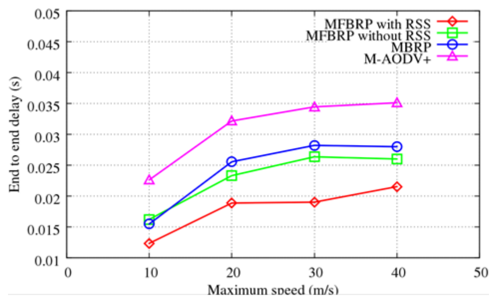

Fig. 12. Average end to end delay comparison under different maximum speed

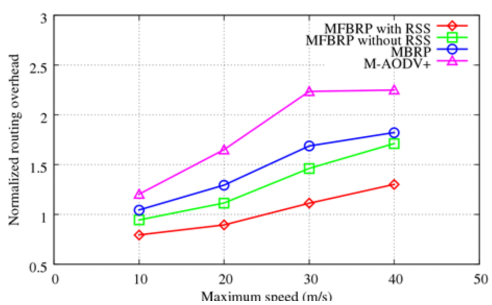

Fig. 13. Normalized overhead routing comparison under different maximum speed

select most stable and robust routes from vehicles to RSUs. Link stability is measured basing not only on the parameters of mobility but also on the effect of channel fading. This results in better performance and helps to maintain the good quality of the network. Simulation results show that our enhancing relay selection scheme achieves better performance than routing protocol MBRP and M-AODV+ over a range of network performance measures.

As the perspectives of the presented work, we will evaluate our approach in more realistic scenarios, especially in the urban area with high vehicle density and buildings. Even if IEEE 802.11p is a powerful and reliable protocol in VANET communications, there are still several issues which need to study IEEE 802.11p exhaustively in the context of V2V and V2I such as channel access, channel interferences, quality of service requirements, multichannel operation, exposed and hidden node effects, etc. We think in the future, to improve IEEE 802.11p to provide entertainment applications especially Internet access.

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An Efficient Routing Protocol in Mobile Ad-hoc Networks by using Artificial Immune System

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***Abstract*—Characteristics of the mobile ad-hoc networks such as nodes high mobility and limited energy are regarded as the routing challenges in these networks. OLSR protocol is one of the routing protocols in mobile ad hoc network that selects the shortest route between source and destination through Dijkstra's algorithm. However, OLSR suffers from a major problem. It does not consider parameters such as nodes' energy level and links length in its route processing. This paper employs the artificial immune system (AIS) to enhance efficiency of OLSR routing protocol. The proposed algorithm, called AIS-OLSR, considers hop count, remaining energy in the intermediate nodes, and distance among node, which is realized by negative selection and ClonalG algorithms of AIS. Widespread packet - level simulation in ns-2 environment, shows that AIS-OLSR outperforms OLSR and EA-OLSR in terms of packet delivery ratio, throughput, end-end delay and lifetime.**

Keywords—AIS-OLSR; Routing protocol; Mobile ad hoc network; AIS

I. Introduction

MANET is a mobile ad hoc network, temporary and instantaneous networks that develops for special purpose. Indeed, wireless networks are collection of wireless mobile nodes which are infrastructure less, autonomous and without any centralized management networks. Therefore, nodes in this type of network are responsible for dynamically discovering each other. Based on nature of dynamic, the network topology of this type of network change continuously. Because manet are mobile, connections changing are unpredictable. The biggest challenge of this kind of network is faced with, routing packet efficient till reach to destination without creation overhead. So, must be proposed some methods for routing that can route with overhead less. Several routing algorithms are presented by MANET networks, which each of them have features, advantages and disadvantages.

There are various methods of classifying routing protocols in mobile ad-hoc networks; however, most of them depend on routing strategy and network structure. In general, there are two types of routing protocols: first, is table-driven or proactive routing in which protocols try to get comprehensive, updated information of each node of network. In other word, these protocols save routes' information even they are not using. Therefore, each node requires one or more tables to maintain routing information. The second type is on demand or reactive. These types of protocols create and find a route in terms of supply with overflow transferring of request packets, once source tries to send a message. [1]. Optimized link state routing (OLSR) protocol is a table-driven routing protocol in mobile ad hoc network routing [2], discussed in many studies. OLSR protocol works based on Dijkstra's algorithm which, in turn, determines the shortest (but not necessarily most accurate) route based on hop counts. The shortest route might have a larger delay or its nodes might have congestion and, then, the data packets are dropped once reaching to them. High speed of some nodes in short routes might also lead to a sooner failure of the routes. Therefore, route selection in this protocol is controlled by a large number of variables [3]. In this work, an attempt is made to improve OLSR protocol using artificial immune system for optimum routing of the mobile ad hoc networks. To improve routing process, parameters including remaining energy in the route intermediate nodes, hop counts, and distance between the intermediate nodes have been applied. This paper is organized as follows: In second Section, OLSR protocol in mobile ad hoc networks is introduced. Section 3 introduces the artificial immune system. Section 4 is allocated to introducing works carried out on artificial immune system. In section 5, the proposed method is discussed. Section 6 evaluated the efficiency of the proposed method. Finally, section 7 brings the concluding remarks.

II. OLSR Routing Protocol

As a proactive protocol, OLSR is a routing protocol presented by mobile ad hoc networking (MANET) in the internet engineering task force (IETF) for mobile ad hoc network [4, 5 and 6]. The network nodes alternatively exchange topology information to each other, so the optimum route between two nodes is constantly available. OLSR is also a link state protocol. The difference between the optimization performed in this protocol as compared to that of other link establishes in the creation of MPR concept. Within this protocol, the network nodes are required to select a bunch of their neighbors as the MPR group. The group is needed to be selected in a way that all nodes have a two hop distance with their selector node. A given node (for example node N) which is selected as the MPR node, alternatively transmits the information to network from its selector node. These alternative messages are delivered and processed by all neighbors of the node N, but only MPR neighbors of node N resend them. Indeed, this mechanism not only reduces the network control overload, but also introduces a limited number of links to the network nodes [7, 8, 9 and 10]. As the first step, OLSR recognizes its neighbors through sending Hello packets to the neighbors around each node. Then, using the information obtained, it creates a table indicating the relationship between the nodes with the neighbors. Next, the nodes will transmit their information with their number in a TC packet to the neighboring nodes. However, TC packets transmission is performed using the MPR nodes. In this way, all nodes presented in the network are aware about the existing information and their connection with other nodes. This information are stored in a table for each node. As the next step, each node must select the optimum route for the neighboring nodes using the collected information. The route selection process is carried out based on the least hop counts through Dijkstra's algorithm. After this step, each node is provided with a routing table containing the optimum routes to neighboring nodes. In this case, network is stable [11, 12, 13, 14 and 15]. Once switching nodes location, the abovementioned process is repeated and the tables are updated.

III. Artificial Immune System

The artificial immune systems are designed based on the available knowledge functions of the immune system in vertebrates. Generally, the artificial immune systems are algorithms inspired by biology. These are computer algorithms where their principles and characteristics are defined based upon studying the adaptive properties a, resistance of the biological samples as well. The artificial immune system is a pattern of machine learning .Machine learning is the computer ability to perform a task through experience or the data learned.Any substance resulting in the body immune reaction is called as antigen. The immune reaction in the body is performed by secreting some proteins called as antibodies [16].

The natural immune system involves various levels. The first level prevents entering the outsider creatures or antigen through the skin. In the next level, the body is equipped with an innate immune system which generally copes with outsiders. The immune response at this level is the same against all antigens. The acquired immunity is the next level, with a customized coping method for any given antigen. Antigen is recognized by the white blood cells known as lymphocytes [17]. The algorithms designed for artificial immune system mainly model the acquired mechanism; apply in solving a wide range of computer problems. The artificial immune systems designed algorithms can be categorized into several groups: negative selection algorithm, Clonal selection algorithm, immune networks algorithm, and theory of danger [18 and 19]. The main idea of the Clonal selection method is to multiply only the cells whose antibodies are able to recognize the antigens [20, 21 and 22]. For negative selection algorithm, this idea is to produce a number of detectors and apply them for a new data categorization in the form of insider and outsider. In artificial immune systems, creation of a stable memory structure to tolerate antigens' further attacks is considered as the main idea [23 and 24]. In other words, the immune system ability to respond again to the same antigen may increase following by immune system reaction to a stranger, outsider antigen. The main difference between danger theory and the classic view is that in danger theory the human immune system does not respond to all insider cells, rather responds merely to those dangerous insiders [25].

IV. Related Works

In [26] the balancing of load between the mesh routers is provided by using Optimized Link State Routing protocol (OLSR) with Expected Transmission count (ETX) i.e. OLSR-ETX. They modified the OLSR-ETX to prop up the wired-cum-wireless WMN. The modified new OLSR-ETX routing protocol is named as Wired-cum-Wireless WMN OLSRETX (W3-OLSR-ETX). Results show that W3-OLSR-ETX is better than AODV.

One of the key factors of the OLSR routing protocol is the MPR selection algorithm, which is based only on the reachability of each neighbor, not taking into consideration how they are moving. As a result, the selected MPR set may be unstable. One way to improve the stability of the MPR set is through spatial mobility metrics that are able to promptly monitor the degree of movement correlation between a node and its neighbors. Mr. cavalcanti showed that current metrics have limitations on capturing the spatial correlation in the various states of collective motion. Through an enhanced spatial mobility metric, they propose a MPR selection algorithm, which was integrated into a new mobility-aware OLSR protocol. they proposed a mobility-aware adaptive OLSR routing protocol, which is based on a new algorithm for MPR selection. The original MPR algorithm is based only on the number of reachable neighbors (a density metric) for defining the MPR set, not taking into account how nodes are moving. In contrast, the proposed solution adds a spatial mobility metric called Improved and Smoothed Degree of Spatial Dependence (ISDSD), so that the neighbors that have both a high reachability but also a high spatial movement correlation is selected. As a result, the selected MPR set tends to remain unchanged for a longer time, resulting in greater stability of the routes, which makes the protocol more efficient. The new technique provided a performance gain in terms of packet delivery ratio and end-to-end delay, besides presenting fewer out of order packets [27]. Chen et al, proposed a high-throughput routing protocol for wireless sensor networks through extending the OLSR protocol with opportunistic routing and network coding. Opportunistic routing and network coding leverages the receiver and transmitter diversity. Opportunistic routing is able to leverage the wireless channel's characteristic of broadcasting and opportunistically deliver data through multiple routing paths. In addition, OLSR can provide the information about network topologies and other parameters that opportunistic routing needs but cannot gain by itself. The results show that the proposed routing protocol can achieve much higher throughput than the OLSR protocol [28]. Ouacha et al. [29] described another link-based OLSR adaptation. The proposed method considers that nodes periodically exchange their positions, so that they can estimate the direction of motion and the remaining time that the node remains as a neighbor. The RWP model was the only employed in the modeling and evaluation of the proposed solution. Tamil selvi [30] proposed the secured OLSR protocol for MANET. The author presented the MPR selection based on BEST MPR selection, which reduced the number of TC message generated. Hence, the routing overhead is reduced in the network. Threshold cryptography was applied to the selected MPR nodes to provide security. The secret key of the source is split into number of shares based on count of MPR nodes in the network. The destination can pull through the TC message only if threshold numbers of shares are provided. The main disadvantage of this method was when threshold number of shares was compromised. This can be overcome by the share update method mechanism. This is proposed in the next section. In paper [31] they proposed new routing algorithm named Energy Saver Path Routing using Optimized Link State Routing (ESPR-OLSR) protocol because routing in MANET is serious issue because network topology which is changeable due to nodes mobility. Routing algorithm uses specific metrics to determine the optimum path between senders and receivers such as shortest minimum cost and minimum total power transmission etc. Many routing protocols have been proposed in last few years. Especially energy efficient routing is most important because all the nodes are limited battery power. Failure of one node may affect the entire networks. If a node runs out of energy, the probability of network partitioning will be increased. Since every mobile node has, limited power is become one of the main threats to the lifetime of the MANET. So routing in MANET should be in such a way that it will use the remaining battery power in an efficient way to increase the lifetime of the node network. Cervera et al. [32] presented Disjoint Multipath OLSR (DM−OLSR) function to address the following problems: 1) a partial view of the network topology, 2) flooding disruption attacks, and 3) load balancing in OLSR based networks. In DM−OLSR, the nodes select their MPRs with additional coverage during the topology discovery phase and compute, when possible, t+1 strictly disjoint paths during the route computation phase. To increase the chances of computing multiple disjoint paths from a source node to a destination node, during the topology discovery phase, the node select their MPR set with additional coverage and with the TCR parameter as zero. DM−OLSR improves the network topology view of the system nodes, and handles eventual flooding disruption attacks to the multipath construction mechanism. H¨arri et al. [33] defined the concept of Kinetic Multipoint Relaying (KMPR) where, instead of a node being periodically added to the MPR set, it is added for a period of time, which is estimated from the nodes' velocities. The authors evaluated the KMPR algorithm in scenarios generated by the RWP model. The adapted OLSR protocol showed a reduction in the number of broadcast retransmissions and end-to-end delay. The main limitations of that work are three: (1) assumption of constant velocity during the time the nodes remain neighbors; (2) disregarding the node pause time in modeling and evaluation of the algorithm; and (3) only the RWP was used. Mr Zhihao Guo and et al [34], presented Energy Aware OLSR (OLSR_EA). Their Energy Aware OLSR labeled as OLSR_EA measures and predicts per-interval energy consumptions using the well-known Auto-Regressive Integrated Moving Average time series method. They develop a composite energy cost, by considering transmission power consumption and residual energy of each node, and use this composite energy index as the routing metric. OLSR-EA is able to prolong network lifetime and save total energy in MANET scenarios with a variety of traffic loads, node mobilities, and both homogeneous and heterogeneous power consumptions among the nodes. Cervera et al. [35] presented taxonomy of flooding disruption attacks that affect the topology map acquisition process in Hierarchical OLSR (HOLSR) network, and preventive mechanisms to mitigate the effect of this kind of attack. According to their work, it is possible to mitigate the effect of flooding disruption attack by selecting MPR set with additional coverage or generating control traffic with redundant information.

V. PROPOSED ROUTING ALGORITHM: AIS-OLSR

Among the most important features in selecting a suitable route, one can name three parameters including route hop counts, remaining energy in the intermediate nodes, and the distance among nodes. Hop count is inversely related to route value; the higher is the hop count, the more probable is the route to be unsuitable. The remaining energy in the intermediate nodes is directly related to route value; the higher the route energy, it is wiser to take that route as once the intermediate nodes energy is depleted, the route will be dropped and transmission will be interrupted. Besides, selecting the routes with higher energy content leads to energy consumption unified distribution in the mobile ad hoc nodes, considered as a critical issue in mobile ad hoc networks constraining energy problem. The third parameter is the distance between source and destination nodes in the mobile ad hoc networks, which contributes finding the shortest route in terms of length between two source and destination nodes through a routing process. As previously mentioned on performance of OLSR protocol, to detect their neighbors, the nodes initially transmit a HELLO message to neighbors, store the delivered information in a table and distribute TC messages in the network using MPR points. Thus, all the networks nodes are aware about the existing connections and connection details to each node. The related information is stored in a table for each node.

A. Composition of AIS-OLSR

As previously mentioned, a large number of algorithms have been purposed for artificial immune systems each of which applied in various domains. In the present work, negative selection and Clonal G algorithms were applied.

B. Using Negative Selection Algorithm

Negative Selection algorithm creates based on T cells. T cells distinguish insider and outsider cells. It has two stages, the first one, which is learning stage, is like teamwork, and ends; it refers cells that identify and remove insiders. Then, stage two, which is test or implementation phase, compares antigens with remaining T cells of first stage, and removes if identified. The major function of this algorithm is identifying pattern.

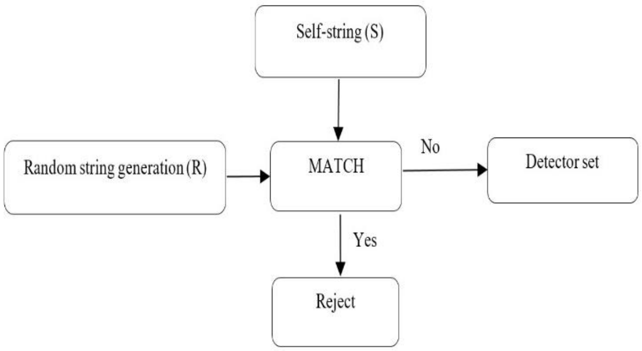

Fig. 1. Negative Selection algorithm learning

In this regard, these algorithms are used to create a set of antibodies selecting the optimum route among them as follows:

Algorithm 2: Negative Selection Algorithm

```
Input:  A  S ⊂ U ("self-set"); a set M ⊂ U ("monitor set"); an integer n
Output:  For each element m ∈ M, either "self" or "non-self"
Procedure  Training phase
{
  d ← empty set
     while |D|< n do
  d ← random detector
}
```

Fig. 2. Pseudo-code Negative Selection algorithm

The source node in the standard OLSR through reviewing its routing table and the routes to the destination selects that route with minimum hop counts using the Dijkstra's algorithm. However, the process taken in the present work is as follows: The source node picks the routes, from routing table, leading to destination, but to select the optimum route, first, it applies the negative selection algorithm. In this algorithm, the antibodies are the routes reaching to destination in the routing table, while antigen is the mechanism, which tests two conditions including routes' energy and hop counts. Each time, through segregation phase, one antibody (route) is compared to one antigen until comparing all antibodies. Then, the worst routes in terms of energy and hop counts are rejected. During comparing antigen with antibodies (routes) being rejected or kept, each antibody (route) is compared to an antigen. If the given antibody (route) energy content is less than the threshold energy of the intermediate nodes, it is rejected; otherwise, it is entered to an array being analyzed in terms of hop counts.

This threshold is calculated by the formula 1,

$$\frac{The\ energy\ of\ node\ i}{Maximum\ initial\ energy\ of\ the\ nodes} \qquad (1)$$

Where in Equation (1), (i) is the intermediate nodes of each route. The number of arrays is decided based upon the number of antibodies (routes) intended to be in the group. Each route passing through the previous step enters to the array and the array is arranged based on the total hops until the destination. Then, by entering the next route, it is compared to the array. If route hop counts is greater than that of the routes in the array it will be rejected, otherwise it may replace a route with maximum hop count (and that route is rejected from the array) and the array is rearranged. This process is followed until all the routes are tested and those remained in the array enter to the detection set. Therefore, according to the negative selection algorithm, if the given antibody (route) matches with conditions (energy of the intermediate node is low and hop counts is high), the route will be rejected; otherwise it is shifted to the next phase – detection set. Indeed, instead of separating the insiders from outsides, the better routes are separated from the worse ones and the better ones are selected as the members of detection set.

Algorithm 1: Pseudo-code comparing Antigen with Antibody

```
Input: Antigen (Route's)
Output: Array of Routes
Procedure  Comparing Antigen with Antibody
{
If  energy(node i) <  Threshold then
{
   Delete (Route i)
Else  if
{
Array    ← Route i
Array Sort  Order by  hop count
}
}
If  hop count (Route i)  <  hop count ( Array Route)  then
{
Delete (Route i)
Else if
Max (hop count)  ←  Route
}
}
```

Fig. 3. Pseudo-code comparing Antigen with Antibody

In the next phase, two other actions are needed to be followed: 1) If necessary, hyper-mutation is performed; and 2) the best antibody (optimum route) is selected and kept in the immune memory, which is done using the Clonal G algorithm in this work.

C. Using ClonalG algorithm

CLONALG algorithm, using its critical property, optimization, is introduced as the best approach in this area. The algorithm creates early cells, and selects colony on each antigen. Then, resulting antibodies will be used as initial memory cells in next iteration; the process retrieves until end condition, which is usually implementing determined replicas. Thereby, memory cells in each iteration can be created with higher affinity. Considering affinity plays a critical role in cells colonization. In fact, higher affinity causes greater proliferation and lower affinity will lead to less proliferation. On the other hand, mutation, which inversely relates with affinity, also plays a key role in this algorithm, namely higher affinity, less mutation.

CLONAL-G Algorithm

1. **Initialize:** Create a random population of individuals
2. **Antigenic Presentation:** For each antigenic pattern, do
   - 2.1. **Affinity Evaluation:** present antigen to each member of Population and determine affinity.
   - 2.2. **Clonal Selection and expansion:** Select n highest affinity Elements of population. Clone these with rates proportional to affinity.
   - 2.3. **Affinity maturation:** mutate all clones with rates inversely Proportional to affinity and add them to population.
   - 2.4. **Memory:** keep element of population with highest affinity to Antigen.
   - 2.5. **Meta-dynamics:** replace the m lowest affinity elements of Population with new ones.
3. **Cycle:** Repeat step 2 until stopping criterion is met.

Fig. 4. Pseudo-code CLONALG algorithm

TABLE. I. CORRESPONDENCE BETWEEN IMMUNE SYSTEM AND CLONALG ALGORITHM

Immune system	CLONAL-G
Antigen	Best routes in terms of energy and step
Antibody	Studying energy and step conditions
Affinity index	Proportion of total route nodes' energy to hop ınt
Mutation	Comparing routes in term of distance

Antigens, provided at this stage, are the very antigen set of former stage superior in terms of energy and steps comparing other antigens. Antibodies structure also studies energy status and route steps.

D. Affinity

Different studies refer antigen and antibody binding level as both distance and affinity [33]. The present research measures affinity by ratio of route nodes total energy to step numbers of all affinity routes; then, selects routes with the highest affinity. Therefore, routes with highest affinity will be selected and remained in later steps and other routes will be removed.

E. Mutation and colonization

Once algorithm identified routes with higher affinity, mutation will initiate, if needed. Mutation rate depends on affinity, meaning that if affinity is high, no mutation takes place and security memory saves the route so that source node selects this route in sending packets to destination. On other side, routes' close affinity causes mutation. In fact, routes are initially ordered based on the highest affinity in a set; next, N number of this set with higher affinity will be selected to mutate. Mutation, here, compares routes in term of another criterion namely distance criterion, and selects that route with the shortest distance between source and destination. Finally, solution will be selected from remaining routes at the last step. The best route is the one with the most energy and least distance. This optimized route places in memory, which will be introduced as the best route for data transfer (Fig.5). AIS-OLSR protocol performance to OLSR and EAOLSR protocol, which is an improved version of OLSR protocol in term of energy level, is presented using packet delivery rate, end-to-end delay, network throughput, and network lifetime.

```
For all Routes Calculate :

    Affinity= (Energy Route Nodes) / (hopcount)

  If   Affinity (Route_i)  >  Max Affinity then
    Self-Memory  ←  Route_i

   Else

     {
Mutation

      For  j=1 to N  do

        {
          Distance (Route_j)

          Self-Memory  ←  Minimum (Route_j)
        }
     }
```

Fig. 5. Pseudo-code Mutation and colonization

F. Implementation Issues

As earlier stated, OLSR basic protocol operates with the shortest hop count and uses Dijkstra's algorithm for routing. It is assumed that all nodes are equipped with a geographic positioning system (GPS) always knowing their coordinates. Through applying the proposed method in OLSR algorithm, three new fields including "geographical position", "distance", and "energy" are added to the HELLO message packet. Here, the geographical position field is used to measure the distance between nodes, while the distance field is used to transfer the distance between nodes in any jump to the intermediate node. Finally, the energy field indicates the amount of remaining energy.

Bits:	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
OLSR header:	Packet Length — Packet Sequence Number
Message:	Message Type — V time — Message Size
	Originator Address
	Time To Live — Hop Count — Message Sequence Number
	MESSAG
Message:	Message Type — V time — Message Size
	Originator Address
	Time To Live — Hop Count — Message Sequence Number
	MESSAG
Message:	Message Type — V time — Message Size
	Originator Address
	Energy — **Distance** — **Geographic**
	MESSAG

Fig. 6. New format of Message HELLO packet

Each node starting to transmit HELLO message, first puts zero value in the distance field, longitude and latitude values in the geographical positioning field, and its energy content value in the energy field then send to the neighboring nodes. Based on the delivered longitude and latitude values, the receiving node in turn calculates the distance using eq. 2 and sums it up to the value in distance field and keeps it in its table as distance. Then, it transmits this value, its geographical position, and its energy content in response to node relaying HELLO message. Therefore, after the HELLO message is distributed, all nodes are having a table in which detecting all their neighbors; identifying their distance to neighboring node and the energy content of the neighboring nodes:

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \qquad (2)$$

In Equation (2), (x1, y1) and (x2, y2) are the geographic positions of the node communicating the HELLO message, D is distance between source and destination node and the neighboring node, respectively. Then, each node sends its own and neighbors information in the form of a TC message including three distance, longitude and latitude, as well as energy fields, with hop count and number fields (which are in the main frame of the protocol) to the MPR points through which TC messages are distributed in the network. Once the TC messages are distributed, all network nodes will have a table consisting of all nodes information utilized in routing process. Through the standard OLSR protocol, only hop counts criterion is used for routing. However, in the method purposed in this work, two other criteria including energy and distance are also considered in the artificial immune system.

VI. Performance Evaluation

To show performance of the AIS-OLSR routing protocol in comparing with the standard version of OLSR and EOLSR protocol That is an improved version of the OLSR protocol in terms of energy, , some criteria including packet delivery rate, end to end delay, throughput, and Network life time were applied .

Simulation was carried out in a NS2 (network simulator 2) [32] environment and the artificial immune system was implemented using the C++ programming language.

TABLE. II. Simulation Parameters

Parameters	**Value**
Channel Type	Channel/Wireless channel
Publication Type	Two ray ground
Network Interface	Wireless Phy
Antenna	Omni Antenna
Simulation Area (m x m)	1000 X 1000
MAC layer	MAC/802.11
Traffic Type	CBR
Queue Type	Drop Tail
Number of nodes	100
Primary energy	10 Jules
Threshold	0.5 Jules
Time simulation	200 s

A. Packet delivery rate (PDR)

PDR equals the number of successfully delivered data packets delivered to destination nodes to the total number of transmitted data packets from the source node [37]. Thus, we can define PDR as shown in Equation (3).

$$PDR = \frac{Receive\ packets}{Sent\ packets} * 100 \qquad (3)$$

As shown in fig. 7, the protocol presented in this work (AIS-OLSR) involves more desired PDR than that of OLSR and EA-OLSR, due to selecting better and more optimized routes.

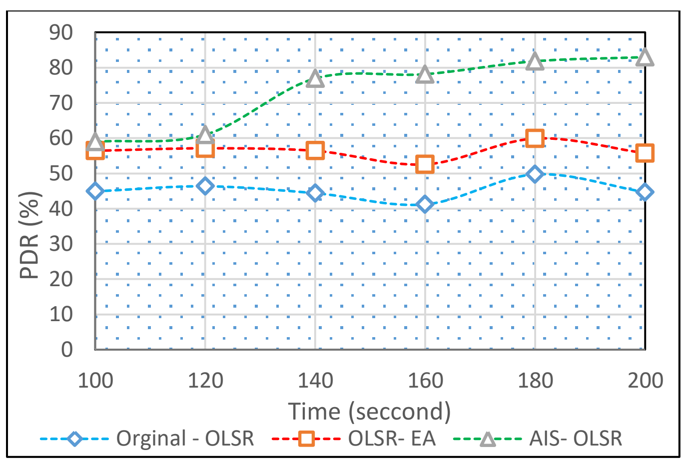

Fig. 7. PDR vs pause time

B. End to end delay

End to end delay sent by node (i) (source node) to packet j which is temporarily delivered to destination is as follows. Thus, we can define $End_{to_{end_{delay}}}$ as shown in Equation (4).

$$End_{to_{end_{delay}}} = Start_{time_{i,j}} - End\_time_{i,j} \quad (4)$$

Where, $Start_{time_{i,j}}$ is the delivery time of packet j from node i and $End\_time_{i,j}$ is delivery time of this packet by destination node. As shown in fig. 8, the proposed protocol AIS-OLSR end-to-end delay is less than that of the standard OLSR protocol and EA-OLSR as selecting the optimum routes in terms of energy, hop count, and distance.

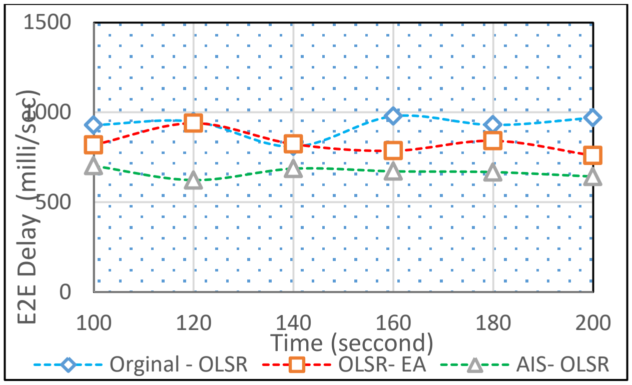

Fig. 8. End to End Delay

C. Throughput

Throughput is regarded as the best criterion to compare the efficiency of routing protocols, obtained from dividing the destination delivered data to the data delivery time. Criteria such as PDR and end-to-end delay are also engaged in throughput: the more these criteria are, the higher the throughput would be. Fig.9 presents throughput in OLSR, EA-OLSR and AIS-OLSR protocols. This increase in throughput value in AIS-OLSR to OLSR and EA-OLSR is attributed to selecting better routes and the increased PDR is related to the reduction in end-to-end delay. AIS-OLSR protocol successfully delivered more amounts of data in a shorter time since the optimum routes had been selected.

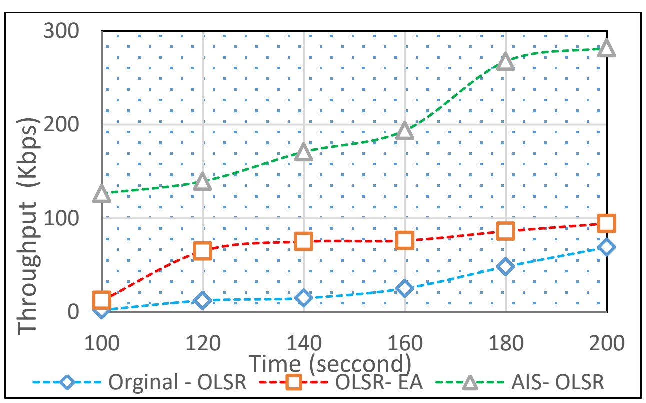

Fig. 9. Throughput vs pause time

D. Network Life Time

Node remaining energy is one of major issues in mobile ad-hoc networks presented here. As stated, consumed energy level directly influences network lifetime; therefore, network lifetime increases using high-energy routes. Fig. 10 shows that suggested protocol (AIS-OLSR) outperforms other two protocols in network lifetime indicating supremacy of this protocol in energy usage and increased network lifetime.

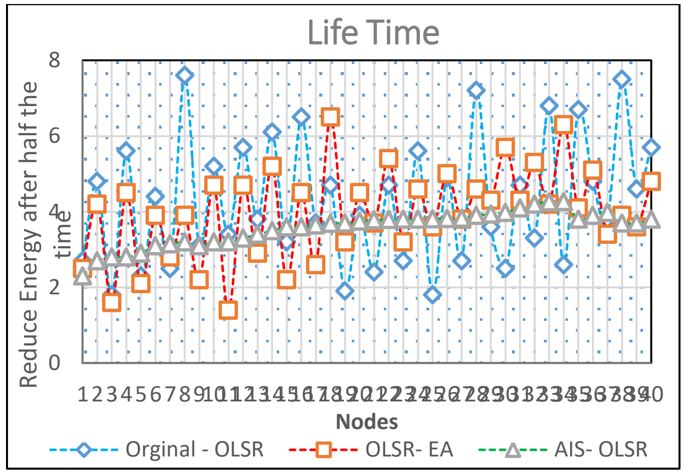

Fig. 10. Network life time vs ones

VII. Conclusion

In this paper, the OLSR protocol was applied to study selecting the optimum route among the available routes during mobile ad hoc networks routing process. Therefore, the artificial immune system was applied to select the best, optimum route. Three parameters including hop counts, intermediate nodes energy contents, and source and destination nodes distances were applied in this work to select the optimum route, whereas through the standard OLSR, only hop counts criterion is applied. The simulation results AIS-OLSR protocol indicated that artificial immune system could improve routing protocol efficiency in terms of end-to-end delay decrease, throughput increase, raising the number of delivered data packets and network lifetime increase.

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Mitigating Address Spoofing Attacks in Hybrid SDN

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***Abstract*—Address spoofing attacks like ARP spoofing and DDoS attacks are mostly launched in a networking environment to degrade the performance. These attacks sometimes break down the network services before the administrator comes to know about the attack condition. Software Defined Networking (SDN) has emerged as a novel network architecture in which date plane is isolated from the control plane. Control plane is implemented at a central device called controller. But, SDN paradigm is not commonly used due to some constraints like budget, limited skills to control SDN, the flexibility of traditional protocols. To get SDN benefits in a traditional network, a limited number of SDN devices can be deployed among legacy devices. This technique is called hybrid SDN. In this paper, we propose a new approach to automatically detect the attack condition and mitigate that attack in hybrid SDN. We represent the network topology in the form of a graph. A graph based traversal mechanism is adopted to indicate the location of the attacker. Simulation results show that our approach enhances the network efficiency and improves the network security**

Keywords—Communication system security; Network Security; ARP Spoofing Introduction

I. Introduction

Software Defined Network (SDN) is a new paradigm shift in a networking environment that brings a lot of new innovations and revolutions in traditional networking techniques. It aims to resolve the several limitations of the traditional networks by decoupling the control plane from the data plane. In SDN, network devices i.e., switches, routers have become simple forwarding devices which only implement the data plane logic [19]. The control or network intelligence is implemented in a centralized unit called controller. Different applications for routing, load balancing, network measurement etc. are implemented on the controller [1][2].

Although there are lots of benefits of SDN, yet it is not widely adopted by the organizations due to budget constraints, the effectiveness of traditional routing and some other reasons. An organization has to establish a new network from scratch to adopt SDN paradigm. Recently, a new network architecture is proposed that is based on a limited number of SDN switches deployed among legacy switches. This type of network is called Hybrid SDN. If an organization wants to update its traditional network to SDN, it needs to change the entire network devices to SDN-based devices, which requires a lot of money to buy new devices. In order to save this extra cost, a Hybrid SDN paradigm is adopted to take complete advantages of SDN [3][4].

In SDN network, security mechanisms are adopted to protect users from a different type of attacks. New kinds of attacks like (Link Flooding Attack) LFA [5] and other DDoS [6] attacks can be launched in the network through (Address Resolution Protocol) ARP Spoofing [7] or IP Spoofing method. ARP or IP Packets are usually used to know the MAC address or the IP address of the system in the network. These packets can be modified easily by an adversary party and the MAC address or the IP address can be changed to a particular host from the adversary party. Authors in [8-10] discuss the techniques to prevent these attacks in SDN. However, currently in hybrid SDN, no proper mechanism to deal with these types of attacks. These attacks further lead to Man-in-the-middle attack, eavesdropping, modification attack and masquerade attack.

In this paper, we propose an automatic ARP spoofing detection and mitigation mechanism for hybrid SDN. This new mechanism prevents the LFA, ARP Spoofing and DDoS attack in hybrid SDN. Our solution adds a separate module (server) in the network where ARP packets are received. Topology information of the whole network is collected at the proposed server and flows are installed on devices to get ARP traffic. Furthermore, ARP packets are analyzed for a possible attack in the hybrid SDN. In this new mechanism, SDN controller is protected from attackers by diverting unnecessary processing to the proposed server. Furthermore, a graph based traversal method is adopted to detect the proper location of the attacker. Our research contributions are

- We are considering a newly emerging network architecture called hybrid SDN.
- To the best of our knowledge, we are the first to deal with this problem in Hybrid SDN.
- For hybrid SDN, we identified the problem that ARP spoofing can poison the network topology. Due to these attacks, different types of applications running on the controller are badly influenced. Furthermore, it may

result in the form of entire network failure. We address this problem as follows.

- We automatically get the network topology information from legacy switches, SDN switches and also from DHCP server at proposed server.
- We construct a graph for the network topology having connectivity information of all users.
- We installed flow rules on the SDN switches and configure the legacy switches to forward ARP packets to the server.
- At the server, we analyze the ARP packets to detect the possible attack condition.

Rest of paper is organized as Section II presents the related work. Problem definition is explained in Section III. The proposed solution is described in Section IV. Implementation and performance evaluation is presented in Section V and Section VI concludes the paper.

II. Related Work

Masoud [9] describes two different mechanisms to handle ARP spoof attacks, one is SDN_Dynamic and the other is SDN_static. These two mechanisms are used to detect ARP spoof packets in the network but this scheme creates an overhead at the controller and can decrease the performance of the network. For example, in this case, if adversary party continuously launches an attack then controller analyze all the packets and this will increase the load of the controller and decreases the performance of the controller. In this situation, the controller cannot block malicious traffic at the switch. Figure 1 shows system design for this approach.

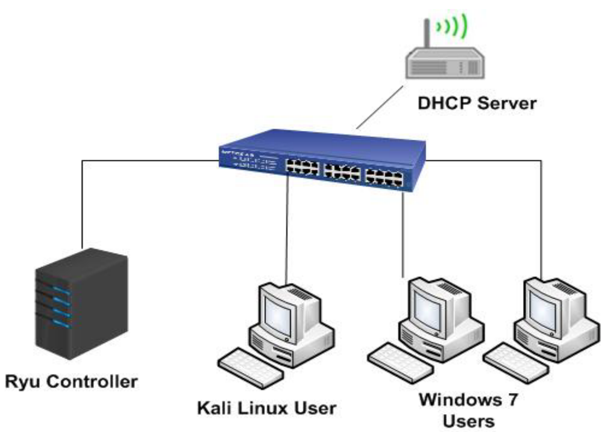

Fig. 1. System Design for [9]

Huan Ma et al. [18] in data centers ARP broadcast storm can be handled in the SDN environment by using SDN switches. Because for every packet received on the SDN switch, flow rule is checked if flow entry is not found then this packet is forwarded to the controller. In a traditional environment, ARP broadcast storm cannot be controlled and this creates a lot of traffic in the network and may become the cause of traffic congestion. Data centers consist of many VMs and multiple network domains. If a VM is moved from one network domain to another network domain then One of the VMs launches ARP packet for the moved machine then this creates ARP broadcast storm in the network and a lot of overhead. To prevent this overhead one can use SDN technology and can control this extra type of traffic from the controller [8] [13].

Roberto di Lallo [14] presents the features of SDN that ARP packets can be controlled through SDN switches in multiple subnets, limiting the ARP traffic at the edge switch of the subnets. The controller keeps the information of all the network devices and from this information, ARP request packet can be controlled at the edge of the network. For this purposes, controller installs the required flow rules at the switch. Controller also keeps track of the network devices in the table called CAT (Controller ARP Table). This table is updated time to time when new requests for the resources of the network arrived.

Fabian Schneider [15] describes how to handle ARP traffic in SDN. ARP traffic is a big problem in SDN environment if it is not controlled in a proper way. It may also be generated if network devices are not configured properly. This bulk of traffic created by ARP packets causes an unnecessary overhead on the network. This issue has been tackled by properly configuring CAT (Controller ARP Table) table and installing flow entries in the SDN switch properly.

Sezer et al. [22] discuss issues of performance, security, scalability and interoperability when deploying carrier grade network based on software defined networking. After analyzing performance vs programmability tradeoff in detail, the author in [22] concludes that hybrid SDN is suitable for old traditional networks. The scalability issues with respect to the communication overhead between the switches and controller, the communication between the controller in the multi-controller environment, maintenance of the backend database in controller analyzed and conclude with the suggestion of hybrid approach where SDN node may share some load to reduce communication and processing overhead of the SDN controller. Security issues in SDN investigated as the centralized controller and the switches may be attacked through DOS attack so the security model must be defined to secure the SDN controller and switches by using currently available security mechanism. The issue of interoperability reviewed in SDN deployment which is desirable, because the complete transition from traditional to SDN paradigm is not possible in most of the cases.it is suggested that the protocol and standard should be made for interoperability between the SDN and legacy devices.

Lei Wang [5] describe Link Flooding Attack is a new type of DDoS (Distributed Denial of Service) attack. In DDoS attack, legitimate or authorized user cannot gain access to the network resources. In this case, adversary party attacks the target server to cut down the resources. LFA is an advanced type of DDoS attack in which selected group of connectivity links to the server is under attack with a different type of malicious traffic. In this attack, the server cannot distinguish the malicious traffic from regular traffic. Due to this attack, the performance of the network and the server affected very badly and the legitimate user cannot gain the access to the server [16].

According to Michael [17] Man-in-the-Middle Attack against Open Daylight SDN Controller, exploit many vulnerabilities of the SDN Network. The author raised many security issues of the SDN environment and showed that controller is a single point failure of the network. The author performed an experiment of Man in a Middle attack by using ARP spoofing method. The author succeeded to launch an attack and intercepted the traffic between a client and the Open Daylight controller [20].

For the large scale SDN enterprises the unified virtual monitoring function (SuVMF) middlebox architecture is introduced in [21]. The objective of the SuVMF is to monitor traffic and resources of the large enterprise network to ensure the effective use and security of resources. SuVMF architecture composed of three main components namely Filtering and Common Processing (FCP) Module, Transformation and Adaptation (TA) Module, Basic Common Monitoring (BCM) and User Defined Monitoring (UM) Module as shown in Figure 2. Filtering and Common Processing Module is responsible for collecting network events, event mitigation function, packet and flow filtering, time stamping, anomaly traffic detection, host detection and other related functions. Transformation and Adaptation Module provides communication between remote managements and controllers by supporting OpenFlow and SNMP protocols. OpenFlow Statistics collections Proxy (OSP) is responsible for the collection of statistics from the OpenFlow switches and provides it to the controller. Detection and Mitigation Abnormality (DMA) component is responsible for the detection of abnormal behavior of different components in the network. The proposed middlebox architecture provides integrated services for the hybrid SDN network and reduces the load on the controller.

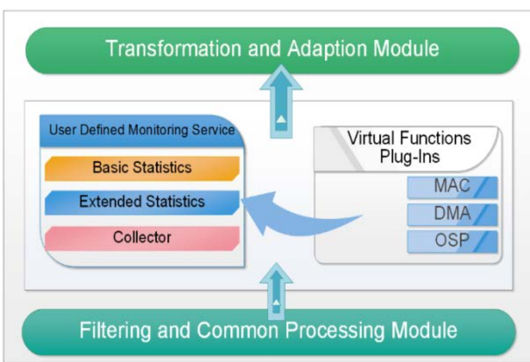

Fig. 2. SuVMF basic and User Defined Monitoring Functions

Ahmed et al. [10] describe different traditional network threats like ARP Spoof attack or Distributed Denial of Service attack can affect the whole network badly. In traditional networks, these kinds of threats cannot be eliminated completely due to lack of centralized control of the network. But there are third party tools to mitigate such threats. For example, Dynamic ARP Inspection (DAI) is a Cisco Device protocol and it can be used to check ARP spoofing packet but for this tool, the network must be configured with all cisco devices having same protocol. But there is also a chance of false positive attack that affects the network performance. The author presents the solutions for mitigating such attack by monitoring port level packets. But this solution is limited to the only single controller and for simple local Area Network (LAN).

From the above literature, it is clear that ARP spoofing and DDoS attacks have not been discussed in hybrid SDN. It is a big issue because, in a communication network, ARP protocol is mostly used to get IP/MAC information. Due to these attacks, packets may be traveled to an unauthorized node. Thus, security of the network is at risk as shown through some examples in Problem Statement. To mitigate these attacks in hybrid SDN, there are following challenges.

- Getting network topology information from legacy switches using customized mechanism
- Identification of legacy switches and their interfaces forming a hybrid SDN
- Getting ARP packets from legacy devices at controller and at proposed server need to be customized technique.
- Analysing the ARP packets for possible threats at proposed server.
- Identification of devices that are generating malicious traffic
- Blocking the malicious devices for further processing against controller

III. Problem Definition

SDN controller is the main component of the SDN network, due to his reason SDN controller becomes more vulnerable to several types of attacks. Most common type of attack is ARP spoofing attack in which malicious node sends ARP packets. Successful attacks can effectively poison the network topology information and a fundamental building block for core SDN components. With the poisoned network visibility, the upper layers services and application of SDN controller may be completely misconfigured and badly influenced. This situation leads to serious hijacking, denial of service attacks and network failure in some cases. Several SDN studies show that all current major SDN controllers (e.g., Floodlight, Open Daylight, Beacon, and POX) are affected by these attacks. if such fundamental network topology information is poisoned then all the dependent network services become immediately affected and causing catastrophic problems. For example, the routing services/apps inside the controller can be manipulated to incur a black hole route or man-in-the-middle attack.

Suppose there is an enterprise network for an organization as shown in Figure 3. There are four legacy switches l1, l2, l3, l4 and two SDN switches SDN switch A and SDN switch B. A controller is connected to these SDN switches. Eight users PC1-PC8 are connected to legacy switches as per requirement. An attacker's PC is connected to the network when an attack is launched.

Ideal Condition

In Ideal condition as shown in figure 3, PC1 with IP address 10.0.0.1 wants to communicate with PC 5 with IP address 10.0.0.6. PC1 does not have the MAC address of PC5. PC1 send the ARP packet to the legacy Switch and legacy switch broadcast this packet. This packet gets received at SDN switch A. SDN switch A checks the flow entries for received ARP packet. If it does not find the flow entry for that packet, then the packet is forwarded to the controller. The controller checks the packet and finds its path to the destination and generates the flow rules for this packet. Now packet moves according to flow entries installed on the corresponding switches and receives the destination MAC address.

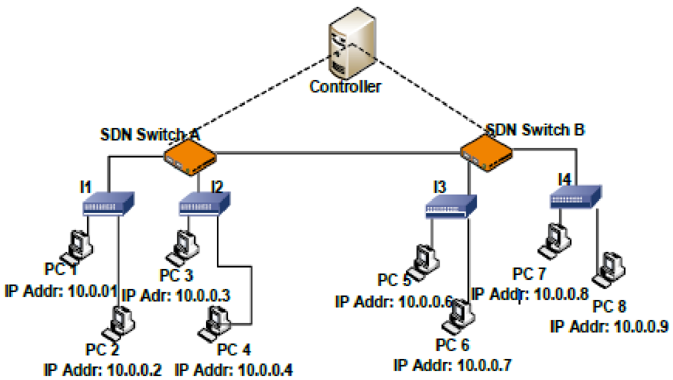

Fig. 3. Ideal Condition

A. Attack Condition

In Attack phase, Kali Linux user as an attacker launches broadcast Gratuitous ARP message with the IPv4 address of PC5 i.e 10.0.0.6. Gratuitous ARP is a broadcast packet that is used by network devices to announce any change in their IPv4 address or MAC address. By sending a Gratuitous ARP message with the IPv4 address of PC5, attacker deceives as PC5 and captures all the network traffic of PC5 as shown in Figure 4.

Once the attack is successful, network information kept by the controller is poisoned and the adversary can take control of the network and capture all the network traffic. After getting network information Kali Linux user with IP address 10.0.0.6 launches a DDoS attack. Due to this attack, the controller continuously remains busy with PC5, while all other users are waiting for a response to their queries. In this way, the whole network is affected due to these attacks. Consequently, controller performance is degraded and legitimate users are unable to get a response from the controller.

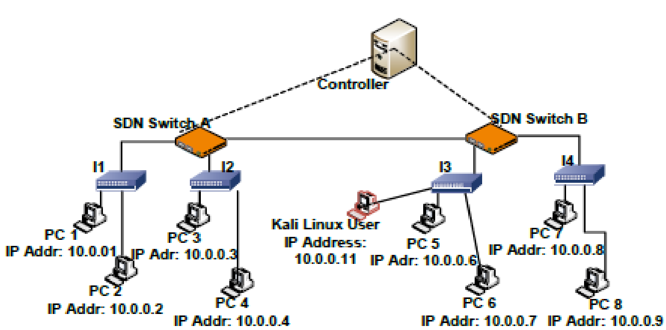

Fig. 4. Attack Condition

These problems of ARP spoofing and DoS attacks occur in hybrid SDN. SDN controller only controls the data flow through SDN switches. In addition to these, the legacy switches use traditional network protocols to forward the data. In order to configure legacy devices in hybrid SDN, customized mechanism is required to be implemented by the SDN controller. To mitigate these attacks in hybrid SDN, an intelligent attack detection and network recovery mechanism is required.

IV. PROPOSED SOLUTION

In order to handle the problems of ARP spoofing and DDoS attack as discussed in the problem statement, we proposed an automatic network device identification mechanism, which detects the ARP spoofing attacks in hybrid SDN and mitigates these attacks with the help a proposed server. We model the Hybrid SDN (HN) as HN = (L, D), where L is a set of the undirected edges and D denotes the set of nodes (devices). D is subdivided into two subsets; T consists of traditional (legacy) switches, and O consists of both Openflow based SDN switches and a controller. Thus, $D = T \cup O$. A path from source $s \epsilon D$ to destination point $t \epsilon D$ such that $s \neq t$ is represented as a list of traversed links, the mathematical path is represented as $r(s, t) = \{s, v1, v2...vk, t\}$ and where v1, v2 ...vk $T \cup O$.

In Figure 5, we have shown the overall system in which an individual server is used to handle the ARP requests. We have implemented our proposed solution on this server. This solution consists of multiple components. The first component is used to get topology information from SDN switches and legacy switches. A customized algorithm is used to get topology information from legacy switches through SDN switches. The second component installs the flow rules on the switches and configures the legacy switches so that ARP traffic is forwarded to proposed server. The third component is consisting of the modules that deal with ARP requests generated by different users.

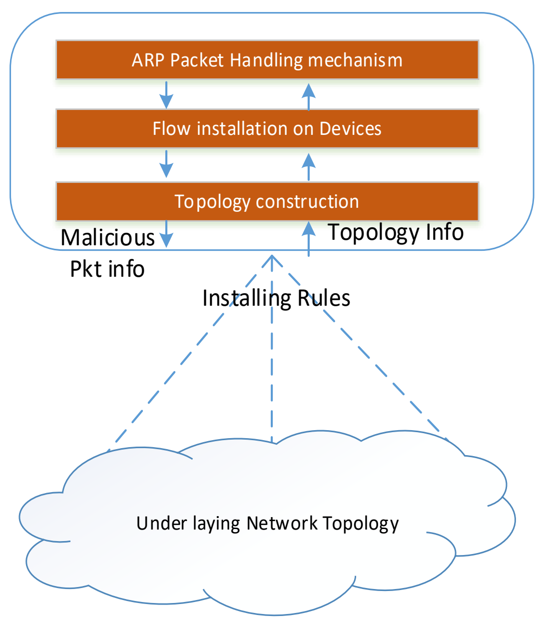

Fig. 5. Overall System Design

A. Topology Information

We get the network topology information of SDN and legacy devices at the proposed server. An Openflow device exchanges its link state information with proposed server after fix time interval. Link state information of legacy devices is collected from the remote log information of legacy devices switches. Thus, after getting the link state information from all forwarding devices, the edges are stored in a set E and the nodes are stored in a set V. We construct an undirected graph G where forwarding devices are represented as nodes, and links are represented as edges.

In graph construction algorithm, an edge from E and its respective vertices are selected and added to graph G. Then next edge and its respective vertices are selected, and then added to G. This process is repeated till all edges and vertices are added to G. Algorithm 1 explains the graph construction.

Algorithm 1: Graph Construction
Input: L is No of Links, N is No. of Nodes (Devices)
Output: An undirected Graph R

```
R= {0}
While (Links or Nodes are presents)
    Select the Link from the L and Node from N
    if Link connects two Nodes in different subsets then
        merge the subsets;
        add the link to R;
    end if
    if all the subsets are merged then
        the instance is solved
    end if
end while
```

B. Installation of Flow rules on switches

After getting topology information from all the devices in the network, we need to install flows on the switches so that ARP traffic may be directed towards the proposed server for analysis. In order to install flow rules on all SDN switches, we instructed the controller to install flow rules at the switches. Legacy switches are configured to forward ARP traffic towards the SDN switch. Once we have got ARP traffic on proposed server then further analysis is performed on it. The following algorithm explains the flow rule installations for ARP packets as follows:

Algorithm 2: Installation of Flow rules
Input: Number of Packets,
Output: Route to forward packet

```
Controller gets switches information
Controller installs flow rules on switches for Packets
if (Pkt belongs to ARP) || (Pkt.dest == FF:FF:FF:FF:FF:FF)
    Pkt sent to the Specific Port for verification
else
    Pkt Sent to Controller || Forward according to Flow
end if
```

C. Detecting ARP Spoofing attack

After getting topology information from all devices in the network and installation of flow rules, we formed a graph that stores the whole network information. This information is used in verification of APR request generator. In order to detect the attack condition, proposed server checks the packets of a particular host. At first step, it checks that the packet either belongs to our network or not. Secondly, it checks that ARP request belongs to this network or not. If ARP request belongs to the corresponding network, then appropriate action is taken. Furthermore, we explained it in following scenarios.

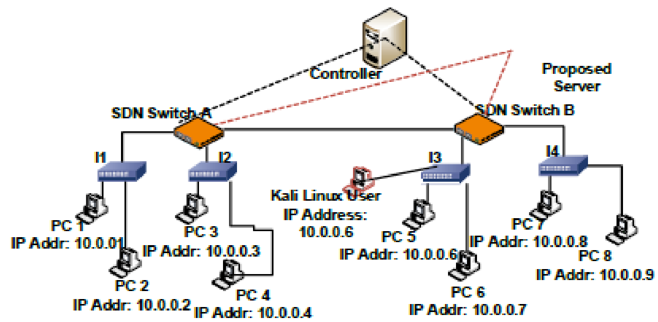

Fig. 6. Proposed Solution Scenario

In the first scenario, Whenever ARP packet is generated by a user in the network and if the user is attached to a legacy switch then this packet is forwarded to SDN switch. When the packet reaches an SDN switch, flow entries for that packet are checked. If the flow entries or rules did not match at the switch, then SDN switch sends the packet to the proposed server as shown in Figure 6. This packet is analyzed by the proposed server for possible attack scenario as describe in algorithm 3. If this packet belongs to our network, then it would be forwarded with a response by the proposed server otherwise, it will be dropped.

For example, when PC1 with IP address of 10.0.0.1 launches an ARP packet according as shown in Figure 6. The legacy switch receives the ARP packet and it forwarded to nearest SDN switch. SDN switch checks the type of received packet and if it is ARP request then it is forwarded to our proposed server. The server examines the packet whether it belongs to our network or from outside. if the packet belongs to our network then it will be entertained with ARP reply message to PC1 via SDN switch and further communication is possible. On the other hand, if the packet does not belong to our network means its IP and MAC addresses are not matched with the database then it is dropped. Because if this ARP packet is not dropped then it may be get modified and used by any adversary party to launch an attack.

In the second Scenario, if an adversary party sends a packet to the network and pretends like a legitimate user by spoofing the IP address of the other user. Then a packet of this user looks like our network and in that case over server checks the IP address with the all recorded MAC to IP mapped table. If the entry is found, then check the source MAC address of the packet with the mapped MAC address. If the entry is matched with MAC address, then server responses with appropriate MAC address otherwise server will drop the packet. If multiple numbers of packets are generated from sending node, then the corresponding port also be blocked.

Algorithm 3: Detection of ARP attack
Input: ARP Packets or Broadcast Address, n nodes,
Output: Get flow rules
Initialize CAT [] table
for i in range(1,n)
  Add IP address and MAC Address in CAT[]
end for
if (Pkt.src not in CAT[] and Pkt.dest not in CAT[])
    drop the Pkt
  else
  if (Pkt contain ARP**)**
    Check IP and MAC Addresses match in CAT[]
    send IP/MAC address
  end if
  if(Pkt.dest == broadcast Pkt && Pkt.Src in CAT[]**)**
    install rule for broadcast
  endif
end if

D. Attacker's location using graph traversal

In order to mitigate the ARP attack in hybrid SDN when attacker pretend to be a legitimate user by using both IP and MAC address. A graph based traversal mechanism is used to detect the actual location of legitimate user and attacker's location. On the base of this location information, we can block the malicious user's port. In Hybrid SDN, the controller has the overall network view and topology information of all nodes. This information also indicates the connections between users and respective switches. We generate the graph for the whole topology after a fixed time interval. This graph has all the connectivity information of all devices in the network. Whenever a malicious device sends ARP request to the server and tries to spoof the network then graph traversal is used to detect actual location of the attacker. A modified depth-first search (DFS) mechanism is adopted to track the attacker's location. At first stage, we have the original topology of the network and after attacker's ARP requests, topology gets modified. By using graph traversal mechanism, attacker' location is identified and respective port is blocked for further communication.

Algorithm 1: Graph Traversal
Input: graph G, attacker IP(A)
Output: Location of Attacker IP address
enqueue (G, m)
While (queue is not empty)
  do dequeue (h, i)
  if (h is unchecked**) then**
      mark i
      add compare IP(i) with IP(A)
      if (IP(A) == IP(i) then
        generate alarm, return location
      else
        parent(i) ← h
      end if
  end if
  for each link (i, j)
    do enqueue (i, j)
  end for
end while

In Figure 7, a flow diagram for the whole system is shown. It represents the step by step procedure of proposed solution.

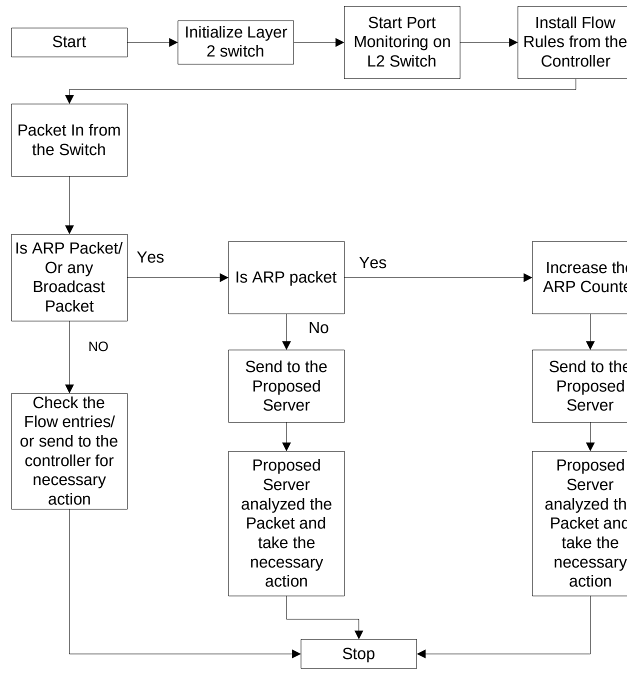

Fig. 7. Flow Diagram

V. Implementation and Performance Evaluation

We have used the following simulation set up and implemented our proposed solution. We conducted our experiments on Ubuntu virtual Machine with 4 core and 4 GB RAM running on hypervisor server consisting of 16 GB RAM with 32 cores. Mininet [23] Simulation tool is used to create a virtual environment in which different tests are conducted. In Mininet we add multiple SDN switches, legacy switch, hosts and controller according to our scenarios discussed in problem statement and in proposed solution. Links are created between the switches, host, and controller. To enable a switch as a legacy switch we disconnected it with controller and OpenvSwitch (OVS) fail mode to be "standalone". POX [24] controller is used to install flows on the switches and to control the entire system. We have compared our results with the technique explained in [10]. Although, this technique is used in pure SDN and we are considering hybrid SDN where both type of network devices are present i.e. legacy and Openflow. Yet there is no mechanism available to deal with ARP spoofing attack in hybrid SDN.

Our proposed solution topology is shown in Figure 6 in which one controller, two SDN switch and three legacy switches are used with 9 host machines. The one machine with IP address 10.0.0.11 is used for the attacking purpose, where "kali Linux" OS is installed. This machine is used to generate ARP and other spoofed packets to poison the network topology. Our proposed server is connected to the controller for the data exchange and rules installation on the SDN Switches.

A. Implementation of Proposed Scenario

To evaluate our proposed solution, we measured several parameters like attack detection time, attack mitigation time and load on the CPU and throughput of our proposed algorithm using different attack scenarios. We used the several attacks like spoofed ARP request, ARP request attack, ARP reply attack and DDoS attacks. Each of these attacks is discussed below.

1) Discussion on Spoofed ARP

In Spoofed ARP request attack victim's cache table is poisoned with the fake entry of the host. This type of attack is usually used to intercept the traffic of the victims. This attack can be achieved by injecting thousands of spoofed ARP request packet into the network and victim PC cache is updated with wrong entries. This type of attack can be mitigated by our proposed solution in hybrid SDN. There are two types of spoofed ARP request attack. First, ARP request attack is same as the Spoofed ARP request attack. In ARP request attack an adversary party launches an ARP request packet by using the IP address of the other legitimate user and other users update their cache with this request. Consequently, communication between the legitimate users is not possible and the adversary party can get the traffic of legitimate user. To avoid such situations in hybrid SDN, SDN controller can handle the ARP request packet by installing the flow entries on switch for our proposed server. Second, ARP Reply attack is launched by an adversary party launches a Gratuitous ARP packet or an ARP reply by itself with the fake IP address or the MAC address in the network. Other users update their cache with wrong entries and the communication between the legitimate users is halted and the adversary party can get the traffic of the entire network host.

2) Discussion on DDos attack

DDoS uses the technology of ARP spoofed method to launch a DDoS attack on the network. This type of attack is usually launched to degrade or cut down the performance of the network and the legitimate users fail to access network resources.

To evaluate our proposed solution, we used a different network parameter like CPU load, attack detection time, attack mitigation time and throughput.

- Attack Detection time is the total time in which adversary party launch attack on the network and the controller detect the attack on the network.
- Attack mitigation time is a time to mitigate an attack after the detection of the attack in the network.

Figure 8 shows the comparison of attack detection time and attack mitigation time for the proposed algorithm and the existing technique. From Figure 8, one can conclude that our proposed algorithm performs better against malicious attacks than the existing approach. We can also secure our traditional network using hybrid SDN technology with limited investment in term of SDN switches deployment.

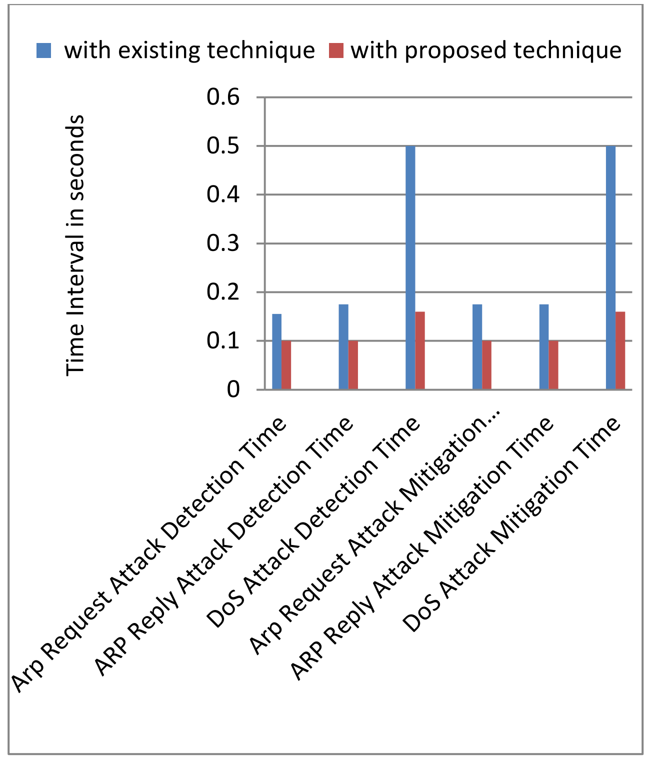

Fig. 8. Time Experiment

CPU load is a parameter to check the load of CPU when attacker launches an attack and controller run the algorithm to mitigate the attack. In our case, CPU utilization is a little bit higher than with the existing approach but this is the normal utilization of CPU. It didn't affect the performance of the network because this utilization is at proposed server not at the controller. The graphs of the CPU utilization are shown in Figure 9.

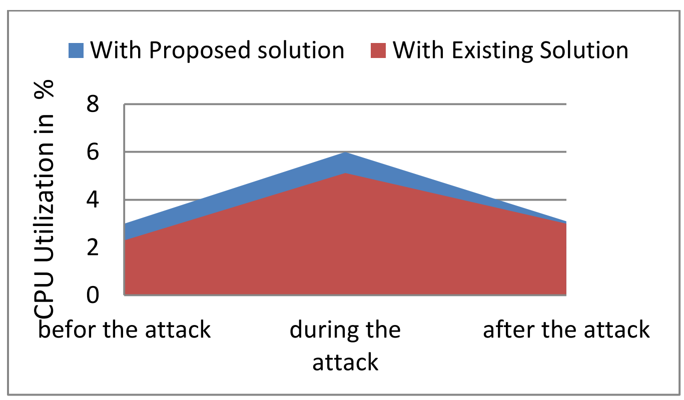

Fig. 9. CPU Utilization

Another factor to measure network performance is throughput. Throughput is the maximum utilization of the resources of a network system. In our case, we take the throughput of the link between the host and the controller before the attack and after the attack. We compare the throughput of our proposed algorithm with the existing approach as shown in Figure 10.

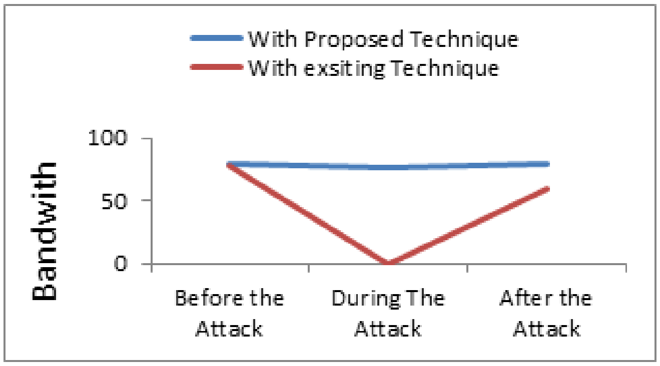

Fig. 10. Throughput between the links

We measure the successful packet delivery ratio. Figure 11 shows the results of successful packet delivery with respect to the time interval. The results indicate that successful delivery ratio is much better for proposed solution as compared to existing mechanism. When an attack is launched then our system automatically detects the attack and minimizes its effect on the system.

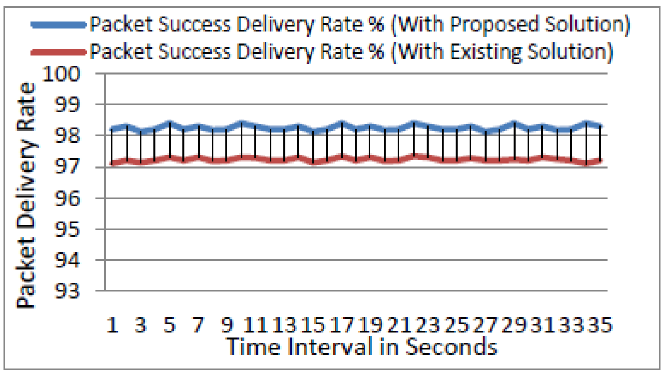

Fig. 11. Packet Success Delivery Rate

VI. Conclusion

In this paper, we examine layer 2 attacks in hybrid SDN and proposed a novel attack detection and mitigation technique. ARP spoofing and DDoS attacks are the most common attacks that affect the network performance very badly. In communication networks, most of the attacks are launched by spoofing the packet and poisoning the network topology by using ARP spoofing method. Our proposed solution consists of an individual server and customized mechanisms to get the network topology information. After this step, flow rules are installed on the switches for ARP packet to be forwarded to the server. We detect the attacker by analyzing ARP request from the source. We also used graph based traversal mechanism to detect the attacker location by verifying legitimate users. Experimental results showed that these threats have been resolved by using our mechanism. Furthermore, our solution supports multiple controllers in the network and can be used in pure SDN network also.

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Low Error Floor Concatenated LDPC for MIMO Systems

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***Abstract*—Multiple-Input and Multiple-Output, or MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. MIMO technology has attracted attention in wireless communications; because it offers significant increases in data throughput and spectral efficiency without additional bandwidth or increased transmit power. To achieve the mentioned above performance Bit Error Rates (BER) should be low. For this reason efficient encoding and decoding algorithms should be used. MIMO systems rely on error-control coding to ensure reliable communication in the presence of noise. Forward Error Correction Codes (FEC) such as convolutional and block codes were investigated for MIMO systems. Low Density Parity Check (LDPC) shows good performance except that an error floor may appear at high Signal to Noise Ratio (SNR). In this work we propose a concatenated error control code that reduces the error floor of LDPC codes suffering from error floor. The proposed scheme is a good candidate for high rates real time communication since it reduces the decoding latency as well.**

Keywords—LDPC; error floor; MIMO; error control

I. Introduction

One important issue with wireless communication systems is providing high data rates. MIMO systems provide high channel capacity and so may provide high throughputs which are promising for 4G and 5G. However, high data throughputs are conditioned with low bit error rates. Error control codes are deployed to decrease BER and so increase channel throughputs. In the literature, both convolutional codes (CC) and block codes were investigated for MIMO systems. CC and LDPC codes were improved in many types of research by serial and parallel concatenation. CC gained interest because of their decoding process based on the Viterbi decoder [1]. They attracted more attention because of their use in Turbo codes. Turbo codes were first proposed by Berrou in [2] where the authors proved that turbo codes may attain near Shannon capacity performance.

One competitor of turbo codes is the linear block Low Density Parity Check (LDPC) [3], [4]. It was shown that the LDPC codes are good enough to achieve performance close to the channel capacity. Potentials of LDPC codes for MIMO system were revealed in many researches [5], [6] and [7]. In [8] , simulation results showed that LDPC outperforms turbo codes in both correlated and uncorrelated Rayleigh channels. In [9], they showed that LDPC decoding presents a lower complexity than turbo codes because of the ability to stop whenever a code word is reached. In addition, LDPC decoder could be implemented in parallel which improves its performance for long codes. Authors in [10], compared LDPC to CC with respect to decoding latency consideration. They showed that at low and intermediate latency, CC with Viterbi and stack sequential decoders outperform LDPC.

In this work, a concatenated code which improves both LDPC BER performance at high SNR and channel decoding latency is proposed. This paper is organized as following: In section II, a concatenation of three channel codes with LDPC as inner code is proposed. Afterward in section III, undertaken simulation results are provided revealing good performance of the concatenated scheme compared to a standalone LDPC channel code mainly in case of error floor presence. In section IV, a discussion of the found results is conducted.

II. Literature Review

LDPC codes suffer from error floors that appear at high SNRs [11]. Error floors could be reduced through post-processing or concatenation [12]. In [13], both CC and LDPC are improved by their serial concatenation. LDPC is used as an outer code and CC is used as an inner code. They showed that the LDPC-CC scheme improves both CC and LDPC codes mainly at high SNR. In [14], authors used an iterative detection decoding schema where both soft input soft output MMSE with successive interference cancellation and LDPC are processed iteratively. They showed that the iterative detection decoding scheme improves BER by a 2dB in a 2 by 2 MIMO system. Some studies focused on the design of the LDPC parity matrix to improve the later code performance. In [15], authors designed an irregular LDPC parity matrix; where weights of variable nodes and check nodes are variable. They showed that using appropriate irregular codes improves the BER performance. In [16], a BICM interleaver was used to reduce the error floor. In [17] a two-staged weighted bit flipping decoding algorithm was proposed. The proposed algorithm reduces the error floor although it has high complexity which remains lower than a simple bit flipping algorithm. In [18] , a Progressive Edge Growth algorithm which takes advantage from the LDPC graph structure is used at the decoder to improve the LDPC performance. In [19], authors proposed a method of lowering the error floor by intelligently inserting a pilot bits or known bits in the message frame. This provides high log-likelihood information which improves decoding output. In [20], Quantum LDPC codes construction decreases the error floor.

III. System Architecture

A concatenation of three channel codes is proposed; LDPC is the inner code, BCH is the outer one and CC is the mid one as given in Fig. 1 Serial concatenation of channel codes were first introduced by Forney [21]. This technique induces longer codes with better BER and lower decoding complexity. Generally, CC codes are serially concatenated to Reed Solomon (RS) codes [22]. RS is used as an outer code to correct the error bursts resulting from the CC Viterbi decoder.

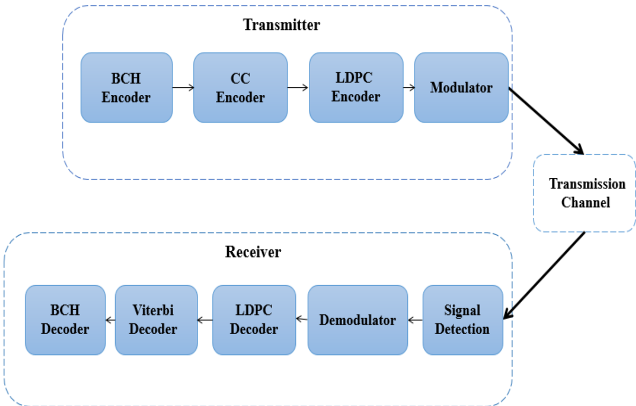

Fig. 1. Proposed Architecture

The received signal is estimated by a Vertical Bell Laboratories Layer Space-Time Minimum Mean Square Error (VBLAST-MMSE) based detector [23]. After the demodulator a belief propagation LDPC decoder is implemented followed by a soft decision Viterbi decoder and finally a BCH decoder. Viterbi decoder main flaw is the generation of burst of error which we mitigate through the use of BCH decoder.

A. Convolutional Codes [1]

In convolutional codes, the encoding process is based on the use of a generator polynomial implemented as a shift register. Convolutional codes are defined as $C(n, k, l)$ codes where n is number of output bits, k is the number of input bits and l is constraints length representing number of memory registers. The Trellis based structure of the convolutional codes make the Viterbi decoding suitable for them.

B. Low Density Parity Check Code

Low Density Parity Check codes were proposed by Gallager in 1962 [3]. They were first ignored for almost a decade then they regain interest. LDPC regains interest because of its linear structure and iterative decoding process. LDPC codes are represented by their parity check matrix. Each row in the parity check matrix represents a parity equation. The number of columns represents the code length. Regular LDPC codes are codes where the number of ones per rows is constant (row weight) and number of ones per columns are constant (column weight) [24]. Whereas irregular codes are the ones where number of ones per rows are not equal (row weight) and number of ones per columns are not equal (column weight). LDPC codes maybe represented by their parity matrix as in Eq.1:

$$H = \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix} \quad \text{Eq. 1}$$

LDPC codes are also represented by the bipartite Tanner Graph, Fig. 2. Tanner graph have two sets of nodes Check nodes and Variable nodes. Check nodes represent the rows of the parity check matrix. Variable nodes represent the columns of the matrix. Following is the Tanner graph of the parity matrix H.

Several regular and irregular parity check matrix construction methods were proposed in the literature. Indeed, Tanner graph structure and hence parity check matrix structure alter the code performance; girth length, trapping set size. Small girth leads to error floors with iterative decoding. Error floor is one main challenging problem of LDPC codes [25].

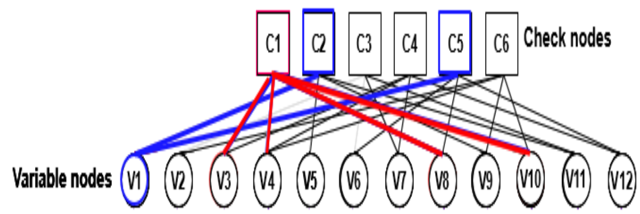

Fig. 2. LDPC Tanner Graph

Message passing decoding algorithm is used between nodes to correct errors. Message passing for hard decoding is implemented through bit flipping algorithm. On the other hand, soft decoding is implemented by the belief propagation (BP) algorithm. In BP likelihood information is exchanged between variable and check nodes. Check nodes and variable nodes keep exchanging the likelihood information until a null syndrome or a maximum number of iterations are reached [3]. Bit flipping algorithm attracts many researches because of its low complexity compared to BP even though it suffers from lower performance and higher error floor.

C. BCH Codes

The Bose, Chaudhuri, and Hocquenghem (BCH) codes form a large class of powerful random error-correcting cyclic codes. For any positive integers $m \geq 3$ and $t < 2^{m-1}$, there exists a binary BCH code with block length $n = 2m - 1$, number of parity-check digits $n - k \leq mt$ and minimum distance $dmin \geq 2t + 1$. We call this code a t-error-correcting BCH code. BCH code is chosen for this concatenated scheme for its flexibility in the sense that different coding rate codes are easily constructed. Actually, BCH is used instead of Reed Solomon for the simplicity of code construction for different coding rates and for its low encoding decoding complexities.

IV. Simulation Results

Simulations were conducted on the worst cases of LDPC codes; short, with small girth in a Rayleigh flat fading channel. Binary Phase Shift Key (BPSK) modulation with a VBLAST-MMSE detector is implemented. A (15, 11) BCH code and a [5, 7] code with ½ coding rate CC code with constraint length equal to 3 were considered. Simulations were conducted for both girth four and free of girth four LDPC codes. Also, a bit flipping decoding was considered for its low complexity and clear error floor.

In Fig. 3, Simulations were conducted for girth four LDPC parity check matrix. The ¼ LDPC-BCH-CC scheme is compared to a standalone ¼ LDPC code. The VBLAST-MMSE-concatenated code achieves better BER compared to the standalone LDPC code. Also, by comparing BER of the standalone LDPC for different MIMO systems it is noticed that receive antenna diversity improves LDPC BER performance and reduces the error floor. Obviously, the concatenated model reduces the error floor obtained in a 1 by 2 MIMO system. In addition, the coding gain of the concatenated scheme increases from 0.5dB in a 2 by 8 MIMO system to reach almost 1.5dB in a 1by 2 MIMO system at 10^{-2}. As stated previously authors in [13] proposed a concatenation of a 5/6 LDPC and ½ CC with CC as an inner code outperforms slightly a ½ LDPC code in a SUI-3 channel model.

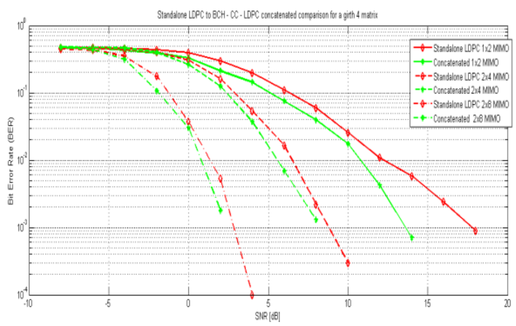

Fig. 3. Concatenated to standalone codes comparison for girth four LDPC matrix

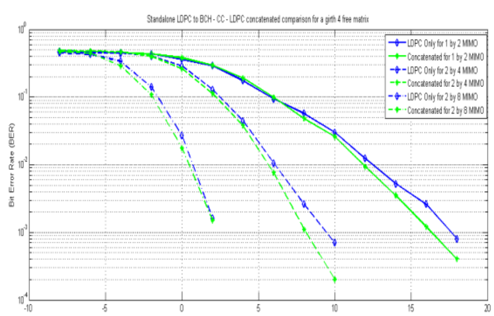

Fig. 4. Concatenated to standalone codes comparison for girth four free LDPC matrix

In Fig. 4, simulations were conducted for girth four free LDPC parity check matrix. The ½ coding rate LDPC code is the MacKay regular matrix 96.33.964 [4]. Notice that the coding gain increases when MIMO receive diversity decreases as in Fig. 3. Also, notice that the gain obtained for a girth four LDPC matrix is better than the gain obtained for a girth four free LDPC matrix.

V. Discussion

Simulation results showed that BCH, CC and LDPC concatenated code outperforms a standalone LDPC code which may suffer from error floors mainly when the parity check matrix has a girth equal to four. In fact, the CC decoder corrects errors remaining after the LDPC hard decoder. In addition to error floor reduction this concatenated scheme improves the decoding latency. In **[27]**, authors stated that the LDPC decoding latency equals the arrival time of one block plus the average computational time needed for decoding and buffering which depends on the number of iterations. Whereas the decoding latency of a convolutional code equals the arrival time of one incoming trellis (or tree) section (k*m information bits for an (n, k, m) convolutional code) plus the Viterbi decoder computation time which is a constant. So, when using a ½ LDPC decoder with CC and a short BCH code the decoding latency is reduced compared to a ¼ standalone LDPC. Also, the storage need of a Trellis decoder related to the constraint length is much lower than the buffer needs of an iterative block LDPC decoder. This raises the importance of using a BCH-CC-LDPC concatenated schema for real time communications for the next communication systems generations.

VI. Conclusion

Channel codes should provide high channel efficiency with small code rate, low decoding complexity and low BER. It was shown in the literature that LDPC codes outperforms both CC and turbo codes which were dominating just before LDPC. Main disadvantages of LDPC code are the appearance of an error floor at high SNR and the high decoding latency. In this work, a concatenation of BCH-CC-LDPC for MIMO system is proposed. A concatenation of a reduced LDPC code rate with a CC convolutional code and a BCH code instead of using one standalone LDPC reduces the error floor mainly in case of girth four LDPC matrix. Also, the concatenated scheme improves the performance of a low receive diversity MIMO system. Finally, the concatenated schema enhances the system decoding latency because an LDPC decoder is replaced by a CC decoder and a short BCH decoder which have lower decoding latencies than LDPC. The performance of the proposed system could also be enhanced in case of LDPC convolutional codes.

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