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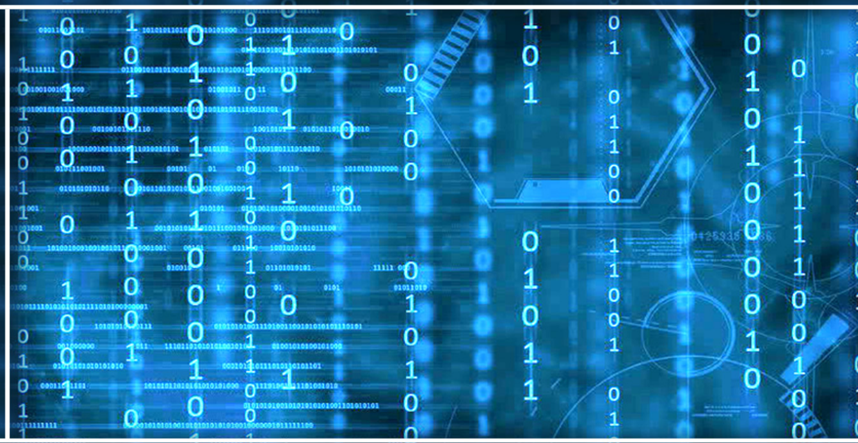

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Editorial Preface

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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Coronary Heart Disease Diagnosis using Deep Neural Networks

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***Abstract*—According to the World Health Organization, cardiovascular disease (CVD) is the top cause of death worldwide. In 2015, over 30% of global deaths were due to CVD, leading to over 17 million deaths, a global health burden. Of those deaths, over 7 million were caused by heart disease, and greater than 75% of deaths due to CVD were in developing countries. In the United States alone, 25% of deaths were attributed to heart disease, killing over 630,000 Americans annually. Among heart disease conditions, coronary heart disease is the most common, causing over 360,000 American deaths due to heart attacks in 2015. Thus, coronary heart disease is a public health issue. In this research paper, an enhanced deep neural network (DNN) learning was developed to aid patients and healthcare professionals and to increase the accuracy and reliability of heart disease diagnosis and prognosis in patients. The developed DNN learning model is based on a deeper multilayer perceptron architecture with regularization and dropout using deep learning. The developed DNN learning model includes a classification model based on training data and a prediction model for diagnosing new patient cases using a data set of 303 clinical instances from patients diagnosed with coronary heart disease at the Cleveland Clinic Foundation. The testing results showed that the DNN classification and prediction model achieved the following results: diagnostic accuracy of 83.67%, sensitivity of 93.51%, specificity of 72.86%, precision of 79.12%, *F*-Score of 0.8571, area under the ROC curve of 0.8922, Kolmogorov-Smirnov (K-S) test of 66.62%, diagnostic odds ratio (DOR) of 38.65, and 95% confidence interval for the DOR test of [38.65, 110.28]. Therefore, clinical diagnoses of coronary heart disease were reliably and accurately derived from the developed DNN classification and prediction models. Thus, the models can be used to aid healthcare professionals and patients throughout the world to advance both public health and global health, especially in developing countries and resource-limited areas with fewer cardiac specialists available.**

Keywords*—*Cardiovascular disease; heart disease; coronary artery disease; classification; accuracy; diagnosis; diagnostic odds ratio; deep learning; deep neural network; machine learning;* F-*score; global health; public health;* K-S *test; precision; prediction; prognosis; ROC curve; specificity; sensitivity

I. Introduction

According to the World Health Organization, cardiovascular disease (CVD) is the top cause of mortality worldwide. In 2015, over 30% of global deaths was due to CVD, leading to over 17 million deaths, a global health burden [1]. Of those deaths, over 7 million were caused by heart disease, and greater than 75% of deaths due to CVD were in developing countries [1]. Over 50% of the deaths caused by heart disease were in men [1]. In the United States alone, 25% of deaths is attributed to heart disease, killing over 630,000 Americans annually [2].

Heart disease is an umbrella term that includes many types, including congenital, coronary, and rheumatic heart diseases. Among those conditions, coronary heart disease is the most common, causing over 360,000 American deaths due to heart attacks in 2015 [2]. According to the Centers for Disease Control and Prevention, it is estimated that approximately every 40 seconds, an American experiences a heart attack [2]. Consequently, heart disease expenditures have risen to over $200 billion annually in the United States alone [2]. Furthermore, by 2030, health care costs due to heart disease are expected to double according to the American Heart Association [3].

Coronary heart disease occurs due to atherosclerosis, long-term buildup of plaque in the arteries of a patient caused by the elevation of low-density lipoprotein (LDL) cholesterol in plasma [4]. As the walls of the coronary arteries of the patient accumulate plaque, the arteries narrow over time. Subsequently, this results in reduced blood flow to the muscles of the heart leading to decreased heart movement. Once the artery is partially or completely blocked, there is an increased risk for a heart attack, also known as a myocardial infarction.

Risk factors of coronary heart disease include family history, smoking, high LDL cholesterol levels, high blood pressure, age, and uncontrolled diabetes [5]. Lifestyle and medical factors that can lead to greater risk of heart disease include sedentary lifestyle, unhealthy diet, obesity, and excess alcohol consumption. Symptoms of coronary artery disease include chest pain, pressure, shortness of breath, sweating, heart palpitations, dizziness, weakness, and nausea [4].

To diagnose heart disease severity in patients, current methods that are used include exercise stress tests, chest X-rays, heart scans (CT), cardiac magnetic resonance imaging (MRI), coronary angiograms, and electrocardiograms (EKG) [5]. Early, accurate diagnoses of coronary heart disease in patients are essential for administering early and optimal treatments in order to increase their chances of long-term survival. However, in many resource-limited areas throughout the world, cardiovascular specialists may not be available to perform these diagnostic tests. Furthermore, in many cases, missed diagnoses as well as erroneous diagnoses and treatments place the health of patients at risk. Early detection

*Both authors contributed equally to this work.

of heart disease can lead to preventative measures, such as medications, lifestyle changes, angioplasty, and/or surgery, to reduce disease progression and morbidity [5]. Therefore, accurate and early heart disease diagnoses in patients are crucial for lowering mortality rate and improving their long-term survival rates.

Early diagnosis of coronary heart disease can be challenging, and computer-aided methods have been created to detect and diagnose heart disease in patients. Increasingly utilized among computer-aided detection methods in medical institutions is machine learning, a technology that analyzes clinical data, processes it, and provides diagnoses for medical conditions. Research reports have utilized the following computer-aided detection methods to diagnose heart disease in patients based on their clinical data: decision trees [6], artificial neural network [7], support vector machine learning [8], fuzzy neural network [9], ensemble machine learning [10], binary particle swarm optimization [11], rotation forest classifier [12], principal component analysis-based evolution classifier [13], K-star algorithm [14], Bayesian algorithm [15], rule organization method [16], and neuro fuzzy classifier [17].

In this research, an advanced deep neural network approach is developed and utilized to predict coronary heart disease in patients and increase diagnostic accuracy using classification and prediction models based on deep learning [18, 19]. For this research, the developed classification and diagnosis models contain two parts: a deep neural network learning-based training model and a prediction model for the presence of heart disease. The training model is first created using deep learning algorithms based on a deeper multilayer perceptron with regularization and dropout in system and architecture. Based on the training model, the diagnosis model is then utilized to predict whether or not patients have coronary heart disease. The subsequent performance of the deep learning model for heart disease diagnosis is evaluated in terms of the performance measure parameters, including diagnostic accuracy, probability of misclassification error, sensitivity, specificity, precision, area under the ROC curve (AUC), Kolmogorov-Smirnov (K-S) measure, receiver operating characteristic (ROC), and *F*-score.

II. MATERIALS AND METHODS

In Section A, the clinical data for coronary heart disease are described. Then, in Section B, the classification and prediction models for coronary heart disease prognosis based on the deep neural network system and architecture are described. Sections C and D present the theory of the deep neural network classification and prediction models. Finally, in Section E, the methods for evaluating the performance of the deep neural network model are discussed.

A. Heart Disease Data

Used in this research, the clinical heart disease data were from 303 patients at the Cleveland Clinic Foundation (CCF) located in Cleveland, Ohio in the United States. The dataset was obtained from the Heart Disease Database made available in the UCI Machine Learning Repository [20]. Each of the 303 clinical instances contained 75 attributes and a target attribute. The target attribute represented an integer valued from 0 to 4, signifying absence [0] or presence [1, 2, 3] of heart disease in patients. For this research, binary values of 0 and 1 were reassigned to the target attributes for the absence or presence of heart disease in patients, respectively. The dataset included 91 female patients (30.03%) and 212 male patients (69.97%), and their ages ranged from 29 to 77 years with the average being 54 years old of the 303 clinical instances from the Cleveland Clinic Dataset, 282 clinical cases were utilized and the remainder were excluded from the research due to missing data values. Of the 282 total clinical instances, 125 of the cases (44.33%) had heart disease while 157 were cases (55.67%) that were absent of heart disease. Each clinical instance was described with 76 raw attributes. However, only 29 of the raw attributes were utilized in the development of the deep neural network models due to missing values among the other raw attributes. Details regarding the 29 raw attributes are listed in Table 1. In the development of the deep neural network model, the entire data set of 282 total clinical instances was randomly separated into a training data set of 135 clinical instances (47.87%) and testing data set of 147 clinical instances (52.13%).

TABLE I. THE 29 ATTRIBUTES AND DESCRIPTIONS USED IN DEVELOPING THE DEEP NEURAL NETWORK MODEL

Variable	Attribute Description	Variable	Attribute Description
Age	Years	**Htn**	Hypertension
Sex	1= male 0 = female	**Tpeakbp**	Peak exercise blood pressure (part 2)
CP	Chest pain rating: 1 = typical angina 2 = atypical angina 3 = non-anginal pain 4 = asymptomatic	**Restecg**	Resting ECG 0 = normal, 1 = ST-T wave abnormality (> 0.05 mV), 2 = left ventricular hypertrophy
Tpeakbps	Peak exercise blood pressure (part 1)	**Tresrbp**	Blood pressure at rest (mm Hg)
Chol	Serum cholesterol (mg/dl)	**Exang**	Exercise induced angina 1 = yes, 0 = no
Ekgmo	Month of exercise ECG reading	**Lvf**	Left ventricular failure
Ekgday	Day of exercise ECG reading	**Oldpeak**	Exercise-induced ST depression
Ekgyr	Year of exercise ECG reading	**Cmo**	Cardiac cath: month
Dummy	Dummy variable	**Cday**	Cardiac cath: day
Xhypo	1 = yes, 0 = no	**Cyr**	Cardiac cath: year
Prop	Beta blocker used during exercise ECG 1 = yes, 0 = no	**Nitr**	Nitrates used during exercise ECG 1 = yes, 0 = no
Thaldur	Exercise test duration (min)	**Thalach**	Maximum heart rate achieved
Xhypo	1 = yes, 0 = no	**Thalrest**	Resting heart rate
Pro	Calcium channel blocker used during exercise ECG 1 = yes, 0 = no	**Diag**	Heart disease diagnosis: angiographic 0 (< 50% diameter) 1 (> 50% diameter)

B. Deep Neural Network System and Architecture

In this section, the deep neural network system and architecture are presented for coronary heart disease diagnosis based on the CCF dataset using deep learning algorithms, hyper-parameters, and turning and controls block.

Displayed in Figure 1 are the system and architecture of the designed deep learning models, which includes two subsystems: (1) a deep neural network training classification model, and (2) a deep neural network diagnosis model for heart disease.

The deep learning training classification model as illustrated in Figure 1 is based on a deeper multilayer perceptron employing more deeper number of hidden layers with linear and non-linear transfer functions, regularization and dropout, a sigmoid function for binary classification using deep learning technologies. An input data matrix, which included N clinical instances and R attributes of heart disease, where R = 28, was simultaneously fed into the deep neural network training model, which propagated all input patterns of coronary heart disease to determine all unit outputs of linear and non-linear transfer functions. A hyper-parameter turning and control block not only enabled adjustment of a set of hyper parameters but also controlled the batch size and the number of epochs during the training of the deep neural network classification model. The batch size was used to determine the input data matrix with N clinical instances, where, in this research, N = 80. The number of epochs in deep learning represents the number of times in which all training data pass through the learning algorithm to adjust the deep neural network weights.

While training the deep neural network classification model, comparisons of all unit outputs with the desired pattern responses of the coronary heart diseases from the target variable class were used to determine the errors. The error was further multiplied by the hyper-parameter, which was subsequently adjusted by learning algorithm block. Then, weights in the deep neural network classification model were updated after the minimization of error at each stage through the unit weight adjustment where input data and the corresponding target variable data were used to train the deep neural network model until it approximated a function within a prior defined error value. This training process was repeated until the sum of squared errors was minimized to the smallest possible below the prior defined error value, or repeated until the total number of epochs was utilized.

After completion of the training for the DNN classification model, the final weights were fed into the deep neural network prediction (also known as diagnostic) model. Then, the DNN prediction model was used to detect and diagnose coronary heart disease patterns for outcome predictions of future patients during the testing process.

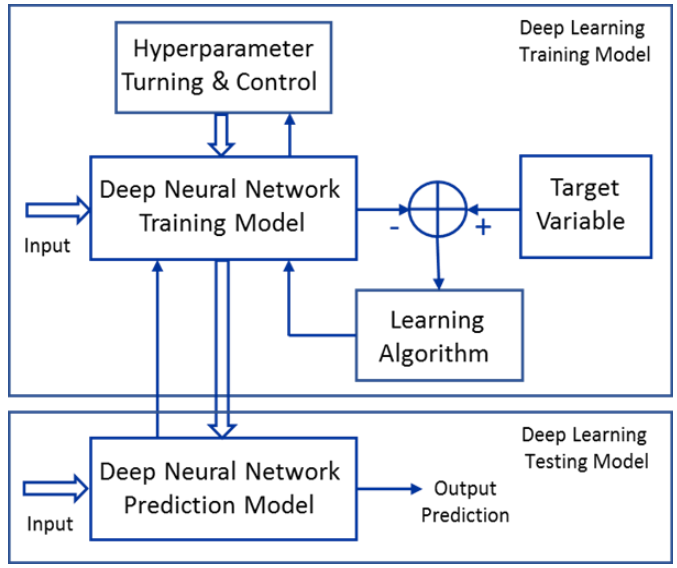

Fig. 1. System and Architecture of the Designed Deep Neural Network Models, Including the Deep Learning Training and Testing Models for Heart Disease Diagnosis used in this Research.

C. Deep Neural Network Classification Model

The deep neural network classification model is like a massive parallel distributed processor that learns and stores experiential knowledge [21]. Knowledge is acquired by the DNN system and architecture through a learning process [22], which is referred to as machine self-learning capabilities. Interneuron connection strengths, which is also known as weights in the network system and architecture, are used to store the knowledge [23, 24]. During training, a learning algorithm is utilized to modify the weights of linear and non-linear transfer functions within all of the neuron units in the network for the DNN classification model, thereby achieving a desired design objective usually in terms of the minimum mean squared error (MMSE) in an optimal sense. In other words, the learning algorithm adjusts all the weights of the DNN classification model based on the input data and output data of the target variable to obtain the best or optimal performance during each iterative process of the training sessions.

Structurally, the DNN model differs from a traditional multilayer perceptron neural network classification model. One of the key differences is regarding the network depth, which depends on the number of hidden layers in the network. Generally, if a neural network classification model has three or more hidden layers in the network architecture, it is considered a deep neural network classification model [19]. Thus, the higher hidden layers in the deep neural network build new abstractions on top of previous hidden layers. This thereby allows the DNN architecture to learn better solutions for the DNN classification model.

On the other hand, for DNN classification models, a key issue is overfitting [19, 25], which is the central problem in the field of deep learning because the DNN classification model performs effectively using a training dataset, but the model may perform less well with a test dataset using novel data [19]. This is because the DNN classification model is a complex system and architecture due to the large number of parameters based on a training dataset. However, in most cases, training data size is often not large enough. Therefore, overfitting can result in a high diagnostic accuracy based on the training dataset but a relatively less high diagnostic accuracy with the testing dataset when presented with novel cases. Thus, to prevent overfitting, the DNN classification model usually utilizes a regularization algorithm, which would decrease the complexity of the DNN model while maintaining the same number of large parameters.

The most common regularization algorithms is L_2 regularization [19, 22, 26] or *weight decay* and is a direct function approach that can regularize the DNN classification model. However, in order to minimize a L_2 norm, the regularization algorithm is used to penalize large weights by using a hyper-parameter λ, which is used to define the relative importance of the L_2 norm for decreasing loss on the training dataset. Thus, training a DNN classification model $f_\theta(x_i)$ involves finding a weight function θ (***w***, ***b)*** where ***w*** and ***b*** represent weights and bias, so that expected regularization loss is minimized and given by [19]:

$$E(\theta, D) = arg\min_\theta \left\{\frac{1}{D}\sum_{(x_i,t_i)\in D} E(f_\theta(x_i), t_i)\right\} + \lambda\|\theta\|_p, \quad (1)$$

Where D represents a training dataset and (x_i, T_i) represent samples in the training dataset; x_i represent inputs, and T_i are target variable data. The hyper-parameter λ is then utilized to control the regularization algorithm. The first function in the regularization algorithm in Eq. (1) represents an error function while the second function is known as a regularization error given by,

$$\|\theta\|_p = \left(\sum_{j=0}^{N} |\theta_j|^p\right)^{\frac{1}{p}}. \quad (2)$$

Note that Eq. (2) is the L_p norm in terms of the parameters θ and p. As can be seen, when p = 1, Eq. (2) is the L_1 regularization. Eq. (2) is the L_2 regularization when p = 2. On the other hand, the error function in Eq. (1) depends on output data of the target variable and assigns a penalty to predictions according to their consistency with the targets. In addition, the regularization error in Eq. (2) allocates a penalty depending on factors besides those of the targets' variable data.

Equally important, dropout is an effective regularization technique utilized to prevent overfitting in the DNN architecture [27]. Dropout is an alternative technology, which is used during each iterative training process to randomly eliminate neural network units and their connections in the DNN model system. The dropout technology enables us to train only smaller subsets of the deep neural network system and architecture in the deep neural network classification model [19]. As a result, dropout can effectively prevent single neural node units from dominating the deep neural network and causing over-adaptation.

D. Deep Neural Network Prediction Model

Performance quality of the deep neural network prediction (or diagnostic) model is heavily dependent on the DNN classification model during training. In this research, final weights of the deep neural network prediction model were loaded from the deep learning training model subsystem after the training processing was completed.

Generally, the DNN prediction model with (L-1) hidden layers has an output function [19, 24]:

$$\boldsymbol{Y} = \Phi_L((\cdots \Phi_3(\Phi_2(\Phi_1(\boldsymbol{X}\boldsymbol{W}_1 + \boldsymbol{B}_1)\boldsymbol{W}_2 + \boldsymbol{B}_2)\boldsymbol{W}_3 + \boldsymbol{B}_3)\cdots)\boldsymbol{W}_L + \boldsymbol{B}_L), \quad (3)$$

Where input matrix data $\boldsymbol{X}$ is fed into the layer for input; $\boldsymbol{W}_n$ and $\boldsymbol{B}_n$, $n = 1, 2, \ldots, L$, are weight matrix and bias vectors, respectively, for one of the n hidden layers; the transfer function Φ_n, $n = 1, 2, \ldots, L$, is either linear or nonlinear. The last layer at n = L is known as an output layer, and the other layers are hidden layers in the DNN system and architecture. As a result, the DNN prediction model in Eq. (3) can be used to detect coronary heart disease in future patients with novel clinical data during a diagnostic process.

E. Evaluation Methods of Deep Neural Network Model

Performances of deep learning models in diagnoses are often evaluated using the following measures: diagnostic accuracy, misclassification error, specificity, sensitivity, precision, *F*-score, AUC, and *K-S* test [10, 19, 24, 30-34]. Thus, in order to evaluate the diagnostic performances of the deep neural network models presented in this research, the above measures, displayed in Table 2, will be used based on both the training and testing datasets, where true positive = TP, false positive = FP, true negative = TN, and false negative = FN.

TABLE II. EVALUATION METHODS AND EQUATIONS FOR PERFORMANCE OF THE DEEP NEURAL NETWORK MODEL

Evaluation Methods	**Equations**
diagnostic accuracy	(TP + TN)/(TP + FN + FP + TN)
probability of misclassification error (PME)	(FN + FP) / (TP + FN + FP + TN) where diagnostic accuracy = (1 - PME)
sensitivity (recall)	TP / (TP + FN)
specificity	TN / (FP + TN)
precision	TP / (TP + FP)
F- Score	$\frac{(1+\beta^2)(\text{Precision} \times \text{Recall})}{\beta^2 \cdot Precision + Recall}$ In this research, β = 1ιs used; *F*-score is the harmonic mean of precision and recall.
area under ROC curve (AUC)	Graphical plot of sensitivity and (1-specificity); AUC = 0.5 is random chance; AUC = 1.0 is 100% diagnostic accuracy
K-S test	Model output probabilities; *K-S* test ranges between 0% and 100%; The *K-S* test measures degree of separation of distribution of the diagnostic results; *K-S* test = 100% represents perfect separation.

Additionally, a diagnostic odds ratio (DOR) is often used to evaluate effectiveness of a diagnostic test in medical testing. The DOR can be defined in a mathematical formula given by:

$$DOR = \frac{TP/FP}{FN/TN} = \frac{Sensitivity \times Specificity}{(1-Sensitivity) \times (1-Specificity)}\,. \quad (4)$$

The logarithm of the DOR is close to a normal distribution [35]. The corresponding standard error (SE) of the ln{DOR} distribution is approximately obtained by,

$$SE\{\ln(DOR)\} = \sqrt{\frac{1}{TP} + \frac{1}{TN} + \frac{1}{FP} + \frac{1}{FN}}. \quad (5)$$

This allows us to derive an approximate 95% confidence interval of the ln{DOR} in the following:

$$\ln(DOR) \pm 1.96 \times SE\{\ln(DOR)\}\,. \quad (6)$$

Using a method of back-transformation, computing the anti-log of this expression in Eq. (6) provides the 95% confidence interval of the DOR in the following:

$$e^{\ln(DOR) \pm 1.96 \times SE\{\ln(DOR)\}}. \quad (7)$$

Note that a value of the DOR in Eq. (4) usually ranges from 0 to ∞. A higher DOR value represents a more optimal performance. In order to be considered useful tests, the value of the DOR should be at least greater than one. Thus, the prediction (or diagnosis) model test is distinguishing correctly using the DNN model to identify whether or not heart disease is present in new patient cases.

III. Results

In this research, an enhanced deep neural network system and architecture are proposed for increasing the accuracy of heart disease diagnoses. The developed DNN model contains classification and prediction models, which are based on a deep multilayer perceptron with linear and non-linear transfer functions, regularization and dropout, and a binary sigmoid classification using deep learning technologies, thereby creating strong and enhanced classification and prediction models.

The proposed DNN classification model has a DNN architecture, including 28 input units, first and second hidden layers, and a binary output unit. 105 neurons in the first layer and 42 neurons in the second layer are connected with each Rectified linear unit activation functions [19, 24] along with a 50% dropout. The output unit in the final stage of the DNN architecture is connected to a sigmoid activation function [19, 24]. During training of the DNN, dropout rates in both hidden layers are randomly applied, resulting in random connections within the DNN architecture. Thus, the dropout technology is capable of reducing overfitting problems in the DNN model.

For evaluating the performances of the developed classification and prediction models based on the deep neural network algorithm, using the holdout method [36], a nonparametric approach was utilized to calculate the diagnostic accuracy and probability of misclassification error. The entire CCF dataset was randomly separated into two mutually exclusive data sets. In this research, 135 clinical instances were allocated to the training data set while 147 clinical instances were included in the testing data set. Both the datasets were normalized using the function [x – min(x)] divided by [max(x) – min(x)], in which *x* is an input data.

Training the DNN classification model using the training dataset was based on a batch size of 80, number of epochs of 5000, and learning rate of 0.00005 with a root mean square error (RMSE) in an optimization sense. Then, the designed DNN model was tested using the testing dataset.

Based on the results, Figure 2 displays the accuracy curve of a cutoff point at the output layer during testing process. As can be seen, when the cutoff point increases from 0 to 0.5, the accuracy of the designed DNN model increases; when the cutoff point increases from 0.5 to 1, the model accuracy decreases accordingly. Thus, to achieve maximum accuracy, the best cutoff point is 0.5 optimally.

In Figure 3, the ROC curve of the testing dataset is displayed, where AUC for detection of heart disease in the CCF dataset was 0.8922. AUC is utilized to rank the quality of the diagnostic model performance by graphing a curve from a series of trade-off points for sensitivity and (1-specificity) results, which were classified for presence of heart disease [30, 32]. Generally, the closer the AUC value is to 1, the higher the diagnostic accuracy in correctly detecting for the presence or absence of heart disease.

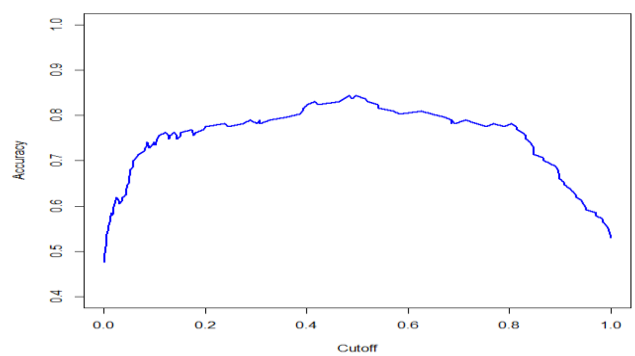

Fig. 2. An Accuracy Curve associated with a Cutoff Point at the Output Layer during the Testing. This Chart can be used to Determine the Cutoff Point in Terms of Probability, Thereby Ensuring the Maximum Value of Accuracy for the Developed DNN Model.

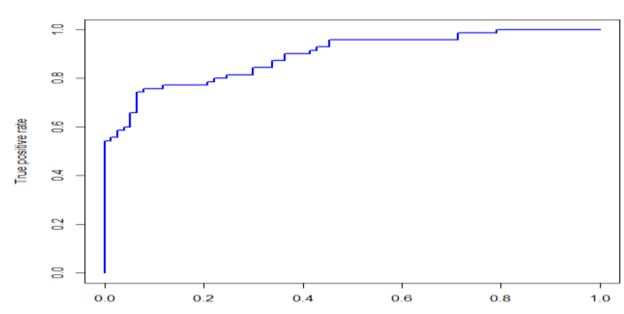

Fig. 3. In this ROC Curve, True Positive Rate Represents Sensitivity and False Positive Rate is the Difference (1 – Specificity). In this Research, AUC for the DNN Model was 0.8922 using the Testing Dataset.

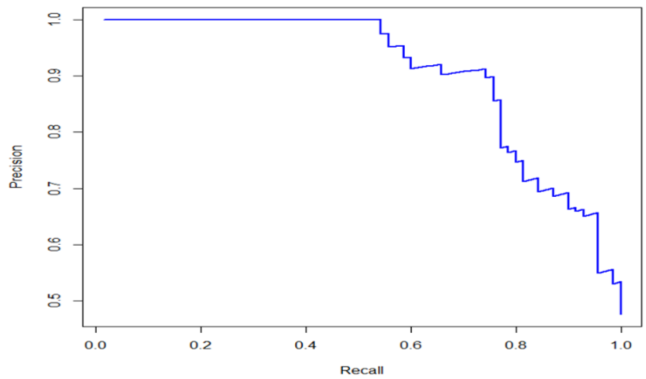

Fig. 4. This Shows a Relationship Curve between the Recall (or Sensitivity) vs. the Precision. When the Recall Increases, the Precision Decreases. When Precision Increases, Recall Decreases. This Chart can be used to Determine the Balance between Recall and Precision, Leading to *F*-Score Calculation.

Figure 4 displays a relationship curve between recall (or sensitivity) at the *x*-axis and precision at the *y*-axis, which is used to determine balance points between recall and precision as well as to calculate the *F*-score for the DNN classification and prediction model. As can be seen, when the recall increases from 0 to 0.55, the precision maintains a constant of 1; when the recall continues to increase from 0.55 to 1, the precision starts decreasing from 1 to 0 accordingly. On the other hand, when the precision increases from 0 to 1, the recall decreases from 1 to 0. Thus, in order to make ensure that the model can operate in an optimal sense, one of the common methods is to maximize a value of the *F*-score calculation using the equations displayed in Table 2.

In Figure 5, the *K-S* chart was created by using the model output probabilities of the DNN prediction model based on the testing dataset. The *K-S* test is nonparametric and measures degree of separation for the distribution of diagnostic results for heart disease in patients. With *K-S* test results ranging between 0% and 100%, a higher *K-S* test result represents a better diagnostic model in detecting disease in patients. In our research, the highest *K-S* value is 66.62%, located at the 4th decile population.

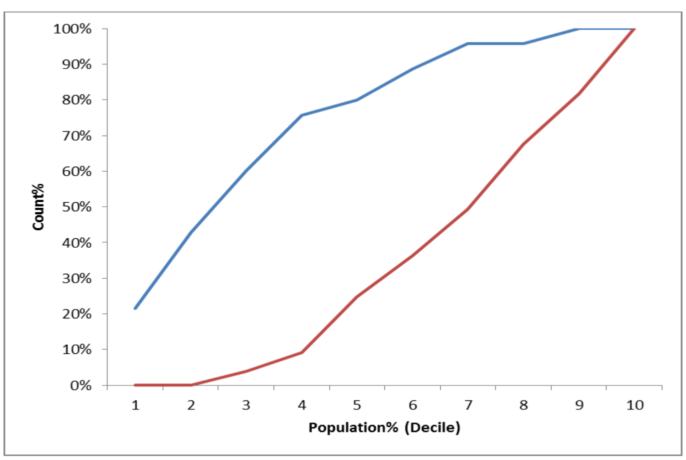

Fig. 5. The Highest *K-S* Value Achieved by the DNN Model is 66.62%, Located at the 4th Decile Population.

TABLE III. TESTING RESULTS FOR THE MODEL PERFORMANCE BASED ON THE TESTING DATA OF 147 CLINICAL INSTANCES USING THE DNN PREDICTION MODEL

	Heart Disease Presence	**Heart Disease Absence**	**Total**
Predicted Presence	TP = 51	FP = 5	56
Predicted Absence	FN = 19	TN = 72	91
Total	70	77	147

TABLE IV. TESTING RESULTS OF MODEL PERFORMANCE FOR THE TESTING DATA SET OF 147 CLINICAL CASES USING THE DEEP NEURAL NETWORK PREDICTION MODEL

Evaluation Methods	**Testing Results**
Diagnostic Accuracy	83.67%
Probability of Misclassification Error	16.33%
Sensitivity	93.51%
Specificity	72.86%
Precision	79.12%
F-Score	0.8571
Area under the ROC curve (AUC)	0.8922
K-S Test (highest at the 4th decile)	66.62%
Diagnostic Odds Ratio (DOR)	38.65
95% confidence interval of the DOR	[13.55, 110.28]

Displayed in Table 3 are the testing results for the performance of the DNN models. In Table 4, testing results of the model performances for the CCF testing data set of 147 clinical cases were calculated based on the above values, resulting in the diagnostic accuracy of 83.67%, probability of misclassification error of 16.33%, sensitivity of 93.51%, specificity of 72.86%, precision of 79.12%, *F*-score of 0.8571, AUC of 0.8922, the highest *K-S* test of 66.62% at the 4th decile population, DOR of 38.65, and 95% confidence interval for the DOR of this test of [38.65, 110.28].

Based on the testing results, medical application of the deep neural network learning model can be reliably and clinically useful in diagnosing patients with chest pain and ranges of heart disease presentation with high accuracy. The results can also be used to aid both healthcare professionals and patients, especially those in low-resource areas and developing countries where there are fewer cardiac specialists.

IV. DISCUSSION

In this research, the deep neural network classification and prediction models were created based on a deep learning algorithm. The DNN models were used to diagnose coronary heart disease and were applied to dataset of 303 clinical instances from the Cleveland Clinic Foundation. The models were trained and tested using randomly generated training and testing datasets, respectively. The performances of the developed DNN models were evaluated using diagnostic accuracy, probability of misclassification error, specificity, precision, AUC, sensitivity, *F*-score, and *K-S* test.

Displayed in Table 4, testing results of the developed DNN model performances for the CCF testing data set of 147 clinical cases were calculated based on a set of measurement parameters, including diagnostic accuracy of 83.67%, probability of misclassification error of 16.33%, sensitivity of 93.51%, specificity of 72.86%, precision of 79.12%, *F*-score of 0.8571, AUC of 0.8922, *K-S* test of 66.62%, DOR of 38.65, and 95% confidence interval for the DOR of this test of [38.65, 110.28]. Therefore, based on these testing results, the developed deep neural network classification and prediction models would be 83.67% accurate in diagnosing coronary heart disease in a new patient. The high sensitivity result of 93.51% is essential because it represents the probability of positive test result detection among those with the heart disease, and this indicates that given a new patient comes to the clinic with undiagnosed heart disease, the model is 93.51% accurate in detecting and making an accurate diagnosis. Since early and accurate detection of heart disease is essential for early intervention and prolonging chances of long-term survival, this high sensitivity score along with the relatively high *F*-score of 0.8571 and AUC of 0.8922 demonstrate that the developed DNN models were able to achieve a high accuracy in coronary heart disease diagnosis in patients.

Compared to related papers, several different methods were developed using the CCF heart disease data set. These included decision trees [6], SVM learning [8], a new type of discriminant function model using Bayesian algorithm [15], Bagging approach [37], and ensemble machine learning [10]. However, the majority of the methods associated with these developed models only used 13 input attributes compared to the 28 input attributes used in this research, enhancing the advanced deep neural network. These previous methods had model performance accuracies within a range of 61.93% to 80.14% using CCF clinical data. Furthermore, the sensitivity for detecting heart disease in patients using the above methods ranged from 70.97% to 77.9%. Our research using the deep neural network method exceeded both diagnostic accuracy and sensitivity of the above approaches with results of 83.67% and 93.51%, respectively. Furthermore, in the previously published method using ensemble machine learning [10], which also used 28 input attributes for developing the model, had sensitivity value of 70.97%, *F*-Score of 0.76, probability of misclassification error of 19.86%, and accuracy of 80.14% with *K-S* test value of 58.66%. In comparison, the developed deep neural network learning model in this research achieved a higher value of sensitivity at 93.51%, lower probability of misclassification error of 16.33%, higher diagnostic accuracy of 83.67%, higher *F*-Score of 0.8571, and further enhanced the *K-S* test value by an increase of 13.57% to 66.62%.

Our testing results indicate that the accuracy of the developed deep neural network classification and prediction models is relatively higher than most of those of previously published methods. Our testing results also used a relatively larger testing dataset of 147 novel clinical instances than the training dataset size of 131 clinical instances compared to the other methods using the holdout method. This suggests that if given a new patient with unique clinical data, the developed model would be able to diagnose with high reliability and accuracy. Therefore, the deep neural network learning models would be effective in reducing the number of inaccurate diagnoses, subsequently prevent erroneous treatments, and thereby enhance the health of patients. Furthermore, the developed DNN models provided a more reliable and greater diagnostic accuracy in detecting coronary heart disease in patients and improving chances of long-term survival.

V. Conclusion and Future Work

In this paper, the deep neural network learning classification and prediction models were developed and evaluated based on diagnostic performance of coronary heart disease in patients using sensitivity, specificity, precision, *F*-score, AUC, DOR, 95% confidence interval for DOR, and *K-S* test. The developed deep learning classification and prediction models were built with a deep multilayer perceptron eqipped with linear and non-linear transfer functions, regularization and dropout, and a binary sigmoid classification using deep learning technologies to create a strong and enhanced classification and prediction model.

The developed deep neural network classification and prediction models were trained and tested using the holdout method and 28 input attributes based on the clinical dataset from patients at the Cleveland Clinic. Based on the testing results, the developed deep learning models achieved diagnostic accuracy for heart disease of 83.67%, probability of misclassification error of 16.33%, sensitivity of 93.51%, specificity of 72.86%, precision of 79.12%, *F*-score of 0.8571, AUC of 0.8922, the *K-S* test of 66.62%, DOR of 38.65, and 95% confidence interval for the DOR of this test of [38.65, 110.28]. These results exceed those of currently published research. Therefore, the developed deep learning classification and prediction models can provide highly reliable and accurate diagnoses for coronary heart disease and reduce the number of erroneous diagnoses that potentially harm patients. Thus, the models can be used to aid healthcare professionals and patients throughout the world to advance both public health and global health, especially in developing countries and resource-limited areas where there are fewer cardiac specialists available.

In future research, we would investigate other enhanced methods that would further raise the diagnostic accuracy of the deep learning model by utilizing deep learning based on morphologic class pattern predictions [19] in order to further enhance the performances of the DNN models for heart disease diagnoses in patients worldwide. Furthermore, current advances in deep learning, including recurrent neural network, deep convolutional neural network, long short-term memory neural network, deep brief network based on restricted Boltzmann machines [38], and deep auto-encoder [39] may be utilized to further increase the accuracy of heart disease diagnoses for patients [40].

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References

[1] World Health Organization (WHO), "Cardiovascular diseases (CVD)," http://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds), 2017.

[2] Centers for Disease Control and Prevention (CDC), "Heart disease fact sheet,"https://www.cdc.gov/dhdsp/data_statistics/fact_sheets/fs_heart_disease.htm, 2015.

[3] E. J. Benjamin, S. S. Virani, C. W. Callaway, A. R. Chang, S. Cheng, S. E. Chiuve, M. Cushman, and F. N. Delling, et. al., "Heart disease and stroke statistics-2018 update: a report from the American Heart Association," *Circulation,* Vol. 137, No. 12, pp. 67- 492, 2018.

[4] Centers for Disease Control and Prevention, "Facts about heart disease," http://www.cdc.gov/heartdisease/docs/consumered_heartdisease.pdf, 2013.

[5] E. G. Nabel and E. Braunwald, “A tale of coronary artery disease and myocardial infarction," *New England Journal of Medicine,* Vol. 366, pp. 54-63, 2012.

[6] M. Shouman, T. Turner, and R. Stocker, “Using decision tree for diagnosing heart disease patients,” *Proceedings of the 9th Australasian Data Mining Conference*, pp. 23–29, Ballarat, Australia, 2011.

[7] O. Y. Atkov, S. G. Gorokhova, A. G. Sboev, E. V. Generozov, E. V. Muraseyeva, S. Y. Moroshkina, and N. N. Cherniy, "Coronary heart disease diagnosis by artificial neural networks including genetic polymorphisms and clinical parameters," *Journal of Cardiology*, Vol. 59, Issue 2, pp. 190-194, 2012.

[8] A. D. Dolatabadi, S. E. Khadem, B. M. Asl, “Automated diagnosis of coronary artery disease (CAD) patients using optimized SVM,” *Computer Methods and Programs in Biomedicine,* Vol. 138, Issue C, pp. 117-126, 2017.

[9] P. Gayathri and N. Jaisankar, “Comprehensive study of heart disease diagnosis using data mining and soft computing techniques,” *International Journal of Engineering and Technology*, Vol. 5, No. 3, pp. 2947-2957, 2013.

[10] K. H. Miao, J. H. Miao, and G. J. Miao, "Diagnosing heart disease using ensemble machine learning," *International Journal of Advanced Computer Science and Applications*, Vol. 7, No. 10, pp. 30-39, 2016.

[11] H. M. Sawbwa, N. Ghali, and A. E. Hassanien, "Detection of heart disease using binary particle swarm optimization," *Proceedings of the Federated Conference on Computer Science and Information Systems*, pp. 177-182, 2012.

[12] A. Ozcift and A. Gulten, “Classifier ensemble construction with rotation forest to improve medical diagnosis performance of machine learning algorithms,” *Journal of Computer Methods and Programs in Biomedicine*, Vol. 104, pp. 443-451, 2011.

[13] L. Pasi and L. Jouni, “A classification method based on principal component analysis and differential evolution algorithm applied for prediction diagnosis from clinical EMR heart data sets,” *Computational Intelligence in Optimization*, Vol. 7, pp. 263-283, 2010.

[14] W. Wiharto, H. Kusnanto, and H. Herianto, “Intelligence system for diagnosis level of coronary heart disease with K-star algorithm,” *Healthcare Informatics Research*, Vol. 22, No. 1, pp. 30-38, 2016.

[15] R. Detrano, A. Janosi, A. Steinbrunn, W. Pfisterer, M. Schmid, J. Sandhu, S. Guppy, K. Lee, and V. Froelicher, “International application of a new probability algorithm for the diagnosis of coronary artery disease,” *American Journal of Cardiology*, Vol. 64, pp. 304-310, 1989.

[16] D. Pal, K. Mandana, S. Pal, D. Sarkar, and C. Chakraborty, “Fuzzy expert system approach for coronary artery disease screening using clinical parameters,” *Knowledge-Based System*, Vol. 36, pp. 162-174, 2012.

[17] H. R. Marateb and S. Goudarzi, “A noninvasive method for coronary artery diseases diagnosis using a clinically-interpretable fuzzy rule based system,” *Journal of Research in Medical Sciences*, Vol. 20, No. 3, pp. 214-223, 2015.

[18] J. Schmidhuber, "Deep learning in neural networks: An Overview." *Neural Networks*, Vol. 61, pp. 85-117, 2015.

[19] J. H. Miao and K. H. Miao, "Cardiotocographic diagnosis of fetal health based on multiclass morphologic pattern predictions using deep learning classification," *International Journal of Advanced Computer Science and Applications*, Vol. 9, No. 5, pp. 1-11, 2018.

[20] D. J. Newman, S. Hettich, C. L. Blake, and C. J. Merz, *UCI Repository of Machine Learning Databases*, University California Irvine, Department of Information and Computer Science, 2018.

[21] Y. Bengio, "Learning deep architectures for AI", *Foundations and Trends in Machine Learning*, Vol. 2, No. 1, pp 1-127, 2009.

[22] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*, The MIT Press, 2016.

[23] F. Q. Lauzon, "An introduction to deep learning," The *11th International Conference on Information Science, Signal Processing and their Applications*, Montreal, QC, pp. 1438-1439, 2012.

[24] G. J. Miao, K. H. Miao, and J. H. Miao, “Neural pattern recognition model for breast cancer diagnosis,” *Journal of Selected Areas in Bioinformatics*, Vol. 2, Issue 8, pp. 1–8, 2012.

[25] C. Gavin, and T. L. C. Nicola, “On over-fitting in model selection and subsequent selection bias in performance evaluation,” *Journal of Machine Learning Research*, Vol. 11, pp. 2079−2107, 2010.

[26] J. Kukačka, V. Golkov, and D. Cremers, “Regularization for deep learning: a taxonomy,” *Artificial Intelligence*, pp 1-27, 2017.

[27] N. Srivastava, G. Hinton, A. Krizhevsky, I. Sutskever, and R. Salakhutdinov, “Dropout: a simple way to prevent neural networks from overfitting,” *Journal of Machine Learning Research*, Vol. 15, pp. 1929-1958, 2014.

[28] G. E. Hinton, N. Srivastava, A. Krizhevsky, I. Sutskever, and R. R. Salakhutdinov, “Improving neural networks by preventing co-adaptation of feature detectors,” *Neural and Evolutionary Computing*, pp. 1-18, 2012.

[29] D. Warde-Farley, I. J. Goodfellow, A. Courville, and Y. Bengio, “An empirical analysis of dropout in piecewise linear networks,” *Machine Learning*, pp. 1-10, 2014.

[30] K. H. Miao and G. J. Miao, “Mammographic diagnosis for breast cancer biopsy predictions using neural network classification model and receiver operating characteristic (ROC) curve evaluation,” *Multidisciplinary Journals in Science and Technology*, *Journal of Selected Areas in Bioinformatics*, Vol. 3, Issue 9, pp. 1–10, 2013.

[31] J. H. Miao, K. H. Miao, and G. J. Miao, “Breast cancer biopsy predictions based on mammographic diagnosis using Support Vector Machine learning,” *Multidisciplinary Journals in Science and Technology*, *Journal of Selected Areas in Bioinformatics*, Vol. 5, No. 4, pp. 1–9, 2015.

[32] M. Sokolova, N. Japkowicz, and S. Szpakowicz, “Beyond accuracy, F-score and ROC: a family of discriminant measures for performance evaluation.,” A. Sattar and B. Kang (eds), Advances in Artificial Intelligence, Lecture Notes in Computer Science, Vol. 4304, Berlin, Heidelberg, 2006.

[33] A. M. Law, “A tutorial on how to select simulation input probability distributions,” *The IEEE Proceedings of the 2013 Winter Simulation Conference*, pp. 306–320, 2013.

[34] T. B. Arnold and J. W. Emerson, “Nonparametric goodness-of-fit tests for discrete null distributions,” *The R Journal*, Vol. 3/2, pp. 34-39, 2011.

[35] A. S. Glas, J. G. Lijmer, M. H. Prins, G. J. Bonsel, and P. M. M. Bossuyt, "The diagnostic odds ratio: a single indicator of test performance". *Journal of Clinical Epidemiology*, Vol. 56, No. 11, pp. 1129–1135, 2003.

[36] G. J. Miao and M. A. Clements, *Digital Signal Processing and Statistical Classification*, Artech House, Inc., 2002.

[37] M. C. Tu and D. Shin, “Effective diagnosis of heart disease through Bagging approach,” *The IEEE 2nd International Conference on Biomedical Engineering and Informatics*, pp. 1-4, 2009.

[38] G. Hinton, “A practical guide to training Restricted Boltzmann Machines,” *University of Toronto, Department of Computer Science*, Version 1, pp. 1-21, 2010.

[39] Q. V. Le, “A tutorial on deep learning part 2: autoencoders, convolutional neural networks and recurrent neural networks,” *Google Inc*, Mountain View, California, pp. 1-20, 2015.

[40] Y. LeCun, Y. Bengio, and G. Hinton. "Deep Learning" *Nature*, Vol. 521, pp 436-444, 2015.

Human Related-Health Actions Detection using Android Camera based on TensorFlow Object Detection API

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***Abstract*—A new method to detect human health-related actions (HHRA) from a video sequence using an Android camera. The Android platform works not only to capture video images through its camera, but also to detect emergency actions. An application for HHRA is to help monitor unattended children, individuals with special needs or the elderly. The application has been investigating based on TensorFlow Object Detection Application Program Interface (API) technique with Android studio. This paper fundamentally focuses on the comparison, in terms of improving speed and detection accuracy. In this work, two promising new approaches for HHRA detection has been proposed: SSD Mobilenet and Faster RCNN Resnet models. The proposed approaches are evaluated on the NTU RGB+D dataset, which it knows as the present greatest publicly accessible 3D action recognition dataset. The dataset has been split into training and testing dataset. The total confidence scores detection quality (total mAP) for all the actions classes are 95.8% based on the SSD-Mobilenet model and 93.8% based on Faster-R-CNN-Resnet model. The detection process is achieved using two methods to evaluate the detection performance using Android camera (Galaxy S6) and using TensorFlow Object Detection Notebook in terms of accuracy and detection speed. Experimental results have demonstrated valuable improvements in terms of detection accuracy and efficiency for human health-related actions identification. The experiments have executed on Ubuntu 16.04LTS GTX1070 @ 2.80GHZ x8 system.**

Keywords*—Android camera; TensorFlow object detection API; emergency actions; detection accuracy

I. Introduction

Generally, the elderly, children and the people with special needs are considered to be in need of care and supervision of their behavior all the time. Safety is a priority especially when their caregivers are not available to prevent accidents like falling, passing out or nausea due to an existing medical conditions or unforeseen dangers to prevent such accidents as in falling, nausea This led us to build an application to detect the abnormal actions through the Android platform and in the future, it can be manipulated to send a alerting message to the observer to provide the necessary assistance as soon as possible. The Object detection is a common concept for computer vision methods for definition and labeling objects. Human action detection is one of the top massively studied topics that can be used for surveillance camera. Most of the techniques include substantial limitations when it comes to the specific form of computational resources, the dependence of the motion of the objects, disability to differentiate one object from another, the absence of proper data analysis of the measured trained data, and a major interest is over the speed of the movement and illumination. Therefore, drafting, applying and recognizing new methods of detection that manage the present limitations, are much needed. The techniques of object detection can be applied both to still images or video images. The objective of human action detection is to detect each appearance of a specific action in a video and to localize every detection identified together in space and time. Recently, the video action recognition performance has improved based on Deep Learning (DL) approaches. Human action detection task is challenging compared to the human action recognition because of the change in size of the human and in addition to the spatio-temporal location. Generally, deep learning has been connected with data centers and large clusters of great-powered GPU machines. Nonetheless, it can be highly expensive and time-consuming to transfer all of the data in the device and deliver it across a network connection. Implementation on a mobile makes it possible to deliver real interacting applications using a method that is not possible when you should wait for a network round trip. The smartphone is being added to video surveillance systems almost everywhere at any time. In other words, the video surveillance system for mobile has spread and expanded significantly in recent times so you can monitor your home or business when you are away. Smartphone devices with a camera are a massive part of our daily lives. However, there is a growing interest in the interaction between the users and their devices. The interaction between the user, the phone, and real-world objects [1] represents the many variations of smart device applications.

Objects detection utilizing a mobile camera has many functions like video surveillance, object stability, and collision revocation.Most techniques have been used to detect tracking objects from a non-stable platform. Whereas these techniques require the movement parameters of the camera to be recognized, that is frequently not easily obtainable or are incapable of object detection if the tracking object’s size is small. In this paper, we aim to present a new detection application for video images of human health-related actions using Android phone’s camera. The software is based on Deep learning system running on TensorFlow’s Object Detection API using Android platform. A robust tool gives it straight to construct, train, and use object detection models. In most of the cases, training a complete convolutional network from scratch is time-consuming and needs massive datasets. Accordingly, this problem can be resolved by utilizing the power of transfer learning with a pre-trained model [2] using the TensorFlow API.

An Android platform has been used toward the object recognition applications [1], which works on images taken through a built-in camera. Android is gradually growing to be the commonly utilized platform amongst the smartphone technologies as a monitor. The user can have access to the correct human action from the object by which the required action is marked upon the detected object. The recognition of the object detection in a video frames on an android is completely developed. Once the object is appropriately detected, it could be saved and accessible for future applications.

The contributions of this study are as follows.

- Videos of human actions are selected based on health needs and it defined emergency actions that must be taken consideration because it is important to detect them quickly and with high accuracy.
- Most advanced methods have been utilized for training the various human action classes in order to guarantee that it learns all the samples of the entire video frames.
- Model performance has been evaluation through detection accuracy by measuring the confidence source mAP for each action class and total mAP for all the classes.
- The number of steps of the training and evaluation processes can be controlled to get the least error (classification loss) to make the classification of the action class correct and also make the location of the human action as the lowest error (localization loss) to bounding detection box on the right place.
- By using the Android camera, the efficiency and power of the model detector can be enhanced. That is because; the Android detection results were compared to the detection process using TensorFlow Object Detection Notebook technique.

The paper is organized as follows. Section II discusses the related works. Details of object detection technique is presented in Section III. Section IV explains TensorFlow object detection API technique. The Feature extraction algorithm defined with details in Section V. Section VII presents the proposed technique that includes the experimental settings, training and evaluation processes and detection approach with experimental results. Discussion of the significance of this work is discussed in Section IX. Finally, Section X concludes this work.

II. Related Works

Human action detection using image-processing methods on smartphones as Android device is a developed conception. Wherefore only, a meager published literature was usable. Most of the obtainable literature focuses on the desktop applications. The topic studied in [3] showcases a collection of critically trained elements in a star model that is called Pictorial Structure. It can be said that this paper could be viewed as a 2-layer model, consisting of the first layer and the second layer will include the star model. The research in [4] utilizes the common field information which was related to [5] which was based on the manually designed Histogram of Gradients (HOG) descriptors. [6] represents the objectness measure by simply utilizing 8 × 8 binarized normed gradients (BING) features. This process is easy and quick and it is done by calculating the objectness of each image boundary box at any scale by using a few atomic operations. The paper [7] presents a design for bidirectional retrieval of images and sentences by using a deep, multi-modal embedding of visual and natural language data. In addition, they also display a structured max-margin objective, which enables their model to incorporate these parts over modalities. A design that creates natural language descriptions of images and their regions is shown in research [8] while approaching supported datasets that include images and their sentence information in order to learn about the inter-modal correlation between language and visual images. Their model is set up on an aggregate of Convolutional Neural Networks over image regions and bidirectional Recurrent Neural Networks over sentences. The work in [9] examines the conclusion of disfiguring part models from 2D images to 3D spatio-temporal volumes in order to study their efficiency for action detection in video.

Action detection model presented in [10] , first decomposes human actions towards temporal key poses and then to spatial action parts. Precisely, they began by clustering cuboids around every human joint to dynamic-pose lets by using a new descriptor. The structure of paper [11] merges strong computer vision techniques for forming bottom-up region with modern improvements in learning high performance of convolutional neural networks. The resulting system based on R-CNN is called: Regions with CNN features.

III. Object Detection Technique

Generally speaking, the object detection methods apply an image classifier to an object detection function which is becoming efficient methods; it involves changing the size and a position of the object in the test image and then utilizing the classifier to recognize the object. The multi- bounding box method [12] is a familiar model that has been reported in. Over the past few years, a method covering the extraction of several filter regions of objects utilizing region proposals as performed by R-CNN. Thereafter, the process of making classification decision [13] with filter regions utilizing classifiers has been described. However, the R-CNN method could be time consuming because it needs a larger amount of crops, which will result to duplicate the calculation from overlapping crops. Such calculation verbosity was resolved by the use of a Fast R-CNN [14] that inserts the completed image once within a feature extractor so the crops would end up sharing the calculation amount of feature extraction.

In this work has used the developed software tool for the Android camera; it focuses on two recent TensorFlow object detection API models: SSD_Mobilenet framework, and the Faster R-CNN-Resent framework. The algorithm proposed for HHRA detection model is important to understand how efficient the framework performs.

IV. TENSORFLOW OBJECT DETECTION API

TensorFlow Object Detection API's package is a process to resolve object detection problems. This is a technique of detecting real-time objects in an image. In agreement with the documentation and the paper [2] that shows the library, what makes it exclusive is that it is capable to trading accuracy for speed and memory application (vice-versa). Therefore, you can modify the model to satisfy your requirements and your platform, like a smartphone. The Tensorflow Object Detection API library contains multiple out-of-the-boxes object detection structures like SSD (Single Shot Detector), Faster R-CNN (Faster Region-based Convolutional Neural Network), and R-FCN (Region-based Fully Convolutional Networks).

In addition to different feature extractors such as MobileNet, Inception, and Resnet; those extractors are actually important since they represent a major part in the speed/achievement trade-off of the framework. In fact, training from scratch to cover an entire convolutional network is time consuming and requires hugs datasets. To avoid this problem, transfer learning is applied with a pre-trained model relating the TensorFlow API. The transfer learning [15] is a machine learning approach where a model advanced for a function is reused as the outset point for a model on a second function. It is a common strategy in deep learning where pre-trained models are adopted as the starting point on computer vision processing function given the large calculation and time resources wanted to develop neural network models. The benefit of utilizing a pre-trained model is that alternatively of creating the model from scratch, a model trained for a similar problem can be applied as a starting point for training the system. In this work, the experiments have used the pre-trained model/checkpoints SSD MobileNet and Faster R-CNN- Resent [16] from the TensorFlow Zoo.

A. Faster R-CNN

A Faster R-CNN network [12] uses as input a whole image and a group of object proposals. Accordingly, the first processes the whole image including some convolutional (conv.) and max pooling layers to generate a conv. feature map. Next, for every object proposal, a region of interest (RoI) extracts a fixed-length feature vector of the feature map. Every feature vector is supplied to a concatenation of fully connected (fc) layers, which eventually branch for two relationship output layers: one that creates softmax probability rating through N object categories and addition to taking all "background" category plus adding a layer that produces outputs four real-valued numbers for each of the N object categories. Each collection of 4 values encodes filtered bounding-box positions for one of the N categories. The RoI pooling layer utilizes max pooling to change the features under each actual region of interest in a slight feature map by a fixed spatial range of $H \times W$, where H and W denote a layer hyper-parameters. A RoI in [12] is a rectangular window in a conv. feature map. Every RoI is determined over a four-variable (r, c, h, w) where it defines its top-left corner (r, c) and its height and width (h, w). The RoI max-pooling operates through dividing the $h \times w$ RoI window into an $H \times W$ grid of sub-windows of estimated size ($h/H \times w/W$). Thereafter the max-pooling values in every sub-window within the corresponding output grid cell. Faster R-CNN has two processes for object detection. First process, images are processed utilizing a feature extractor model (e.g., MobileNet, VGG,) named the Region Proposal Network (RPN), and at the same time several medium-level layers are applied to expect the category bounding box proposals. Second process, the box proposals are utilized to crop features from the same medium feature map, which are then inputted to the rest of the feature extractor model with a view for predicting a category label and its bounding box will improve for every proposal. Lastly, the Faster R-CNN does not crop proposals straight from the image; instead, it runs the crops again over the feature extractor, which will drive to more replicated computations.

B. SSD

A Single Shot Multibox Detector (SSD) [17] was presented in 2016 by researchers from Google. The SSD is a rapid single-shot object detector for multiple classes. It utilizes a one feed-forward convolutional network to assume classes straightforward and anchor stabilizer without needing another step for each proposal classification process. The important feature of SSD is the employ of multi-scale convolutional bounding box outputs connected to various feature maps at the highest of the network. The VGG-16 was applied as the core network because of its effective performance in high-quality image classification functions and transfer-learning training in order to enhance the results. The bounding box technique of SSD is driven by Szegedy's project [18] on MultiBox, and an Inception mode convolutional network is used. The MultiBox's loss task mixed two significant parts that performed their path to SSD. The first part is confidence loss that measures how confident the system is of the objects of the calculated bounding box. However, the second part is location loss, which measures the distance of the network's predicted bounding boxes from the ground truth ones through the training process.

The SSD applies smooth L1-Norm [19] to determine the location loss. Regarding classification process, the SSD performs object classification. Therefore, for every predicted bounding box, collections of N categories predictions are calculated for each likely category in the dataset. Furthermore, feature maps are a description of the interest features of the image at various scales, hence working MultiBox on multiple feature maps rises the likelihood of any object whether large or small which to be eventually detected, localized and properly classified.

V. FEATURE EXTRACTION

The aim of feature extraction is to decrease a variably sized image to a packed set of visual features. Typically, image classification models are built by applying strong visual feature extraction techniques. While they depend on either conventional computer vision approaches, (e.g. filter based methods, histogram techniques, etc.) or on deep learning approaches, they all have the same goal: extract features from the input of image which are appropriate for the task, and apply these features in a classification process to define the class of the image. In object detection systems, a convolutional feature extractor is a base network that is implemented in the input data to obtain advanced features. The collection of the feature extractor is supposed to be highly significant, which is because of the number and types of layers, the number of parameters and other characteristics, which immediately influence the execution of the detector. In this paper, two feature extractors which have been selected are the most used in the area of computer vision.

A. Resnet

Deep learning networks have been developed and moved to a high level of sophistication in detection applications when a Microsoft Research released for a Deep residual networks (Resnets) [20]. The Resnets that are above 100-layer deep have demonstrated state-of-the-art accuracy for challenging recognition functions on ImageNet [21] and MS COCO [22] competitions that included object detection, image classification, and semantic segmentation. The validity of Resnets has been confirmed by multiple visual recognition applications and by non-visual applications including speech and language. Deep Network is of significant interest in neural network architectures, however, deeper networks are further challenging to train. The residual learning structure helps the training of these networks and allows them to be deeper activate performance in both visual and non-visual functions. In the deeper network, the additional layers much better approximate the mapping than its conventional counterpart and decrease the error.

The residual function utilize $F(x) = H(x) - x$, that can be reorganized into $H(x) = F(x) + x$, where $F(x)$ and x performs the accumulated non-linear layers and the identity function (input=output) respectively. Moreover, the main concept of Resnet is to inserting a termed “identity shortcut connection” that jumps one or more layers. Generally, Resnets involves several stacked “Residual Units”, where each unit can be represented in a common form:

$$y_l = h(x_l) + F(x_l, W_l), \tag{1}$$

$$x_{l+1} = f(y_l), \tag{2}$$

Where x_l and x_{l+1} are input and output of the l-th unit, and F represents a residual function. In [20] h(x_l) = x_l represents an identity mapping and f is a ReLU [23] function. The basic concept of Resnets is to learn the collective residual function F with regard to $h(x_l)$, with an important option of applying an identity mapping $h(x_l) = x_l$, this is achieved by linking an identity overstep connection (“shortcut”).

B. Mobilenet

Mobilenet [24] was created for active inference in different mobile vision functions. The network structure of Mobilenet depends on depthwise separable convolution. It is an advanced state of the inception module, wherever parted spatial convolution for each channel is used which indicated as depthwise convolutions [25]. The 1x1 convolution with all the channels to combines the output indicated as pointwise convolutions are applied. As a result, the division in depthwise and pointwise convolution increase the efficiency performance furthermore, it enhances the accuracy, while a cross-channel and spatial correlations mapping is learned independently. The MobileNet has been displaying to reach an accuracy identical to VGG-16 on ImageNet with exclusive 1/30th of the calculation cost and model magnitude. Its structuring blocks set are depthwise separable convolutions which factorize a standard convolution for a depthwise convolution and a 1 × 1 convolution as shown in Fig.1ultimately, decrease the pair of the calculation cost and a number of hyper-parameters.

VI. Tensorflow in Andriod

The Android model of the TensorFlow library [26] is a single project that builds and installs four sample applications (TF Detect, TF Classify, TF Stylize, and TF Speech) [27], which all use the same underlying code. The sample applications all take input video from a phone's camera. The TF Detect app is going to be used in this work. The base of the TensorFlow is written in C++ to begin towards building the process for the Android. In order to establish for Android, JNI (Java Native Interface) has to be applied to call the C++ functions such as loadModel, obtain predictions, etc. A shared object (.so) file will be built, that is a C++ compiled file and a jar file that will involve JAVA API, which calls for the native C++, and the JAVA API will be called to make things achieved simply. There are software, dependencies, and packages required: Android Studio, Android SDK and Android NDK. Android Studio import a new project using the directory from the TensorFlow repo called “Android”.

Essentially, NDK (Native Development Kit) [28] is a great tool in the evolution of mobile applications. Particularly if you need to improve a multiplatform application, the NDK is excelled in this field. Since the same code written in C++ for Android can be ported and run the same way on the iOS, Windows or any other platform without changing the original code. This really keep a lot of time in the development of applications, which are advanced for doing run on multiple platforms; as games and other traditional applications.

SDK (software development kit) [29] is a tool with more tool applications, data files, and model code. The SDK supports you in developing code, which uses a special system such as extension code for utilizing features of an operating system (Windows SDK), drawing 3D graphics by a specific system (DirectX SDK), or writing a code to make a device like a mobile phone perform what you need.

VII. Proposed Technique

In this paper, the proposed model aim to detect human health-related actions from videos of N frames by using Android camera. The dataset splits into training and testing dataset. First step is to label the dataset by drawing a bounding box (ground truth) around each video frame of human health-related action. Then, save them as XML file. The XML file converts to a CSV file and thereafter, TensorFlow that is called “TFRecords” converts the CSV file into a format that is readable. The proposed HHRA model uses two per-trained models of TensorFlow object detection API that are Faster R-CNN-Resnet and SSD-Mobilenet for training the dataset. Model evaluation will be done during and after training. Lastly, it will demonstrate how to export the model to Android for detect the action type using Android camera. Under the object detection algorithm utilizing deep learning, there are many parameters that are learned from the data. Fig.1 describes the basic block diagram for proposed the HHRA model in this paper. The setting of TensorFlow object detection API of the models that used in this work as following as

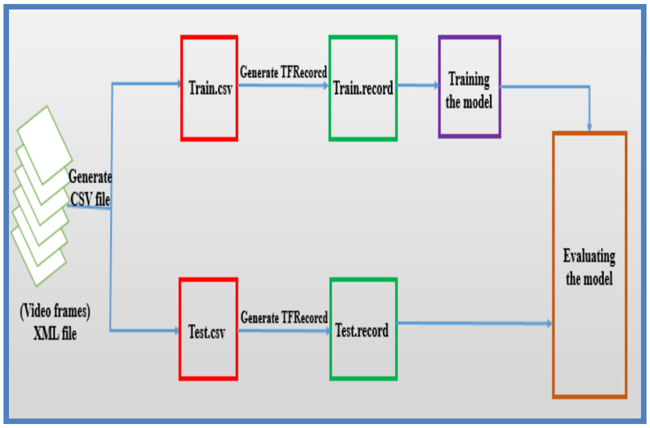


Fig. 1. Basic Block Diagram for Proposed the HHRA Model.

A. *Faster R-CNN-Resnet*

The methodology mentioned in the [12] [20] is used in this work. It has been using the weights by an abbreviate normal distribution with a standard deviation of 0.01. The intial_learning_ rate is 0.003 and a momentum _optimizer value is 0.9 with batch size equals 1. A loss function procedures the softmax function for classification loss and the smooth L1 function for localization loss. A function is used as the activation function. The input for each video frame was resized to 606 × 1024 pixels.

B. *SSD-Mobilenet*

Following the methodology mentioned in the papers [17] [24] it has been initializing the weights by an abbreviate normal distribution with a standard deviation of 0.03. The intial_learning_ rate is 0.003 with a learning_ rate_ decay of 0.9997 and a momentum _optimizer_value is 0.9 with batch size equals 32. A loss function uses the sigmoid function for classification loss and the smooth L1 function for localization loss. A ReLU function is used as the activation function. The input for each video frame was resized in this framework to 300 × 300 pixels.

VIII. Experimental Results and Analysis

A. *Dataset and Preprocessing*

The proposed detection method are evaluated on the NTU RGB+D dataset [30], which is defined as the present biggest widely obtainable 3D action recognition dataset. The dataset includes more than 56k action videos and contents 4 million frames. In this paper, seven different human health-related actions of video sequences were selected from NTU RGB+D dataset (Falling, Nausea, Headache, Neck pain, Sneezing, Staggering, and Stomachache) presented as frames sequences for training using TensorFolw object detection models and testing using Android's camera. The training dataset was created by manually tagging the human action in the video frames using LabelImg software [31] because it is needed to have a ground truth of what exactly the object is. In other words, it is important to draw a bounding box around the person with his action as shown in Fig.2, so the system knows that this "action" inside the box is the actual human action. Each person with his action was tagged as a name of the human activities related to the type of action (a health-related action). LabelImg saves the annotations as XML-files in PASCAL VOC format is prepared for creating TFRcords (Tensor Flow record format). Each dataset requires a label map connected with it, which represents a mapping from string class names to integer class IDs. Label maps should always start from ID1. In this work, there are seven IDs related to seven human health-related actions. The 1920x1080 sized video frame (and the corresponding annotation files) were later resized to improve the model training efficiency. Once all the frames were labelled, the next step was to split the dataset into a train and test the dataset.

B. *Training and Evaluation*

In this work, the pre-trained with one of the models (SSD_Mobilenet or Faster R-CNN-Resnet) was fine-tuned for NTU RGB+D dataset using manually labeled video frames of HHRA saved this tagged data as an XML file and adapted this XML file to a CSV file. Next, the CSV file is converted to TFRecord file by satisfying the similar specifications as shown in Fig.1. The entire training process is addressed by a configuration file recognized as the "pipeline". The pipeline is split into several essential structures that are responsible for determining the model, the training and evaluation process parameters, and both the training and evaluation dataset inputs. Actually, the TensorFlow advises that the training should apply one of their own and already trained models as an outset point. The idea behind this is that training a completely new model from scratch might need an excessive amount of time. Therefore, the TensorFlow gives various configuration files, which only needs a number of changes that correspond to a new training environment. The results of the training and the evaluation stages can be observed by applying TensorFlow's visualization platform, TensorBoard [32]. This tool can observe various metrics such as the training time, total loss, number of steps and much more. The TensorBoard also runs while the model is being trained, making this an excellent tool to confirm that the training is going in the right direction. The given checkpoint file for the models is applied as a beginning point for the fine-tuning process.

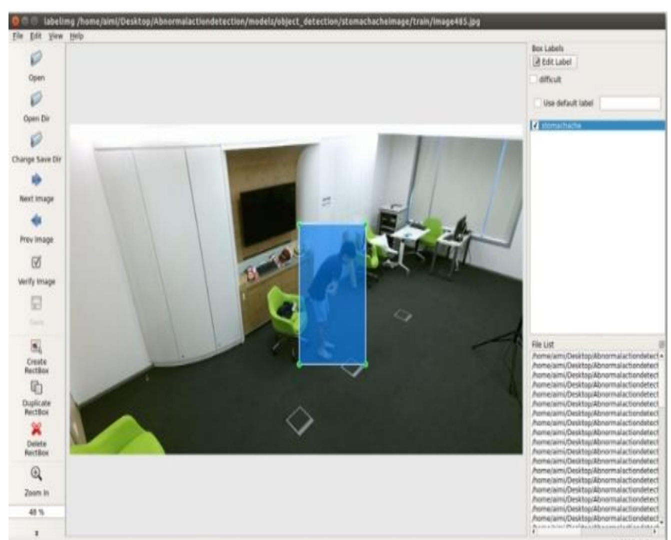


Fig. 2. Sample of Stomachache Action Frame Surrounded by a Bounding Box.

The changes are made so that the variable num_classes, num_steps to pause the training earlier, fine_tune_checkpoint to point to the location of the model downloaded, and the input_path and label_map_path variables of the train_input_reader and eval_input_reader to point to the training and testing dataset, as well as the labels map. Primarily, training data as well as evaluation data are needed during the training process. The training data is necessary to learn the model on these data, while the evaluation data is required to evaluate the accuracy of the trained model if the model has learned all the video frames for each class. Region proposals are clustering-based method, which tries to group pixels and produce proposals based on the created clusters.

In the evaluation stage, the mAP measures the trained model percentage of correct predictions for all seven actions labels. The IoU is particular to object detection models and a case for Intersection-over-Union. This measurement represents the overlap between the bounding box generated by HHRA model and the ground truth-bounding box, described as a percentage. The mAP graph is averaging the percentage of correct bounding boxes and labels of the HHRA model resumed with “correct” in this case relating to bounding boxes that had 50% or more overlap with their corresponding ground truth boxes.

The HHAR model is improved for loss functions which combining two functions (classification and localization):

u: True class label, $u \in 0,1,. . . ., K$; by convention, , the catch all background class has u=0.

p: Discrete probability distribution (per RoI) over k+1 classes:

$p = (p_0, . . . , p_k)$, computed by a softmax over the k+1 outputs of a fully connected layer.

v: True bounding box $v = (v_x, v_y, v_w, v_h)$.

t^u: Predicated bounding box correction, $t^u = (t_x^u, t_y^u, t_w^u, t_h^u)$.

The loss function sums up the rate of classification and bounding box prediction: $\mathcal{L} = \mathcal{L}_{cls} + \mathcal{L}_{box}$. For “background” RoI, $\mathcal{L}_{box}$ is avoided by the indicator function $1[u \geq 1]$, describe as:

$$1[u \geq 1] = \begin{cases} 1 & if\ u \geq 1 \\ 0 & otherwise \end{cases} \quad (3)$$

The overall loss function is:

$$\mathcal{L}(p, u, t^u, v) = \mathcal{L}_{cls}(p, u) + 1[u \geq 1]\, \mathcal{L}_{box}(t^u, v) \quad (4)$$

$$\mathcal{L}_{cls}(p, u) = -\log p_u \quad (5)$$

$$\mathcal{L}_{box}(t^u, v) = \sum_{i \in \{x,y,w,h\}} L_1^{smooth}(t_i^u - v_i) \quad (6)$$

The bounding box loss L_{box} measure the difference between t_i^u and v_i applying a robust loss function. The smooth L_1 loss[8] is implemented here and it is supposed to be less sensitive to outliers.

$$L_1^{smooth}(x) = \begin{cases} 0.5x^2 & if\ |x| < 1 \\ |x| - 0.5 & otherwise \end{cases} \quad (7)$$

C. Evaluation the Model

To evaluate the model during the training and after it, each time the training produces a new checkpoint, the evaluation tool will perform predictions using the video frames available in a given directory.

Evaluation metrics: the greatest significant evaluation metrics for such implementation are precision, recall, F1-score and mAP. Precision represents how applicable detection results are (Eq.8):

$$Precision = \frac{TP}{(TP+FP)} \quad (8)$$

Where TP = true positive, FP = false positive.

Recall: represents the percentage of objects, which are detected including the detector. (Eq. 9):

$$Recall = \frac{TP}{(TP+FN)} \quad (9)$$

Where FN = false negative.

It is important to mention that which the there is an opposite correlation between precision and recall and which these metrics are dependent on the model score threshold [33].

In the light of this, the model detector has the power to detect a big percentage of objects in an image; however, it as well produces a large number of false positives. While the model detector by a big threshold for detection only generates a small false positive, but, it likewise quits a greater percentage of objects, which remain undetected. The best equivalence between these two depends on the applicability.

D. Localization and Intersection over Union

Intersection over Union (IoU) is an evaluation metric applied to estimate the accuracy of an object detector on a relevant database as shown in Fig.3. Concerning to evaluate database as shown in Fig.3. Concerning to evaluate the model on the function of object localization, it must determine how strong the model predicted the location of the object as shown Fig.4. Ordinarily, this is accomplished including drawing a bounding box around the object of interest. The localization function is normally evaluated on the Intersection over Union threshold (IoU).

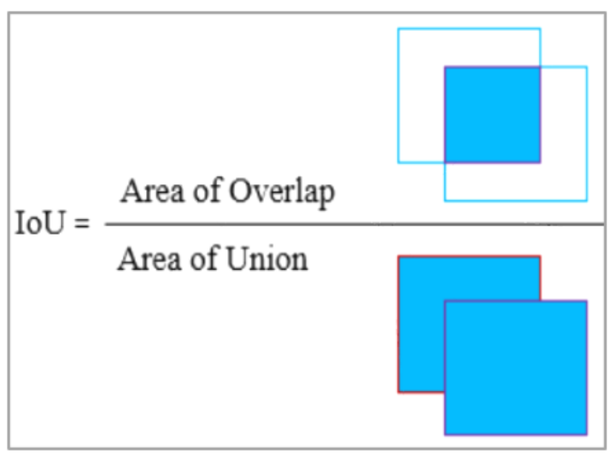


Fig. 3. Calculate IoU between Ground-Truth and Predicted Bounding Boxes.

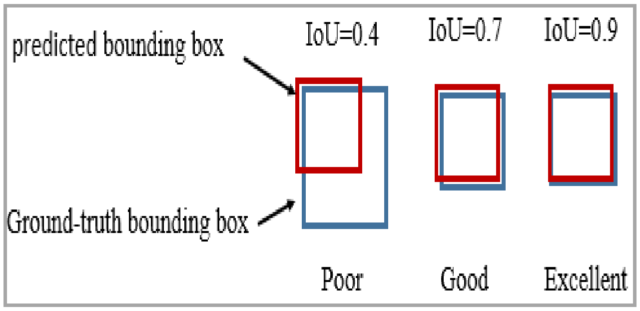


Fig. 4. An Instance of Calculating IoU for Different Bounding Boxes.

The TensorFlow Object Detection API usages "PASCAL VOC 2007 metrics" [34] location an estimated instance is described as a TP while Intersection over Union (IoU) is above 50% [33] (Eq.10):

$$IoU = \frac{area(groundtruth\ bounding\ box \cap predicted\ bounding\ box)}{area(ground\ truth\ bounding\ box \cup predicted\ bounding\ box)} > 0.5 \quad (10)$$

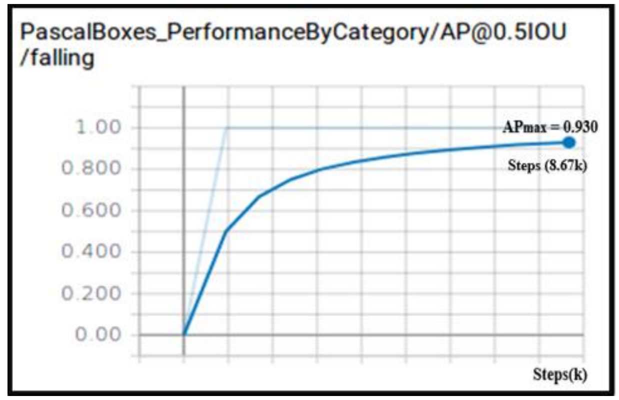
One object can be associated with only one bounding box; however, if some bounding boxes are predicted for an object, one is regarded as TP and the others FP. However, if an object is without a predicted bounding box, which is associated with it, then it is recognized as an FN.

E. Mean Average Precision (mAP)

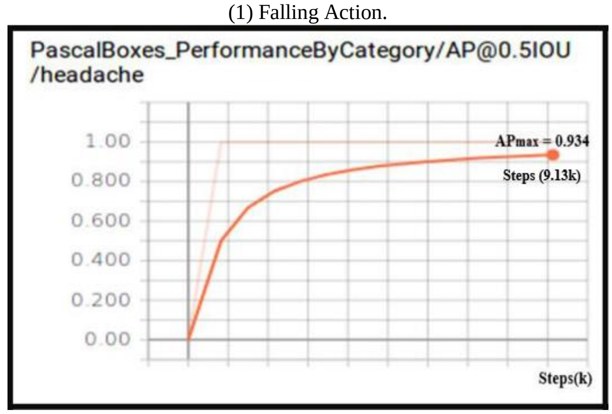
The mAP is the result of precision and recall "precision-recall" on detecting bounding boxes. It is a satisfactory way for a measuring of how the network to understands the objects of importance and how it evades invalid information. The greater the score of the mAP, the more accurate is the network. Generally, the mAP enhance the information in "precision-recall" curve a single number. Thereafter, for each prediction, a recall rate and a precision rate is estimated. The average precision (AP) is the average of class predictions measured over various thresholds, in PASCAL metrics, the thresholds are from scale [0, 0.1, . . ., 1], i.e., its average of precision values for various recall levels. It is an effort to achieve characteristics of the detector in a single number. The AP is defined as the region under the precision-recall curve. In this work, the AP curves for each human health-related action class based on both the per-trained models (Faster R-CNN-Resnet and SSD-Mobilenet) (see Figs.5-6)). A vertical axis represents the AP values while a horizontal axis represents the steps (epochs). Table1 lists the results for maximum AP values at 0.5IoU with last number of steps being each human health-related action.

TABLE I. MAXIMUM AP VALUES AT 0.5IOU WITH THE NUMBER OF STEPS (K=1000) FOR EACH HUMAN HEALTH-RELATED ACTION BASED ON FASTER R-CNN-RESNET AND SSD-MOBILENET MODELS

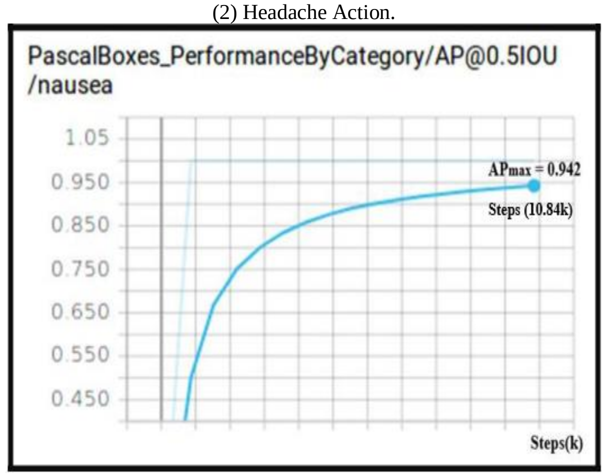
	Faster-R-CNN-Resnet		**SSD-Mobilenet**	
	AP@ 0.5 IoU	**Steps(k)**	**AP@ 0.5 IoU**	**Steps(k)**
falling	**0.930**	**8.67**	**0.975**	**47.66**
headache	**0.934**	**9.13**	**0.917**	**50.65**
nausea	**0.942**	**10.84**	**0.979**	**55.68**
neck pain	**0.934**	**10.30**	**0.967**	**58.34**
sneeze	**0.938**	**10.20**	**0.973**	**44.74**
staggering	**0.934**	**11.04**	**0.959**	**52.31**
stomachache	**0.953**	**15.07**	**0.965**	**41.09**



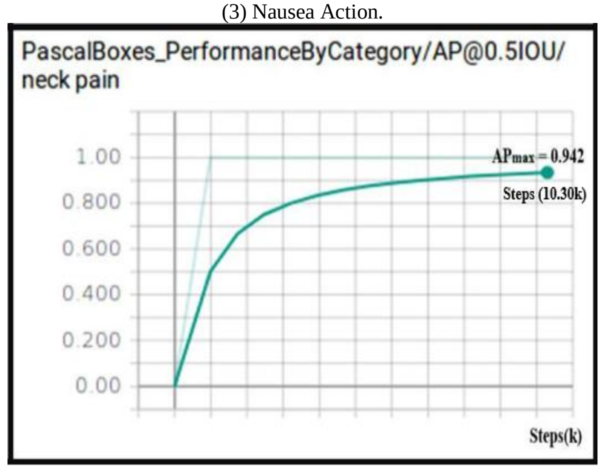
(1) Falling Action.



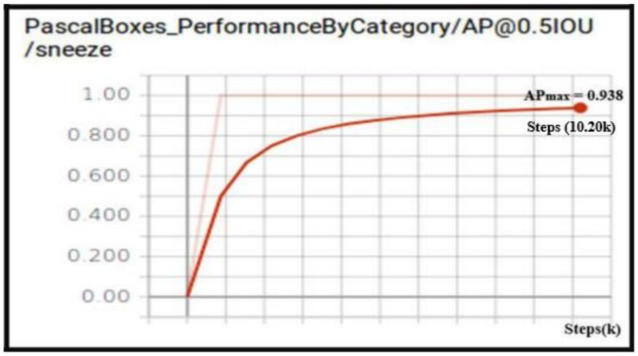
(2) Headache Action.



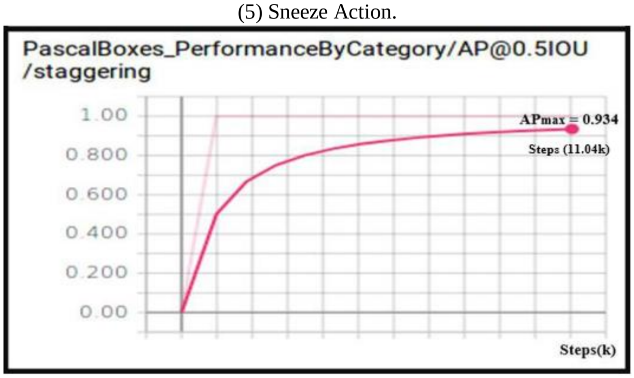
(3) Nausea Action.



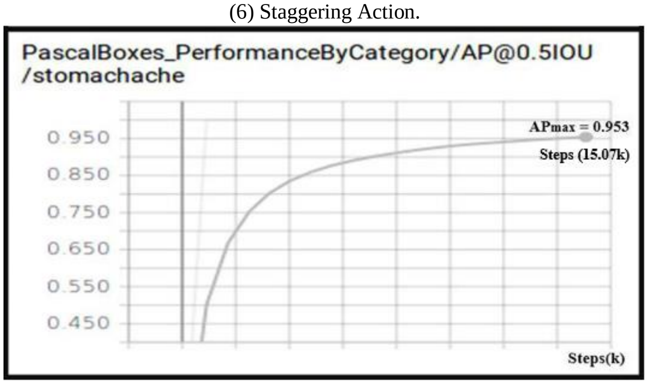
(4) Neck Pain Action.



(5) Sneeze Action.



(6) Staggering Action.

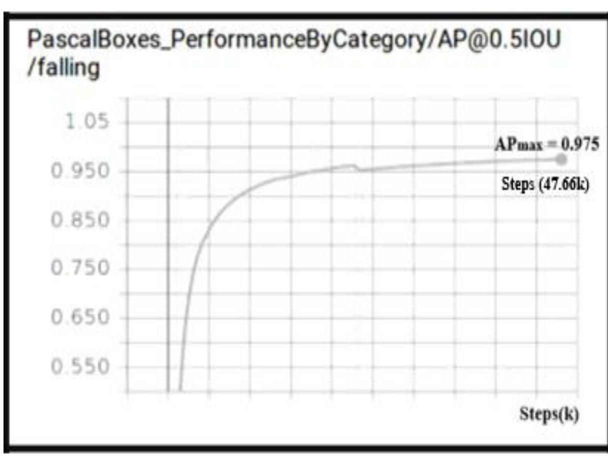


(7) Stomachache Action

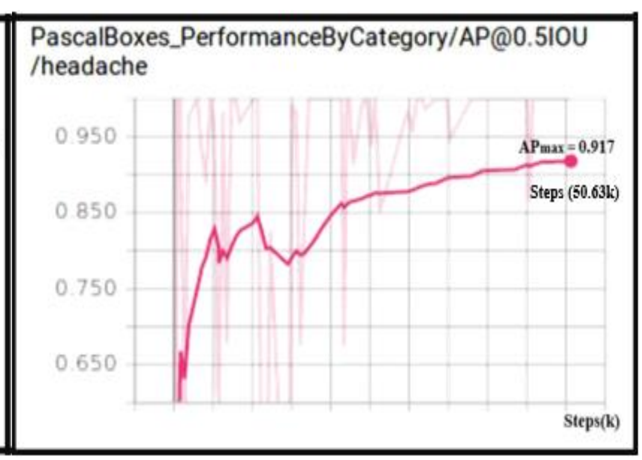
Fig. 5. AP Curves for Each Human Health-Related Action. Maximum AP Values at 0.5IoU with Last Number of Steps (k=1000) are based on Faster R-CNN-Resnet Model.

F. The Results

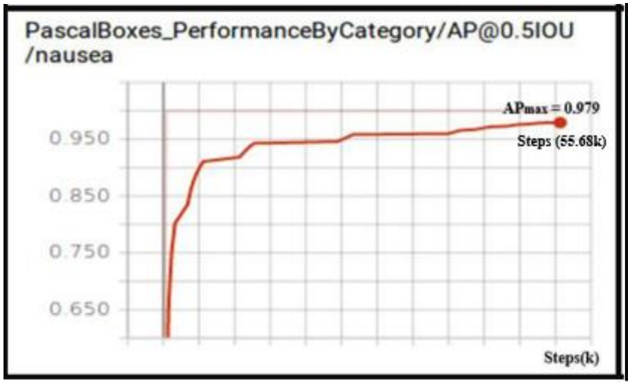
As the training process progresses, the expectation is to reduce total loss (errors) to its possible minimum (about a value of 1 or less). By observing the tensorboard graphs for total loss for Faster R-CNN-Resent and SSD-Mobilenet models (see Fig.6), it should be possible to get an idea of when the training process is complete (total loss decrease with further iterations/steps(epochs)). The parameter num_steps defines how many training steps they will run before stopping. This number actually depends on the size of the dataset along with how long the user wants to perform the training of the model. The utilized metric for achievement is a mean average precision (mAP) which is a single number used to summarize the area under the precision-recall curve. The mAP is a measure of how well the model generates a bounding box that has at least a 50% overlap with the ground truth bounding box in the test dataset. The mAP value reached to higher confidence at 0.5IoU (see Fig.7) for each action class of both pre-trained models. The higher the mAP values the higher the detection accuracy (the higher the better). However, the SSD-Mobilenet takes a long time to reach the high mAP value compared to mAP's Faster-R-CNN-Resnet time. The classification loss curve in Fig.8 indicates the validation of human action class which is classified and matched with the previous trained class. As the values of the classification loss decrease to zero, it shows that the classification accuracy is high and the efficiency of the detector performance becomes more advanced. The Fig.9 (a,b) displays the results for both models where there are seven classification loss curves corresponding to each human action health-related class. Generally, all actions have consistent decreasing classification loss values, which give the power of the model performance in the classification of each video frame of the similar class type. As for the localization loss curve in Fig.10, it describes the predicate bounding box that matches with the ground-truth bounding box. As the loss value is reduced, less error will be present in the action detection and the Intersection over Union will be high, which all indicates that the detection of the action is in the right direction. The smoothed L1 loss is used for localization and is weighted.



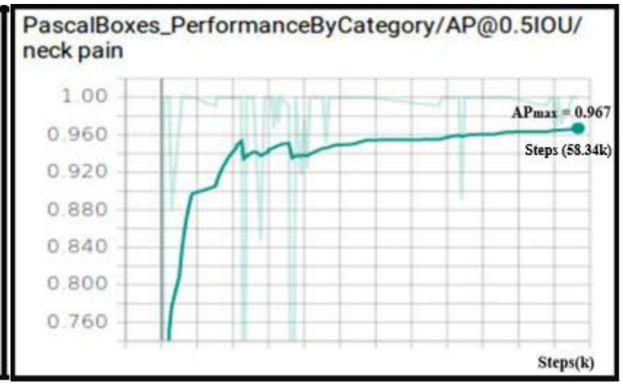
(1) Falling Action.



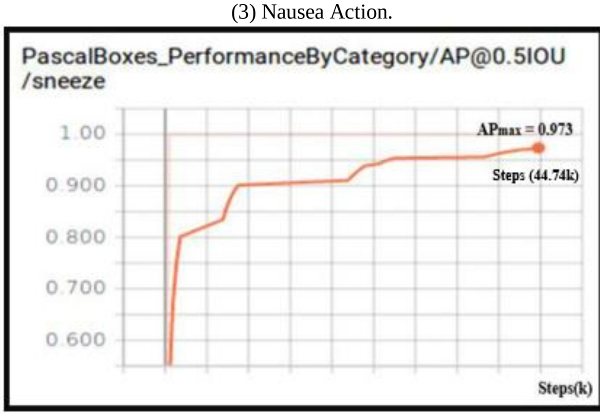
(2) Headache Action.



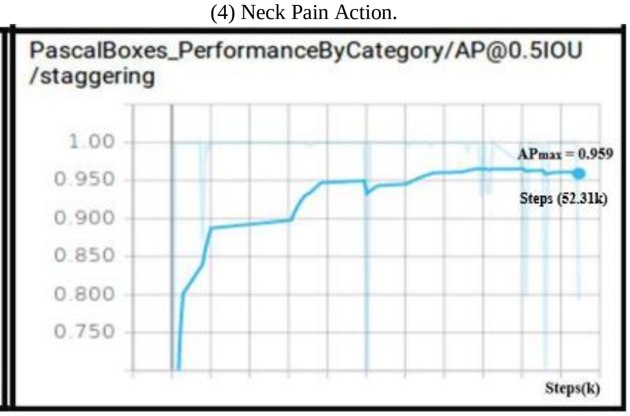
(3) Nausea Action.



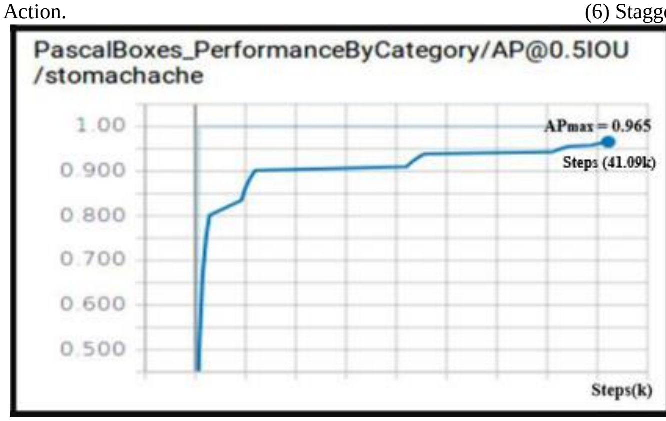
(4) Neck Pain Action.



(5) Sneeze Action.



(6) Staggering Action.



(7) Stomachache Action

Fig. 6. AP Curves for each Human Health-Related Action. Maximum AP Values at 0.5IoU with Last Number of Steps (k=1000) are based on SSD-Mobilenet Model.

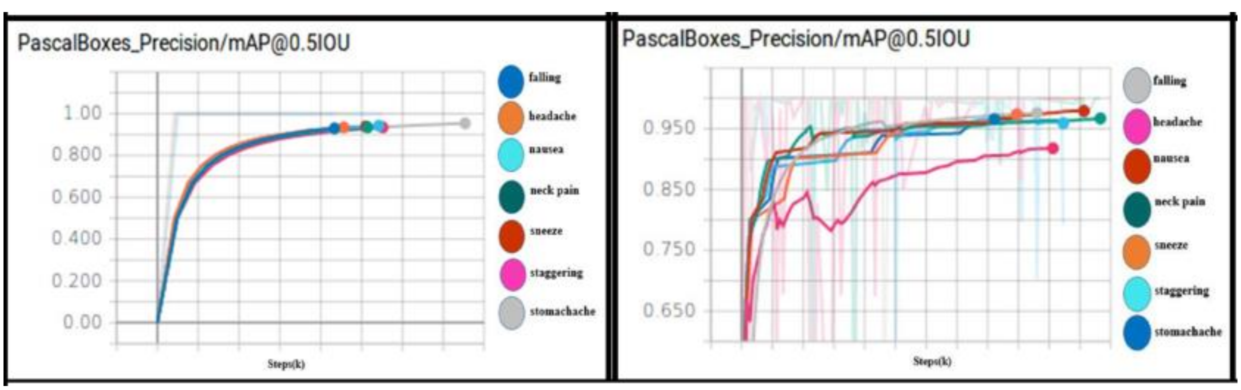


Fig. 7. Maximum mAPs @0.5IoU for Seven Human Heath Related Actions Classes are based on Two Per-Trained Models (the left (Faster R-CNN-Resnet),the Right (SSD-Mobilenet)) respectively.

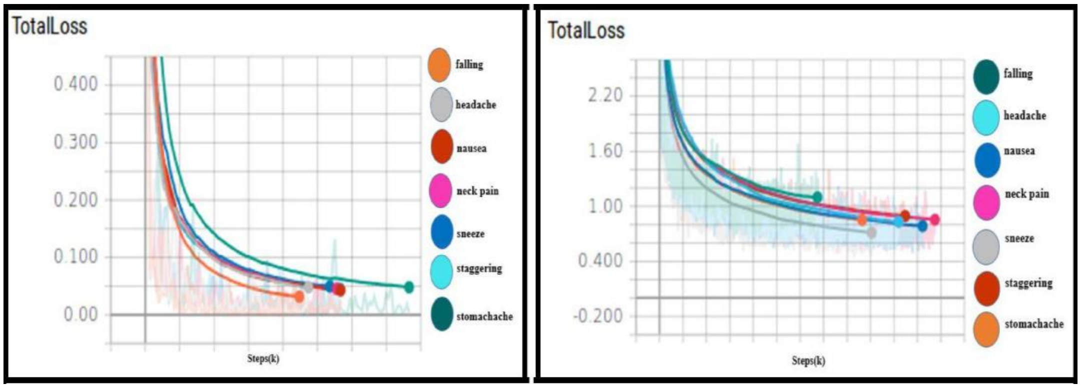


Fig. 8. Minim Total Losses for Seven Human Heath Related Actions Classes are based on Two Per-Trained Models (the left (Faster R-CNN-Resnet), the Right (SSD-Mobilenet)) respectively.

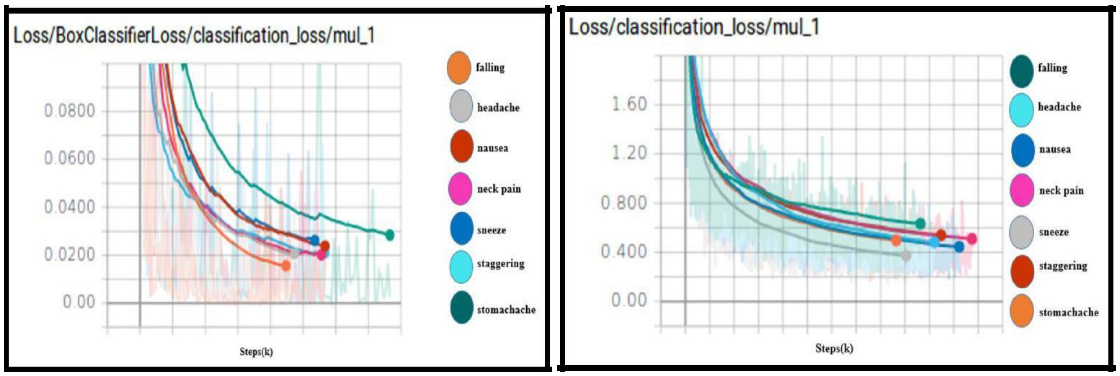


Fig. 9. Minim Classification Losses for Seven Human Heath Related Actions Classes are based on Two Per-Trained Models (the Left (Faster R-CNN-Resnet), the Right (SSD-Mobilenet)) respectively.

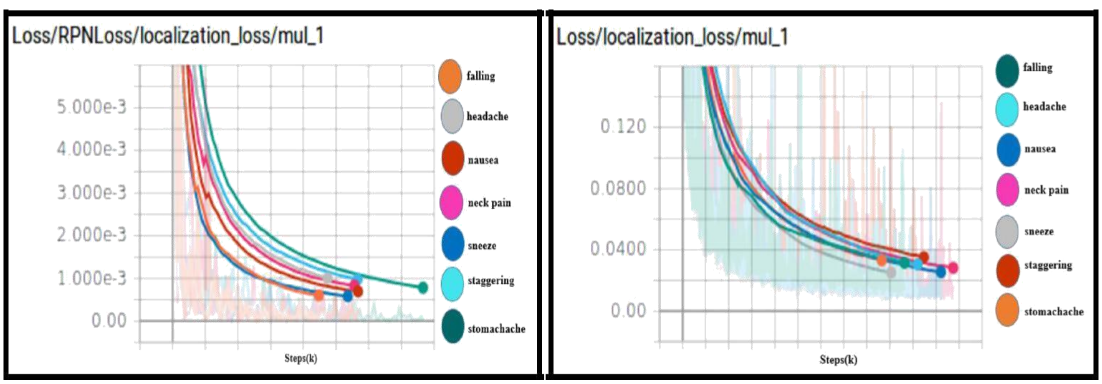


Fig. 10. Minim Localization Losses for Seven Human Heath Related Actions Classes are based on Two Per-Trained Models (the Left (Faster R-CNN-Resnet), the Right (SSD-Mobilenet)) respectively.

TABLE II. THE RESULTS FOR EACH ACTION OF THE PRE-TRAINED MODEL (FASTER R-CNN-RESNET). STEPS (K=1000), TIME (H=HOUR, M=MINUTES, S=SECOND)

Actions	mAP@ 0.5 IoU	Total loss	Classification loss	Localization loss	Steps(k)	Time(h-m-s)
falling	0.9300	0.0312	0.0156	6.0513e-4	8.44	2-13-58
headache	0.9347	0.0479	0.0206	1.0070e-3	9.47	2-25-57
nausea	0.9425	0.0429	0.0237	6.9610e-4	11.34	2-47-57
neck pain	0.9437	0.0451	0.0201	8.3558e-4	11.12	2-31-57
sneeze	0.9389	0.0493	0.0261	5.8604e-4	10.37	2-37-57
staggering	0.9347	0.0455	0.0210	9.7959e-4	11.32	2-23-57
stomachache	0.9539	0.0480	0.0283	7.8347e-4	15.32	3-23-57

TABLE III. THE RESULTS FOR EACH ACTION OF THE PRE-TRAINED MODEL (SSD-MOBILENET). STEPS (K=1000), TIME (D=DAY, H=HOUR, M=MINUTES, S=SECOND)

Actions	mAP@ 0.5 IoU	Total loss	Classification loss	Localization loss	Steps(k)	Time(d-h-m-s)
falling	0.9758	0.9872	0.6332	0.03147	48.19	1d-2h-13m-45s
headache	0.9178	0.8323	0.4829	0.03056	51.04	18h-19m-34s
nausea	0.9793	0.7855	0.4448	0.02550	56.11	20h-11m-44s
neck pain	0.9670	0.8548	0.5094	0.02826	58.75	1d-0h-29m-45s
sneeze	0.9737	0.7144	0.3718	0.02514	45.26	16h-3m-45s
staggering	0.9590	0.8949	0.5391	0.03517	52.38	1d-0h-11m-45s
stomachache	0.9657	0.8515	0.4973	0.03313	43.22	19h-49m-46s

TABLE IV. TOTAL MAP FOR ALL ACTIONS BASED ON TWO PRE-TRAINED MODELS

Total mAP	
Faster R-CNN-Resnet	SSD-Mobilenet
93.8%	95.8%

Tables 2 and 3 summarize all the parameters (mAP, Total loss, Classification loss, Localization loss) of the training and evaluation processes in addition to the number of the steps with the time that they consumed to achieve these requirements. Table 4 labels the mean average precision (total mAP) for all the actions classes of the both per-trained models. The total mAP that belongs to the SSD-Mobilenet model is somewhat higher than the total mAP of the Faster-R-CNN-Resnet model.

G. Testing (Detection) and Results

To validate the HHRA model's performance for action detection in videos, comprehensive examinations have been achieved on a special type of human action that has related on the health from the NTU RGB+D datasets. In order to accomplish the greatest predictable detection accuracy, sets of human actions frames with different health-related actions and various environments are tested. In this work, the detection process for testing the video frames of seven different human health-related actions is implemented in two ways to the evaluation of the detection performance using the TensorFlow Object Detection Notebook and the Android camera in terms of accuracy and detection speed. The first way is by trying out the TensorFlow Object Detection Notebook with couple pre-trained models (Faster R-CNN-Resnet and SSD-Mobilenet). While the detection using Android camera only uses the SSD-Mobilenet model because the TensorFlow in Android does not support the Faster-R-CNN-Resnet model yet. To perform the detection process in both ways, must export the model as a static inference graph trained on the human health-related dataset, as well as the corresponding label map. The TensorFlow object detection API library provides the script, named export_inference_graph with using the latest checkpoint number at the last step that stopped the training process. It has used the 16.04LTS GTX1070@2.80GHZ x8 system to run the object detector on each frame from seven different human health-related actions of the NTU RGB+D dataset to detect the action type. The detection process has been applied on 50 frames of each video action for seven different actions.

1) TensorFlow's object Detection Notebook: As mentioned above after the requirements is completed, the detection process is accomplished by using TensorFlow's Object Detection Notebook. In pre-trained Faster R-CNN-Resnet model, the bounding detection boxes for each frame from seven different human health-related actions consumed around 120 seconds over all the 50 frames of the testing dataset. While, the bounding detection boxes for each frame in pre-trained SSD-Mobilenet model are finalized within a 95 seconds time span. The detection results in two pre-trained Faster R-CNN-Resnet and SSD-Mobilenet models for samples of frames of each human health-related action are shown in Fig.11. The results displayed a high detection accuracy for all the actions. According to the SSD-Mobilenet model, the results include diverse detection values ranging from intermediate to high values of different action frames.However, there are misdetections in the headache action where SSD-Moblienet failed to demonstrate the bounding detection box in some frames and misdetection that shows the bounding detection boxes in a wrong action placement as shown in Fig.12.

2) TensorFlow in andriod: Once the requirements are completed, as mentioned in sections (VI and VIII-G), the model will be imported to an Android phone (Galaxy S6). This is the time for testing the video frames based on pre-trained SSD-Mobilenet model by capturing them from the phone's camera also bounding detection boxes have been visualize for each frame with the name of the action class and detection percentage accuracy as described in Fig.13. In order to evaluate the impact of the TensorFlow in Android for the detection results, the detection accuracy is improved up to high values and it speed up the detection time.

The action detection from the phone's camera consumes roughly 25 seconds for all 50 video frames. In the headache action, there are two misdetections, however, when the detection using the Android camera, these two problems have been solved. The action detection for all frames come to be all properly visible and the bounding detection boxes have become in the correct action location.

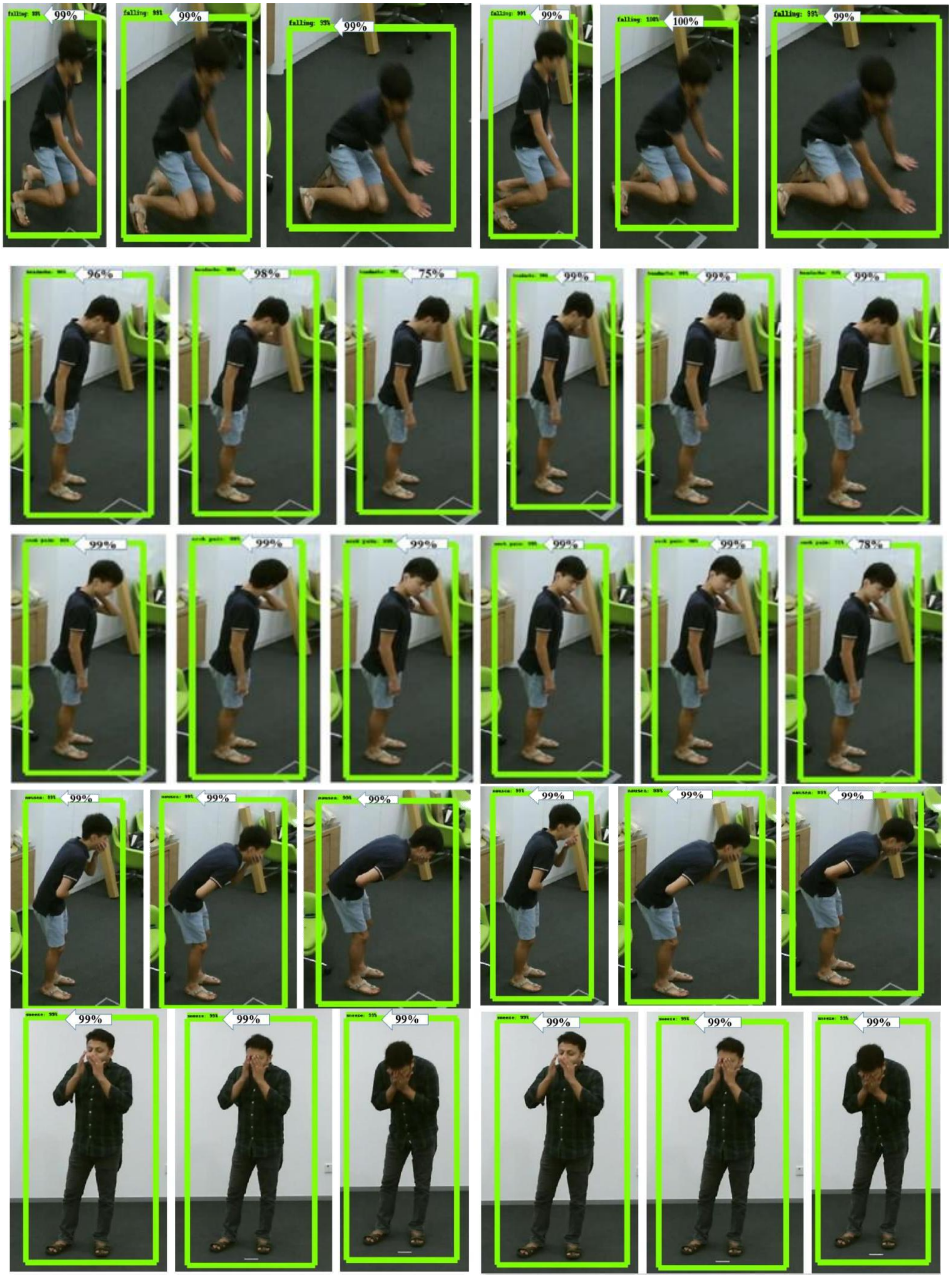
Falling

Headache

Neck pain

Nausea

Sneeze



Staggering

Stomachache

Fig. 11. Samples of The Detection Results that used TensorFlow Object Detection Notebook Technique are based on Two Pre-Trained Models (the First Three Images from the Left are based on Faster R-CNN-Resnet Model, while the Last Three Images from the Right are based on SSD-Mobilenet)) respectively. The Results Include the Bounding Detection Box for Every of the Seven Human Health-Related Actions Including (Name of the Action Class & Detection Percentage Accuracy).

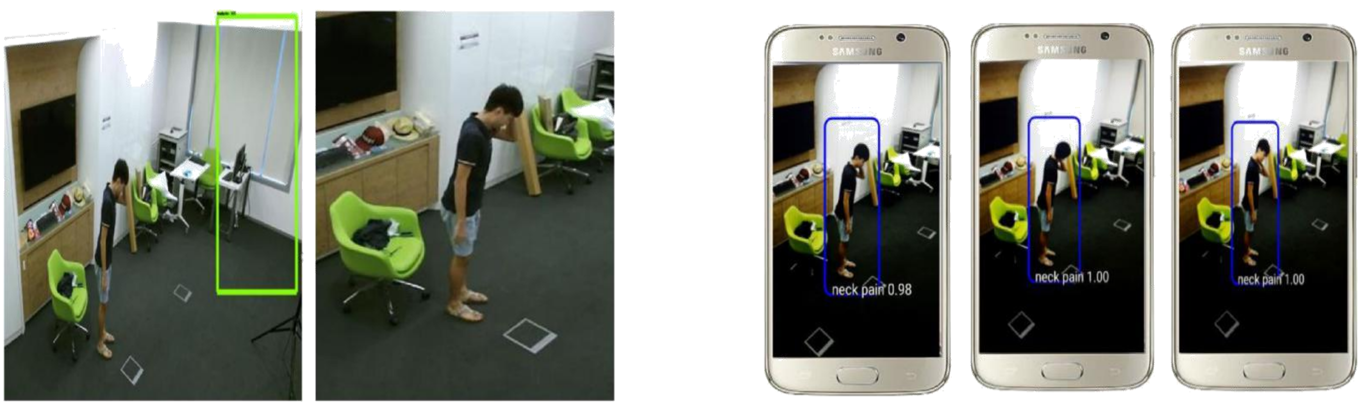


Fig. 12. Misdetections for Some Frames of the Headache Action are based on the Pre-Trained SSD-Mobilenet (the left (Bounding Detection Box Showed in the Wrong Location), the Right (No Bounding Detection Box in the Frame).

IX. Discussion

In this paper, human health related action videos have been detected by using the implemented TensorFlow object detection API technique. The two new pre-trained (Faster R-CNN-Resnet and SSD-Mobilenet) models have been applied for training human actions dataset. The average precision (AP) is the average of class predictions estimated over several thresholds. The detection accuracy (mAP) at 0.5IoU is a high value with different num_steps. This is due to the fact that the network deals with the video images, therefore it takes a long time to train the entire samples of each frame for every action and depend on the type of the model's architecture. The parameter num_steps determines how many training steps they will run before stopping. This number certainly depends on the size of the dataset along with how long the user wants to train the model. Localization loss represents the predicted bounding box which matches with the ground-truth bounding box. However, the loss value is decreased and the Intersection over Union is high, which means that the detection of the action is in the correct location. The classification loss shows the effectiveness of human action class which is classified and matched with the previous trained class. When the classification loss values decrease and are near zero that means that the classification accuracy is outstanding and the performance of the detector becomes more high-level. The Android detection results were compared to the detection process TensorFlow Object Detection Notebook technique. These two distinct processes were used to examine which one does a better job in measuring the detection speed and how accurate the detection is. In the end, utilizing the Android smartphone's camera revealed that the seven types of human health-related actions were precisely detected with high accuracy and reasonable detection speed rate.

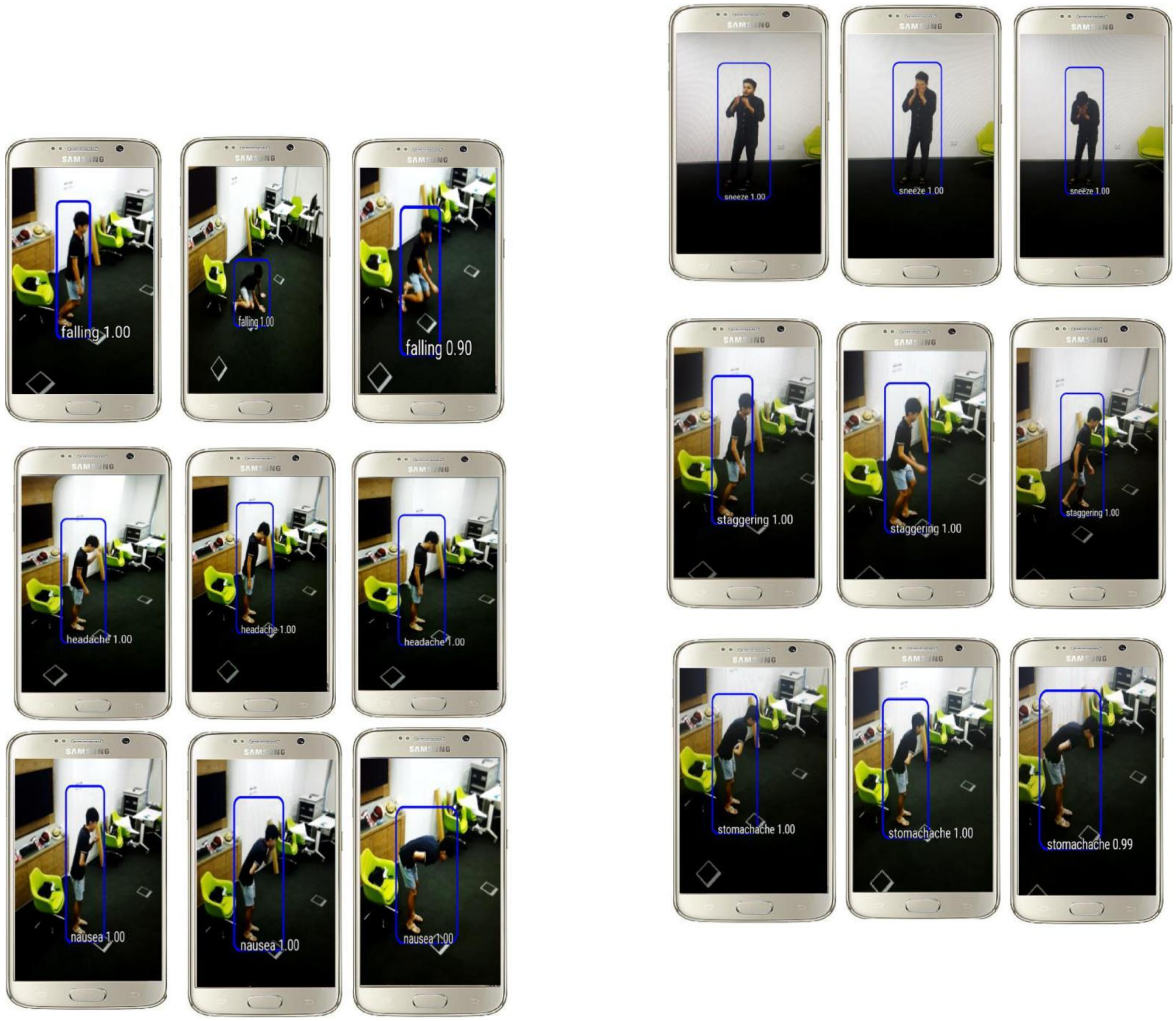


Fig. 13. Samples of The Detection Results that used Android Camera are based on the Pre-Trained SSD-Mobilenet Model. The Results Include the Bounding Detection Box for Seven Human Health- Related Actions Classes Including (Name of the Action Class & Detection Percentage Accuracy).

X. Conclusion

In Conclusion, the health-related actions can be detected with high-speed detection and its great accuracy. It can figure out the correct action required to deal with the appropriate situation using the smartphone camera. A new detector model was built for seven different human health-related video actions using two techniques of TensorFlow object detection API, which are TesnsorFlow object detection notebook and TensoFlow in Android, using the phone's camera. In addition, the HHRA detection model was trained and evaluated using NTU RGB+D dataset based on two pre-trained models (Faster-R-CNN-Resnet and SSD-Mobilenet). According to the results, in the best-detectable category, the mAP total achieved 93.8% for the Faster R-CNN-Resnet and 95.8% for SSD-Mobilenet. In addition, the lowest error was calculated through both losses of classification and localization and the results were satisfactory. Furthermore, the detection speed and the high-performance efficiency have been improved by the use of the smartphone. In the future, we plan to the opportunity to train using Google Cloud to decrease the training and evaluation time. Moreover, new methods can be developed to detect the further human actions classes.

References

[1] K. Matusiak, P. Skulimowski, and P. Strumillo, “Object recognition in a mobile phone application for visually impaired users,” IEEE 6th Int. Conf. Hum. Syst. Interact., pp. 479–484, 2013

[2] pkulzc, “TensorFlow Object Detection API repository,”github.com, 2018. [Online]. https://github.com/tensorflow/models/tree/master/research/object_detection. [Accessed: 16-Jul-2018].

[3] P. F. Felzenszwalb and D. P. Huttenlocher, “Pictorial structures for object recognition,” Int. J. Comput. Vis.,vol. 61, no. 1, pp. 55–79, 2005.

[4] P. F. Felzenszwalb, R. B. Girshick, D. Mcallester, and D.Ramanan, “Object Detection with Discriminatively Trained Part Based Models,” IEEE Trans. Pattern Anal. Mach.Intell., vol. 32, no. 9, pp. 1–20, 2009.

[5] N. Dalal and B. Triggs, “Histograms of oriented gradients for human detection,” Proc. - 2005 IEEE Comput. Soc.Conf. Comput. Vis. Pattern Recognition, CVPR 2005, vol.I, pp. 886–893, 2005.

[6] M. M. Cheng, Z. Zhang, W. Y. Lin, and P. Torr, “BING: Binarized normed gradients for objectness estimation at 300fps,” Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit., pp. 3286–3293, 2014.

[7] A. Karpathy, A. Joulin, and L. Fei-Fei, "Deep Fragment Embeddings for Bidirectional Image Sentence Mapping," pp. 1–9, 2014.

[8] A. Karpathy and L. Fei-Fei, "Deep Visual-Semantic Alignments for Generating Image Descriptions," IEEE Trans. Pattern Anal. Mach. Intell., vol. 39, no. 4, pp. 664–676, 2017.

[9] Y. Tian, R. Sukthankar, and M. Shah, "Spatiotemporal deformable part models for action detection," Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit., pp. 2642–2649, 2013.

[10] L. Wang, Y. Qiao, and X. Tang, "Video Action Detection with Relational Dynamic Poselets," Eccv, 2014.

[11] S. Ren et al., "Rich feature hierarchies for accurate object detection and semantic segmentation," Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit., vol. 794, pp. 1–15, 2015.

[12] S. Ren, K. He, R. Girshick, and J. Sun, "Faster r-cnn: Towards real-time object detection with region proposal networks," Nips, pp. 91–99, 2015.

[13] C. Sun and K. Murphy, "Speed/accuracy trade-offs for modern convolutional object detectors," vol. 3, 2017.

[14] pkulzc, "TensorFlow Object Detection API repository," github.com, 2018.[Online].Available: https://github.com/tensorflow/models/tree/master/research/object_detection. [Accessed: 16-Jul-2018].

[15] L. Torrey and J. Shavlik, "Transfer Learning," Mach. Learn., pp. 1–22, 2009.

[16] V. Rathod and N. Wu, "Tensorflow detection model zoo," 2017. [Online].Available: https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/detection_model_zoo.md.[Accessed: 25-Jun-2018].

[17] W. L. B et al., "SSD : Single Shot MultiBox Detector," vol. 1, pp. 21–37, 2016.

[18] C. Szegedy, S. Reed, D. Erhan, D. Anguelov, and S. Ioffe, "Scalable, High-Quality Object Detection," 2014.

[19] Karpathy, "Smooth L1 Loss," mohitjainweb.files.wordpress.com, 2015. [Online].Available: https://mohitjainweb.files.wordpress.com/2018/03/smoothl1loss.pdf. [Accessed: 15-Jul-2018].

[20] K. He, X. Zhang, S. Ren, and J. Sun, "Deep Residual Learning for Image Recognition," 2016 IEEE Conf. Comput. Vis. Pattern Recognit., pp. 770–778, 2016.

[21] O. Russakovsky et al., "ImageNet Large Scale Visual Recognition Challenge," Int. J. Comput. Vis., vol. 115, no. 3, pp. 211–252, 2015.

[22] T. Y. Lin et al., "Microsoft COCO: Common objects in context," Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), vol. 8693 LNCS, no. PART 5, pp. 740–755, 2014.

[23] V. Nair and G. E. Hinton, "Rectified Linear Units Improve Restricted Boltzmann Machines," Proc. 27th Int. Conf. Mach. Learn., no. 3, pp. 807–814, 2010.

[24] A. G. Howard et al., "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications," 2017.

[25] M. Siam, M. Gamal, M. Abdel-Razek, S. Yogamani, and M. Jagersand, "RTSeg: Real-time Semantic Segmentation Comparative Study," no. 1, 2018.

[26] Tensorflow, "https://github.com/tensorflow," 2016. [Online]. Available: https://github.com/tensorflow/tensorflow/tree/master/tensorflow/examples/[Accessed: 20-Jun-2018].

[27] B. Readme, A. Inception, L. Repre, and R. Third, "TensorFlow Android Camera Demo Prebuilt Components : Building in Android Studio using the TensorFlow AAR from JCenter," pp. 2–5, 2018.

[28] F. Liu, Android Native Development Kit Cookbook. Birmimgham B3 2PB, UK, 2013.

[29] Campbell Scientific, "CSI Software Development Kit Beginner's Guide," s.campbellsci.com,2006.[Online].Available: https://s.campbellsci.com/documents/de/manuals/sdkbeginnersguide.pdf. [Accessed: 20-Jul-2018].

[30] A. Shahroudy, J. Liu, T.-T. Ng, and G. Wang, "NTU RGB+D: A Large Scale Dataset for 3D Human Activity Analysis," 2016.

[31] S. Nadella, L. Manifest, M. Readme, O. S. H. Sierra, and M. Os, "LabelImg,"github.com, [Online].Available: https://github.com/tzutalin/labelImg. [Accessed: 05-Jun-2018].

[32] V. Toolkit, "TensorBoard Key Concepts Summary Ops : How TensorBoard gets data from TensorFlow," github.com, 2018. [Online]. Available: https://github.com/tensorflow/tensorboard. [Accessed: 24-Jul-2018].

[33] P. Mustamo, "Object detection in sports: TensorFlow Object Detection API case study," no. January, 2018.

[34] M. Everingham, L. Van Gool, C. K. I. Williams, and J. Winn, "The P ASCAL Visual Object Classes (VOC) Challenge," Int. J., pp. 303–338, 2010.

Isolated Automatic Speech Recognition of Quechua Numbers using MFCC, DTW and KNN

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***Abstract*—The Automatic Speech (ASR) area is defined as the transformation of acoustic signals into string words. This area has been being developed for many year facilitating the lives of people so it was implemented in several languages. However, the development of ASR in some languages with few database resources but with a large population speaking these languages is very low. The development of ASR in Quechua language is almost null which leads culture and population isolation from technology and information. In this work an ASR system of isolated Quechua numbers is developed where Mel-Frequency Cepstral Coefficients (MFCC), Dynamic Time Warping (DTW) and K-Nearest Neighbor (KNN) methods are implemented using a database composed by recorded audio numbers from one to ten in Quechua. The recorded audios to feed the data base were uttered by natives man and women speakers of Quechua. The recognition accuracy reached in this research work was 91.1%.**

***Keywords*—Automatic Speech Recognition; MFCC; DTW; KNN**

I. INTRODUCTION

Technology has been facilitating people's lives since it became an integral part of their lives. It makes the communication with computers easy and one of the ways to do that is emulating human intelligence to understand what a person says aloud. [1]. The interaction between a person and a computer using the voice becomes simpler and more comfortable because it does not need special skills such as hand coordination and speed when typing with a keyboard [2]. For this reason ASR systems were developed in many languages, including languages that have few resources in database, with the aim of making people's interaction with computers easy and thereby facilitating access to information. and technology [3] [4] [5].

ASR is the area of artificial intelligence that transform the audio signals spoken by a person into a sequence of words that can be understood for a computer [6]. It has been researched for years how a person can communicate with a computer in the same way a person communicates with another person [7]. The development of ASR covers issues from research on voice recognition to the implementation of dictionaries based on the speech spoken by a person and all of these issues divide the ASR into three types, ASR: from isolated words, continuous and connected words [8].

ASR systems of isolated words take as input individual words or a list of words with a well defined pause between them and each of the words is processed individually [1]. In this research work an ASR system is developed for isolated words, to be precise, for natural numbers from one to ten in Quechua, which is an official language in Peru.

Quechua is essentially an agglutinative language and this peculiarity makes Quechua different from the rest of the dominant languages in South America, thus this language is suffering a strong social pressure [9]. This goes hand in hand with the fact that the development of technology in these languages is very low which leads to the isolation of Quechua-speaking people from information and technology. The development of an ASR system in Quechua will enable people who speak only this language to use the technology to greater extent without the knowledge of operating with computer keyboard developed in foreign language and understanding information published also in foreign language.

This research paper presents the development of an ASR system of isolated words having a limited database. The rest of this research is organized as follows: Section II describes a review of the works related to this work. Section III provides the theoretical framework of ASR. Section IV develops the methodology used to implement the ASR system that this work proposes. Section V analyzes the results obtained from the ASR system and finally in section VI summarizes the conclusions reached through the development of this work.

II. RELATED WORKS

Atif in [10] developed a system for automatic recognition of isolated words with English language. In the phase of extraction of characteristics of an audio, MFCC was used and DTW and KNN were used in the recognition and classification block. DTW to make match the features of different audios and KNN to classify taking the characteristics that more resemble. The audios used were acoustically balanced and free of ambient noise. The recognition accuracy achieved in the work of these authors is 98.4%.

Wani in [2] developed an automatic recognition system for isolated words with the Hindi language. It is taken into account that many people who speak this language can not speak English, which is the language which the ASR systems were most developed with, and they can not access easily to this technology. For feature extraction, MFCC technique was used, and KNN and GMM (Gaussian Mixture Model) were implemented in the recognition phase. In order for the system to be independent of the speaker, the training audios of different speakers between men and women were obtained. Wani's work reaches a recognition accuracy of 94.31%.

In Indonesia, an ASR was developed using a tool based on HMM and with a limited database. [11] needed to build an acoustic model, a language model and a dictionary to develop the ASR for the Indonesian language. Own models of the numbers were developed which were used as input for CMUSphinx toolkit, which is the tool they used. The use of acoustic models already implemented to evaluate them under different SNR conditions was also investigated. The best recognition accuracy achieved is 86% and by experiment different noise level conditions the best accuracy is 80%.

Anand in [5] developed a modern ASR of wide vocabulary with an application in people with visual disabilities. In feature extraction phase, MFCC was used and in the classification and recognition phase an acoustic model was developed using thirty hours of HMM-based audio. To handle pronunciation variation, a hybrid model was used between rule-based methods and statistical methods. The audio recordings were collected from 80 native speakers of the Malay language. The best recognition accuracy achieved is 80% and the developed system was integrated into OpenOffice Writter as a text entry interface through voice.

On the other hand, Ranjan develops an ASR system for isolated words from a language dialect called Maithili [12]. To obtain the necessary acoustic vectors for classification, the author implements MFCC. The system developed by Ranjan is an ASR system based on the HMM model. The acoustic model and the language model are developed with HMM. The recognition accuracy reached in the work described is 95%. However, future work is planned to improve accuracy in noise environments.

Speech recognition for people with amputated vocal cords differs to some degree from a common ASR. While it is true that the duration and intonation of words and vowels are practically the same, the pre-processing of the signals must be deeper. This problem is contemplated and developed by Malathi in [13] using MFCC for feature extraction of the audios and thus built the acoustic vectors. The classification or recognition was developed with GMM and Gradient Descent Radial Basis Function (RBF) Networks. The learning rate of the network are made proportional to probabilities density obtained from GMM. The result of the research was applied to patients who pronounced words only with the esophagus.

Bhardwaj [14] developed three schemes or types of ASR with the same methodology to evaluate the behavior of this methodology in different contexts. The types of ASR that are evaluated are: dependent on the speaker, multi speaker, and independent of the speaker. The methodology used starts by implementing MFCC for feature extraction of the audio. The acoustic model and the language model are based on HMM. To classify the words in Hindi, the language which they worked with, they used the K-Mean algorithm. The recognition rate for the independent speaker ASR was 99%, for the multi-speaker it was 98%, while for the independent speaker ASR it was 97.5%.

Ananthi developed an ASR for people with hearing problems [15]. If the words of an announcer are interpreted by the computer and are simultaneously transcribed into text, a person with hearing impairment can easily understand any person. An ASR of isolated words based on HMM is developed in Ananthi's work. Because the focus of the work we are describing is aimed to the use of ASR in a fluent conversation, the implementation of DWT is discarded since it only works properly in isolated word ASR. The result of this work was successfully implanted in a population of people with hearing problems.

III. ASR

ASR systems are composed of two main blocks, a feature extraction block and a classification block [10]. The feature extraction block obtains values from an audio and these are passed to the classification block that is responsible for predicting the word or sequence of words corresponding to the input audio [16].

To express the audio signals in numeric values, there are a lot of algorithms and methods in feature extraction block. Some of these methods are: Principle Component Analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), Linear Predictive Coding (LPC), Cepstral Analysis, Mel-Frequency Scale Analysis, Filter-Bank Analysis, Mel-Frequency Cepstrum Co-efficients (MFCC), Kernal Based Feature Extraction, Dynamic Feature Extraction, Wavelet based features, Spectral Subtraction and Cepstral Mean Subtraction (CMS) [17]. According the review we made of related works, the most common and appropriate methods used in this type of ASR for feature extraction are MFCC and LPC and in this research work, the method we used is the first one, MFCC.

In the classification block, there are two main components, the acoustic model and the language model [18]. The acoustic model models how the pronunciation of a word is represented, and on the other hand, the language model models the probability that a word fits a sequence of words. Hidden Markov model (HMM) and Neural Networks are the most common techniques for modeling an acoustic model and N-Gram model to model a language model. These techniques are common in continuous and wide vocabulary ASR [18] [19] [11] [20]. However, for ASR of isolated words and with a limited data set, there are techniques that behave better in these cases. In this type of ASR, only acoustic model is built to classify the words and the techniques like Dynamic Time Warping (DTW) and K-Nearest Neighbor (KNN) are the ones which reach better results to find similarity between the signals of two or more audios [10] [2].

After analyzing the architecture of a conventional ASR and ASR of isolated words ASR, the ASR that will be developed in the present work adapts the architecture of the ASR of isolated words that is constituted of two main blocks, which is the block of feature extraction and the block of classification, and in each block the algorithms that best adapt to our problem are implemented according to the state of the art review. The blocks of the architecture as well as the algorithms to be used are presented in Fig.1.

IV. Methodology

The ASR of isolated words that is developed in this work implements the MFCC technique for feature extraction. To classify the representation of the audio signals that MFCC provides, the DTW and KNN techniques are used. Before start

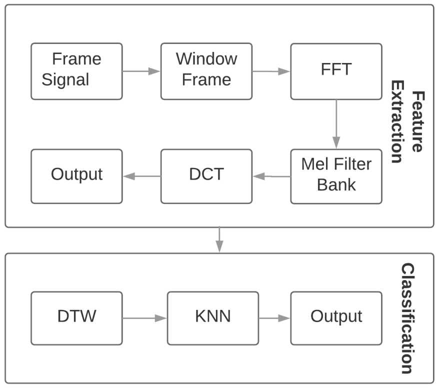

Fig. 1. Architecture of implementation of ASR.

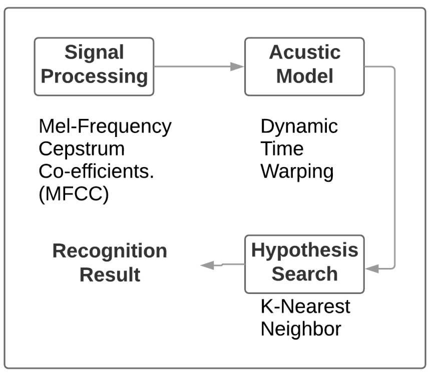

Fig. 2. Methodology of implementation of ASR Quechua.

the described process, the input audios go through a noise reduction and elimination filter. This methodology can be seen in Fig. 2.

A. Database

As a first step to implement this ASR, a Quechua database was developed. For them, isolated words from different native speakers were recorded. The numbers from 1 to 10 were obtained by recording thirty people between men and women, fifteen men and fifteen women. The numbers uttered and recorded can be seen in Table I, and each number was saved in an audio file with .wav. Each number was spoken by the thirty people, so in total we had three hundred audio to be processed and put them in the ASR system we implemented.

B. Feature Extraction.

In this stage, MFCC is implemented and it is considered the most important stage where parametric representation of the audio signals determine how effective is the performance of the next stage, which is classification. MFCC is based on human auditory perception that can not perceive frequencies above 1000 Hz [21][22], in other words it is based on known variation of the human ears critical bandwidth with frequency . The best representation of these audio signals is the Mel scale, which is approximately linearly below the 1000Hz frequency

TABLE I. NUMBERS IN QUECHUA

One	Uc
Two	Iskay
Three	Kimsa
Four	Tawa
Five	Pisqa
Six	Soqta
Seven	Qanchis
Eight	Pusaq
Nine	Isqon
Ten	Chunka

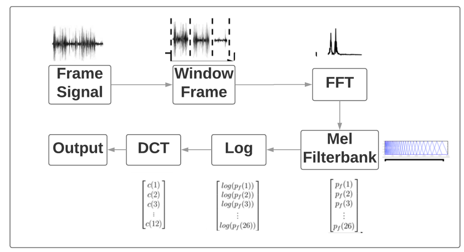

Fig. 3. Mel-Frequency Cepstrum Co-efficients.

and logarithmically above. The entire MFCC process can be seen in Fig. 3 and then each of the phases is developed.

1) Audio Pre-Processing.: Because we needed the acoustic vectors with the same longitude, we had to edit every audio's duration in order to have them with exactly one second of duration. These numbers were spoken in an acoustically balanced and noise free environment, thus it was not necessary to used any noise reduction technique. Every recording was saved in .wav format of 16-bit PMC and 8000Hz frequency. The signal obtained after pre-processing an audio can be seen in time series in Fig 4.

2) Pre-Emphasis.: We apply pre-emphasis to the original signal to amplify the high frequencies. According to [23] the pre-emphasis filter can be used in several ways: a) It balances the frequency spectrum since high frequencies usually have lower magnitudes than those of high frequencies. b) Avoid numerical problems during the operations of Fourier transformations. c) You can also improve the Signal-to-Noise Ratio (SNR). This filter is applied to a signal x using (1).

$$y(t) = x(t) - \alpha(t-1) \quad (1)$$

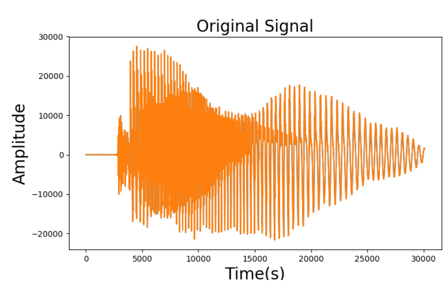

Fig. 4. Original Signal.

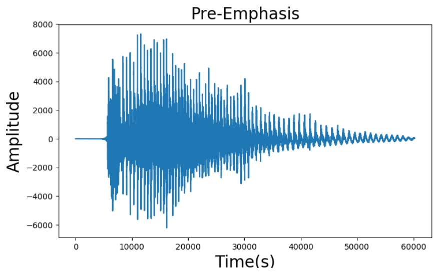

Fig. 5. Pre-Emphasis

After applying the pre-emphasis filter to the original signal, a new signal is shown, which can be seen in Fig 5. We can see that the amplitude of high frequency bands was increased and the amplitudes of lower bands was decreased so it will help to get slightly better results.

3) Framing and Windowing.: With the signal obtained from the pre-emphasis filter, a process is done in which the signal is divided into small frames, and this process is called framing. The reason for doing this process is that when doing the fourier transformation, which is the next step, you lose frequency contours if you work on the entire signal.

After dividing the signal into frames overlapped with each other, a Window function is applied to each frame to remove discontinuities and in this work the Hamming function is used. In this work, the Hamming function is used to counter the assumption made by Fast Fourier Transform (FFT) that the data is infinite and to reduce the spectral leak [23]. The equation of the Hamming function that is applied to each frame is described in (2) where ”n” is the total number of samples in a single frame.

$$w(n) = 0.54 - 0.46\cos(\frac{2\pi n}{N-1}) \tag{2}$$

After applying the Hamming function, the output signal is plotted as shown in Fig. 6.

4) Fast Fourier Transform.: FFT is applied to the signal obtained in the previous section to transform each frame of N samples from a time based domain to a frequency based domain [21]. In other words, a frequency spectrum is calculated where N is generally 256 or 512, and (3) is used to calculate this result. The output of the FFT method is shown in Fig. 7 where the domain of the signal is the frequency.

$$P = \frac{|FFT(x_i)|^2}{N} \tag{3}$$

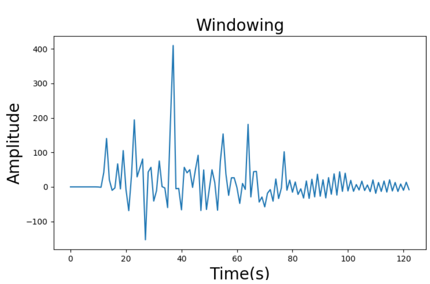

Fig. 6. Windowing

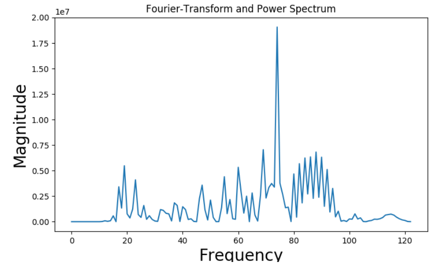

Fig. 7. Fast Fourier Transform

5) Mel Filter Bank.: The frequency range of the FFT spectrum is very wide and a voice signal does not follow a linear scale [21][24]. Filter Bank is then worked to transform the signal from Hertz to Mel scale as shown in Fig. 8 where the Mel filter bank comprises of triangular shaped overlapping filters. To calculate the filter banks, triangular filters are used, and the frequency in Hertz (f) can be converted to a Mel scale using (4).

$$m = 2595\log_{10}(1 + \frac{f}{700}) \tag{4}$$

6) Discrete Cousin Transform (DCT).: This is a process to convert the spectrum in Mel scale to a time-based domain. The result of this process is called MFCC. The set of coefficients obtained is called acoustic vectors [21]. In other words, until this phase, the inputs that were audios, are transformed into a sequence of acoustic vectors, which in turn, will form the set of inputs for the classification algorithms. The result is shown in Fig. 9.

C. Classification and Recognition

To evaluate the recognition accuracy, the development of the classification and recognition stage plays a very important role. In this work, DTW and KNN are used to find matches between different acoustic vectors obtained in the feature extraction phase. In DTW, the dynamic programming approach is used to find similarities between two time series, which basically have the same structure as the previously obtained acoustic vectors. For classification in continuous ASR is more accurate to use other techniques such as HMM or Neural

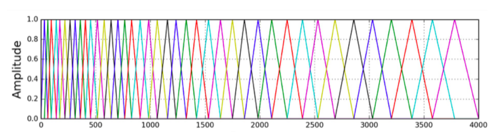

Fig. 8. Filter bank on a Mel-Scale

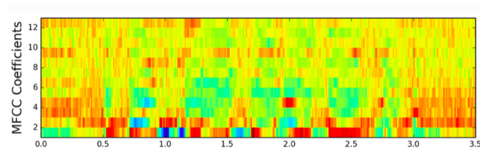

Fig. 9. MFCCs

Networks applied with different approaches such as Deep Learning [25]. These techniques are used because they try to imitate the human language learning taking into account variations of dialects or types of pronunciations. In this work an ASR of isolated words is worked so it is more appropriate to use DTW and KNN.

1) Dynamic Time Warping.: It is an algorithm to find the minimum distance between two sequences or time series dependent on certain values such as time scales, which was initially used only for ASR jobs but its application was extended to fields such as Data Mining [26][27]. Consider two time series P and Q with a length of n and m respectively.

P = p1, p2, p3, ... pn

Q = q1, q2, q3, ... qm

An mxn matrix is built and for each intersection the distance between the two points (pi, qj) is calculated using the Euclidean Distance formula described in (5).

$$d(p_i, q_j) = \sqrt[2]{(p_i - q_j)^2} \tag{5}$$

Then the minimum accumulated distance is calculated using (6). DTW can have many variations with interesting improvements but each optimization is developed under a specific domain and it is difficult to use it in fields like ASR [28].

$$D(i,j) = min[D(i-1,j-1), D(i,j-1), D(i-1,j)] + d(i,j) \tag{6}$$

2) K-Nearest Neighbor.: Given an "n" point, K-Nearest Neighbor is an algorithm that finds all values closest to "n" within a set of values that make up the training database [29]. In ASR, a feature vector takes the value of "n", and KNN finds the vectors closest to "n" taking as reference a distance metric as the Euclidean distance that is calculated between all the vectors with the DTW algorithms.

V. Analysis of Results

The experiment was conducted on a database of three hundred natural number audios from one to ten in Quechua. Each audio in .wav format had exactly a duration of 60 seconds. Each number was pronounced by thirty different people, between men and women.

The database was divided into two sets, one for training that corresponds to 70% of the audios and another for the test that corresponds to 30% of the audios. Of the 90 numbers that passed the classification method, the number of correctly classified numbers was 82. Using (7) the accuracy of recognition of the ASR developed in this research work is calculated, which at the end of the experiment reached a value of 91.1%.

$$Accuracy = \frac{words\ detected\ correctly}{number\ of\ words\ in\ data\ set} \tag{7}$$

The results were also analyzed in the form of a normalized confusion matrix where we can see more details of the performance of the ASR system [30]. The confusion matrix for our system can be shown in Fig. 10 where the result of the classification is taken for each number. In the matrix, it is shown the accuracy of recognition for each label that is useful to analyze which numbers are correctly recognized or partially well recognized. Furthermore, we can identify the numbers with low recognition accuracy to analyze its features and improve the system to achieve a high recognition rate.

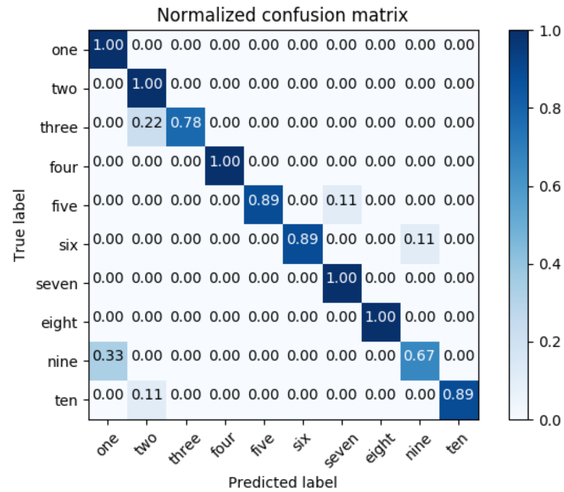

Fig. 10. Confusion Matrix

VI. Conclusion and Future Work

This research work develops an ASR system for isolated words using the MFCC, DTW and KNN techniques. The architecture in which we worked is divided into two blocks, feature extraction block and, the classification and recognition block. In each block we used algorithms that adapt better to our problem. In feature extraction block, it was developed implementing MFCC that consists of a series of algorithms that work sequentially. In the classification block, the acoustic vectors obtained in feature extraction block were classified using DTW and KNN. The results were evaluated using (7) which at the end of the work reached a value of 91.1%. The results were also analyzed in the form of a confusion matrix which shows us the recognition accuracy for every number to identify which numbers are the most recognized and which ones are partially recognized.

As future work it is proposed to improve the ASR system developed in this work including all the words that are spoken in Quechua. Next it is proposed to develop this system as a continuous speech recognition system capable of understanding and processing an speech spoken by any Quechua native people in a fluent way.

References

[1] S. Masood, M. Mehta, Namrata, and D. R. Rizvi, "Isolated word recognition using neural network," *2015 Annual IEEE India Conference (INDICON)*, pp. 1–5, 2015.

[2] P. Wani, U. G. Patil, D. S. Bormane, and S. D. Shirbahadurkar, "Automatic speech recognition of isolated words in Hindi language," in *Proceedings - 2nd International Conference on Computing, Communication, Control and Automation, ICCUBEA 2016*, 2017.

[3] M. A. Hasegawa-Johnson, P. Jyothi, D. McCloy, M. Mirbagheri, G. M. d. Liberto, A. Das, B. Ekin, C. Liu, V. Manohar, H. Tang, E. C. Lalor, N. F. Chen, P. Hager, T. Kekona, R. Sloan, and A. K. C. Lee, "ASR for Under-Resourced Languages From Probabilistic Transcription," *IEEE/ACM Transactions on Audio, Speech, and Language Processing*, vol. 25, no. 1, pp. 50–63, 1 2017.

[4] C. Wei and Y. Yang, "Mandarin isolated words recognition method based on pitch contour," *Proceedings - 2012 IEEE 2nd International Conference on Cloud Computing and Intelligence Systems, IEEE CCIS 2012*, vol. 1, pp. 143–147, 2013.

[5] A. V. Anand, P. S. Devi, J. Stephen, and V. K. Bhadran, "Malayalam Speech Recognition System and Its Application for visually impaired people," *2012 Annual IEEE India Conference (INDICON)*, pp. 619–624, 2012.

[6] D. OShaughness, "Automatic Speech Recognition," *CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies*, 2015.

[7] O. L. A. M. Ali, H. A. Shedeed, M. F. Tolba, and M. Gadalla, "Morphame-Based Arabic Language Modeling for Automatic Speech Recognition," in *Mathematical Applications in Science and Mechanics*, 2013, pp. 152–157.

[8] S. Nur, A. Mohamad, A. A. Jamaludin, and K. Isa, "Speech Semantic Recognition System for an Assistive Robotic Application," *IEEE International Conference on Automatic Control and Intelligent Systems*, 2016.

[9] J. Edgar Vargas Muñoz, J. Antonio Cruz Tello, and R. Alexander Castro Mamani, "Let's Speak Quechua: The Implementation of a Text-to-Speech System for the Incas' Language," 2012. [Online]. Available: http://www.unsaac.edu.pe/

[10] "Isolated Word Automatic Speech Recognition (ASR) System using MFCC, DTW & KNN," *The 2016 Asia Pacific Conference on Multimedia and Broadcasting*, 2016.

[11] H. Prakoso, R. Ferdiana, and R. Hartanto, "Indonesian Automatic Speech Recognition System Using CMUSphinx Toolkit and Limited Dataset," in *International Symposium on Electronics and Smart Devices (ISESD) November 29-30, 2016*, 2016.

[12] R. Ranjan and R. Dubey, "Isolated Word Recognition using HMM for Maithili dialect," *2016 International Conference on Signal Processing and Communication, ICSC 2016*, pp. 323–327, 2016.

[13] P. Malathi and G. R. Suresh, "Recognition of isolated words of esophageal speech using GMM and gradient descent RBF networks," *2014 International Conference on Communication and Network Technologies, ICCNT 2014*, vol. 2015-March, pp. 174–177, 2015.

[14] I. Bhardwaj and N. D. Londhe, "Hidden Markov Model Based Isolated Hindi Word Recognition," *2nd International Conference on Power, Control and Embedded Systems*, 2012.

[15] S. Ananthi and P. Dhanalakshmi, "Speech Recognition System and Isolated Word Recognition based on Hidden Markov Model (HMM) for Hearing Impaired," *International Journal of Computer Applications*, vol. 73, no. 20, pp. 30–34, 2013.

[16] N. F. Chen and H. Li, "Computer-assisted pronunciation training: From pronunciation scoring towards spoken language learning," in *2016 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA)*. IEEE, 12 2016, pp. 1–7.

[17] K. S and C. E, "A Review on Automatic Speech Recognition Architecture and Approaches," *International Journal of Signal Processing, Image Processing and Pattern Recognition*, vol. 9, no. 4, pp. 393–404, 2016.

[18] M. Kumar, N. Rajput, and A. Verma, "A large-vocabulary continuous speech recognition system for Hindi,," *IBM journal of research and development*, vol. 48, no. 5.6, pp. 703–715, 2004.

[19] A. T. DeepaGupta, "Kannada Speech to Text Conversion Using CMU Sphinx," *International Conference on Inventive Computation Technologies*, 2016.

[20] M. Vikram, N. Sudhakar Reddy, and K. Madhavi, "Continuous Automatic Speech Recognition System Using MapReduce Framework," *IEEE 7th International Advance Computing Conference*, 2017.

[21] L. Muda, M. Begam, and I. Elamvazuthi, "Voice Recognition Algorithms using Mel Frequency Cepstral Coefficient (MFCC) and Dynamic Time Warping (DTW) Techniques," *Journal of Computing*, vol. 2, no. 3, pp. 2151–9617, 2010.

[22] S. C. Sajjan and C. Vijaya, "Comparison of DTW and HMM for isolated word recognition," *International Conference on Pattern Recognition, Informatics and Medical Engineering, PRIME 2012*, no. 1, pp. 466–470, 2012.

[23] H. Fayek, "Speech Processing for Machine Learning: Filter banks, Mel-Frequency Cepstral Coefficients (MFCCs) and What's In-Between," 2016. [Online]. Available: http://haythamfayek.com/2016/04/21/speech-processing-for-machine-learning.html

[24] M. Najafian, W.-N. Hsu, A. Ali, and J. Glass, "Automatic Speech Recognition of Arabic Multi-Genre Broadcast Media," *2017 IEEE Automatic Speech Recognition and Understanding Workshop (ASRU)*, pp. 353–359, 2017.

[25] F. D. Rahman, N. Mohamed, M. B. Mustafa, and S. S. Salim, "Automatic speech recognition system for Malay speaking children: Automatic speech recognition system," in *Proceedings of the 2014 3rd ICT International Senior Project Conference, ICT-ISPC 2014*, 2014.

[26] M. B. Lazreg, M. Goodwin, and O. C. Granmo, "Vector representation of non-standard spellings using dynamic time warping and a denoising autoencoder," *2017 IEEE Congress on Evolutionary Computation, CEC 2017 - Proceedings*, pp. 1444–1450, 2017.

[27] Y. Lou, H. Ao, and Y. Dong, "Improvement of Dynamic Time Warping (DTW) algorithm," *Proceedings - 14th International Symposium on Distributed Computing and Applications for Business, Engineering and Science, DCABES 2015*, pp. 384–387, 2016.

[28] A. Sharabiani, H. Darabi, S. Member, A. Rezaei, S. Harford, H. Johnson, and F. Karim, "Efficient Classification of Long Time Series by 3-D Dynamic Time Warping," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 47, pp. 1–16, 2017.

[29] I. Trabelsi, R. Amami, and N. Ellouze, "Automatic emotion recognition using generative and discriminative classifiers in the GMM mean space," *2nd International Conference on Advanced Technologies for Signal and Image Processing, ATSIP 2016*, pp. 767–770, 2016.

[30] X. Kong, J.-Y. Choi, and S. Shattuck-Hufnagel, "Evaluating Automatic Speech Recognition Systems in Comparison With Human Perception Results Using Distinctive Feature Measures," pp. 5810–5814, 2017.

RASP-FIT: A Fast and Automatic Fault Injection Tool for Code-Modification of FPGA Designs

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***Abstract*—Fault Injection (FI) is the most popular technique used in the evaluation of fault effects and the dependability of a design. Fault Simulation/Emulation (S/E) is involved in several applications such as test data generation, test set evaluation, circuit testability, fault detection & diagnosis, and many others. These applications require a faulty module of the original design for fault injection testing. Currently, Hardware Description Languages (HDL) are involved in improving methodologies related to the digital system testing for Field Programmable Gate Array (FPGA). Designers can perform advanced testing and fault S/E methods directly on HDL. To modify the HDL design, it is very cumbersome and time-consuming task. Therefore, a fault injection tool (RASP-FIT) is developed and presented, which consists of code-modifier, fault injection control unit and result analyser. However, in this paper, code modification techniques of RASP-FIT are explained for the Verilog code at different abstraction levels. By code-modification, it means that a faulty module of the original design is generated which includes different permanent and transient faults at every possible location. The RASP-FIT tool is an automatic and fast tool which does not require much user intervention. To validate these claims, various faulty modules for different benchmark designs are generated and presented.**

Keywords*—Code generator; Fault emulation; Fault injection; Fault simulation; Instrumentation; Parser

I. INTRODUCTION

Hardware Description Languages (HDL) have been involved in improving various methodologies related to digital system testing during the last few decades. This reduces the gap between the tools and methodologies used by design and test engineers. Using HDL, the design engineers can verify and test the design at an early stage, and there is no need to convert the design into a compatible format [1]. Verilog HDL is one of the most widely used languages for implementing the design structure for Application Specific Integrated Circuit (ASIC) and FPGA-based designs [2]. These designs are mostly written in HDL and a bit-stream file is generated, which is downloaded into the FPGA chip to implement the design. The FPGA development flow consists of various processes, e.g. synthesis, translate, place & route, and then a bit-stream generation. Various fault injection tools have been devised in the past several years for FPGA-based designs, which work on different stages of the development flow [3], [4] as shown in Fig. 1. It depicts the way of injecting faults at various stages of FPGA development flow.

Generally, FI techniques are divided into four: namely hardware, software, simulation, and emulation-based. Particularly, for FPGA-based systems, emulation and simulation-based techniques are involved in testing, dependability analysis and fault simulation/emulation applications [5]. Designs implemented on the FPGA are also prone to errors and failures, due to radiations and several other reasons, so it is necessary to test and verify the designs. Both testing and verification involve a deliberate introduction of faults in the System Under Test (SUT). Fault injection technique is used in the process of evaluation of fault effects and fault tolerance [6]. The fault injection technique consists of the deliberate insertion of faults into the particular target system and monitors the responses to observe the effects of the faults. In a nutshell, the fault injection technique provides:

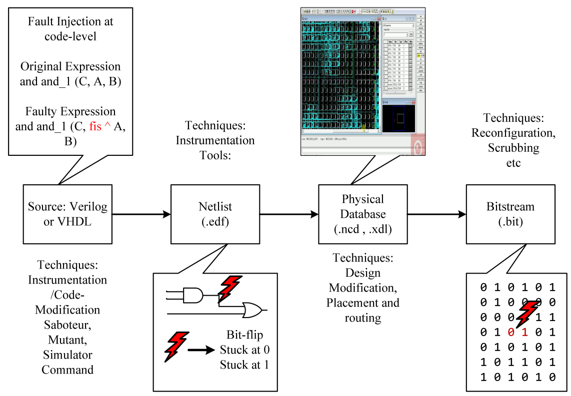


Fig. 1. Fault injection techniques at various stages of the FPGA development flow.

- Statistical estimation of soft-errors for dependability analysis.
- Evaluation of design characteristics for reliability.
- Measurement of the effectiveness of fault tolerance capability of design.
- Ability to find the critical components of an overall design.
- The way to test the digital design and obtains the test vectors for the automatic test equipment.
- Fault coverage and code coverage for the design in the verification process.

There are several reasons for involving FPGA in developing of fault injection techniques and tools, such as prototype availability of designs (for simulation), fast emulation (also the high speed of injections), more on-chip area availability and

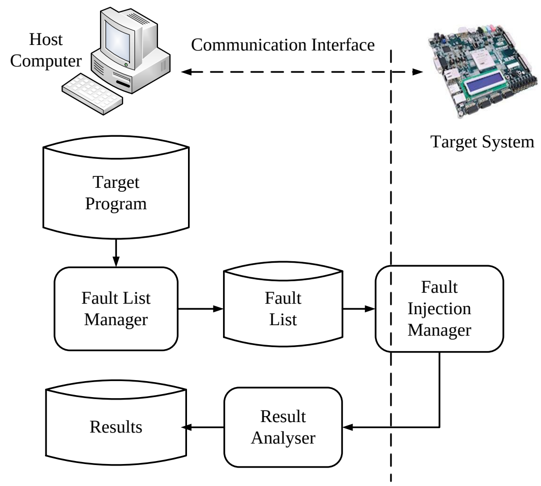


Fig. 2. Fault injection environment [7].

(full & partial) reconfiguration techniques. The main issue in developing a fault injection tool is describing the mechanism to inject, select, and activate a particular fault. In general, any fault injection tool consists of these three basic building blocks such as fault list manager, fault injection manager, and a result analyser as shown in Fig. 2. FI tools for FPGA designs are classified into two main categories and divided further as shown in Fig. 3.

The RASP-FIT (RechnerArchitektur and SystemProgrammierung)–German name of the institute–Fault Injection Tool is presented in this work, which consists of three main parts such as Fault Injection Algorithm (FIA), fault injection control unit, and result analyser [5]. In this paper, the FIA is focused which takes synthesizable Verilog file as an input, parses the code, finds the locations and instruments/modifies the file to generate the faulty design to perform the fault injection and fault simulation/emulation analysis of ASIC and FPGA-based designs. The tool, with its graphical user interface, is developed in Matlab. This fault injection tool deals with various fault models (e.g. bit-flip & stuck-at 1/0) and able to generate any number of faulty designs (required by the user) of the original design with evenly distributed faults in them. It adds the proposed fault control unit (e.g. the FISA Unit) with the required

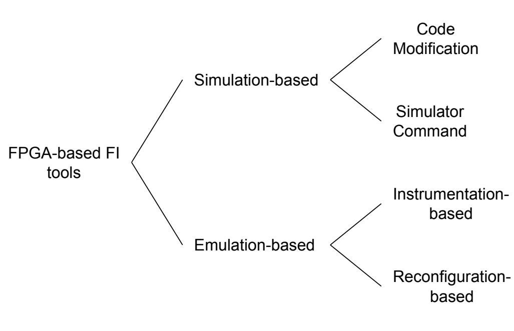


Fig. 3. FPGA-based fault injection techniques and tools.

ports in the faulty HDL design. The RASP-FIT tool is fast and user-friendly and it takes an appropriate time for the generation of faulty modules of the original design. Various benchmark circuits are considered and their compilable faulty modules are generated and presented. The complexity of a design, the way of injecting faults at each code abstraction level and the total number of faults injected in the design versus time taken by this tool is evaluated and presented in this work.

This paper is organized as follows: Section II presents some background information. An automatic Verilog code modifier tool is presented in Section III. Section IV presents the description of the RASP-FIT tool developed in Matlab. Section V shows the results of the instrumentation of Verilog design code at various abstraction levels with timing analysis. Section VI concludes the paper.

II. Background

The ongoing miniaturisation of digital systems makes them more and more sensitive to faults, which complicates the design process of fault-tolerant systems. In this situation, fault injection plays an important role in the process of testing, verifying system's robustness and fault-tolerance capabilities. In the last few years, the fault injection technique is directly applied to the FPGA-based designs, written in HDLs, mainly Verilog or VHDL. Using HDL, designers can use different existing test methods and develop new ones with little effort [1]. Fault injection techniques and tools for FPGA-based designs are divided into two major categories in the literature.

A. Simulation-based Fault Injection Tool for FPGA

Simulation-Based Fault Injection (SBFI) techniques can be categorized into two, i.e. Code Modification (CM) and Simulator Command (SC). The first technique requires modification of HDL code by adding saboteurs and mutants, whereas, the signal or variable values are changed through simulator commands in the second technique [8]. The advantages of using SBFI technique are [9], [10]:

- There is no risk of damage of the SUT.
- Cost effective because no real hardware is used.
- Higher observability and controllability during fault injection campaigns.
- Modelling of both transient and permanent faults is achieved with ease.
- Supports all abstraction levels.

At the code level, the fault injection techniques for the FPGA designs usually come in the category of SBFI. There are many tools that are designed and available for VHDL in the literature, e.g. VERIFY [11], (MEFISTO-C, HEARTLESS, VFIT, FTI) [12], [9], FSFI [13] etc. All these tools are developed for VHDL based designs using SC, saboteur and mutant techniques. The application of Verilog PLI includes test generation during fault simulation. This environment is capable of fault injection, generation of some random patterns and check the responses of injected faults [1]. In some approaches, top-level design module is modified, along with the simulator command technique as presented in [23].

B. Emulation-based Fault Injection Tool for FPGA

The FPGA design & development flow consists of many stages, where modification of the design is possible for the fault injection analysis. Emulation-based fault injection techniques can be categorized into two, i.e. instrumentation and reconfiguration. The advantages of using emulation based fault injection technique are [9], [12]:

- Injection time can be improved as compared to SBFI
- Time and area overhead reduction using partial reconfiguration technique
- Higher observability and controllability

Authors studied the recently developed fault injection tools based on instrumentation technique in the FPGA development flow, such as, tools that work on the net-list developed after the synthesis process [14], [15], [16], some tools based on the instrumentation technique on the code level [18], [17], and using some hybrid techniques (simulation/emulation) [19], [20], [21], [22]. HDL environment is able to generate a list of faults and it is used for fault emulation/simulation of the target system. Authors in [24] presented a code modifier which is developed in C++ language for structural Verilog net-list. A multiplexer is injected as a stuck-at fault model in the code. In comparison with this work, the RASP-FIT tool injects bit-flip and stuck-at (1/0) fault models using simple gates XOR, OR, AND with NOT, respectively. Hence, the RASP-FIT tool provides a small number of additional input ports and area overhead.

The main goal is to develop a fault injection tool, which performs fault injection analysis, fault simulation/emulation, testing, and dependability analysis directly on HDL designs for FPGAs and ASICs. This can reduce the gap between the tools and methodologies used by design and test engineers which speed-up the process of testing, produce cost-effective methods and reduce the time to market. In this paper, code-modification techniques of RASP-FIT tool for various abstraction levels are presented in detail.

III. Automatic Code Generator (A Verilog Code-Modifier)

The concept of automatic code generation involves a number of various techniques such as code completion or code insertion. The code transformation is a technique, where a piece of code is transformed into a target language from a source code [25]. In this work, an automatic code generator is developed to generate a compilable faulty module of the original design, written at Verilog HDL. These faulty designs can be used for fault S/E analysis and testing of FPGA-based designs. The automatic code modifier serves following basic functions:

1) Reading of design file (code parsing).
2) Instrumentation of design code and generation of faulty design code.
3) Addition of fault control unit in each faulty module.
4) Writing of instrumented/modified code to a file having *.v extension.

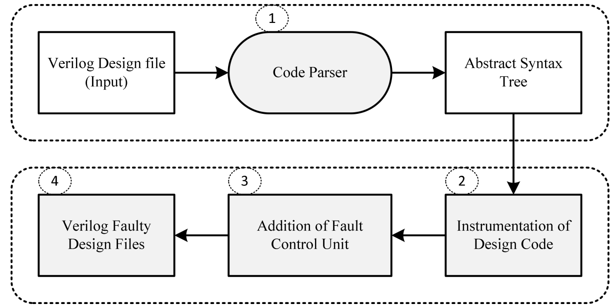


Fig. 4. Block diagram of the automatic code generation process.

The block diagram summarizes these functions, developed under RASP-FIT tool as a Verilog code modifier is shown in Fig. 4.

A. Code Parsing Technique in RASP-FIT

The code parser is a fundamental component of the RASP-FIT tool, which analyses the design code written in Verilog HDL. Normally, a parser generates an Abstract Syntax Tree (AST) from the design code for further analysis. As described earlier, the Verilog code for FPGA-based designs is written at various abstraction levels. The automatic code modifier developed under RASP-FIT is able to modify/instrument the design at any abstraction level for fault injection analysis. The interpretation of the developed parser technique in RASP-FIT for fault injection is shown in Fig. 5 for a gate level design. For different abstraction levels, the way of injecting faults in the design is also different. Detailed about each level is given in the sequel.

1) Gate-level Designs: At gate abstraction level, the basic cell of the design is a logic gate. A logic circuit which contains a few hundreds of logic gates are typically designed at this level [4].

TABLE I. Pre-Defined Gate Primitives in Verilog HDL

S. No.	Gate primitives	I/O positions
1	and, or, nor, nand xor, xnor	First terminal is output, one or more inputs
2	buf, not	One or more outputs, last terminal is input
3	bufif0, bufif1, notif0, notif1	First terminal is output, Second terminal is input, Third terminal is control

Gate level coding of any design in Verilog HDL consists of built-in gate primitives e.g.`(and, or, nand, nor, xor, bufif0, etc.)`, and user-defined primitives. In these primitives, some ports are assigned as outputs and some as inputs. Their positions are defined in Verilog HDL. Table I shows a review of built-in primitives with their positions of inputs/outputs. By default, the RASP-FIT tool injects faults at the input positions, whereas, these positions can also be defined in the library for user-defined primitives. To inject faults at output ports, the RASP-FIT tool adds buffer (buf) to each port. The way of fault modification at this level for the bit-flip fault model is shown in Fig. 6. In this figure, `f0,f1` represents the bit-flip faults in this line of the code.

```
// Verilog
// c17 benchmark circuit ISCAS'85
// Ninputs 5
// Noutputs 2
// NtotalGates 6
// NAND2 6

module c17 (N1,N2,N3,N6,N7,N22,N23);

input N1,N2,N3,N6,N7;
output N22,N23;
wire N10,N11,N16,N19;

nand NAND2_1 (N10, N1, N3);
nand NAND2_2 (N11, N3, N6);
nand NAND2_3 (N16, N2, N11);
nand NAND2_4 (N19, N11, N7);
nand NAND2_5 (N22, N10, N16);
nand NAND2_6 (N23, N16, N19);

endmodule

'//' Comments (single or multi-line '/*
    */') are ignored and removed in faulty
    copies of original design.

ModuleName: c17, (used in generation of
    other copies names as c17_faultycopy1,
    c17_faultycopy2, ... etc.)

Input Port List : Keep it in the container.
    Map() with their dimensions (if vector)
    .
Output Port Declaration: Output port's name
     are changed with the inclusion of
    outVar_f1 or outVar_f2 etc for further
    comparison in fault injection.
Wire Declaration: Keep it in the container.
    Map() with their dimensions (if vector)
    .
nand : Recognise gate_level design (Gate-
    level Library added in the tool
    contains prototypes of built-in and
    user defined primitives).
Consturct fault list & count fault
    locations : 12
End of code
```

Fig. 5. Parsing of a Verilog design file.

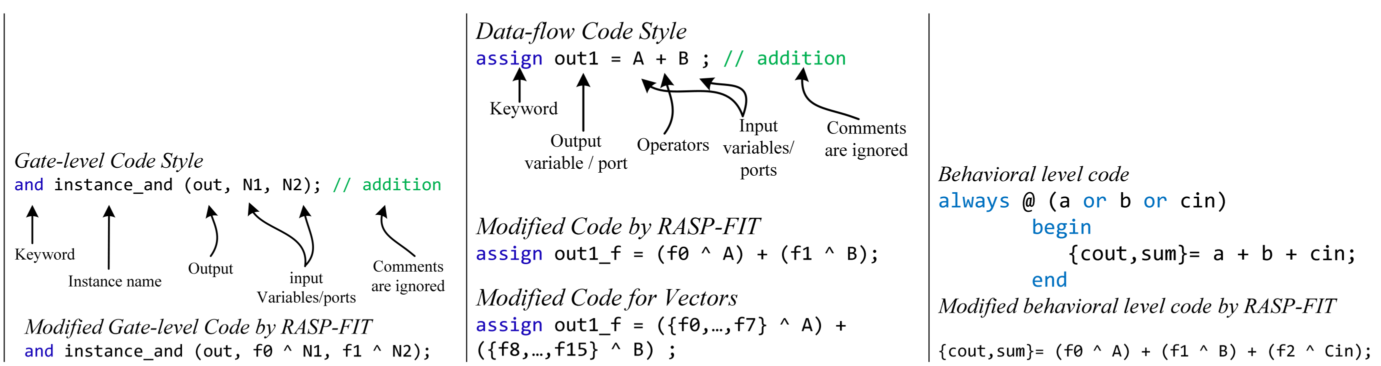


Fig. 6. Fault injection style for different abstraction level.

TABLE II. VERILOG OPERATORS ADDED IN RASP-FIT FOR DATA-FLOW ABSTRACTION LEVEL

Operators (Op) used in a Data-flow Abstraction Level	**Original Expression**	**Faulty Expression by RASP-FIT Tool**	**Precedence**
Unary Operators			
Unary (+, -)	assign B = -A;	assign B = fn ˆ -A;	Highest
∼, & , — , ∼&, ∼—, ˆ, ∼ ˆ,	assign B = OpA	assign B = fn ˆ OpA;	
Binary Operators			
Arithmetic (+, -, *, /, %, **)	assign C = operand1 Op operand2;	assign C = (fn ˆ operand1) Op (fn+1 ˆ operand2);	
Relational (<, >, <=, >=)	–	–	
Equality (= = =, != =, = =, !=)	–	–	
Logical (&&, — —)	–	–	
Ternary Operator			
Conditional (? :)	assign C = expr1 ? expr2 : expr3;	assign C = expr1 ? (fn ˆ expr2) : (fn+1 ˆ expr3);	Lowest

2) Data-flow Designs: For small circuits, up to a few thousand of gates, the gate level modelling approach can work very well. However, the large circuits consist of hundreds of thousands of gates and gate-level modelling is not feasible to test and verify the circuit. Data-flow modelling provides a powerful way to implement large and complex designs. Data-flow is a bit higher level of abstraction than gate-level modelling.

The `assign` command is the heart of Verilog data-flow abstraction level [26], [27]. Fig. 6 shows the fault injection logic for data-flow designs. A simple expression is shown with `assign` statement. For a single bit variables, only one fault is injected per variable. Similarly, in the second modified expression, these variables are considered a byte long variables. Therefore, with the help of concatenation and bit-wise reduction operators, we can inject faults in the vectors. Note that, integer variables (`integer`) are considered 32-bit wide, for the code modifier developed under RASP-FIT tool. It reads and stores the declaration variables with their lengths for fault injections. Table II describes the summary of most widely used operators in data-flow designs with the examples of correct and faulty expressions for bit-flip fault model.

3) Behavioural Designs: Modelling a circuit with logic gates and continuous assignments reflects quite closely the logic structure of the circuit being modelled; however, these constructs fail to describe complex high-level aspects of a system [28]. Verilog provides designers with the ability to describe the whole design functionality in an algorithmic manner, which represents the behaviour of the design [27]. Verilog's behavioural construct is similar to C language construct and it provides greater flexibility to designers.

Verilog behavioural models contain procedural statements that control the simulation and manipulate variables of the data types. The major components of behavioural constructs consist of: always and initial blocks, blocking and non-blocking assignments, conditional statements, multi-way branching, looping statements, sequential and parallel blocks etc. Note that, the vectors are treated with the same approach as described in a data-flow abstraction level. Prototypes for each expression and operators are added to the code modifier. When the code modifier reads the line of code and extracts the command (keyword), it injects the fault accordingly. Faults are injected into the right-hand side of the expression as shown in Fig. 6.

B. Instrumentation Technique for Verilog HDL

The instrumentation is a technique in which extra circuitry added to the design for fault injection/simulation applications, which is commonly known as 'saboteur'. In normal operation, it remains inactive, but when it is activated, it injects faults in the SUT during the fault injection process. The benefit of using this technique is that it does not have time limitations during circuit operation. In FPGA development flow, instrumentation of additional circuits can be done at various stages, e.g. in net-list, bit-stream, and HDL design code. In the RASP-FIT tool, `(XOR, OR, AND with NOT)` gates are used to inject bit-flip, and stuck at 1/0 faults respectively.

1) Fault Models in Verilog HDL: The fault models are developed to be used in pretending the defects in the test process and dependability analysis. Faults can be classified into various categories, such as permanent, transient and intermittent faults. In simple words, a fault is a manifestation of error [29]. Some fault models are widely used in digital circuit testing, fault simulation/emulation, and dependability analysis. These fault models are stuck at fault and Single Event Upset–commonly known as bit-flip–(SEU) fault. The fault injection technique at code level should describe the way to inject these faults in the code, which pretend as real faults occurred in the system, given in the sequel.

Stuck-at Fault Model in Verilog HDL: The stuck-at fault is a fault on a line or its interconnecting gates, which causes the logic value to be appeared on the line never changes. There are two categories of such fault model, i.e. stuck at 1 (sa-1) and stuck at 0 (sa-0) [1], [30]. In the sa-1 fault model, a logic value '1' appears to a signal line in the logic circuit, whereas, in the sa-0 fault model a logic value '0' appears on a line. Two faults per line can occur, these are sa-1 or sa-0 at the input or the output of a logic gate. In Verilog HDL, these faults can be injected into the gate, data-flow, and behavioural abstraction levels as shown in Fig. 6.

Bit-flip Fault Model in Verilog HDL: The bit-flip fault model is also widely used in order to calculate SEU. An SEU occurs when a bit is changed from logic '0' to logic '1' and vice versa.

Table III presents the summary of all fault models along with the Verilog operators used in RASP-FIT code modifier.

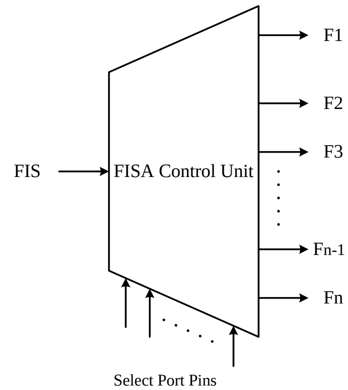
`fn` and `Var` show the particular fault and the declared input, wire or reg ports in the design, respectively.

TABLE III. SUMMARY FOR FAULT MODELS AND VERILOG OPERATORS

S.No.	Fault model	Verilog operator	Verilog code
1	Stuck-at 1	| (OR logic)	(fn | Var)
2	Stuck-at 0	∼,& (AND logic)	(∼fn & Var)
3	Bit-flip (SEU)	ˆ(XOR logic)	(fn ˆVar)

C. Fault Control Unit: FISA Unit

DEMUX-based Fault Injection, Selection, & Activation (FISA) unit is developed to control the selection and activation of the injected faults in the fault simulation/emulation applications as shown in Fig. 7. The proposed fault control unit is a simple unit and it provides the high controllability and observability about the selection and activation of faults. The FIS signal has a logic value '1'. When the select port is assigned a value from a test-bench (in simulation), then that fault is selected and activated in the target system. The fault injection analysis under RASP-FIT includes the code for the FISA unit in each faulty copy of the target design [3]. As we are generating a faulty module of the original design at the code level, we need to write this code in the design. It is very time-consuming to write HDL code manually for the fault control unit when a number of faults are large enough. For that purpose, a function `(gen_always)` is created and integrated into the RASP-FIT tool. The output of the function is shown in Fig. 7 and it is added to the faulty design as shown in Fig. 9.




```
wire fis = '1'; // Declaration part
reg f0,f1,f2;

always @ (select) begin
  if (select == 2'd0) begin
    f0=fis;f1=0;f2=0; end
  else if (select == 2'd1) begin
    f0=0;f1=fis;f2=0; end
  else if (select == 2'd2) begin
    f0=0;f1=0;f2=fis; end
  else begin
    f0=0;f1=0;f2=0; end
  end
```

Fig. 7. Proposed DEMUX-based FISA control unit (above), and it's Verilog code (below).

IV. DEVELOPMENT OF RASP-FIT IN MATLAB

The RASP-FIT tool is developed in Matlab along with its graphical user interface. The tool consists of three major functions, namely, `fault_injection()`, `static_compaction()` and `hardness_analysis()`. All these functions are developed in Matlab under the function `RASP_FIT()`. It is a tabbed-based GUI as shown in Fig. 8. Each tab performs certain specific functions.

In this paper, the fault injection capability of this tool is presented. The `fault_injection()` function consists of approximately 563 lines of code having 20 functions. A Verilog code modification is described in detail in Section V. At the graphical user interface, the user must provide a synthesizable Verilog design file as an input, select the type of fault model for injection in the design from a drop-down menu and enter the number of faulty modules required. By clicking on the `Generate` button, faulty modules will be generated along with the top file. The faulty modules are saved under the name (`moduleName_faultycopy1.v`, `moduleName_faultycopy2.v` and so on) at the same location/folder. The top file, which contains the comparator logic and memory declaration for storing results of the comparisons, is saved under the name (`moduleName_top.v`). These modified designs are now used for the fault simulation/emulation, digital testing and dependability analysis, with FPGA tools, without much effort.

V. RESULT AND DISCUSSION

The RASP-FIT tool has the capability to modify (instrument) the Verilog code, written at any abstraction level. As described earlier, there are three main abstraction levels, e.g. gate-level, data-flow, and behavioural levels. The fault injection technique is widely used in fault simulation/emulation, digital testing and dependability analysis. To perform fault injection, we need a faulty module of an original module (i.e. golden module). In our case, the golden module is available in Verilog code for FPGA-based designs. In order to generate a compilable faulty code of the original design with the inclusion of faults and fault control unit, we need to modify the code which is a cumbersome and time-consuming task. When the complexity of design is increased, it injects more faults and takes more time to generate faulty copies.

In this work, we have used different benchmark circuits (ISCAS'85, ISCAS'89, EPFL and some behavioural designs). These benchmark circuits are written in gate-level, data-flow and behavioural abstraction levels. The complexity of design in terms of logic gates and time taken for these design is described tabularly. Details are given in the sequel.

A. Gate Abstraction Level Code

To validate a test methodology, the ISCAS'85 and ISCAS'89 benchmark circuits are most widely used. These benchmark circuits consist of combinational and sequential circuits. The ISCAS'85 consists of 11 combinational benchmark circuits, whereas the ISCAS'89 consists of 23 sequential

Fig. 8. Tabbed-based GUI of the proposed tool (RASP-FIT).

circuits. In this work, the capability of the RASP-FIT tool to generate a compilable faulty code is highlighted, however, we have used these benchmark circuits to validate the proposed test approach (which is not discussed here).

1) Compilable Faulty Design: Fig. 9 shows the original design and the compilable faulty design of the simple circuit from ISCAS'85 benchmark circuits for illustration purpose. There are some points to be noted here:

1) In the original design, the module name is `c17`, whereas, in faulty design, the module name is changed to `c17_1`, which shows the first copy of the faulty design.
2) The output ports of a faulty design are renamed with the extension of `(_f1)` for the first copy of the faulty design and for the second copy `(_f2)` and so on. This is done for the comparison purpose in fault injection experiments with the fault-free design.
3) The fault selection port (i.e. select port) is added to the faulty copy as an input port, which is used to choose a particular fault for injection and its activation.
4) The selected fault is activated by assign a logic '1' value. For that purpose, a `wire fis` is added to the design.
5) The fault variables `f0,f1,...,fn` are used to assign the 'fis' value in an `always` block, so these variables must be declared as `reg` variables.
6) DEMUX-based FISA unit is added to select and activate the fault. When no fault is activated, the circuit performs the same operation as of the original design.
7) This tool is capable of injecting faults in a full design or in a partial design. The user can specify any number of copies, and this tool evenly distributes the number of faults in each copy of the design.

2) Timing Analysis for Gate-Level Designs: The RASP-FIT tool takes appropriate time to generate faulty designs. We have performed the experiments on the various gate-level benchmark circuits from ISCAS'85 and ISCAS'89. The complexity of design in terms of logic gates are described in Table IV and Table V for the ISCAS'85 and ISCAS'89 benchmark circuits, respectively. Also, these tables show the total number of faults injected in the design. The time taken by the RASP-FIT tool is measured (in Seconds) using the Matlab commands `(tic,toc)`, and described in the last column of the tables.

TABLE IV. Time Analysis to Generate Faulty Models of ISCAS'85 Gate-Level Designs

S.No.	Gate-level benchmark circuits	No. of logic gates	Total faults	Time (in Seconds)
1	c17	6	12	0.2075
2	c432	160	336	0.4187
3	c499	202	408	0.4578
4	c880	383	729	0.5811
5	c1355	546	1064	1.068
6	c1908	880	1498	1.8334
7	c2670	1269	2152	4.8450
8	c3540	1669	2939	6.4805
9	c5315	2307	4386	13.011
10	c6288	2416	4800	21.935
11	c7552	3513	6145	37.504

TABLE V. Time Analysis to Generate Faulty Models of ISCAS'89 Gate-Level Designs

S.No.	Gate-level benchmark circuits	No. of logic gates/FFs	Total faults	Time (in Seconds)
1	s1494	647/6	1399	1.503
2	s5378	2779/179	4391	8.723
3	s9234	5597/211	8182	21.68
4	s13207	7951/638	11803	82.09
5	s15850	9772/534	14179	118.188
6	s35932	16065/1728	29997	965.05
7	s38417	22179/1636	33664	577.50
8	s38584	19253/1426	34182	1306.90

B. Data-flow Abstraction Level Code

The EPFL benchmark circuits consist of 23 combinational logic circuits, written in a data-flow code style. These circuits are specifically designed for logic optimization but we are using them for fault injection/simulation approaches.

```
// Original design
module c17 (N1,N2,N3,N6,N7,N22,N23);

input N1,N2,N3,N6,N7;
output N22,N23;
wire N10,N11,N16,N19;

nand NAND2_1 (N10, N1, N3);
nand NAND2_2 (N11, N3, N6);
nand NAND2_3 (N16, N2, N11);
nand NAND2_4 (N19, N11, N7);
nand NAND2_5 (N22, N10, N16);
nand NAND2_6 (N23, N16, N19);

endmodule

// Compilable faulty design
module c17_1 (select,N1,N2,N3,N6,N7,N22_f1
    ,N23_f1);
input N1,N2,N3,N6,N7;
output N22_f1,N23_f1;
wire N10,N11,N16,N19;
input[1:0] select;
wire fis=1;
reg f0,f1,f2,f3;
always @ (select)
  begin
    if (select == 2'd0) begin
      f0=fis;f1=0;f2=0;f3=0; end
    else if (select == 2'd1) begin
      f0=0;f1=fis;f2=0;f3=0; end
    else if (select == 2'd2) begin
      f0=0;f1=0;f2=fis;f3=0; end
    else if (select == 2'd3) begin
      f0=0;f1=0;f2=0;f3=fis; end
    else begin
      f0=0;f1=0;f2=0;f3=0; end
  end
nand NAND2_1 (N10,f0^ N1,f1^ N3);
nand NAND2_2 (N11,f2^ N3,f3^ N6);
nand NAND2_3 (N16, N2, N11);
nand NAND2_4 (N19, N11, N7);
nand NAND2_5 (N22_f1, N10, N16);
nand NAND2_6 (N23_f1, N16, N19);
endmodule
```

Fig. 9. Original code (left) & instrumented compilable design code (right) by RASP-FIT.

1) Compilable Faulty Design: A simple code of 4_to_1 multiplexer, written in a data-flow abstraction style is considered to present the output of RASP-FIT tool for data-flow designs. Fig. 10 shows the original design and instrumented faulty design of it. The detail description of the faulty code is described already in gate-level design. The difference lies in the way of the injection of faults in the design. Fig. 6 shows the method of injection in a single bit and vector variables for all abstraction levels.

2) Timing Analysis for Data-flow Designs: We performed the experiments on the various data-flow benchmark circuits from EPFL. The complexity of design in terms of logic gates, the total number of faults in the design, and time taken by the tool in Seconds are described in Table VI and Table VII.

C. Behavioural Abstraction Level Code

At this level, the large and complex designs are written e.g. processor design. In order to perform fault injection testing for these bigger design, a fault-free module is replaced by a generated faulty module. Different basic and large complex behavioural designs are considered from DP32 Verilog processor and presented in Table VIII. Instead of the number of logic gates information, we added the number of slices LUTs (Look-Up Tables) obtained after the synthesis process using Xilinx ISE tools. Fig. 11 shows the original design and instrumented faulty design of it. The way of fault injection mechanism (code parsing) for the different behavioural commands, e.g. case, if-else construct, blocking and non-blocking assignments, always-initial blocks is added in RASP-FIT. The fault injection mechanism for other behavioural commands such as loops, built-in or user-defined macros & functions, and the include

```
// Original design
module mux_4x1 (out, in0, in1, in2, in3, s0
    , s1);

output out;
input in0, in1, in2, in3;
input s0, s1;

assign out = (~s0 & ~s1 & in0)|
(s0 & ~s1 & in1) |
(~s0 & s1 & in2) |
(s0 & s1 & in0);
endmodule

// Compilable faulty design
module mux_4x1_1 (select,out_f1, in0, in1,
    in2, in3, s0, s1);
output out_f1;
input in0, in1, in2, in3;
input s0, s1;
input [3:0] select;
wire fis=1;
reg f0,f1,f2,f3;
always @ (select)
  begin
    if (select == 2'd0) begin
      f0=fis;f1=0;f2=0;f3=0; end
    else if (select == 2'd1) begin
      f0=0;f1=fis;f2=0;f3=0; end
    else if (select == 2'd2) begin
      f0=0;f1=0;f2=fis;f3=0; end
    else if (select == 2'd3) begin
      f0=0;f1=0;f2=0;f3=fis; end
    else begin
      f0=0;f1=0;f2=0;f3=0; end
    end
  assign out_f1 = ((f0 ^ ~s0) & (f1 ^ ~s1) &
       (f2 ^ in0)) |
  ((f3 ^ s0)  &  ~s1 & in1) |
  (~s0 & s1 & in2)|(s0 & s1 & in0);
endmodule
```

Fig. 10. Original code (left) & instrumented compilable data-flow code (right) by RASP-FIT.

TABLE VI. TIME TO GENERATE FAULTY MODULES OF ARITHMETIC DATA-FLOW CIRCUITS FROM EPFL

S.No.	Data-flow benchmark circuits	No. of logic gates	Total faults	Time (in Seconds)
1	Adder	1020	2040	6.512
2	Barrel-shifter	3336	6672	89.898
3	Divisor	44762	114494	4034.22
4	Hypotenuse	214335	428670	-
5	Log2	32060	64120	794.34
6	Max	2865	5730	41.26
7	Multiplier	27062	54124	1153.9
8	Sine	5412	10832	62.93
9	Square	24618	36970	955.66
10	Square-root	18484	49236	1212.9

TABLE VII. TIME TO GENERATE FAULTY MODULES OF RANDOM/CONTROL DATA-FLOW CIRCUITS FROM EPFL

S.No.	Data-flow benchmark circuits	No. of logic gates	Total faults	Time (in Seconds)
1	Round-Robbin arbieter	11839	23678	311.659
2	ALU control unit	174	349	0.484
3	Coding-cavlc	693	1386	2.177
4	Decoder	304	608	1.393
5	I2C controller	1342	2699	10.61
6	Int-to-float controller	260	520	1.601
7	Memory controller	46836	93946	15794
8	Priority encoder	978	1956	3.396
9	look-ahead xy router	257	541	0.806
10	voter	13758	27516	152.30

files are in progress.

```
// Original design
module mux_4x1 (out, in0, in1, in2, in3,
    sel);
output reg out;
input in0, in1, in2, in3;
input [1:0] sel;

always @ (in0 or in1 or in2 or in3 or sel)
  begin
    case (sel)
    2'b00: out = in0;
    2'b01: out = in1;
    2'b10: out = in2;
    2'b11: out = in3;
    endcase
  end
endmodule

// Compilable faulty design
module mux_4x1 (select,out, in0, in1, in2,
    in3, sel);
output reg out_f1;
input in0, in1, in2, in3;
input [1:0] sel;
input [2:0] select;
wire fis=1;
reg f0,f1,f2,f3,f4,f5;
always @ (select)
  begin
    if (select == 3'd0) begin
      f0=fis;f1=0;f2=0;f3=0;f4=0;f5=0; end
    else if (select == 3'd1) begin
      f0=0;f1=fis;f2=0;f3=0;f4=0;f5=0; end
    .
    .
    .
    else begin
      f0=0;f1=0;f2=0;f3=0;f4=0;f5=0; end
  end

always @ (in0 or in1 or in2 or in3 or sel)
  begin
    case ({f0,f1} ^ sel)
      2'b00: out = f2 ^ in0;
      2'b01: out = f3 ^ in1;
      2'b10: out = f4 ^ in2;
      2'b11: out = f5 ^ in3;
    endcase
  end
endmodule
```

Fig. 11. Original code (left) & instrumented compilable behavioural code (right) by RASP-FIT.

VI. Conclusion

Fault S/E helps designers and test engineers in the evaluation, verification of their designs and generation of test patterns. It is used to evaluate fault effects, dependability and measure the robustness of FPGA-based systems, written in HDL. The injection of faults in HDL design requires modification of design to generate faulty target system. In this work, the code modifier for Verilog HDL designs is presented in detail. The RASP-FIT is a fault injection tool, which works at the code level of the designs at various abstraction levels. This tool can inject faults in the whole design, and produce the compilable code. The tool is simple, automatic and user-friendly. Results show that the RASP-FIT tool takes an appropriate time, depends on the size of the design, for the generation of faulty module and fault injection control unit.

References

[1] Z. Navabi, *Digital System Test and Testable Design*. Boston, MA: Springer US, 2011.

[2] H. Ben Fekih, A. Elhossini, and B. Juurlink, *Applied Reconfigurable Computing*, ser. Lecture Notes in Computer Science, K. Sano, D. Soudris, M. Hübner, and P. C. Diniz, Eds. Cham: Springer International Publishing, 2015, vol. 9040.

TABLE VIII. TIME TO GENERATE FAULTY MODULES OF BEHAVIOURAL DESIGNS

S.No.	Behavioural designs	No. of slices LUTs	Total faults	Time (in Seconds)
1	Mux (case)	1	6	0.108
2	Mux (if-else)	1	12	0.112
3	8-bit Full Adder	9	75	0.648
4	Program Counter	12	130	0.785
5	ALU-32bit	173	896	3.359

[3] A. R. Khatri, A. Hayek, and J. Börcsök, *Applied Reconfigurable Computing*, ser. Lecture Notes in Computer Science, V. Bonato, C. Bouganis, and M. Gorgon, Eds. Cham: Springer International Publishing, 2016, vol. 9625.

[4] A. R. Khatri, A. Hayek, and J. Börcsök,"Validation of selecting SP-values for fault models under proposed RASP-FIT tool," in *2017 First International Conference on Latest trends in Electrical Engineering and Computing Technologies (INTELLECT)*. Karachi, Pakistan: IEEE, pp. 1–7, Nov 2017.

[5] A. R. Khatri, A. Hayek, and J. Börcsök, "Validation of the Proposed Fault Injection , Test and Hardness Analysis for Combinational Data-flow Verilog HDL Designs under the RASP-FIT Tool," in *2018 IEEE 16th Int. Conf. on Dependable, Autonomic & Secure Comp., 16th Int. Conf. on Pervasive Intelligence & Comp., 4th Int. Conf. on Big Data Intelligence & Comp., and 3rd Cyber Sci. & Tech. Cong.* Athens, Greece: IEEE Comput. Soc, pp. 544–551, Aug 2018.

[6] L. Entrena, "Fast fault injection techniques using FPGAs," in *14th Latin American Test Workshop - LATW*. Madrid,Spain: IEEE, Apr 2013.

[7] A. Benso, M. Rebaudengo, M. Reorda, and P. Civera, "An integrated HW and SW fault injection environment for real-time systems," in *Proceedings IEEE International Symposium on Defect and Fault Tolerance in VLSI Systems (Cat. No.98EX223)*. Austin, TX, USA, USA: IEEE Comput. Soc, pp. 117–122, 1998.

[8] D. Kammler, J. Guan, G. Ascheid, R. Leupers, and H. Meyr, "A Fast and Flexible Platform for Fault Injection and Evaluation in Verilog-Based Simulations," in *2009 Third IEEE International Conference on Secure Software Integration and Reliability Improvement*. IEEE, pp. 309–314, Jul 2009,

[9] A. Benso and P. Prinetto, *Fault Injection Techniques And Tools For Embedded Systems Reliability Evaluation.* Kluwer Academic Publishers, 2003.

[10] M. Kooli and G. Di. Natale, "A survey on simulation-based fault injection tools for complex systems", in *2014 9th IEEE International Conference on Design & Technology of Integrated Systems in Nanoscale Era (DTIS)*. Santorini: IEEE, pp. 1–6, May 2014.

[11] V. Sieh, O. Tschache, and F. Balbach, "VERIFY: evaluation of reliability using VHDL-models with embedded fault descriptions," in *Proceedings of IEEE 27th International Symposium on Fault Tolerant Computing*. IEEE Comput. Soc,pp. 32–36, 1997.

[12] H. Ziade, R. Ayoubi, and R. Velazco, "A Survey on Fault Injection Techniques," *The International Arab Journal of Information Technology*, vol. 1, no. 2, pp. 171–186, 2004.

[13] W. Chao, F. Zhongchuan, C. Hongsong, and C. Gang, "FSFI: A Full System Simulator-Based Fault Injection Tool," in *2011 First International Conference on Instrumentation, Measurement, Computer, Communication and Control*. IEEE, pp. 326–329, Oct 2011.

[14] W. Mansour, R. Velazco, R. Ayoubi, H. Ziade, and W. El Falou, "A method and an automated tool to perform SET fault-injection on HDL-based designs," in *25th International Conference on Microelectronics (ICM)*. Beirut: IEEE, pp. 1–4, Dec 2013.

[15] W. Mansour, M. A. Aguirre, H. Guzman-Miranda, J. Barrientos, and R. Velazco, "Two complementary approaches for studying the effects of SEUs on HDL-based designs," in *IEEE 20th International On-Line Testing Symposium (IOLTS)*. IEEE, pp. 220–221, Jul 2014.

[16] W. Mansour and R. Velazco, "An Automated SEU Fault-Injection Method and Tool for HDL-Based Designs," *IEEE Transactions on Nuclear Science*, vol. 60, no. 4, pp. 2728–2733, Aug 2013.

[17] W. Mansour and R. Velazco, "SEU Fault-Injection in VHDL-Based Processors: A Case Study"*Journal of Electronic Testing*, vol. 29, no. 1, pp. 87–94, Feb 2013.

[18] M. Shokrolah-Shirazi and S. G. Miremadi, "FPGA-Based Fault Injection into Synthesizable Verilog HDL Models," in *Second International Conference on Secure System Integration and Reliability Improvement*. Yokohama: IEEE, pp. 143–149, Jul 2008.

[19] B. Rahbaran, A. Steininger, and T. Handl, "Built-in Fault Injection in Hardware - The FIDYCO Example," in *Second IEEE International Workshop on Electronic Design, Test and Applications*. Perth, WA, Australia: IEEE, pp. 327–327, 2004.

[20] M. Jeitler, M. Delvai, and S. Reichor, "FuSE - a hardware accelerated HDL fault injection tool," in *2009 5th Southern Conference on Programmable Logic (SPL)*. Sao Carlos: IEEE, pp. 89–94, Apr 2009.

[21] A. Mohammadi, M. Ebrahimi, A. Ejlali, and S. G. Miremadi, "SCFIT: A FPGA-based fault injection technique for SEU fault model," in *Design, Automation & Test in Europe Conference & Exhibition (DATE)*. Dresden: IEEE, pp. 586–589, Mar 2012.

[22] L. Naviner, J.-F. Naviner, G. dos Santos, E. Marques, and N. Paiva, "FIFA: A fault-injection–fault–analysis-based tool for reliability assessment at RTL level," *Microelectronics Reliability*, vol. 51, no. 9-11, pp. 1459–1463, Sep 2011.

[23] A. Rohani and H. G. Kerkhoff, "Rapid transient fault insertion in large digital systems," *Microprocessors and Microsystems*, vol. 37, no. 2, pp. 147–154, Mar 2013.

[24] C. Dunbar and K. Nepal, "Using Platform FPGAs for Fault Emulation and Test-set Generation to Detect Stuck-at Faults," *Journal of Computers*, vol. 6, no. 11, pp. 2335–2344, Nov 2011.

[25] C. Pohl, C. Paiz, and M. Porrmann, "vMAGIC–Automatic Code Generation for VHDL," *International Journal of Reconfigurable Computing*, vol. 2009, pp. 1–9, 2009.

[26] Joseph Cavanagh, *Digital Design Verilog and HDL Fundamentals*. Taylor and Francis Group, LLC, 2011.

[27] S. Palnitkar, *Verilog HDL A guide to Digital Design and Synthesis*. SunSoft Press, 1996.

[28] Sponsored by the Design Automation Standards Committee, *IEEE Standard for Verilog Hardware Description Language*, vol. 2005, no. April 2006.

[29] A. R. Khatri, M. Milde, A. Hayek, and J. Börcsök, "Instrumentation Technique for FPGA based Fault Injection Tool," in *5th International Conference on Design and Product Development (ICDPD'14)*, Istanbul, Turkey, pp. 68–74, Dec 2014.

[30] R. Drechsler, S. Eggersglüß, G. Fey, and D. Tille, *Test Pattern Generation using Boolean Proof Engines*. Springer Science+Business Media, 2009.

A P System for K-Medoids-Based Clustering

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***Abstract*—The membrane computing model, also known as the P system, is a parallel and distributed computing system. K-medoids algorithm is one of the most famous algorithms in partition-based clustering algorithms, and has been widely used in data analysis and modern scientific research. Combining the P system with the k-medoids algorithm, the maximum parallelism calculated by the P system can effectively reduce the time complexity of the k-medoids clustering algorithm. Based on this, this paper proposes a cell-like P system with promoters and inhibitors based on k-medoids clustering, and then an instance is given to illustrate the practicability and effectiveness of the P system designed.**

Keywords*—*P systems; Clustering; K-medoids-based clustering; Membrane computing; Parallel and distributed computing

I. Introduction

Membrane computing[1,2], which is initiated by Pun in 1998, is a branch of molecular computing. The computing models in the framework of membrane computing, also called P systems, are distributed, non-deterministic and maximally parallelized[1]. P systems are inspired from the compartmental structure and the way to process chemical compounds of alive cells, cells in tissue, organs, etc. Up to now, many variants of P systems have been investigated, mainly including cell-like P systems[1,3,4], tissue-like P systems[5-7] and neural-like P systems[8,9]. P systems have been studied in many areas, such as biology[10], linguistics[11], computer science, mathematics[12], etc.[13]. Many variants are universal computationally, likewise it has been proved that P systems have the computing capacity with the equivalent of Turing machine[14,15]. Besides, more information about P systems can be found at the website of Ref[16].

Information plays an increasingly important role in modern society. Consequently, the issue of crucial importance is data analysis. Clustering is a basic and significant composition of data analysis, and it is employed as an ordinary method in modern science research[17]. However, it is not come to an agreement with the complete definition for clustering. The classic one is described as: instances in the same cluster must be similar as much as possible, instances in the different clusters must be different as much as possible and measurement for similarity and dissimilarity must be clear and have the practical meaning[18]. Generally speaking, Clustering algorithms are divided into traditional ones and modern ones, where traditional ones are based on partition[19,20], fuzzy theory[21], distribution[22,23], density[24, 25], grid[26-28], graph theory[29,30], etc. It is applied crossing communication science, computer science, biology science, etc. Clustering is also introduced to membrane computing[31-33]. For the data clustering problem, ref.[33] presents a novel clustering algorithm based on a tissue-like P system with loop structure of cells, called membrane clustering algorithm, to realize a local neighborhood topology, and proves the high efficiency and competitiveness of the proposed algorithm. To deal with self-driven clustering problem, ref.[32] proposes a membrane clustering algorithm based on a tissue-like P system with fully connected structure to solve how many clusters is the most appropriate and what does a good clustering partitioning look like at the same time. It develops an improved velocity-position model as evolution rules and proves the competitiveness of the propose algorithm either. Ref. [31] proposes the k-medoids-based consensus clustering based on a cell-like P system with inhibiters and promoters by means of introducing k-medoids algorithm and cell-like P system with inhibiters and promoters to the consensus clustering, and it is proved to be highly accurate and highly efficient. K-medoids[34] is a melioration of k-means, and these two are the most famous ones of clustering algorithm based on partition. K-medoids deals with discrete data and designates the data point most near to cluster center as medoid. This method is more robust to noise and outliers as compared to k-means due to minimizing a sum of pairwise dissimilarities instead of a sum of squared Euclidean distances, but is suitable for small data sets because of larger calculation. However, the time complexity can be decreased by cell-like P systems with promoters and inhibiters, because it has the inherent mechanism of parallel and distributed computing. In short, the maximum parallelism of P systems contributes to improving algorithm efficiency of unsupervised learning.

In this paper, a P system Π_{kmbc} is proposed to implement a kind of k-medoids-based algorithm which is modified mildly to adjust with the evolution mechanism of P Systems to achieve clustering. The paper is organized as follows: Section II introduces the basic knowledge of the k-medoids algorithm and cell-like P system with priority and promoters; Section III proposes the design of the P system Π_{kmbc} with its k-medoids-based algorithm, definition and rules discussed in detail. Subsequently, an instance is given in section IV; and the conclusions are drawn in Section V.

II. Foundation

A. The k-medoids algorithm

The k-medoids algorithm proposed in 1987[34] is a classical partitioning algorithm of clustering related to the k-means algorithm. Both the k-medoids and the k-means algorithms are to cluster the data set of n objects into k (a known priori) clusters and to minimize the distance between points in the same cluster and a point called medoid which is designated as the center of that cluster. A medoid is a most centrally located point in the cluster.

As the K-Medoids algorithm is improved by the K-Means algorithm, it is partitioning around medoids instead of means. The K-Medoids algorithm is more robust to outliers and noise than the K-Means algorithm due to choosing medoids as centers and minimizing a sum of pairwise dissimilarities. However, the same characteristic is that the actual definition of the distance has various alternatives according to the requirement of actual problems. The smaller the sum of distances between each two data points is, and the more similar the data points in same cluster are, the more dissimilar the data points from different clusters are, the better the clustering result is.

The most representative realization of k-medoids algorithm is the Partitioning Around Medoids (PAM) algorithm. PAM uses a greedy search which may not find the optimum solution, but it is faster than exhaustive search. It works as follows[35]:

1)Initialize: select k of the n data points as the medoids.

2)Associate each data point to the closest medoid.

3)While the cost of the configuration decreases, repeat step 4).

4)For each medoid m, for each non-medoid data point o, repeat step 5) to 6).

5)Swap m and o, recalculate the sum of distances of data points to their medoid.

6)If the total cost of the configuration increased in the previous step, undo the swap.

Algorithms other than PAM have also been suggested in the literature [36,37]. Voronoi iteration method is included, which is more simple and faster than PAM. The steps of Voronoi iteration method are as follows:

1)Initialize: select k of the n data points as the medoids.

2)Repeat step 3) to 4) while the cost decreases.

3)In each cluster, make the data point that minimizes the sum of distances within the cluster the medoid.

4)Reassign each data point to the cluster defined by the closest medoid determined in the previous step.

B. Cell-like P System with Priority and Promoters

There are many variants of P systems already introduced in section 1. This paper is only related to cell-like P systems with priority and promoters. Therefore, this piece gives the basic concepts about cell-like P systems with priority and promoters.

There are three main components to cell-like P system: the membrane structure, objects and rules. As suggested by Fig.1, the membrane structure is a hierarchically arranged set of membranes which are usually identified by labels from a given set and divide a cell-like P system into separated regions. A membrane which does not contain any other membranes is called elementary. The membrane which contains all the other membranes is referred as the skin. Each Membrane only determines a region bordered above by itself and below by the membranes placed directly inside, if any exists. Rules are only effective in the region of the membrane they belong to. Objects which are expressed by characters or string of symbols can evolve to new objects or be transferred to new regions according to the rules in the membrane whose region objects appear in.

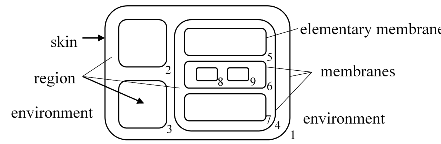

Fig. 1. The membrane structure of cell-like P system[38]

Formally, a cell-like P system (of degree $m \geq 1$) with priority and promoters is of the form

$$\Pi = (O, \mu, M_1, M_2, \cdots, M_m, i_{out}) \quad (1)$$

where,

1)O is the alphabet of objects used in Π;

2)μ is the membrane structure of Π, and degree is m;

3)M_i = (ω_i, R_i, ρ_i) defines the membrane with label i in Π (i=1,2,$\cdots$,m), where ω_i is the multiset including the initial objects in membrane i, object λ (an empty string) means there is no object in membrane i, R_i is a set of rules in membrane i, promoters present in rules, ρ_i specifies a priority relation among the rules in R_i, smaller value means higher executing priority;

4)i_{out} is appointed as output region which saves the results.

The form of rules in Π is: ($u \rightarrow v$) or ($u \rightarrow v|_\alpha$, ρ) or ($u \rightarrow (w)_i$), where, $u \in O^+$, $v \in (O \times Tar)^*$, α is promoter. O^* is the finite and non-empty multiset over O, $O^+ = O^* - \{\lambda\}$, $Tar = \{here, out, in_i | 1 \leq i \leq m\}$. Objects appear in u will be consumed. If v appears in form of $(a, here)$, a will remain in the membrane where the corresponding rule is applied. If v appears in form of (a, out), a will become an object of the region immediately outside the membrane where the corresponding rule is applied. If v appears in form of (a, in_i), a will be produced in membrane i. Object δ appeared in v means dissolving the membrane where δ presents in and releasing all objects in this membrane to the region immediately outside this membrane. The second form means executing $u \rightarrow v$ with the priority of ρ when α exists in the membrane where the corresponding rule is applied. Priority and promoters can both appear in this form or only one. The third form means creating a membrane labeled i and adding w to the multiset in membrane i.

Rules are executed according to the principles of non-determinism and maximal parallelism in each membrane. Only several rules are chosen non-deterministically when more rules can possibly be applied. All rules that can be applied must be applied concurrently. These two principles are limited by reactant in a membrane. As only dealing with cell-like P systems, the rest of this paper refers to the cell-like P system as the P system for brevity.

III. THE DESIGN OF P SYSTEM Π_{kmbc}

This paper aims to obtain a P system Π_{kmbc} for clustering based on k-medoids method. The algorithm for Π_{kmbc} is discussed before the definition of Π_{kmbc} is designed.

A. The algorithm for Π_{kmbc}

The algorithm for Π_{kmbc} is modified from PAM and Voronoi iteration method which are mentioned in subsection A in section II.

Suppose $T = \{p_1, p_2, , p_n\}$ denotes a dataset with n data points which can be multi-dimensional vectors. This paper supposes them two-dimensional, and names the input data set $T_{kmbc} = \{p_i = (x_i^{a_i}, y_i^{b_i}) | 1 \le i \le n, a, b \in N^+\}$ where a_i and b_i represents the number of x_i and y_i respectively. All data points are divided into k (k≤ n) clusters $C = \{C_1, C_2, , C_k\}$. Each data point belongs to and only belongs to one cluster. Default medoids are first k data points of T_{kmbc}.

According to subsection A in section II, distances between un-medoid data points and medoids need to be calculated repeatedly. In order to reduce calculation amount and realize in P systems, the algorithm for Π_{kmbc} introduces definitions of the distance matrix, and the point-medoids distances set, the point-point distances set, the sum of the point-point distances set. In addition, this paper considers squared Euclidean distance.

Suppose D_{nn} the distance matrix:

$$D_{nn} = \begin{pmatrix} 0 & d_{1,2} & \cdots & d_{1,n} \\ 0 & 0 & \cdots & d_{2,n} \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & d_{n-1,n-1} \\ 0 & 0 & \cdots & 0 \end{pmatrix} \quad (2)$$

where $d_{i,j}$ is the distance between p_i and p_j.

Suppose D_i the point-medoids distances set which contains k distances associated with p_i and k medoids, and it meets:

$$D_i = \{d_{j,i}, j \le i \wedge j \in S_m\} \cup \{d_{i,j}, i \le j \wedge j \in S_m\} \subset D \quad (3)$$

where S_m is a set of k numbers which correspond to k subscripts of k medoids, D is a set whose objects equal to all the nonzero objects of D_{nn}.

Suppose $D_i^{'}$ the point-point distances set which contains distances associated with p_i and all the other data points belonged to the same cluster with p_i, and it meets:

$$D_i^{'} = \{d_{j,i}, j \le i \wedge j \in S_{cm}\} \cup \{d_{i,j}, i \le j \wedge j \in S_{cm}\} \quad (4)$$

where, S_{cm} is a set of numbers which correspond to subscripts of all the data points in cluster $C_m (C_m \subset C, m \in [1, k])$. Suppose $d_i^{'}$ the sum of $D_i^{'}$.

It uses unique data point mark ε_i to replace p_i for convenient. Therefore, unique data point marks are assigned to clusters instead of data points benefited from introducing all the definitions above.

Suppose z the number of iterations, and it is assigned artificially.

Based on PAM and voronoi iteration method, all the definition introduced, the algorithm for Π_{kmbc} is mainly composed of initialization, initial assignment and iterative assignments. The algorithm flow for Π_{kmbc} is shown in Fig.2. The detailed flow of the algorithm is described as follow.

The algorithm for Π_{kmbc} computes D_{nn} and select first k of the n data points as the medoids at first. It compute D_i for each p_i in T_{kmbc} and associates each data point mark to the closest medoid according to the minimal item in D_i next. For un-medoid data point p_i, this algorithm elects the minimal item $d_{i,j}$ or $d_{j,i}$ in D_i, then assigns ε_i to the cluster whose medoid is p_j. Then iterative steps go. The first step of iterative steps is to compute $D_i^{'}$ and $d_i^{'}$ for each data point and to designate the new medoid according to the minimal $d_i^{'}$ in each cluster. That is to elect theS p_i which corresponds to the minimal $d_i^{'}$ as the new medoid in each cluster. The second step of iterative steps is to reassign each data point mark to the cluster defined by the closest medoid determined in the previous step. Moreover, the implement of assignments in iterative step are similar to that of the initial assignment. Due to the mechanism of parallel and distributed computing, all data points are processed in parallel in this algorithm.

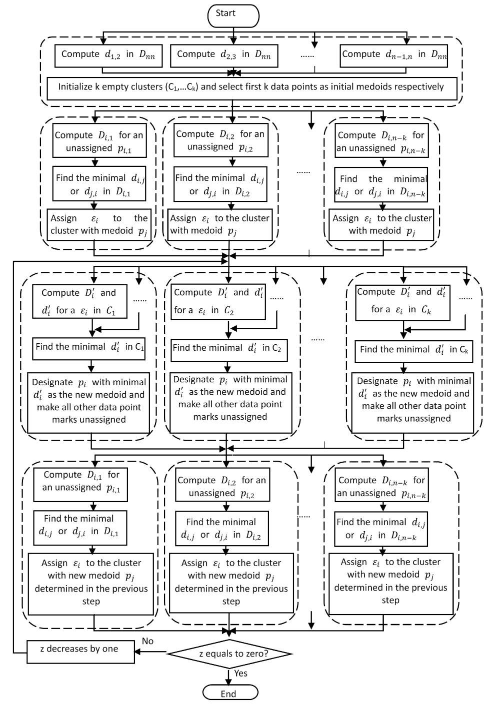

Fig. 2. The algorithm flow for Π_{kmbc}

B. The definition of Π_{kmbc}

Based on the algorithm for Π_{kmbc} which discussed in subsection A in section III, the definition of P system Π_{kmbc} is figured out and as follow:

$$\Pi_{kmbc} = (O, \mu, M_A, M_{B_i}, M_C, M_{D_{i,j}}, M_{E_i}, M_{F_j}, i_{out}) \quad (5)$$

where,

1)$O = \{x_i, y_i, x_{i,j}, a_{i,j}, d_i, d_{i,j}, h_i, g_i, t_i, t_{i,j}, \varepsilon_i, \varepsilon_{i,j}, \alpha_i, \beta_i, \gamma_i, \xi_i | 1 \le i, j \le n\} \cup \{s, a_0, a_1, b_1, c, c_1, c_2, d, d_1, d_2, e, z, \alpha, \alpha\prime, \alpha\prime\prime, \beta, \gamma, \delta, \eta, \theta, \lambda, \mu, \xi, \pi, \rho, \sigma, \omega\}$. This multiset includes objects which are related to data points, which control the application of the rules, and which are special in P system (such as δ, λ, s and ω). The most important objects are d_i, $d_{i,j}$, ε_i, $\varepsilon_{i,j}$ and $t_{i,j}$. Objects d_i denote the sum of distances between data point p_i to all other data points in the same cluster. Objects $d_{i,j}$ denote the distance between data point p_i

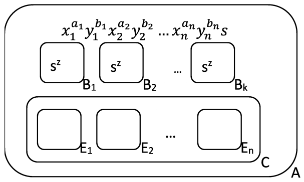

Fig. 3. The initial membrane structure of Π_{kmbc}

to the medoid whose subscript is j. Object ε_i which is unique in Π_{kmbc} denotes data point p_i or medoid p_i (and then it is called data point mark or medoid mark). Object $\varepsilon_{i,j}$ is designed to record the information that cluster i disignates the data point whose subscript is j as the medoid. Object $t_{i,j}$ is designed as transmission mark to record the information that data point p_i belongs to the same cluster with the medoid whose subscript is j. Other objects are designed to ensure the integrity of data information or as flow controller.

2)$\mu = [_A[_{B_1}]_{B_1}[_{B_2}]_{B_2}[_{B_k}]_{B_k}[_C[_{E_1}]_{E_1}[_{E_2}]_{E_2}[_{E_n}]_{E_n}\ ]_C]_A$ is the initial membrane structure of Π_{kmbc} as shown as what Fig.3 illustrates, and it will change with the evolution of Π_{kmbc}. As suggested by Fig.3, membrane A is the skin which contains all other membranes. The class membranes of B_i are designed as clusters in which data point marks distributed to them are placed and new medoids are computed. They also are storage areas of terminal results. Membrane C is designed to deposit the distance matrix. The class membranes of E_i are designed to compute the point-medoids distances set and decide where unassigned data points will belong. One membrane of E_i corresponds with one unassigned data point, and they have the same subscript. With the evolution of Π_{kmbc}, the class membranes of $D_{i,j}$ and F_j are dynamically generated in membrane A and the class membranes of B_i respectively. The class membranes of $D_{i,j}$ compute the distance matrix and are dissolved after computation. One membrane $D_{i,j}$ corresponds with one nonzero element in the distance matrix, and they have the same subscript. The class membranes of F_j compute the point-point distances set and the sum of the point-point distances set and are also dissolved after computation. The delivery of objects between other membranes is achieved in Membrane A. At the same time, information transferring or calculation flow comes true.

3)$M_{mem} = (w_{mem}, R_{mem}, \rho_{mem})$ represents a membrane of Π_{kmbc} in which $mem \in \{A, C\} \cup \{D_{i,j}, E_i, F_j | 1 \le i \le n, 1 \le j \le n\} \cup \{B_i, | 1 \le i \le k\}$, $w_A = T_{kmbc} \cup \{s\}$, $w_{B_i} = \{e^z\}$, $w_C = w_{D_{i,j}} = w_{E_i} = w_{F_j} = \lambda$, R_{mem} and ρ_{mem} are described in hand as R_{mem} for convenience, and more details about R_{mem} are in subsection C in section III.

4)$i_{out} = \{B_1, B_2, \dots, B_k\}$.

In addition, child membrane that dynamically generated in father membrane inherits all rules in father membrane. This paper eliminates the influence of inherited rules on child membrane when designing all the rules in Π_{kmbc}. As a result, rule sets of dynamically generated membranes only contain un-inherited rules for concision. The rules in Π_{kmbc} are elaborated in next subsection and calculation processes too.

C. The rules in Π_{kmbc}

For the sake of being understand, the rule sets R_{mem} in Π_{kmbc} are explained in order of operation flow. Of these, ρ_{mem} whose value is 1 or 2 or 3 specifies a priority relation among a rule set of R_{mem}, and smaller value means higher executing priority.

1)Initialization

a)Preparation

In P system Π_{kmbc}, the rules in R_A associated with the preparation are:

$r_1 : s \rightarrow \alpha_1 \alpha_2 \dots \alpha_{n-1} \theta, 1;$

$r_2 : x_i \rightarrow (x_i, here)(h_i)_{D_{i,i+1}} \dots (h_i)_{D_{i,n}} |_{\alpha_i}, 1, 1 \le i \le n-1;$

$r_3 : \alpha_i \rightarrow \beta_i, 1, 1 \le i \le n;$

$r_4 : y_i \rightarrow (y_i, here)(g_i, in_{Di,i+1}) \dots (g_i, in_{Di,i+n}) |_{\beta_i}, 1, 1 \le i \le n-1;$

$r_5 : \beta_i \rightarrow \gamma_{i+1}, 1, 1 \le i \le n-1;$

$r_6 : x_i \rightarrow (x_i, here)(h_i, in_{D1,i}) \dots (h_i, in_{Di-1,i}) |_{\gamma_i}, 1, 2 \le i \le n;$

$r_7 : y_i \rightarrow (y_i, here)(g_i, in_{D1,i}) \dots (g_i, in_{Di-1,i}) |_{\gamma_i}, 1, 2 \le i \le n;$

$r_8 : \gamma_i \rightarrow (\varepsilon_{i-1}, here)(\alpha, in_{D1,2}) \dots (\alpha, in_{Dn-1,n}) |_{\gamma_i}, 1, 2 \le i \le k+1;$

$r_9 : \gamma_i \rightarrow \lambda, 1, k+2 \le i \le n;$

Rule of type r_1 is used to start the system, rules of types r_2-r_9 is used to create the class membranes of $D_{i,j}$ which are to compute D_{nn} for preparing initialization and to move objects which are data objects and flow controllers to these membranes. After rules of type r_2 and r_4 are applied, each membrane of type $D_{i,j}$ is created finished and contains objects who has the same subscript with the first subscript of itself. After rules of type r_6 and r_7 are applied, each membrane of type $D_{i,j}$ contains objects who has the same subscript with the second subscript of itself. Rule of type r_8 moves specific flow controllers to membrane $D_{i,j}$. Other rules assist in process control.

b)Compute and deposit D_{nn}

Rule set $R_{D_{i,j}}$ is associated with computation of D_{nn}, and each subscript i and j in $R_{D_{i,j}}$ equals to the first and second subscript of membrane $D_{i,j}$ respectively:

$r_1 : h_i \rightarrow a_0, 1;$	$r_2 : a_0 \rightarrow a_1, 1;$
$r_3 : g_i \rightarrow b_1, 1;$	$r_4 : a_1 h_i \rightarrow \lambda, 1;$
$r_5 : a_1 \rightarrow c, 2;$	$r_6 : h_j \rightarrow c, 2;$
$r_7 : b_1 g_j \rightarrow \lambda, 1;$	$r_8 : b_1 \rightarrow d, 2;$
$r_9 : g_j \rightarrow d, 2;$	$r_{10} : \alpha^k \rightarrow \alpha, 1;$
$r_{11} : \alpha \rightarrow \alpha^{'} \alpha^{''}, 2;$	$r_{12} : c \rightarrow c_1 c_2, 1;$
$r_{13} : d \rightarrow d_1 d_2, 1;$	$r_{14} : c_1 \rightarrow c_1 d_{i,j} |_{c_2}, 1;$
$r_{15} : c_2 \alpha^{'} \rightarrow \alpha^{'}, 1;$	$r_{16} : d_1 \rightarrow d_1 d_{i,j} |_{d_2}, 1;$
$r_{17} : d_2 \alpha^{''} \rightarrow \alpha^{''}, 1;$	$r_{18} : \alpha^{'} \alpha^{''} \rightarrow \beta, 2;$
$r_{19} : c_1 \rightarrow \lambda |_{\beta}, 1;$	$r_{20} : d_1 \rightarrow \lambda |_{\beta}, 1;$
$r_{21} : \beta \rightarrow (\delta, here)(\eta, out), 1;$	

With the specific flow controller, rules in membrane $D_{i,j}$ start being executed. Rules of type r_4-r_9 are used to turn the differences of the first and second dimensions of the two data points to objects type of c and d. After rules of type r_{12}-r_{17} are applied for limited times, each membrane of type $D_{i,j}$ contains objects $d_{i,j}$ with the quantities of squared c and squared d.

Rule of type r_{21} means dissolving the membrane and send a specific flow controller which reflects the end of computation out.

The rule in R_A associated with depositing D_{nn} moves objects of type $d_{i,j}$ to membrane C:
$r_{10} : d_{i,j} \to (d_{i,j}, in_C)|_\eta, 1, 1 \leq i \leq n-1, 2 \leq j \leq n, i \leq j;$

c)Initialize k medoids

The rules in R_A associated with the initialization of k medoids are:
$r_{11} : \varepsilon_i \to (\varepsilon_i, in_{B_i})(\varepsilon_i, in_C)|_\eta, 1, 1 \leq i \leq k;$
$r_{12} : \theta \to (\alpha, in_C)|_\eta, 1;$
$r_{13} : \eta \to \lambda, 1;$

After rule of type r_{11} is applied, each membrane B_i contains a data point mark who has the same subscript with the membrane. Other rules assist in process control.

2)Initial assignment

Rules of type r_{10}-r_{12} in R_A are used to move objects associated with computing D_i and the minimal item in D_i to membrane C . After that, rules of type r_1-r_6 in R_C are used to copy these objects into appointed membranes of type E_i:
$r_1 : d_{i,j} \to a_{i,j}|_{\varepsilon_i\varepsilon_j}, 1, 1 \leq i \leq n, 1 \leq j \leq n;$
$r_2 : d_{i,j} \to (d_{i,j}, here)(d_{i,j}, in_{E_j})|_{\varepsilon_i}, 2, 1 \leq i \leq n, 1 \leq j \leq n;$
$r_3 : d_{i,j} \to (d_{i,j}, here)(d_{i,j}, in_{E_i})|_{\varepsilon_j}, 2, 1 \leq i \leq n, 1 \leq j \leq n;$
$r_4 : \varepsilon_i \to (\varepsilon_i, in_{all}), 1, 1 \leq i \leq n;$
$r_5 : \alpha \to (\beta, here)(\alpha, in_{all}), 1;$
$r_6 : a_{i,j} \to d_{i,j}|_\beta, 1, 1 \leq i \leq n, 1 \leq j \leq n;$

Thus, each membrane of type E_i contains k medoid marks and k objects of type $d_{i,j}$ or $d_{j,i}$ which are all the items of D_i. Rule set R_{E_i} is associated with the computation of the minimal item in D_i, and each subscript i in R_{E_i} equals to the subscript of membrane E_i:
$r_1 : d_{i,j} \to d_j, 1, 1 \leq j \leq n;$ $r_2 : d_{j,i} \to d_j, 1, 1 \leq j \leq n;$
$r_3 : \alpha \to \beta, 1;$ $r_4 : \varepsilon_j d_j \to \eta\varepsilon_j, 1;$
$r_5 : \varepsilon_j\beta \to \gamma t_{i,j}|_\eta, 2, 1 \leq j \leq n;$ $r_6 : \beta \to \gamma, 3;$
$r_7 : \varepsilon_j \to \lambda|_\gamma, 1;$ $r_8 : d_j \to \lambda|_\gamma, 1;$
$r_9 : t_{i,j} \to (t_{i,j}, out)|_\gamma, 1;$ $r_{10} : \eta \to \lambda|_\gamma, 1;$
$r_{11} : \gamma \to \lambda, 1;$

When p_i is a un-medoid data point, rules of type r_4 and r_5 in R_{E_i} are used to consume d_j for all j existed in the membrane until there is no d_j left for a certain j, then turn the ε_j corresponding to the certain j to $t_{i,j}$. As consequence, transmission mark $t_{i,j}$ means that un-medoiod data point p_i belongs to the cluster with the medoid p_j, and rule of type r_9 is used to move $t_{i,j}$ out. Furthermore, rules of type r_7-r_{11} in R_{E_i}) are used to empty the objects in the membrane for the convenience of the next computation.

When p_i is a medoid, there is no need to compute, but some objects are contained in membrane E_i after the execution of rules of type r_2-r_5 in R_C. For the convenience of the next computation, rules of type r_3, r_6, r_7 and r_{11} in R_{E_i} are executed.

As transmission marks are contained in membrane C, rules of type r_7-r_{10} in R_C are used to move them out:
$r_7 : \beta t_{i,j} \to \gamma t_{i,j}, 1, 1 \leq i \leq n, 1 \leq j \leq n;$
$r_8 : d_{i,j} \to (d_{i,j}, here)(d_{i,j}, out)|_\gamma, 1, 1 \leq i \leq n, 1 \leq j \leq n;$
$r_9 : t_{i,j} \to (t_{i,j}, out)|_\gamma, 1;$
$r_{10} : \gamma \to (\mu, out), 1;$

Rule of type r_{14} in R_A is used to send a flow controller of type α to each membrane B_i:
$r_{14} : \mu \to (\alpha, in_{B_1}) \dots (\alpha, in_{B_k}), 1;$

With the flow controllers, k marks of type $\varepsilon_{i,j}$ which reflect that the ith cluster has a medoid with subscript j right now are copied into membrane A due to the execution of rule of type r_1 in R_{B_i}:
$r_1 : \alpha\varepsilon_j \to (\xi\varepsilon_{i,j}, out)(\varepsilon_j, here)|_\alpha, 1, 1 \leq j \leq n;$

Finally, there are objects of type $t_{i,j}$ and $\varepsilon_{i,j}$ in membrane A. That is to say, all the objects for initial assignment are completely prepared. Rules of type r_{15}- r_{18} in R_A are associated with initial assignment and preparation for the following step:
$r_{15} : d_{i,j} \to (d_{i,j}, in_{B_1}) \dots (d_{i,j}, in_{B_k}), 1, 1 \leq i, j \leq n;$
$r_{16} : t_{i,j} \to (\varepsilon_i, in_{B_m})|_{\varepsilon_{mj}}, 1, 1 \leq i, j \leq n, 1 \leq m \leq k;$
$r_{17} : \xi^{k-1} \to \lambda, 1;$
$r_{18} : \xi \to (\beta, in_{B_1}) \dots (\beta, in_{B_k}), 2;$
$r_{19} : \varepsilon_{i,j} \to \lambda, 1, 1 \leq i \leq n, 1 \leq j \leq n;$

Rule of type r_{16} is used to send data point marks to the certain membranes of type B_i under the premise of $t_{i,j}$ and $\varepsilon_{i,j}$. As a result, initial assignment is achieced. Meanwhile, D_{nn} and flow controller β are send to each membrane B_i due to rules of type r_{16} and r_{18}.

3)Iterative assignment

a)Update medoids

As membranes of type F_j are dynamically generated in each membrane B_i, the rules in R_{B_i} associated with it are:
$r_2 : \varepsilon_j \to (\varepsilon_j, here)(t_j)_{F_j}|_\beta, 1, 1 \leq j \leq n;$
$r_3 : \beta \to \lambda, 1;$
$r_4 : d_{p,q} \to (x_{p,q}, in_{all})|_\gamma, 1, 1 \leq p \leq n, 1 \leq q \leq n;$
$r_5 : \gamma \to (\sigma, in_{all})(\eta, here), 1;$
$r_6 : \eta \to \theta, 1;$

With the flow controller β, rule of type r_2 is used to generate membranes F_j each of which corresponds to a data point in the cluster. Rule of type r_4 is used to move D_{nn} and a flow controller σ to all the membranes F_j. Therefore, each membrane F_j contains all the objects associated with computing $D_i^{'}$ and $d_i^{'}$.

Each subscript j in R_{F_j} equals to the subscript of membrane F_j, and all rules in R_{F_j} are as follow:
$r_1 : x_{i,j} \to d_j|_{t_j}, 1, 1 \leq i \leq n;$
$r_2 : x_{j,i} \to d_j|_{t_j}, 1, 1 \leq i \leq n;$
$r_3 : x_{p,q} \to \lambda, 2, 1 \leq p \leq n, 1 \leq q \leq n;$
$r_4 : t_j \to \lambda|_\sigma, 1;$
$r_5 : \sigma \to \delta, 1;$

In each membrane F_j, rules of type r_1-r_2 turn objects of type x_{ij} to d_j where the first or second subscript of x_{ij} and the subscript of d_j equals to that of F_j. Thus, the quantities of d_j equals to $d_i^{'}$ which is the sum of $D_i^{'}$. Rule of type r_5 is used to dissolve the membrane and release objects of type d_j.

Rules of type r_7-r_8 in R_{B_i} are executed repeatedly to figure the object ξ_j which points to the minimal d_j:
$r_7 : \varepsilon_j d_j \to \varepsilon_j, 1, 1 \leq j \leq n;$ $r_8 : \varepsilon_j\theta \to \mu\xi_j, 2, 1 \leq j \leq n;$

That is to say, p_i whose subscript equals to that of ξ_j will be the new medoid. The rest rules in R_{B_i} are:
$r_9 : d_j \to \lambda|_{\mu}, 1, 1 \leq j \leq n;$
$r_{10} : \xi_j \to \varepsilon_j|_{\mu}, 1, 1 \leq j \leq n;$
$r_{11} : \varepsilon_j \to \lambda|_{\mu e}, 1, 1 \leq j \leq n;$
$r_{12} : e\mu \to \pi, 1;$
$r_{13} : \mu \to \pi, 2;$
$r_{14} : \pi\varepsilon_j \to (\varepsilon_j, here)(\pi\varepsilon_j e, out), 1, 1 \leq j \leq n;$

When the number of iterations left does not equal to zero, rules of type r_9-r_{13} are executed. Rules of type r_{10}-r_{11} are used to designate the new medoid and eliminate other data points in the cluster. Rule of type r_{12} is used to reduce the number of iterations by one.

When the number of iterations left equals to zero, rules of r_9-r_{10} and r_{13} are executed. Rule of type r_{10} is used to designate the new medoid. Each membrane B_i contains data point marks when system stops because rule of type r_{11} is not executed and there is no iterations left.

No matter if the number of iterations left equals to zero or not, rule of type r_{14} is executed to copy the new medoid out and send object e which means one iteration.

b)Reassignment

The rest rules in R_A are:
$r_{20} : \varepsilon_i \to (\varepsilon_i, in_C)|_{\pi}, 1, 1 \leq i \leq n;$ $r_{21} : \pi^k \to \pi, 1;$
$r_{22} : \pi \to (\alpha, in_C), 2;$ $r_{23} : e^k \to e, 1;$
$r_{24} : e^z \to \omega, 2;$ $r_{25} : \omega \to (\omega, out), 1;$

When the number of iterations left does not equal to zero, rules of type r_{20}-r_{23} are executed. Rules of type r_{20} and r_{22} are used to move new medoid marks and the flow controller to membrane C. Then, reassignment gets start with flow controllers playing their roles and the specific flow of reassignment is identical with that of initial assignment.

When the number of iterations left equals to zero, rule of type r_{24} reaches the conditions of usage, and rules of type r_{20}-r_{25} are executed. Rule of type r_{24} is used to create ω which has the meaning of end of the system. Rule of type r_{25} is used to send ω out membrane A to end the system, and the execution of rules of type r_{20}-r_{22} does not impact the clustering results.

D. Complexity Analysis

In this subsection, the time cost in the worst case of Π_{kmbc} is analyzed according to the algorithm flow and the operation flow of rules. It is assumed that executing a rule costs a slice.

In initialization, preparation will be done in four slices. Computing and Depositing D_{nn} starts at the third slice of the previous part and will be done in $7 + Max\_data$ slices. Initialization of k medoids will be done at the last slice of the previous part. It needs $11 + Max\_distance\_sum$ slices to achieve initial assignment. In iterative assignment, updating medoids starts at the last slice of the previous part and will be done in $5 + Max\_distance\_sum$ slices. Reassignment will be done in $11 + Max\_distance\_sum$ slices. The end of Π_{kmbc} will cost one slice. In summary, while the number of iterations is z, the cost of Π_{kmbc} is $20 + 16z + Max\_data + (2z + 1) * Max\_distance\_sum$ slices at most. Obviously, Π_{kmbc} reduces the time complexity of k-medoids algorithm. In above, Max_data is the maximum of all the dimensions of all the data points, and $Max\_distance\_sum$ is the maximum of $d_i^{'}$ mentioned in subsection A in section III.

IV. CALCULATE INSTANCE

In this section, an instance is given to show how to achieve k-medoids-based clustering in P system Π_{kmbc}. Let the number of iterations equals to 4, a data set containing 15 data points is clustered to 3 clusters in this instance. The data set to be processed is as follow: $T_{ins} = \{(1,2),(2,8),(2,7),(2,4),(2,2),(3,7),(3,2),(4,3),(5,6),(6,8),(6,7),(6,5),(7,9),(7,8),(7,7)\}$. And the data points in T_{ins} in turn correspond to data point marks form ε_1 to ε_{15}.

The initialization gets starts as rules mentioned in subsection 1) in subsection C in section III are applied. The configuration of Π_{kmbc} after initialization is shown in Fig.4 and initial three medoid marks are ε_1, ε_2 and ε_3. Then, rules mentioned in subsection 2) in subsection C in section III are applied to achieve initial assignment. At this time, the configuration of Π_{kmbc} becomes as shown in Fig.5, and the temporary clustering results are $\{\varepsilon_1, \varepsilon_4, \varepsilon_5, \varepsilon_7, \varepsilon_8\}$, $\{\varepsilon_2, \varepsilon_{10}, \varepsilon_{13}, \varepsilon_{14}\}$, $\{\varepsilon_3, \varepsilon_6, \varepsilon_9, \varepsilon_{11}, \varepsilon_{12}, \varepsilon_{15}\}$. In the following, there are 4 iterations each one of which includes almost all of the rules mentioned in subsection 3) in subsection C in section III. After the first, second, third and fourth iteration, the configurations of Π_{kmbc} are as shown in Fig.6 to Fig.9. For convenience, define two strings in Fig.4-Fig.9:

$$S_T = \{x_1^1 y_1^2 x_2^2 y_2^8 x_3^2 y_3^7 x_4^2 y_4^4 x_5^2 y_5^2 x_6^3 y_6^7 x_7^3 y_7^2 x_8^4 y_8^3 x_9^5 y_9^6 x_{10}^6 y_{10}^8 x_{11}^6 y_{11}^7 x_{12}^6 y_{12}^5 x_{13}^7 y_{13}^9 x_{14}^7 y_{14}^8 x_{15}^7 y_{15}^7\},$$

$$S_D = \{d_{1,2}^{37} d_{1,3}^{26} d_{1,4}^{5} d_{1,5}^{1} d_{1,6}^{29} d_{1,7}^{4} d_{1,8}^{10} d_{1,9}^{32} d_{1,10}^{61} d_{1,11}^{50} d_{1,12}^{34} d_{1,13}^{85} d_{1,14}^{72} d_{1,15}^{61} d_{2,3}^{1} d_{2,4}^{16} d_{2,5}^{36} d_{2,6}^{2} d_{1,7}^{37} d_{2,8}^{29} d_{2,9}^{13} d_{2,10}^{16} d_{2,11}^{17} d_{2,12}^{25} d_{2,13}^{26} d_{2,14}^{25} d_{2,15}^{26} d_{3,4}^{9} d_{3,5}^{25} d_{3,6}^{1} d_{3,7}^{26} d_{3,8}^{20} d_{3,9}^{10} d_{3,10}^{17} d_{3,11}^{16} d_{3,12}^{20} d_{3,13}^{29} d_{3,14}^{26} d_{3,15}^{25} d_{4,5}^{4} d_{4,6}^{10} d_{4,7}^{5} d_{4,8}^{5} d_{4,9}^{13} d_{4,10}^{32} d_{4,11}^{25} d_{4,12}^{17} d_{4,13}^{50} d_{4,14}^{41} d_{4,15}^{34} d_{5,6}^{26} d_{5,7}^{1} d_{5,8}^{5} d_{5,9}^{25} d_{5,10}^{52} d_{5,11}^{41} d_{5,12}^{25} d_{5,13}^{74} d_{5,14}^{61} d_{5,15}^{50} d_{6,7}^{25} d_{6,8}^{17} d_{6,9}^{5} d_{6,10}^{10} d_{6,11}^{9} d_{6,12}^{13} d_{6,13}^{20} d_{6,14}^{17} d_{6,15}^{16} d_{7,8}^{2} d_{7,9}^{20} d_{7,10}^{45} d_{7,11}^{34} d_{7,12}^{18} d_{7,13}^{65} d_{7,14}^{52} d_{7,15}^{41} d_{8,9}^{10} d_{8,10}^{29} d_{8,11}^{20} d_{8,12}^{8} d_{8,13}^{45} d_{8,14}^{34} d_{8,15}^{25} d_{9,10}^{5} d_{9,11}^{2} d_{9,12}^{2} d_{9,13}^{13} d_{9,14}^{8} d_{9,15}^{5} d_{10,11}^{1} d_{10,12}^{9} d_{10,13}^{2} d_{10,14}^{1} d_{10,15}^{2} d_{11,12}^{4} d_{11,13}^{5} d_{11,14}^{2} d_{11,15}^{1} d_{12,13}^{17} d_{12,14}^{10} d_{12,15}^{5} d_{13,14}^{1} d_{13,15}^{4} d_{14,15}^{1}\}.$$

As suggested by Fig.6, the temporary clustering results are $\{\varepsilon_1, \varepsilon_4, \varepsilon_5, \varepsilon_7, \varepsilon_8\}$, $\{\varepsilon_{10}, \varepsilon_{11}, \varepsilon_{13}, \varepsilon_{14}, \varepsilon_{15}\}$ and $\{\varepsilon_2, \varepsilon_3, \varepsilon_6, \varepsilon_9, \varepsilon_{12}\}$ after the first iteration. As suggested by Fig.7, the temporary clustering results are $\{\varepsilon_1, \varepsilon_4, \varepsilon_5, \varepsilon_7, \varepsilon_8\}$, $\{\varepsilon_{10}, \varepsilon_{11}, \varepsilon_{12}, \varepsilon_{13}, \varepsilon_{14}, \varepsilon_{15}\}$ and $\{\varepsilon_2, \varepsilon_3, \varepsilon_6, \varepsilon_9\}$ after the second iteration. As suggested by Fig.8, the temporary clustering results are $\{\varepsilon_1, \varepsilon_4, \varepsilon_5, \varepsilon_7, \varepsilon_8\}$, $\{\varepsilon_9, \varepsilon_{10}, \varepsilon_{11}, \varepsilon_{12}, \varepsilon_{13}, \varepsilon_{14}, \varepsilon_{15}\}$ and $\{\varepsilon_2, \varepsilon_3, \varepsilon_6\}$ after the third iteration. As suggested by Fig.9, the temporary clustering results are $\{\varepsilon_1, \varepsilon_4, \varepsilon_5, \varepsilon_7, \varepsilon_8\}$, $\{\varepsilon_9, \varepsilon_{10}, \varepsilon_{11}, \varepsilon_{12}, \varepsilon_{13}, \varepsilon_{14}, \varepsilon_{15}\}$ and $\{\varepsilon_2, \varepsilon_3, \varepsilon_6\}$ after the fourth iteration. Finally, data set T_{ins} is clustered into $\{(1,2),(2,4),(2,2),(3,2),(4,3)\}$, $\{(5,6),(6,8),(6,7),(6,5),(7,9),(7,8),(7,7)\}$ and $\{(2,8),(2,7),(3,7)\}$ as suggested by the scatter plot in Fig.10.

V. CONCLUSION

This paper proposes a P system Π_{kmbc} based on k-medoids to achieve clustering in a shorter time. The algorithm for Π_{kmbc} is modified to fit this cell-like P system with promoters and inhibitors. In this P system, a hierarchically arranged

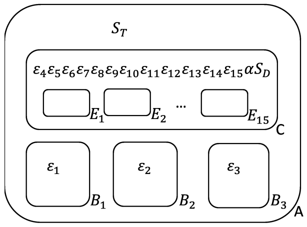

Fig. 4. The configuration of Π_{kmbc} after initialization

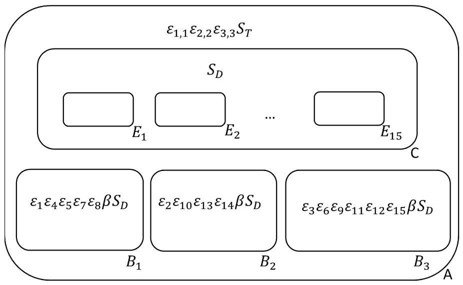

Fig. 5. The configuration of Π_{kmbc} after initial assignment

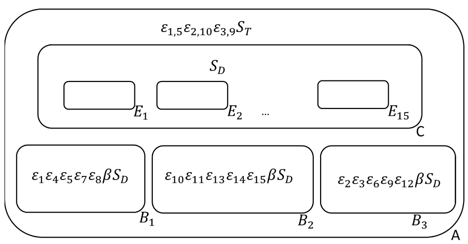

Fig. 6. The configuration of Π_{kmbc} after the first iteration

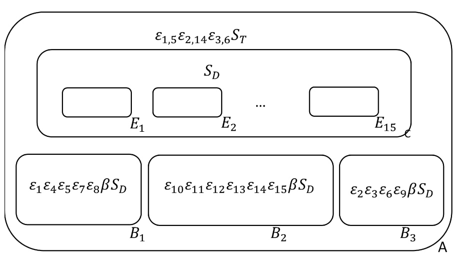

Fig. 7. The configuration of Π_{kmbc} after the second iteration

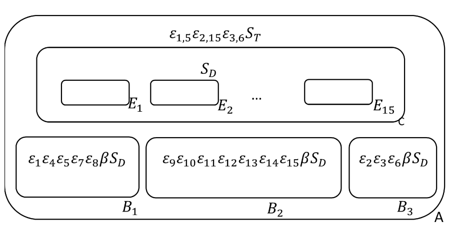

Fig. 8. The configuration of Π_{kmbc} after the third iteration

structure and numerous rules are designed to bring the parallel and distributed computing mechanism into play. An instance is given to illustrate the practicability and effectiveness of the

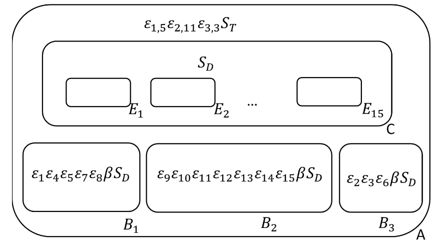

Fig. 9. The configuration of Π_{kmbc} after the fourth iteration

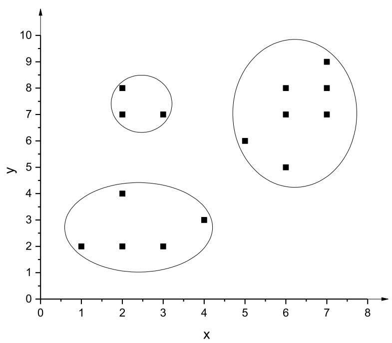

Fig. 10. Clustering results in Π_{kmbc}

P system designed. However, space complexity of Π_{kmbc} is a bit high for purpose of lower time complexity. Our future work includes simplifying the membrane structure and rules to decrease the space complexity and optimizing the algorithm for clustering to enhance learning efficiency.

REFERENCES

[1] Gheorghe, and Păun. *Computing with Membranes.* Journal of Computer and System Sciences. 61.1(2000):108-143.

[2] Chengdu. *A Survey of Membrane Computing as a New Branch of Natural Computing.* Chinese Journal of Computers. 33.2(2010):208-214.

[3] Singh, Garima, and K. Deep. *A new membrane algorithm using the rules of Particle Swarm Optimization incorporated within the framework of cell-like P-systems to solve Sudoku.* Elsevier Science Publishers B. V. 2016.

[4] Chun, and Xiaolong. *Uniform Solution to QSAT by P Systems with Proteins.* Chinese Journal of Electronics. 21.4(2012):667-672.

[5] Pan Linqiang, and Pérez-Jiménez,Mario J. *"Computational complexity of tissue-like P systems.* Journal of Complexity. 26.3(2010):296-315.

[6] Gao, Tong, X. Liu, and L. Wang. *An Improved PSO-Based Clustering Algorithm Inspired by Tissue-Like P System.* International Conference on Data Mining and Big Data Springer, Cham, 2018:325-335.

[7] Zhang, Xing Yi, et al. *Tissue P systems with cell separation: attacking the partition problem.* Science China(Information Sciences) 54.2(2011):293-304.

[8] Wu, Tingfang, Z. Zhang, and L. Pan. *On Languages Generated by Cell-Like Spiking Neural P Systems.* IEEE Transactions on Nanobioscience 15.5(2016):455-467.

[9] Song, Tao, et al. *Small Universal Spiking Neural P Systems with Anti-Spikes.* Journal of Computational & Theoretical Nanoscience 10.4(2013):999-1006.

[10] Frisco, Pierluigi, M. Gheorghe, and M. J. Prez-Jimnez. *Applications of Membrane Computing in Systems and Synthetic Biology.* Emergence Complexity & Computation 7.09(2014):S624.

[11] D. Sburlan. *Membrane Computing Insights. Permitting and Forbidding Contexts.* Ovi Up, Constanta, Romania, 2012.

[12] Gabriel Ciobanu.*Proceedings 6th Workshop on Membrane Computing and Biologically Inspired Process Calculi.* Computer Science 1-2(2012):3-4.

[13] Ciobanu, Gabriel, G. Păun, and M. J. Prez-Jimnez. *Applications of Membrane Computing.* Theoretical Computer Science 287.1(2005):73–100.

[14] Gazdag, Zsolt, G. Kolonits, and M. A. Gutirrez-Naranjo. *Simulating Turing Machines with Polarizationless P Systems with Active Membranes.* Membrane Computing -, International Conference, Cmc 2014, Prague, Czech Republic, August 20-22, 2014, Revised Selected Papers 2014:229-240.

[15] Alhazov, Artiom, et al. *Space complexity equivalence of P systems with active membranes and Turing machines.* Theoretical Computer Science 529.6(2014):69-81.

[16] The P Systems Website. http://ppage.pssystems.eu, 2013-01.

[17] Xu, Dongkuan, and Y. Tian. *A Comprehensive Survey of Clustering Algorithms.* Annals of Data Science 2.2(2015):165-193.

[18] Jain, Anil K, and R. C. Dubes. *Algorithms for clustering data.* Technometrics 32.2(1988):227-229.

[19] Boley, Daniel, et al. *Partitioning-based clustering for Web document categorization.* Decision Support Systems 27.3(1999):329-341.

[20] Velmurugan, T. , and T. Santhanam. *A Survey of Partition based Clustering Algorithms in Data Mining: An Experimental Approach.* Information Technology Journal 10.3(2011).

[21] Ayed, Abdelkarim Ben, M. B. Halima, and A. M. Alimi. *Survey on clustering methods: Towards fuzzy clustering for big data.* Soft Computing and Pattern Recognitio IEEE, 2015:331-336.

[22] Preheim,P. Sarah, et al. *Distribution-Based Clustering: Using Ecology To Refine the Operational Taxonomic Unit.* Applied & Environmental Microbiology 79.21(2013):6593-6603.

[23] Jiang, Bin, et al. *Clustering Uncertain Data Based on Probability Distribution Similarity.* IEEE Transactions on Knowledge & Data Engineering 25.4(2013):751-763.

[24] Loh, Woong Kee, and Y. H. Park. *A Survey on Density-Based Clustering Algorithms.* Ubiquitous Information Technologies and Applications. 2014:775-780.

[25] Bhuyan, Rupanka, and S. Borah. *A Survey of Some Density Based Clustering Techniques.* National Conference on Advancements in Information, Computer and Communication 2013.

[26] Ilango, M. R. , and D. V. Mohan. *A Survey of Grid Based Clustering Algorithms.* International Journal of Engineering Science & Technology 2.8(2010).

[27] Nemade, P. , et al. *Survey on grid clustering approach with intuitionistic fuzzy histogram.* International Journal of Pharmacy & Technology 8.4(2016):25475-25482.

[28] Wang, Ying Hong, et al. *A Grid-Based Clustering Routing Protocol for Wireless Sensor Networks.* Energy Procedia 11(2013):602-609.

[29] Nascimento, Mari C. V. . *Spectral methods for graph clustering A survey.* European Journal of Operational Research 211.2(2011):221-231.

[30] Gallier, Jean. *Spectral Theory of Unsigned and Signed Graphs. Applications to Graph Clustering: a Survey.* 2016.

[31] Liu, Xiyu, Y. Zhao, and W. Sun. *K-Medoids-Based Consensus Clustering Based on Cell-Like P Systems with Promoters and Inhibitors.* Bio-Inspired Computing - Theories and Applications, Springer Singapore, 2016:95-108.

[32] Peng, Hong, J. Wang, and P. Shi. *An automatic clustering algorithm inspired by membrane computing.* Pattern Recognition Letters 68. P1 (2015):34-40.

[33] Peng, Hong, et al. *Membrane Clustering: A Novel Clustering Algorithm under Membrane Computing.* (2014).

[34] Kaufmann, Leonard, and P. J. Rousseeuw. *Clustering by Means of Medoids.* Statistical Data Analysis based on the L1-norm & Related Methods North-Holland, 1987:405-416.

[35] Nikam, B. Valmik, V. J. Kadam, and B. B. Meshram. *Image Compression Using Partitioning Around Medoids Clustering Algorithm.* International Journal of Computer Science Issues 8.6(2011):399-401.

[36] Hastie, Trevor, et al. *The Elements of Statistical Learning.* Springer New York, 2009.

[37] Park, Hae Sang, and C. H. Jun. *A simple and fast algorithm for K-medoids clustering.* Expert Systems with Applications 36.2(2009):3336-3341.

[38] Ping Guo, et al. *Evaluating Logical Expressions by Membrane Systems.* Chinese Journal of Electronics 23.2(2014):278-283.

Emotional Changes Detection for Dementia People with Spectrograms from Physiological Signals

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***Abstract*—Due to aging society, there has recently been an increasing percentage of people with serious cognitive decline and dementia around the world. Such patients often lose their diversity of facial expressions and even their ability to speak, rendering them unable to express their feelings to their caregivers. However, emotions and feelings are strongly correlated with physiological signals, detectable with EEG and ECG etc. Therefore, this research develops an emotion predicting system for people with dementia using bio-signals to support their interaction with their caregivers. In this paper, we focused on a previous study for binary classification of emotional changes using spectrograms of EEG and RRI by CNN, verifying the effectiveness of the method. Firstly, the participants were required to watch simulating videos while collecting their EEG and ECG data. Then, STFT was performed, processing the raw data signals by extracting the time-frequency domain features to get the spectrograms. Finally, deep learning was used to detect the emotional changes. CNN was used for arousal classification, with an accuracy of 90.00% with EEG spectrograms, 91.67% with RRI spectrograms, and 93.33% with EEG and RRI spectrograms.**

Keywords—Emotion classification; people with dementia; EEG and ECG; spectrograms; CNN

I. Introduction

A. Background

According to report from World Population Prospects 2017, the number of people aged 60 or over, is expected to rise from 962 million globally in 2017 to 2.1 billion in 2050 and 3.1 billion in 2100 [1]. Furthermore, rapidly aging populations worldwide result in an increase of people living with age-related illnesses like dementia, causing considerable concern for future health and social care provision [2]. It's estimated that the proportion of the general population aged 60 and over with dementia is between 5 to 8 percent, meaning that 50 million people were living with dementia in 2017, while the total number of people with dementia is predicted to approach 75 million in 2030 and almost triple by 2050 to 132 million [3]. Unfortunately, no treatment is currently available to cure dementia or to alter its progressive course. Therefore, early diagnosis and the promotion of optimal health management, along with the care provided by family and friends are of the utmost importance in caring for people with dementia.

As the illness gradually develops, cognitive impairment and decreased ability to communicate as dementia becomes more severe [4], resulting in an increasing physical, emotional and financial stress for caregivers. As cognitive decline progresses into its later stages, it can become difficult for patients to express their feelings appropriately, making communication with caregivers increasingly difficult. Therefore, in order to support care for such dementia patients in daily life, the need for emotion predicting systems has been put forward in the field. Generally speaking, that is the need to detect the emotions and feelings of dementia patients to support caregivers by helping them to understand what the patients are experiencing.

B. Related Works

In general, the main method used for detecting the emotional state of a subject is through their emotional expressions [5], like speech, facial expression, gesture, and/or physiological signals. There is already a body of work focusing on emotional expressions: speech signal, facial expressions and gestures [6][7][8]. However, physiological signals also reflect internal emotional information, and have increasingly received more attention recently. They are comprised of the signals originating from the central nervous system (CNS): electroencephalogram (EEG), and the autonomic nervous system (ANS): electrocardiogram (ECG), galvanic skin response (GSR), electromyogram (EMG) etc. Recently presented studies have shown that ANS, which includes the sympathetic nervous system and the parasympathetic nervous system, is viewed as a vital component of emotional response [9].

Among the most common methods for measuring physiological signals for emotion recognition are EEG and ECG, which have been shown by cognitive theory and psychological experiments to indicate possible underlying emotional states [10]. EEG analysis is mainly comprised of four frequency bands: delta waves (δ: 0.5-4Hz), usually appearing during deep sleep; theta waves (θ: 4-8Hz), always present during drowsiness; alpha waves (α: 8-13Hz), associated with relaxation and super-learning; beta waves (β: 13-30Hz), related with active thinking and attention [11]. The partial correlations of cortical functions with EEG channels are shown in Fig. 1 [12]. ECG, on the other hand, records the electrical activity of the heart. Based on feature extraction of ECG signals, heart rate variability (HRV) is determined by heart rate (HR) or RR interval, calculated from R peaks. A low HRV can indicate a relaxed state, whereas a high one represents a potential state of stress or depression. While signal power [13] in low frequency (LF: 0.04-0.15Hz) and high frequency (HF: 0.15-0.4Hz) bands also appear to have a close relationship with emotions.

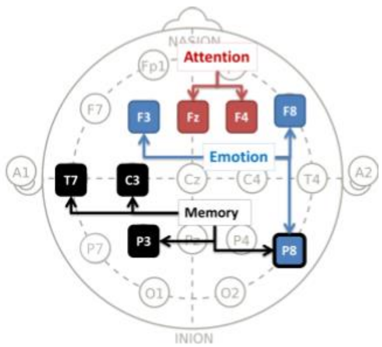

Fig. 1. [12] The Partial Correlations of Cortical Functions with EEG Channels.

While speech and facial appearance might be disguised by a person intentionally or consciously [14], the physiological signs are natural reactions of the body, and as such are very difficult to mask. Since it is difficult to detect the emotions of a dementia patient by speech or facial expression, these signals may be a more reliable way to access that information. This study concentrates on emotion classification based on EEG and ECG, one of which represents the CNS and the other the ANS parameter [15].

C. Convolutional Neural Network

Over these years, there has been a lot of works in the field of affective computing, recognizing emotions from psychological signals by different classification algorithms. The team led by Prof. Picard [16] firstly performed the research on the emotion detection from signals: ECG, GSR and EMG. They extracted the time domain features, like mean value, variance value, first order differential mean value, etc. The Sequential Floating Forward Selection (SFFS) and Fisher Projection (FP) were chosen to select features for classification of 8 kinds. The best accuracy reached 82.5%. Murugappan et al [17], applied KNN and linear discriminate analysis to get an accuracy of 77%-88% using HRV features extracted from ECG. Mohammadi et al [18], utilized the frequency domain features for ECG, and classified by KNN and SVM. Nasehi et al [19] obtained an accuracy of 64.78% from EEG by neural network classifier.

Upon above research and results, it could be concluded that it's feasible to detect emotion state from physiological signals. However, most of them focused on time domain or frequency domain features, few used spectrograms created from time-frequency domain features as image classification using CNN. Also, there were not many studies combing the features together drawn from EEG and ECG data for emotion classification. The paper opted another perspective for feature extraction to get spectrogram images from EEG and ECG. We intended to sort different emotions using CNN conveniently to get good accuracy simultaneously.

Currently, the application of deep learning in the field of image classification is increasingly popular, especially CNNs (convolutional networks), which have been proven extremely effective in computer vision and are perhaps the most widely used approach in the class of machine learning algorithms [20]. Their specific characteristic is that they capture features automatically, which is the integration of feature extraction and classification into a single algorithm only with the "raw" data (like pixels) as inputs [21]. More recently, applying CNNs for bio-signal related problems, such as EEG and ECG, has attracted growing attention from psychologists and researchers [22]. In this paper, we adopt CNNs to process spectrograms (2-D time-frequency data) with the aim to classify emotions, in order to address the above stated needs of dementia patients. With this method, we avoid the need to select frequency bands or channels in the process of feature selection.

II. Experiment and Methods

A. Emotional Data Acquisition

There are many different ways to elicit the target emotions, such as pictures, film clips, music, emotional behaviors, imaging different scenarios and telling stories [23][24][25][26]. Film-clips have been found to elicit target emotions better compared with other methods. In this experiment, six different short video clips [27][24][28] were chosen in advance according to other articles and YouTube rankings to stimulating different emotions (scared, excited, quiet, bored, sad, happy). Each video clip lasts around 2.5-4 minutes and was sandwiched between "quiet time" for 10 seconds, used to provide a short time gap for a smoother transition between emotional states. The entire process lasted for about 20 minutes.

B. Participants and Experiment Protocol

There were 11 healthy young participants, 5 males and 6 females, aged between 24~30 years old, participated in the experiment. Prior to the experiment, each subject was asked to sign a consent form and filled out a questionnaire about their recent mental state. Next, a presentation was given to them about the meaning of the experiment protocol, and scores used for evaluation. We arranged an experimenter available for any questions. After the participants understood about the experiment contents, they were asked to sit down and prepare for the experiment. Then the electrodes were placed on the right position on the skin of the subject. The signals should be checked for stability, after that, there was a practical trial for the participants to get familiar with the whole system. The subjects were requested to relax, minimize movement and concentrate on the videos. After that, there were a few minutes for them to calm down, and then reset their physiological signals during a 1 min quiet state, followed by the each video for a total of 20 minutes. The whole emotion inducing process is as shown Fig. 2.

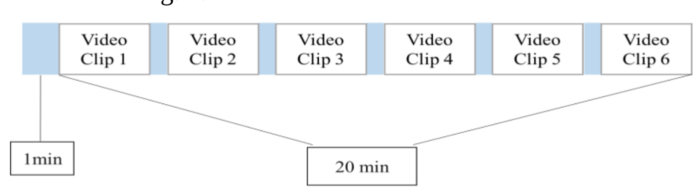

Fig. 2. The Emotion Inducing Process.

C. Materials and Setup

The experiments were conducted in a laboratory environment with suitable conditions (T = 25℃, RH = 50%). EEG and ECG signals were collected on an equipped recording PC (Dell Precision M3800). Stimulating videos were performed on a PC (HP Touch Smart). The subjects were seated approximately 70 cm from the screen. The speaker volume was set at a relatively loud level; however, each subject was asked whether the volume was comfortable or not before the experiment and it was adjusted when necessary.

EEG and ECG signals were recorded simultaneously using Polymate Ⅱ AP216 [29], an all-in-one type bio-signal recording device, at a sampling rate of 1000Hz using 7 active electrodes. Fig. 3 illustrates the whole experiment of one subject, (a) shows the monitor instrument set: Polymate Ⅱ AP216 Dell Precision M3800; (b) shows one subject of the experiment; (c) describes the electrode placement on the subject's body, REF.E channel used as the main electrodes, electrode 1 and 2 set to get ECG, electrode 3, 4, 5 used for EEG with two channels (4, 5 two dipole electrodes and 3 one ground); (d) illustrates the data collecting page on the measurement software AP Monitor [29], which can set up measurement conditions, the information of subjects, also, can monitor the waveform as standard during measurement.

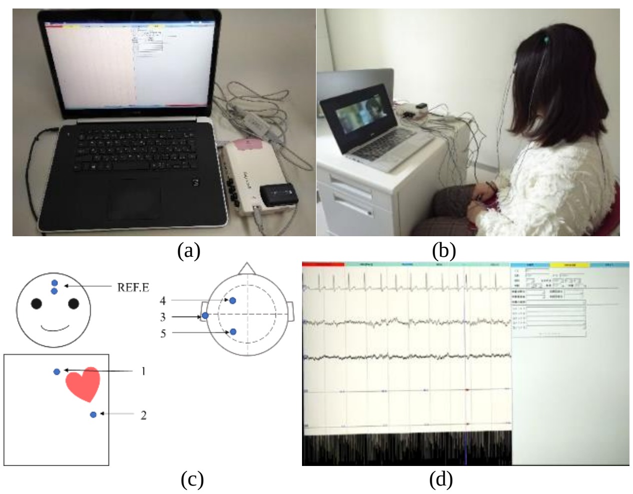

Fig. 3. The whole Experiment Setup. (a) the Monitor Instrument Set: Polymate Ⅱ AP216 and Dell Precision M3800; (b) the Experiment of One Subject; (c) the Electrode Placement; (d) the Signals Collecting Page.

III. Data Analysis

The raw ECG and EEG data measured by the Polymate II AP216 had the noise due to muscle tone, blinking, and other small movements removed by the display software AP Viewer [29]. The software can redisplay the waveform of data recorded with the instrument, and export specified sections of the file during a given period into CSV format.

A. EEG Spectrogram

For EEG feature extraction, the spectrogram analysis of EEG was performed in a time-frequency domain method, using the short time Fourier transform (STFT) and applying a hamming window. The window size for spectrogram analysis was 4s with 3.9s overlapping, sliding window was 0.1s. We recorded the amplitude of each frequency band, consisting of delta wave, theta wave, alpha wave, and beta wave frequencies. The delta band (0-4Hz) was removed to eliminate the remaining noise from pulses, neck movement, and eye blinking [30]. Our research focused on the alpha (8-14Hz) and beta (14-30Hz) frequencies. Alpha waves are typical for relaxed mental state and are most visible in normal daily lives. Beta waves are related to an activated state of mind appeared during intensive mental activity [31]. The analysis method is reported as Fig. 4, which was realized by the API "signal processing" [32] through "SciPy", a Python-based ecosystem of open-source software for mathematics, science, and engineering to render many kinds of functions and algorithms.

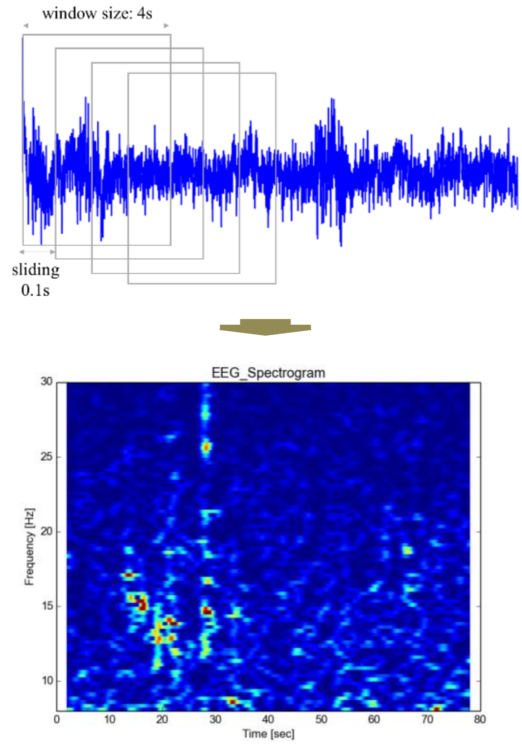

Fig. 4. The Spectrogram Process of EEG Data.

B. ECG Analysis

The whole process of ECG is shown in Fig. 5. To extract features from ECG, the peaks of R-waves on the ECG plot were detected, as Fig. 5(a). After R-peaks detection, the R-R intervals (RRI) were calculated by subtracting the peak time from the previous timing to form the waveform which shows the temporal alternation of the peak timings, as Fig. 5(b). Due to this process, the RRI are sampled sparsely and unevenly. To apply a time-frequency domain analysis, the time intervals need to be resampled by 4Hz to get the evenly data graph, as Fig. 5(c). In the analysis, we used a window size of 60s and a step size of 1s, to get the RRI spectrogram. And the LF (0.04-0.15Hz) and HF (0.15-0.4Hz) amplitudes were obtained from the spectrogram, arranging the frequency from 0-0.5Hz, as Fig. 5(d). To get the RRI, the package "BioSPPy" [33], a toolbox for bio-signal processing written in Python, was adopted. Besides, the RRI spectrograms were achieved by the API "signal processing" [32] through "SciPy".

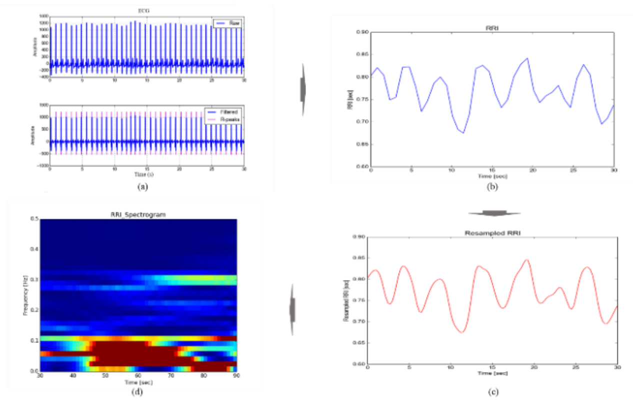

Fig. 5. The Processing Steps of ECG. (a) R-Peaks Detecting; (b) RRI Calculating; (c) RRI Resampling; (d) RRI Spectrogram Processing.

C. Prepare Dataset

As the measured data of 1 subject was incomplete due to her exceeding reaction to the scared scenes, her data was excluded. The other 10 participants, 5 males and 5 females were taken into account for emotion changes detection. Considering that the emotion of participants may change during one video and the adequate information of RRI spectrograms, the spectrogram images were cut into 15s pieces. And the subjects were asked to make an evaluation about the videos per 15s. Then based on their evaluations, the video pieces per 15s were labeled with the scores. However, the evaluations on the fifth video eliciting boredom from subjects showed considerable variation, and so the data was discarded. The video showed somebody playing games by himself because nobody would celebrate his birthday with him. It seemed his words and accents were difficult to understand, so the subjects didn't know what was happening.

The problem of binary classification of arousal for changes in emotion was considered, where a given set of signals is classified by the subject according to how much the emotion was induced by each video. The subjective rating has a 9-point rating scale, so we defined the scores ranging from 1 to 5 as the low arousal class, labeled as 0, and those from 6 to 9 as the high arousal class [33], labeled as 1, as illustrated in Table I. The representative EEG and RRI spectrograms of two states: the high arousal emotion and the low arousal emotion were shown below, as Fig. 6. For the low arousal emotion as in Fig. 6(a), there's no sign of beta waves, while the high arousal emotion as in Fig. 6(b), beta waves are a prominent component of the signal. When feeling relaxed and experiencing no big emotional changes, HF amplitudes are prominent, as in Fig. 6(c). On the other hand, when emotional arousal was higher, the pressured moment may persist, and the LF amplitudes become more predominant, as shown in Fig. 6(d).

TABLE I. THE SCORES OF VIDEOS AND THE CLASSIFICATION LABEL

Scores	**Class**	**Label**
1-5	Low arousal	0
6-9	High arousal	1

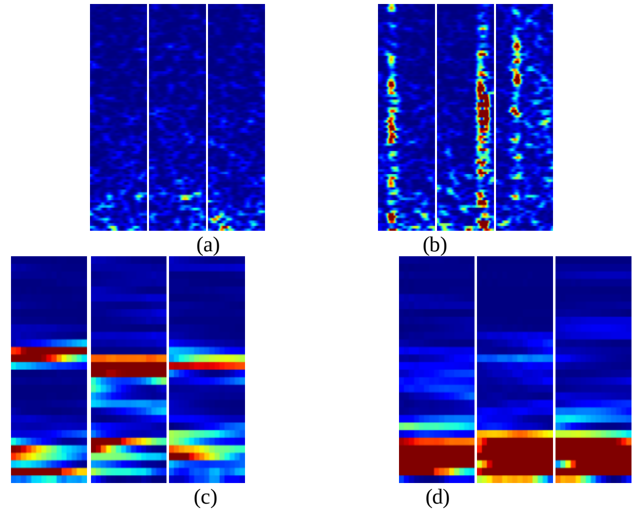

Fig. 6. The Representative EEG and RRI Spectrograms of the Two States. (a) the EEG Spectrograms of the Low Arousal Class; (b) the RRI Spectrograms of the High Arousal Class; (c) the RRI Spectrograms of the Low Arousal Class; (d) the RRI Spectrograms of the High Arousal Class.

D. Results

CNN classification was constructed to detect emotional changes. The network adopted in this study was implemented in "Keras" (Python), and mainly constructed of convolution and pooling layers. The networks for EEG and RRI spectrograms were adjusted according to the different features.

First of all, we tried to apply VGGNet-16 [34], an extensive architecture built for the ImageNet image classification challenge. Both EEG and RRI spectrograms were processed separately with 300 epochs, this took about 34 hours, with 405s per epoch. The accuracy of EEG was 93.33%, while RRI's was 91.67%, this verified the stability and reliability of the dataset.

Then we designed simpler CNN structures for EEG and RRI, these required much less time, at just 40s per epoch. The CNN1 used for EEG had three convolutional layers, three max-pooling layers. A fully connected layer with 256 hidden nodes was added after the last max-pooling layer to obtain the output defined as 0 for the low arousal class and 1 for the high arousal class. The size of all the filters in the convolutional layers was set to 3×3, so the frequency resolution of EEG spectrograms is smaller and the small scale features are considered. We used a dropout probability of 0.3 after the fully connected layer to avoid overfitting.

Next, CNN1 was applied to the RRI spectrograms; however, this seemed to produce greater over-learning. We believe this is because the scales and characteristics of their features are different. Therefore, CNN2 was set for RRI by adjusting some parameters of CNN1. CNN2 had two convolutional layers, and two max-pooling layers, followed by fully connected layers. The size of all the filters in convolutional layers was set to 5×5, to bring out the bigger features of the image. The dropout was used after two max-pooing layers and full connected layer. Dropout regularization has been proved to be an effective way to reducing the overfitting in deep learning [35].

The ReLU activating function for the convolutional layers of both networks was used. Also, the optimizer used for both CNNs was a SGD (Stochastic gradient descent), with a smaller learning rate of 0.0001. After 300 epochs, the accuracy of CNN1 with EEG spectrograms was 90.00%, and the CNN2 for RRI spectrograms was 91.67%. The accuracy curve for each network is as follows in Fig. 7 and Fig. 8.

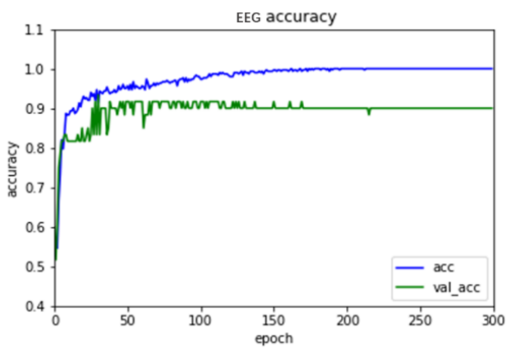

Fig. 7. The Accuracy Curves of CNN1 for EEG Spectrograms.

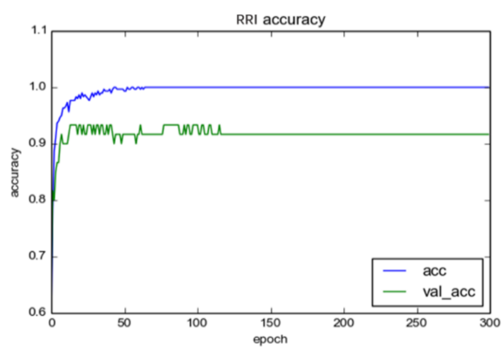

Fig. 8. The Accuracy Curves of CNN2 for RRI Spectrograms.

TABLE II. THE MERGED STRUCTURE OF CNN1 AND CNN2

Input 1	Input 2
EEG spectrograms	RRI spectrograms
CNN1	CNN2
Conv (32, (3×3), ReLU)	Conv (32, (5×5), ReLU)
Max-pooling (2×2)	
	Dropout (0.2)
Conv (32, (3×3), ReLU)	Conv (32, (5×5), ReLU)
Max-pooing (2×2)	
	Dropout (0.2)
Conv (32, (3×3), ReLU)	
Max-pooing (2×2)	
Flatten	
FC-256	
Dropout (0.3)	
FC-2	
Concatenate	
Softmax	
SGD (lr = 0.0001)	

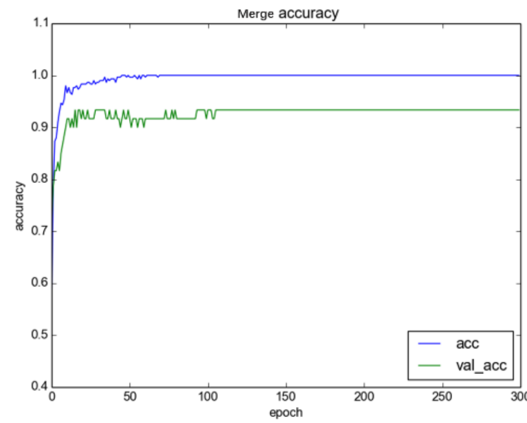

Fig. 9. The Merge Accuracy of CNN1 and CNN2 with Spectrograms of both EEG and ECG.

After that, both EEG and RRI together are considered as features for the binary classification. The merged network structure according to the “concatenate” function from “Merge layers” in “Keras” [36], is shown in Table II. It takes the spectrograms of EEG and RRI as inputs for CNN1 and CNN2 respectively, then merge the two outputs to get the final result. The overall accuracy reached 93.33% after 300 epochs, as illustrated in Fig. 9.

A complete comparison of accuracies between EEG and RRI (Table III), demonstrated that combining features of both EEG and RRI for classification of emotional changes performed better than only EEG or RRI features separately.

TABLE III. COMPARISON OF CLASSIFICATION ACCURACIES BETWEEN EEG, RRI, EEG AND RRI

Signals	**Networks**	**Accuracy**
EEG	CNN1	90.00%
RRI	CNN2	91.67%
EEG+RRI	CNN1+CNN2	93.33%

IV. CONCLUSIONS

In this paper, we strove to build upon prior research in the field of emotion detection for people with dementia and explored new techniques for increasing the effectiveness of deep learning models for EEG and ECG signals. It was proven that with EEG and RRI spectrograms from young people, binary emotional changes classification could be performed well by CNN. This allows for the convenience of automatic feature extraction. As a result, we are hopefully that the emotion detection system supposed in the study could be implemented in practice in caring for the elderly.

However, there are still some limitations. Our results show only binary classification for emotional changes; however, for real applications, recognition of the discrete emotions (e.g. sad, scary, angry, excited etc.) will need to be achieved in the future. Besides that, we found some factors that influence accuracy, including placement of electrodes, number, gender, educational and cultural backgrounds of subjects, number of emotions considered, and type and effect of emotion induction

[37]. Therefore, in further studies we'd like to invite more participants of a similar cultural background to those already involved in our experiment, then try several different stimuli for triggering target emotions to obtain more sample data with the aim of working towards recognition of discrete emotions. Furthermore, we should try to perform the experiment with elderly participants in the future. Taking the accessibility and convenience of signals measurement of the elderly into account, attention would be placed on designing garment-type sensors for physical data collection instead of using active electrodes. We intend to incorporate a silver fiber in the fabric of garments to make a chest belt and head belt for more convenient and flexible data measurement.

ACKNOWLEDGMENT

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REFERENCES

[1] http://www.un.org/en/sections/issues-depth/ageing/index.html.

[2] Alzheimer's Disease International. World Alzheimer report 2015: the global impact of dementia: an analysis of prevalence, incidence, cost and trends, 2015.

[3] http://www.who.int/mental_health/neurology/dementia/en/.

[4] M. Poole, C. Bamford, E. McLellan, R. P. Lee, C. Exley, J. C. Hughes, .etl, "End-of-life care: A qualitative study comparing the views of people with dementia and family carers," Palliat Med., vol. 32(3), pp. 631-642, March 2018.

[5] S. Koelstra, C. Muhl, M. Soleymani, J. S. Lee, A. Yazdani, T. Ebrahimi, .etl, "DEAP: a database for emotional analysis using physiological signals," IEEE Transactions on Affective Computing, vol. 3(1), pp. 18-31, January-March 2012.

[6] A. M. Badshah, J. Ahmad, N. Rahim, S. W. Baik, "Speech emotion recognition from spectrograms with deep convolutional neural network," 2017 International Conference on Platform Technology, Februrary 2017.

[7] S. E. Kahou, C. pal, X. Bouthillier, P. Froumenty, C. Gülçehre, R. Memisevic, "Combining modality specific deep neural networks for emotion recognition in video," ICMI '13 Proceedings of the 15th ACM on International conference on multimodal interaction, pp. 543-550. December, 2013.

[8] H. Gunes, M. Piccardi, "A bimodal face and body gesture database for automatic analysis of human nonverbal affective," IEEE 18th International Conference on Pattern Recognition, August 2006.

[9] Y. L. Hsu, J. S. Wang, W. C. Chiang, C. H. Hung, "Automatic ECG-based emotion recognition in music listening," IEEE Transactions on Affective Computing, pp. 1-1, December 2017.

[10] H. J. Yoon, S. Y. Chung, "EEG-based emotion estimation using Bayesian weighted-log-posterior function and perceptron convergence algorithm," Computers in biology and medicine, vol. 43(12), pp. 2230-2237, 2013.

[11] S. K. Hadjidimitriou, L. J. Hadjileontiadis, "Toward an EEG-based recognition of music liking using time-frequency analysis," IEEE Trans Biomed Eng, September 2012.

[12] D. K. Prasad, S. J. Liu, S. H. A. Chen, C. Quek, "Sentiment analysis using EEG activities for suicidology," Expert Systems with Applications, vol. 103, pp. 206-217, August, 2018.

[13] G. Acerbi, E. Rovini, S. Betti, A. Tirri, J. F. Rónai, A. Sirianni, "A wearable system for stress detection through physiological data analysis," Italian Forum of Ambient Assisted Living, vol. 426, pp. 31-50, 2016.

[14] K. Schaaff, T. Schultz, "Towards an EEG-based emotion recognizer for humanoid robots," The 18th IEEE International Symposium on Robot and Human Interactive Communication, November 2009.

[15] B. R. Lee, D. O. Won, K. S. Seo, H. J. Kim, S. W. Lee, "Classification of wakefulness and anesthetic sedation using combination feature of EEG and ECG," 2017 5th International Winter Conference on Brain-Computer Interface (BCI), February 2017.

[16] R. W. Picard, E. Vyzas, J. Healey. "Toward machine emotional intelligence: Analysis of affective physiological state," IEEE Transactionas on Pattern Analysis and Machine Intelligence, vol. 23, pp. 1175-1191, 2001.

[17] M. Murugappan, S. Murugappan, B. S. Zheng. "Frequency band analysis of electrocardiogram (ECG) signals for human emotional state classification using discrete wavelet transform (DWT)," Journal of Physical Therapy Science, vol. 25, pp. 753-759, 2013.

[18] Z. Mohammadi, J. Frounchi, M. Amiri. "Wavelet-based emotion recognition system using EEG signal," Neural Computing & Applications, pp. 1-6, 2016.

[19] S. Nasehi, H. Pourghassem. "An optimal EEG-based emotion recognition algorithm using gabor features," Wseas Transactions on Signal Processing, vol, 8, pp, 87-99, 2012.

[20] Y. LeCun, Y. Bengio, G. Hinton, "Deep learning," Nature, vol. 521, pp. 436-444, 2015.

[21] O. Tsinalis, P. M. Matthews, Y. Guo, S. Zafeiriou, "Automatic sleep stage scoring with single-channel EEG using convolutional neural networks," arViv.org Statistics Machine learning, October 2016.

[22] Y. F. Ren, Y. Wu, "Convolutional deep belief networks for feature extraction of EEG signal," 2014 International Joint Conference on Neural Networks (IJCNN), September 2014.

[23] F. Agrafioti, D. Hatzinakos, A. K. Anderson, "ECG pattern analysis for emotion detection," IEEE Transactions on Affective Computing, vol. 3, pp. 102-115, August 2011.

[24] M. Soleymani, J. Lichtenauer, T. Pun, M. Pantic, "A multimodal database for affect recognition and implicit tagging," IEEE Transactions on Affective Computing, vol. 3(1), pp. 42-55, Jan.-March 2012.

[25] Y. L. Hsu, J. S. Wang, W. C. Chiang, C. H. Hung, "Autonomic ECG-Based Emotion Recognition in Music Listening," IEEE Transactions on Affective Computing, December 2017.

[26] O. Martin, I. Kotsia, B. Macq, "The eNTERFACE'05 audio-visual emotion database," 22nd International Conference on Data Engineering Workshops, April 2006.

[27] J. J. Gross, R.W. Levenson, "Emotion eliciting using films," Cognition and Emotion, vol. 9, pp. 87-108, 1995.

[28] M. Soleymani, S. A. Esfeden, Y. Fu, M. Pantic, "Analysis of EEG signals and facial expressions for continuous emotion detection," IEEE Transactions on Affective Computing, vol. 7, pp. 17-28, Jan.-March 2016.

[29] https://datarecorder.jp/products/me/ap216.html.

[30] K. E. Ko, H. C. Yang, K. B. Sim, "Emotion recognition using EEG signals with relative power values and Bayesian network," International Journal of Control, Automation and Systems, October 2009.

[31] D. O. Bos, "EEG-based emotion recognition," The Influence of Visual and Auditory Stimuli, 2006.

[32] https://docs.scipy.org/doc/scipy/reference/signal.html.

[33] S. E. Moon, S. Jang, J. S. Lee, "Learning cross-regional dependence of EEG with convolutional neural networks for emotion classification," ICLR 2018 Workshop Acceptance Decision, February 2018.

[34] K. Simonyan, A. Zisserman, "Very Deep Convolutional Networks for Large-Scale Image Recognition," In ICLR, pp: 1–14, April, 2015.

[35] A. Krizhevsky, I. Sutskever, G. E. Hinton, "Imagenet classification with deep convolutional neural networks," Advances in neural information processing systems, pp: 1097–1105, 2012.

[36] https://keras.io/layers/merge/#concatenate.

[37] J. Selvaraj, M. Murugappan, K. Wan, S. Yaacob, "Classification of emotional states from electrocardiogram signals: a non-linear approach based on hurst," Biomed Eng Online, vol. 16, pp. 12-44, May 2013.

The User Behavior Analysis Based on Text Messages Using Parafac and Block Term Decomposition

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***Abstract*—Tensor decompositions represent a start for big data analysis and a start in reduction of dimensionality, object detection, clustering and so on. This paper presents a method to study the behavior of users in the online environment and beyond. A beginning for analyzing this type of data is uniting the Parafac Tensor Decomposition and the Block Term Decomposition.**

***Keywords*—Parafac decomposition; block term decomposition; clustering**

I. Introduction

High-order tensors have become very used for applications in big data analysis and signal processing due to tensor decompositions and their unique properties. The big data used in research experiments can be mathematically described with tensors [1].

Various researches have led to the development of tensors in the recent years, one of the reasons being the growth of data over time. This is also the reason why tensors analysis must receive more attention. The purpose of this paper is to present a new method to analyze big data and to efficiently process huge data set in a reasonable timeframe. In this paper, we describe the steps of processing big data by using Parafac because it returns a unique solution and Block Term Decomposition, by using matrices of elements sorted by the group of which they belong.

Nowadays, the technology feels like it is accelerating and people become more and more dependent of digital electronics. People communicate with each other using text messages or phone calls. In this research work we propose a solution to analyze the behavior of users which use text messages at different moments of the day. The purpose is to classify users which use text messages in the same timeframe. The research is based on Parafac Decomposition, clustering and Block Term Decomposition [2, 3].

II. Related Work

Through various researches, tensor models have been successfully applied in various areas such as: factor analysis, video tracking [4], face recognition [5], medical data analysis [6], and fake user detection in social networks [7] and so on.

In [8], the authors studied the tensors network which provides the possibility to analyze big data because of the good compression, parallel processing, establishing statistical connections between cores, factors, components, operation with noisy and missing data.

III. Parafac Decomposition and The Rank-(L_R,L_R,1) Block Term Decomposition

In this section we will provide mathematically definitions of the tensor, Parafac Decomposition and Block Term Decomposition. Tensors provide a compact and natural representation for multidimensional data.

A tensor $T \in \mathbb{R}^{I_1 \times I_2 \times \ldots \times I_N}$ is a multidimensional array called Nth order tensor or *N*-way tensor, where *N>0*. More exactly, *N* gives us the number of dimensions [9]. A tensor is a generalization of scalars, vectors and matrices. For example, if N=3 [see Fig. 1], then we have a third-order tensor $T \in \mathbb{R}^{I_1 \times I_2 \times I_3}$ and each entry of T is denoted by $x_{i_1 i_2 i_3}$ [10].

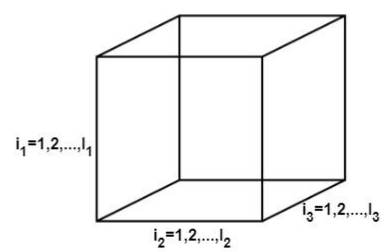

Fig. 1. A third order tensor $T \in \mathbb{R}^{I_1 \times I_2 \times I_3}$ [9]

Canonical Polyadic (also known as CANDECOMP/ Parafac) Decomposition of a higher-order tensor is decomposition in a minimal number of rank-1 tensors [11]. A Parafac decomposition of a third order tensor is given by three loading matrices *A*, *B* and *C* and the sum of squares of the residuals.

The Parafac decomposes a tensor $T \in \mathbb{R}^{I_1 \times I_2 \times \ldots \times I_N}$ as the sum of a finite numbers of rank-one tensors [9]. For a third order tensor $T \in \mathbb{R}^{I_1 \times I_2 \times I_3}$, the Parafac decomposition is written as [see Fig. 2]:

$$\mathrm{T} = \sum_{\mathrm{r}=1}^{\mathrm{R}} \mathrm{a_r} \circ \mathrm{b_r} \circ \mathrm{c_r} + \mathrm{E} \approx [\![\mathrm{A}, \mathrm{B}, \mathrm{C}]\!],[9] \quad (1)$$

Where:

$$\mathrm{A} = [\mathrm{a}_1, \ldots, \mathrm{a_R}], \mathrm{B} = [\mathrm{b}_1, \ldots, \mathrm{b_R}], \mathrm{C} = [\mathrm{c}_1, \ldots, \mathrm{c_R}][9]. \quad (2)$$

R is a positive integer and the symbol $\circ$ denotes the outer product of vectors. The Parafac model gives a unique solution if the loading vectors are linear independent in two of the modes. Another condition of uniqueness is given by Kruskal [12]:

$$k_1 + k_2 + k_3 \geq 2R + 2, [12] \quad (3)$$

Where k_1, k_2, k_3 are the k-ranks of *A*, *B*, *C* and *R* is the number of Parafac components. The *k-rank* of a matrix *A*, denoted $k_{A,}$ is defined as the maximum value *k* such that any columns are linearly independent [9].

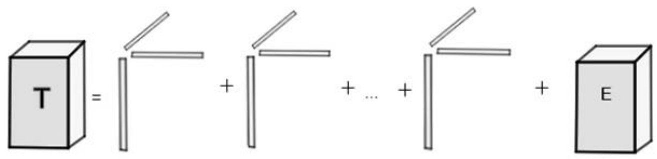

Fig. 2. Parafac decomposition of a N^{th}order tensor [9]

The rank of a tensor *T*, denoted *rank (T)*, is defined as the smallest number of rank-one tensors that generate *T* as their sum. The uniqueness means that it is the only possible combination to sum the tensor with a natural number of the rank-one tensors [9].

The rank-(L_r, L_r, 1) block term decomposition (BTD) is an approximation of a third order tensor by a sum of R terms, each of which is an outer product of a rank L_r matrix and a nonzero vector. Let be *T* a tensor of third order, $A_r \in \mathbb{C}^{I_1 \times L_r}$ and $B_r \in \mathbb{C}^{I_2 \times L_r}$ be rank L_r matrices and let be $c_r \in \mathbb{C}^{I_3}$, c_r nonzero:

$$T \approx \sum_{r=1}^{R} (A_r \cdot B_r^T)^{\circ} c_r \ [13] \quad (4)$$

Is a block tensor decomposition of the tensor T [Fig. 3] [13].

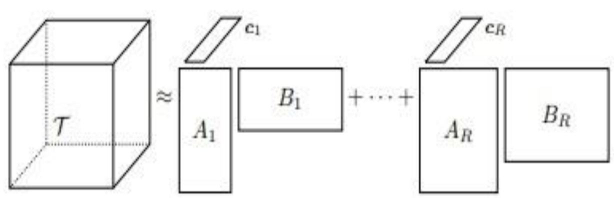

Fig. 3. The rank-(L_r,L_r,1) block term decomposition [13]

In addition, the matrix $A_r \cdot B_r^T \in \mathbb{C}^{I_1 \times I_2}$ has rank L_r. If matrices $[A_1,\ldots,A_R]$ and $[B_1,\ldots,B_R]$ are full column rank and the matrix $[c_1,\ldots,c_R]$ does not contain collinear columns, then the uniqueness of the decomposition is ensured. Also, the rank-(L_r,L_r,1) block term decomposition is a generalization of CPD (Canonical polyadic decomposition) for third order tensors [14].

IV. PROBLEM FORMULATION

Nowadays, the text messages have become increasingly used. People spend much more time using mobile phones because it represents a quick way of communicating and an easy way to multitask. The interest in studying the behavior of users of using text messages is to see how long users communicate over the day and at what time of day communication is more intense.

Assume that six users, *A, B, C, D, E,* and *F*, communicate with each other sending text messages and images. The data can be organized in a tensor of order three [see Fig. 4], where the first two dimensions correspond to users and the third dimension corresponds to time.

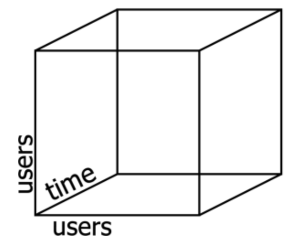

Fig. 4. The communication tensor between users

We used graphs to represent the network communication. As we can observe in the Fig. 5, we have a weighted directed graph. The weighted edges of the graph are given and represent the size of text messages measured in kilobytes. We can observe that users A and B are the most active on using text messages over time and the inactive ones are C and F [15].

The adjacency matrices were done at different moments of the day: first graph 08:00-12:00, second graph 12:00-16:00, third graph 16:00-20:00 and fourth graph 20:00-24:00.

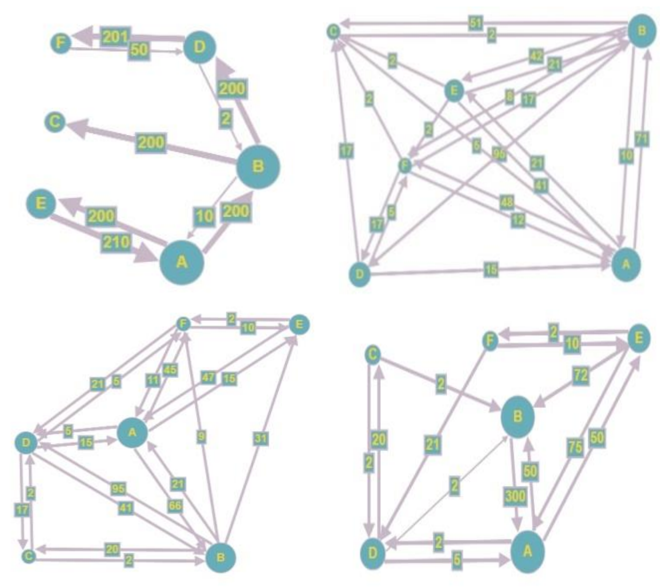

Fig. 5. The weighted directed graphs of the users communication

The purpose is to analyze the change of the communication in time of users and to see if the time of day influence on communication. We used a three dimensional tensor because it preserve a multidimensional structure of data [16]. To analyze the behavior of users of using text messages, we used an empirical data set.

V. Experimental Results

To compute the Parafac decomposition of tensor T, we use the command *parafac (T, fac, Options, const)* from N-Way Tollbox based on MATLAB [17]. The algorithm allows choosing optionally constraints to obtain orthogonal, non-negative or unimodal solutions.

The first two dimensions of tensor $T \in \mathbb{R}^{6\times 6\times 4}$ contain the adjacency matrices of communication of users and the third dimension is time. Using *parafac* function for tensor *T,* where T is the input array, with 23 components and in all factor matrices had been applied the non-negative constrain. The decomposition explain the tensor in proportion of 100%, converge after 50 iterations and the sum of squares of residuals is 0.108. The Parafac decomposition for 10 components [Fig. 6, 7, 8] explain the tensor in proportion of 99.33%, converge after 50 iterations but the sum of squares of residuals is 2655.84. The data was analyzed for 23 components [18].

The non-negative constrain was used to improve the result and to analyze data more realistic. An unconstrained model will fit the data worse than a constrained model [16].

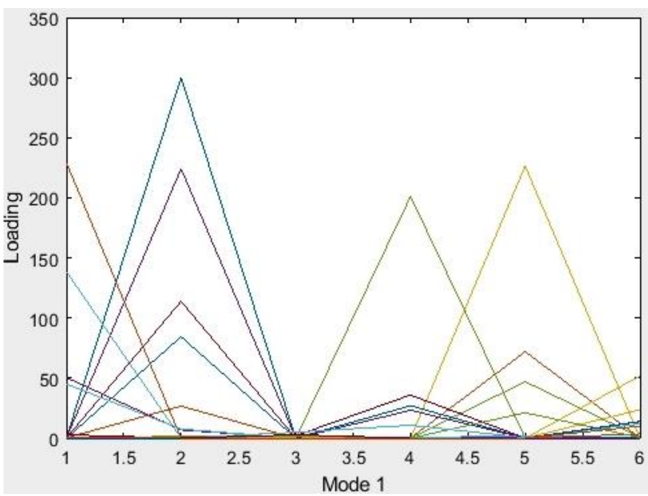

Fig. 6. Graphical representation of the results using 23 components for the first mode

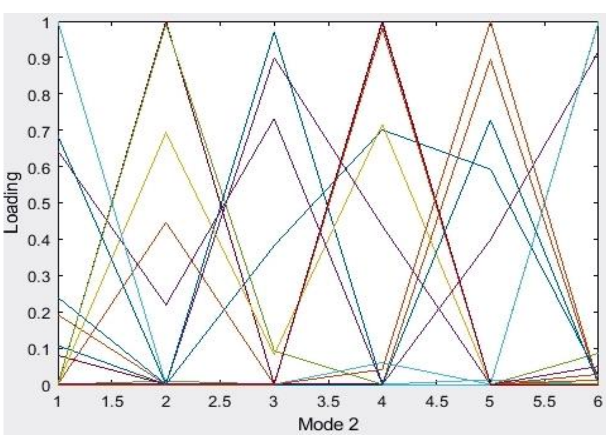

Fig. 7. Graphical representation of the results using 23 components for the second mode

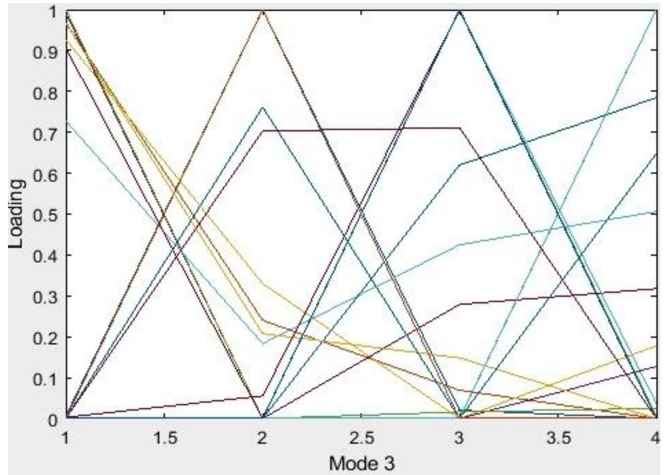

Fig. 8. Graphical representation of the results using 23 components for the third mode

The output of *parafac* function is “Factors” which stores the matrices resulted from applying it. The third matrix contains the degree of communication of users in time.

We want to group the similar vectors to see if there is a similarity between them [see Fig. 8]. If the number of components is big, it will be difficult to be manually handled. In this case, to regroup the similar vectors, it can be used some clustering techniques, like k-means or hierarchical clustering.

Hierarchical clustering groups the data into a multilevel cluster tree or dendrograms and it will help to choose the best level of clustering. To realize a hierarchical clustering must be followed some steps. Firstly, using *pdist* MATLAB function we calculate the distance between objects of C matrix. The second step involves a grouping of objects into a binary, hierarchical cluster tree. Using the information generated by *pdist* function, the *linkage* MATLAB function will link the pairs of objects that are close together into binary clusters. The linkage MATLAB function returns a matrix that encodes a tree containing hierarchical clusters of the rows of the input data matrix. *Linkage* MATLAB function uses distances to determine the order in which it clusters objects.

TABLE I. The Output of Linkage Function

17.0000	21.0000	0
15.0000	24.0000	0
13.0000	18.0000	0.0000
	⋮	
	⋮	
40.0000	43.0000	0.9230
38.0000	44.0000	0.9456

In the Table I, each row identifies a link between objects or clusters. The first two columns identify the objects that have been linked and the last column contains the distance between those objects.

For the sample data set, the *linkage* function of groups objects 38 and 44, which have a distance value of 0.9456. Another example, are objects 17 and 21 which have the closest proximity (distance value is 0).

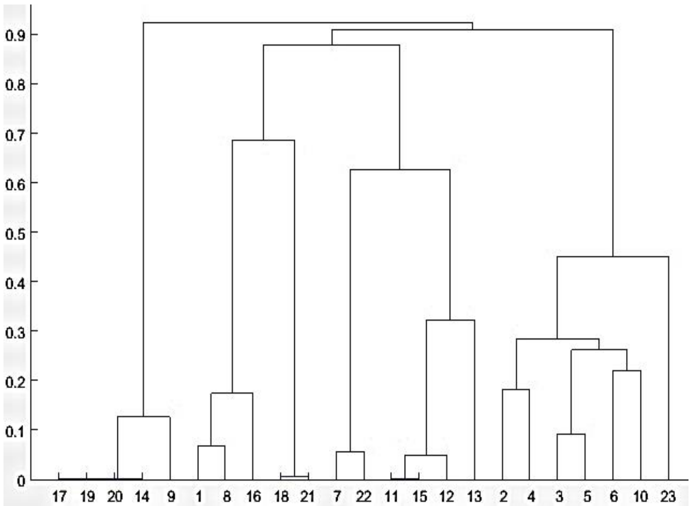

Fig. 9. The dendrogram of hierarchical, binary cluster tree

Using *dendrogram* MATLAB function it is easier to understand when the data is represented graphically [see Fig. 9]. *Dendrogram* MATLAB function generates a dendrogram plot of the hierarchical binary cluster tree.

To verify if the cluster tree was well generated, we can use *cophenet* MATLAB function to compare the datas returned by *linkage* and *pdist* functions. The cophenetic correlation coefficient is unsatisfying, so we used another distances to calculate the distances between objects. Using Euclidian Distance, the cophenetic coefficient was 0.777, the Squared Euclidean distance was 0.458, Standardized Euclidean distance was 0.910, City block distance was 0.581, Minkowski distance was 0.799. Chebychev distance gives the most accurately clustering solution which reflects the data and the cophenetic coefficient was ≈1.000.

The next step is to put the data in clusters. The *cluster* MATLAB function has two ways of clusterization. In natural way, the function allows us to give a threshold, which can be a value from inconsistency coefficients vector (can be found using *inconsistent* MATLAB function).

On my data, we choose the smallest coefficient and it divided them into 15 separate clusters. The second way is to specify your own number of clusters. Firstly, we used the second way. Analyzing the dendrogram, we choose to divide the data into 4 separate clusters [see Table II].

TABLE II. THE OUTPUT OF CLUSTER FUNCTION

IDX = 2 4 4 4 4 1 1 2 4 2 1 1 3 3 3 1 1 2 1 2 1 4 1

The next step is to recreate the three new matrices which contains the columns rearranged of A, B and C, by the group which belongs. After those matrices are created, we can apply Block Term Decomposition. To create a tensor with the original data sorted, we apply *cpdgen* TensorLab function on A, B and C matrices.

Generally, block term decomposition is a regrouping of a decomposed tensor. The Tensorlab function *ll1* can be applied to compute a block term decomposition of a tensor using a multistep approach and it has 2 output formats, *cpd* and *btd* mode. When using the CPD format, the parameter L is required because it provides the necessary information on how the columns are grouped. This function is the best choice because it accepts dense, sparse and incomplete tensors. *ll1* MATLAB function performs a number of steps and provide a good initialization to reduce the computational cost of the decomposition [19].

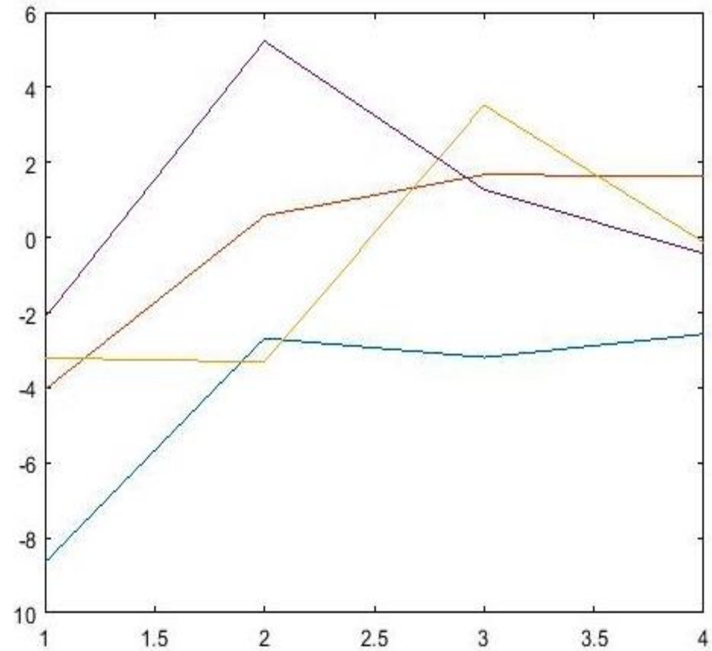

Fig. 10. The output of ll1 function in cpd mode

In Fig. 10, we can see the plot of the matrix C after *ll1* function in *cpd* mode was applied, where L = [9, 5, 3, 6] is the vector which contains the number of elements that each cluster has. In Table III we have the output of the *ll1* function.

TABLE III. THE MATRIX C AFTER LL1 FUNCTION IN CPD MODE WAS APPLIED

-8.6590	-4.0514	-3.2087	-2.1427
-2.6838	0.5798	-3.3145	5.2329
-3.1924	1.6741	3.5252	1.2748
-2.5723	1.6291	-0.1283	-0.4262

In Fig. 10, the blue line belongs to the first group which has a small increase in the use of text messages as time passes. The yellow line belongs to the third group and we can see that users have used the text messages more in the evening. The red line belongs to the second group who uses the text messages more and more throughout the day. The brown line belongs to the second group which have which have a slight increase throughout the day. In conclusion, there is an increase of using text messages in the evening, fact confirmed by the graphs from Fig. 5.

Another analysis of the same dataset where we choose to divide the data into 6 separate clusters [see Table IV] and in Table V we have the output of the *ll1* function.

TABLE IV. THE OUTPUT OF CLUSTER FUNCTION

IDX=4 6 6 6 6 6 2 5 1 6 4 5 4 4 1 2 5 2 1 2 4 1 3

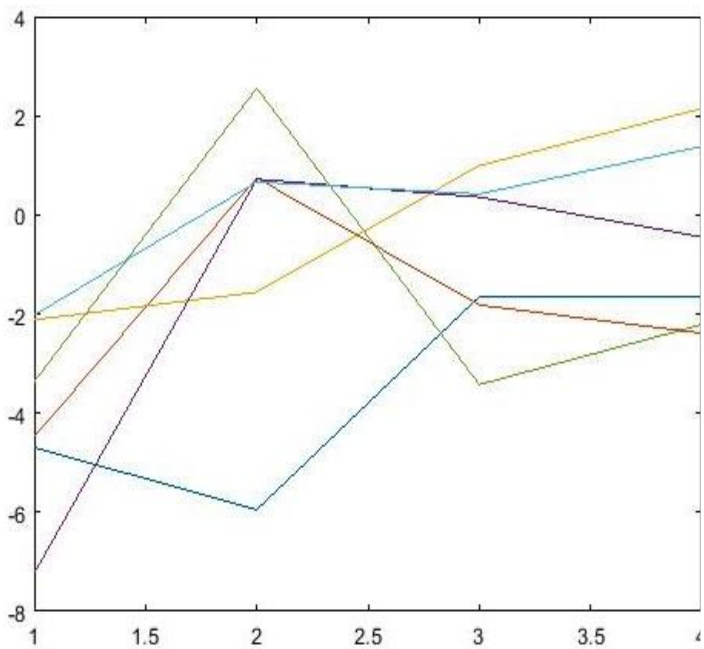

Fig. 11. The output of ll1 function in cpd mode

TABLE V. THE MATRIX C AFTER LL1 FUNCTION IN CPD MODE WAS APPLIED

-4.6948	-4.4791	-2.1156	-7.2278	-3.3653	-2.0216
-5.9477	0.7470	-1.5593	0.7200	2.5560	0.6633
-1.6492	-1.8211	0.9920	0.3592	-3.4240	0.4209
-1.6339	-2.3872	2.1457	-0.4445	-2.2147	1.3810

In Fig. 11, we can see the plot of the matrix C after *ll1* function in *cpd* mode which was applied using 6 clusters and L = [4, 4, 1, 5, 3, 6].

The dark blue line belongs to the first group, which have an increase in the use of text messages as time passes. The yellow line belongs to the third group and we can see that users have used the text messages more in the evening. The green line belongs to the fifth group, which has an increase in the first part of the day and then a decrease in the second part of the day; however, there is a slight increase towards the end of the day. The light blue line belongs to the sixth group, which have a slight increase throughout the day. The purple line belongs to the fourth group, which communicates very little in the first part of the day, but in the second part of the day we can see a huge increase.

In conclusion, using 6 clusters, we can observe that there is an increase of using text messages in the evening, fact confirmed by the graphs from Fig. 5.

In another analysis of the same dataset, we choose to divide the data using the hierarchical clustering in a natural way. The *cluster* function can create clusters by detecting natural groupings in the hierarchical tree [see Table VI]. In Table VII we have the output of the *ll1* function.

TABLE VI. THE OUTPUT OF CLUSTER FUNCTION

IDX= 3 4 4 4 4 4 1 2 5 4 3 2 3 2 1 5 1 3 3 1 2 3 5

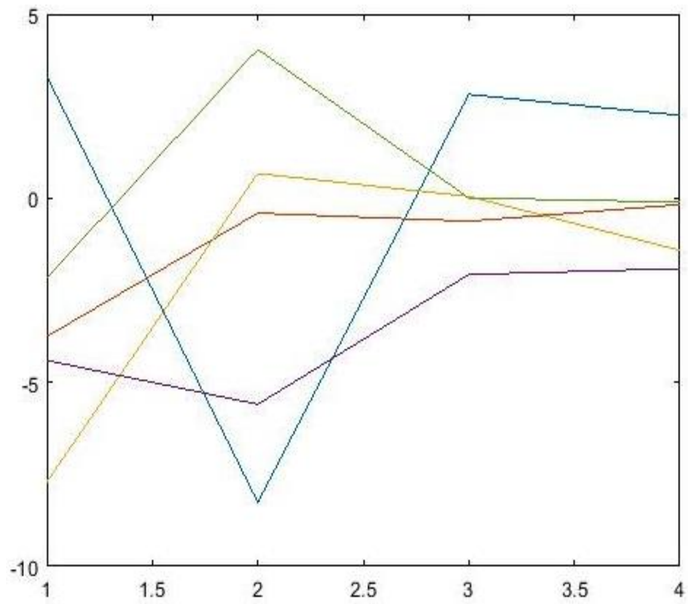

Fig. 12. The output of ll1 function in cpd mode

TABLE VII. THE MATRIX C AFTER LL1 FUNCTION IN CPD MODE WAS APPLIED

3.3097	-3.7560	-7.7130	-4.4060	-2.1640
-8.2634	-0.4053	0.6729	-5.5966	4.0427
2.8190	-0.6237	0.0480	-2.0716	0.0068
2.2518	-0.1741	-1.4155	-1.9127	-0.1062

In Fig. 12, we can see the plot of the matrix C after *ll1* function in *cpd* mode which was applied using 6 clusters and L = [4 4 6 6 3]. The hierarchical clustering was realized in natural way and the inconsistency coefficient was 0.9. It divided them into 5 separate clusters.

After we analyzed the Fig. 12, we can affirm that in the evening the text messages are used by all users at about the same intensity, fact confirmed by the graphs from Fig. 5.

VI. CONCLUSIONS

The existing methods and algorithms become inadequate for processing big data, because it can have huge volume and high complexity. The most important reason for which we started with Parafac decomposition is that the model estimated is easier to analyze, especially when it comes to big data. Adopting the rank-(L_r, L_r, 1) block term decomposition was an important step, because we regrouped the components using a hierarchical clustering. The objective of this paper was to obtain the result of block term decomposition using clustering which helped us to analyze the data.

In summary, big data analysis has potential to be researched because the optimization problems become ineffective for the current data.

REFERENCES

[1] Hemlata, Preeti Gulia, *Big Data Anaytics*, Research Journal of Computer and Information Technology Sciences, Vol. 4(2), 1-4, February(2016).

[2] Qingquan Song, Hancheng Ge, James Caverlee, Xia Hu. (3 May 2018). ArXiv. *Tensor Completion Algorithms in Big Data Analytics*, arXiv:1711.10105 [stat.ML].

[3] Lee J, Choi D, Sael L (2018) CTD: *Fast, accurate, and interpretable method for static and dynamic tensor decompositions.* PLoS ONE

13(7):e0200579. https://doi.org/10.1371/journal.pone.0200579

[4] Xiaqqin Z., Xingchu Shi., Weiming H.,ELSEVIER, Neurocomputing, *Visual tracking via dynamic tensor analysis with mean update*, Vol. 74, Issue 17, October 2011, pp: 3277-3285.

[5] Lee Ying Chong, Lee Ying Chong, Thian Song Ong, Thian Song Ong, Andrew Beng Jin Teoh, Andrew Beng Jin Teoh, } "Tensor manifold-based extreme learning machine for 2.5-D face recognition," Journal of Electronic Imaging 27(1), 013016 (12 February 2018). https://doi.org/10.1117/1.JEI.27.1.013016 . Submission: Received: 23 August 2017; Accepted: 9 January 2018

[6] Joyce C Ho, Joydeep G., Steve R. S., Walter F Stewart, Joshua C Denny, Bradley A M., and Jimeng S. 2014. Limestone: *High-throughput candidate phenotype generation via tensor factorization. Journal of biomedical informatics.*

[7] Cao Q, Sirivianos M, Yang X, Pregueiro T. *Aiding the Detection of Fake Accounts in Large Scale Social Online Services*.2012; p. 197–210.

[8] Andrzej Cichocki,(24 August 2014) *Era of Big Data Processing: A New Approach via Tensor Networks and Tensor Decompositions*, arXiv:1403.2048 [cs.ET].

[9] Tamara Kolda, B. W. (2009). Tensor Decompositions and Applications. *Society for Industrial and Applied Mathematics, 51*(3), pp. 455-500.

[10] Evrim Acar, B. Y. (2008, June). Unsupervised Multiway Data Analysis: a literature survey. *IEEE Transactions on Knowledge and Data Engineering, Vol. 21*, 6-20.

[11] Ignat Domanov, Lieven de Lathhauter, (2013). SIAM Journal on Matrix Analysis and Applications. *On the uniqueness of the canonical polyadic decomposition of third-order tensors-Part II:Uniqueness of the overall decomposition*, Vol. 34, Issue 3, pp; 876-903.

[12] Xijing Guo, Sebastian Miron, David Brie, and Alwin Stegeman, *Uni-mode and Partial Uniqueness Conditions for CANDECOMP/PARAFAC of Three-Way Arrays with Linearly Dependent Loadings*, SIAM Journal on Matrix Analysis and Applications, *SIAM J. Matrix Anal. & Appl.*, 33(1), 111–129. (19 pages) (2012).

[13] Laurent Sorber, Marc Van Barel, Lieven De Lathauter (April, 2013). *Optimization-based algorithms for tensor decompositions: Canonical Polyadic Decomposition, Decomposition In Rank*-(L_r,L_r,1) *Terms And A New Generalization, Vol.* 23, Issue 2, pp 695-720.

[14] Hunyadi, B., Camps, D., Sorber, L. et al. EURASIP J. Adv. Signal Process. Block term decomposition for modelling epileptic seizures (2014) 2014: 139. https://doi.org/10.1186/1687-6180-2014-1397

[15] Nicolas Nisse, *Graph Theory and Optimization Weighted Graphs, Shortest Paths & Spanning Trees*, Université Côte d'Azur, Inria, CNRS, I3S, France, October 2018., URL: https://www.inria.fr.

[16] Dumitrascu Ionut, (May 2014) Block-PARAFAC non-negative decomposition of hyper-spectral images, *Universite de Lorraine, Centre de research en automatique.*

[17] MATLAB MathWorks – MATLAB & Simulink R2015a ,URL: https://www.mathworks.com

[18] Rasmus Bro, Claus A. Andersson. *The N-way toolbox for MATLAB*, 2000

[19] Laurent Sorber, Marc Van Barel and Lieven De Lathauwer. *Tensorlab v3.0*, Available online URL: http://www.tensorlab.net, 2014.

Artificial Intelligence based Fertilizer Control for Improvement of Rice Quality and Harvest Amount

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***Abstract*—Artificial Intelligence: AI based fertilizer control for improvement of rice quality and harvest amount is proposed together with intelligent drone based rice field monitoring system. Through experiments at the rice paddy fields which is situated at Saga Prefectural Research Institute of Agriculture: SPRIA in Saga city, Japan, it is found that the proposed system allows control rice crop quality and harvest amount by changing fertilizer type and supply amount. It, also, is found the most appropriate fertilizer supply management method which maximizing rice crop quality and harvest amount. Furthermore, these rice crop quality and harvest mount can be predicted in the early stage of rice leaf grow. Therefore, rice crop quality and harvest amount becomes controllable.**

Keywords*—Nitrogen content; protein content; rice paddy field; remote sensing; regression analysis; rice crop quality; harvest amount; fertilizer

I. Introduction

In recent years, due to the diversification and lower price of sensing devices, the development of networks as infrastructure for aggregating and analyzing such information, generalization of mobile terminal devices, and higher functionalization of computers, ICT has been fully developed in the agricultural field The machine to utilize has matured. In addition, advances in small actuators and devices and Artificial Intelligence: AI that precisely controls them have also been developed, and technologies that enable the robot to be used in a more atypical environment have also developed. It is said that smartization[1] of agriculture will make full use of such technologies and efficiently realize high quality food production without introducing human power and time costs as before It is a challenging effort.

One of the biggest issues of smartization is agricultural field monitoring in an efficient and an effective manner and minimization of required resources including fertilizer, pesticide, electricity, water supply and labor cost. In particular, fertilizer is one of the biggest resources. Therefore, AI based fertilizer control for minimization of required fertilizer is developed together with the field monitoring system based on drone mounted Near Infrared: NIR cameras.

Vitality monitoring of vegetation is attempted with photographic cameras [1]. Grow rate monitoring is also attempted with spectral reflectance measurements [2]. Bi-Directional Reflectance Distribution Function: BRDF is related to the grow rate for tealeaves [3]. Using such relation, sensor network system with visible and near infrared cameras is proposed [4]. It is applicable to estimate nitrogen content and fiber content in the tealeaves in concern [5]. Also, damage grade is due to insects for rice paddy fields [6]. The proposed method is validated with Monte Carlo simulation [7]. Also Fractal model is applied to representation of shapes of tealeaves [8]. Thus, the tealeaves can be asse3ssed with parameters of the fractal model. Vitality of tea trees are assessed with visible and near infrared camera data [9]. These previously proposed methods do work for rice paddy fields.

Rice paddy field monitoring with drone mounted visible and NIR: Near Infrared camera is proposed [10] while the method for rice quality evaluation through nitrogen content in rice leaves is proposed [11]. The method proposed here is to utilize AI for estimation of fertilizer supply timing and amount of fertilizer together with evaluate rice quality through protein content in rice crop with observation of NDVI: Normalized Difference Vegetation Index which is acquired with visible and NIR camera mounted on drone.

Rice crop quality and amount evaluation method through regressive analysis between nitrogen content and near infrared reflectance of rice leaves measured from crone is proposed and validated successfully [12]. Meanwhile, estimation of protein content in rice crop and nitrogen content in rice leaves through regressive analysis with NDVI derived from camera mounted drone is conducted successfully [13]. On the other hand, relation between rice crop quality (protein content) and fertilizer amount as well as rice stump density derived from drone data is well investigated [14]. Then, estimation of rice crop quality and harvest amount from drone mounted NIR camera data and remote sensing satellite data is carried out [15]. Furthermore, effect of stump density, fertilizer on rice crop quality and harvest amount in 2015 investigated with drone mounted NIR camera data is well reported [16]. Moreover, method for NIR reflectance estimation with visible camera data based on regression for NDVI estimation and its application for insect damage detection of rice paddy fields is proposed and validated [16]. Also, there is the report about digital agriculture (AI-based sowing advisories lead to 30% higher yields)[2].

The proposed method is described in the next section followed by experiments. The experimental results are

[1] https://www.trcbook.com/electro/smafarm.html

[2] https://news.microsoft.com/en-in/features/ai-agriculture-icrisat-upl-india/

validated in the following section followed by conclusion with some discussions.

II. Proposed Method and System

A. Proposed AI based Fertilizer Control for Improvement of Harvested Rice Crop Quality and Harvest Amount

Proposed AI based fertilizer control for improvement of harvested rice crop quality and harvest amount is based on the acquired data of SPAD, spectral reflectance of rice leaves @ 550 nm, 870 nm, plant height, number of stems, culm length after heading, ear length, number of panicles (book / stock) air temperature, relative humidity, atmospheric pressure. Then, AI learns the timing and fertilizer amount of basal fertilizer, fertilizer application, panicle fertilizer. The rules from learned results as follows,

Draining is one of the following: ① Suppression of ineffective tilling. ② Promotion of new root elongation and maintenance of vitality until later. ③ Improvement of soil breathability and elimination of harmful gases. ④There are effects such as lodging reduction. However, if the longevity is delayed, not only these effects will be insufficient, but also it will be impossible to apply proper amount of panicle fertilizer properly. Furthermore, it may adversely affect the panicle of rice. When effective stems (stems that become 17 to 18 ears of one stock) are secured, they fall off early. 7 to 8 days to the extent that small cracks will enter the field. Completion by the early yolk formation stage (heading 25 days), let's prepare for the application. Especially, since it is delayed every year in ordinary plantation areas such as after wheat, let's finish it by late July after 30 days after rice planting as a guide. Even when using one type of base fertilizer type fertilizer, to avoid overgrowth due to continuation of fertilization and to prevent declining in the latter term, carry out a moderate disposal exactly.

Hodo fertilizer is important for securing yield and quality, such as preventing the degeneration of differentiated spikelet, increasing the number of spikelet, preventing leaf color deterioration and withering and promoting grain enrichment. However, if the application period is too early, lodging is increased, and in case of large application or slow application, the crude protein content in the brown rice is increased and the adverse effect such as lowering the taste is given. It is important to properly apply the appropriate amount according to variety, rice planting time, degree of fertility of the field, growing situation of rice, etc. Since the application time of panicle is delayed every year, predict the heading time from rice planting date beforehand, and make a diagnosis by length of larva spreading, leaf color, iodine dyed etc., 3 to 4 days before that, judge the suitable period for application . The standard of Hibari fish and the panicle length were "Kohikari" at 18 days before heading (8 to 10 mm in length of panicle) in consideration of the prevention of lodging, "colorfulness of color" at June plant was 25 days before heading (0.5 panicle length ~ 1 mm), and the other varieties are 20 to 23 days before heading (ear panicle length 1.5 to 2 mm). The application rate is based on the nitrogen content of 2 to 3 kg per 10 a, and it increases and decreases by performing the growth situation, the leaf color or the iodocaine staining diagnosis. In addition, late fertilization just before heading and heading will reduce application, so it will not be applied.

These knowledge and rules are acquired from the past three years rice crop productions. Then knowledge base system is created for increasing rice crop quality and harvest amount with minimizing the required fertilizer. Also, weather data are input to the knowledge base system together with SPAD[3], the number of stem, leaf length, culm length, panicle length, the number of panicle, grain weight, harvest amount and protein content in rice crops.

B. Method for Estimation of Rice Crop Quality and Harvest Amount

Rice crop quality is defined with protein content which is closely related to the nitrogen content in rice leaves. The nitrogen content in rice leaves can be estimated with reflectance in near infrared wavelength region of the rice leaves. Therefore, it is possible to estimate rice crop quality with NIR reflectance of the rice leaves in concern. On the other hand, harvest amount can be estimated with the regressive equation derived from the regression analysis with the harvest amount data and NIR reflectance of the rice leaves in concern.

III. Experiment

A. Example of Time Series Input Data for AI Learning

SPAD, spectral reflectance of rice leaves @ 550 nm, 870 nm, plant height, number of stems, culm length after heading, ear length, number of panicles (book / stock) as well as meteorological data are time series of input data. Then, AI learns the timing and fertilizer amount of basal fertilizer, fertilizer application, panicle fertilizer. One of the examples of the input data of "Hiyokumochi in 2015" of rice paddy field data is shown in Fig.1. In the example, all the parameters are observed on June 24, July 14, 30, August 13, 26, September 16, 24 and October 1. All these data has been gathered for 5 years for Ai learning. One of examples of results of correlations between protein content in rice crops and the other factors are shown in Fig.2.

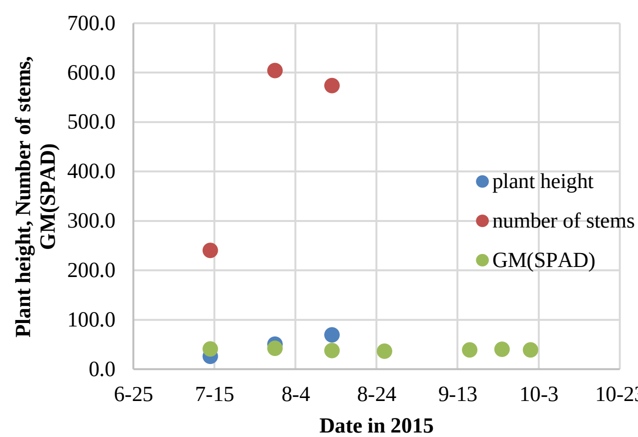


Fig. 1. Input Data of "Hiyokumochi in 2015" of Rice Paddy Field for AI Learning.

[3] https://www.rex-rental.jp/sek/spad-502plus.html

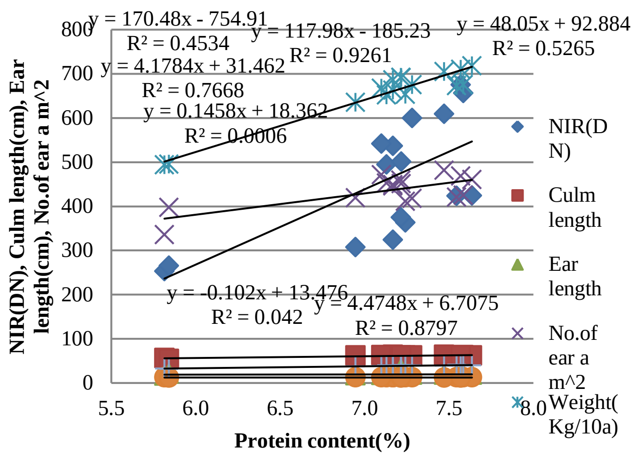


Fig. 2. Examples of Results of Correlations between Protein Content in Rice Crops and the Other Factors.

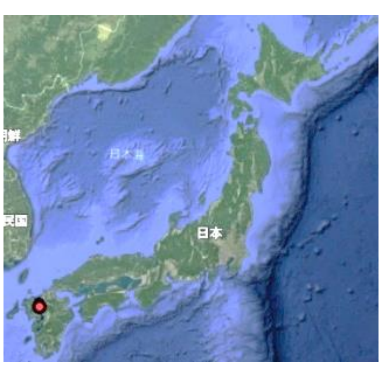
B. Rice Paddy Field in Concern

These measurements have been conducted at the Saga Prefectural Research Institute of Agriculture: SPARI[4] which is situated at 33°13'11.5" North, 130°18'39.6" East, and the elevation of 52 feet. Fig. 3 (a) and (b) shows layout of the test site of rice crop field. Just beside the SPARI, there is the test site of Saga Prefectural Agricultural School of College: SPASC. Black rectangle in the Fig. 3 (a) and (b) shows the test site.

C. Fertilizer Conditions

Paddy field No. 4-3 of the SPACS is divided into 7 different fields with the different fertilizer condition. "Saga-Biyori" of rice species is planted in all of the fields. Fertilizer conditions are shown in Table 1. Slow release fertilizer called "One shot N5.6" is used for the field No. 1.

The area of field No. 1 is 486 m^2. Therefore, 19.4 kg of fertilizer for the field No. 1 means 40 kg/10 a. This is the same condition for the field No. 6. Therefore, the fertilizer of the field No. 6 is 13.1 kg. The areas of the No. 2 to No. 7 are same as 327 m^2. The fertilizer conditions of the field No. 2 and 4 are same. That is "Standard". One the other hand, the fertilizer condition of the field No. 3 is same as the field No. 5. That is "Multi fertilizer".



(a)Test Site on Map(Test Site is Situated at the Red Circle)

[4] http://www.pref.saga.lg.jp/web/shigoto/_1075/_32933/ns-nousisetu/nouse/n_seika_h23.html

(b)Test site on 3D aerial photo image of Google map

Fig. 3. Test Site.

TABLE I. FERTILIZER TYPES AND AMOUNT

NO.	FERTILIZER	N(KG/10A)
1	ONE_SHOT SLOW RELEASE FERTILIZER	5.6
2	STANDAR_5020	7
3	MULTI_FERTILIZER_5222 HIGH YIELD FERTILIZE	11
4	STANDARD_5020	7
5	MULTI_FERTILIZER_5222 HIGH YIELD FERTILIZE	11
6	ONE_SHOT SLOW RELEASE FERTILIZER	5.6
7	NONFERTILIZER	0

One shot fertilizer is supplied to the field No. 1 and 6 at once as Former "diat" or basement. Meanwhile, Standard fertilizer is supplied for the field No.2 and 5 before the plantation as 5 (basement), then fertilizer 2 and "hirona" of 2 after the heading.

On the other hand, Multi fertilizer is supplied to the field No. 3 and before the plantation as 5 (basement), the fertilizer 2 and 2 as well as "hirona" of 2 after the heading.

Growth survey is carried out three times. That is maturity searches, yield, yield components, palatability-related traits (near infrared analysis). Meanwhile, ground based measurements of spectral reflectance are conducted on August 18 2017, August 28 2017, and September 19 2017. If the harvest amount is predicted on August 28, then another fertilizer is supplied to the fields which show grows inadequate for increase the supposed harvest amount. That is the same thing for rice crop quality, protein content in rice crops.

D. Experimental Results

Example of the measured spectral reflectance is shown in Fig. 4. Unfortunately, weather condition is bad, cloudy condition. Therefore, the spectral reflectance of August 18 2017 is just a reference. Another field experiment is conducted on August 28 2017. drone based NIR camera data of the field No. 1 to 7 is acquired.

Natural color image acquired with visible camera is shown in Fig. 5 (a) while Fig. 5 (b) shows the image with the NIR filter attached camera. In the figure, rice paddy fields from the fields A to I correspond to the field No. 1 to 7.

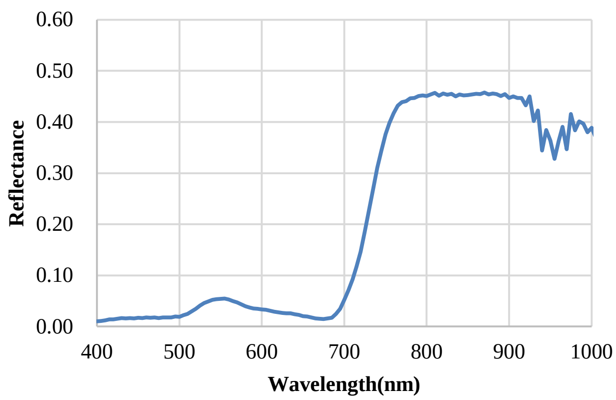


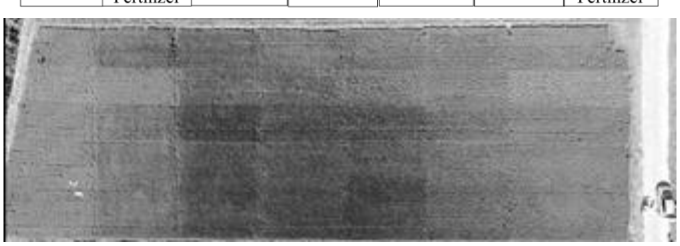
Fig. 4. Example of the Measured Reflectance of the Field No.1 On August 18 2017.

No fertilizer	Slow Release Fertilizer	High Yield Fertilizer	Standard Fertilizer	High Yield Fertilizer	Standard Fertilizer	Slow Release Fertilizer

Field	I	H	G	F	E	D	C	B	A
Ref	0.674	0.699	0.798	0.808	0.745	0.636	0.788	0.733	0.757

(a)Visible Camera Image

No fertilizer	Slow Release Fertilizer	High Yield Fertilizer	Standard Fertilizer	High Yield Fertilizer	Standard Fertilizer	Slow Release Fertilizer



(b)NIR filtered image

Fig. 5. DRONE Derived Reflectance at 800 nm (Aug.28 2017).

Actually, the fields A, B correspond to the field No. 1, the field C correspond to the field No. 2, the field D is corresponding to the field No. 3, the fields E, F are corresponding to the field No. 4, the field G, H, and I correspond to the field No. 5, 6, and 7, respectively.

The spectral reflectance of the field A to I which is measured with the Spectral radiometer is shown in Fig. 6. Then, regressive analysis between the measured protein content and the measured reflectance at 800 nm is carried out. Fig. 7 shows the result from the analysis. R^2 value of the regression is more than 0.6. Therefore, it is possible to estimate protein content in rice crops using the measured reflectance of rice leaves at 800 nm (NIR). That is the same thing for the harvest amount estimation. Fig. 8 shows the results from the regressive analysis between measured harvest amount and the measured reflectance of rice leaves at 800 nm (NIR), R^2 value is not so high though.

Furthermore, SPAD[5] measuring instrument is an instrument that expresses the amount of chlorophyll (chlorophyll) contained in plant leaves as SPAD value (value indicating chlorophyll content) necessary for knowing the health of plants. The chlorophyll meter can be measured instantaneously on the spot without sample collection, and it can be measured even in the rain since it is a muffler specification. Fig.9 shows relation between SPAD measured on August 30 2017 and reflectance at 550 nm on August 28 2017.

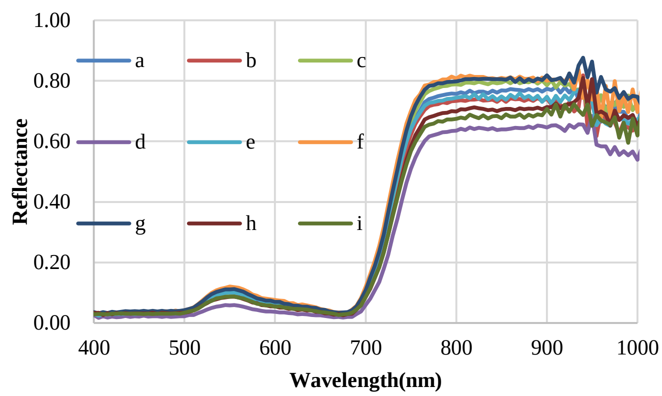


Fig. 6. Measured Reflectance of the Field No.1 on August 28 2017.

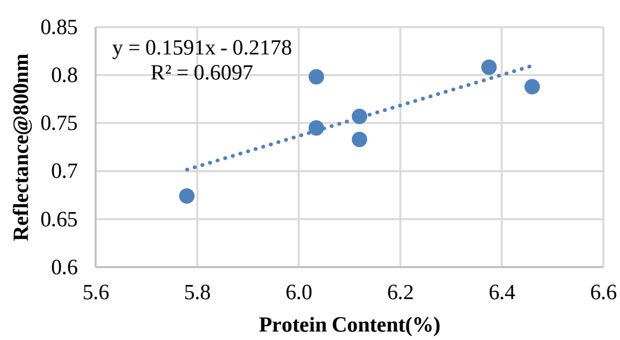


Fig. 7. Relation between Protein Content and Reflectance at 800nm(August 28 2017).

[5]https://www.konicaminolta.jp/instruments/products/color/chlorophyll/index.html

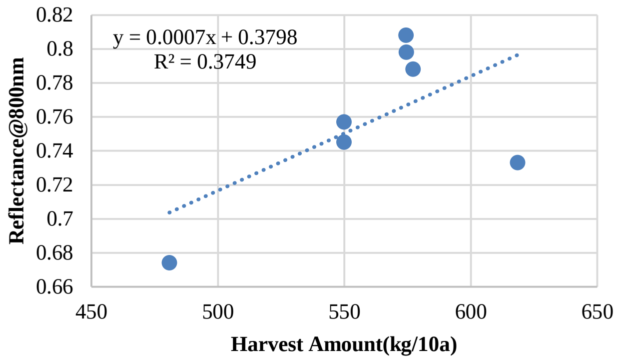


Fig. 8. Relation between Harvest Amount and Reflectance at 800nm(August 28 2017).

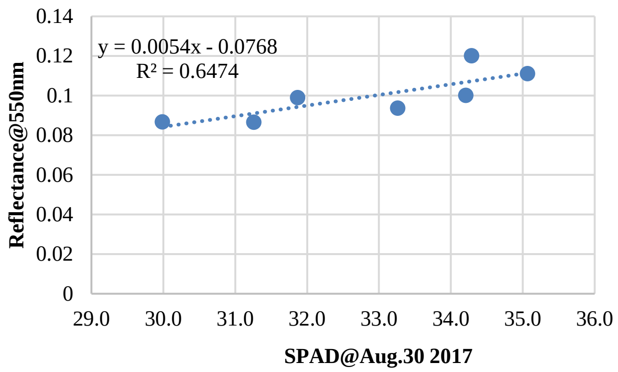
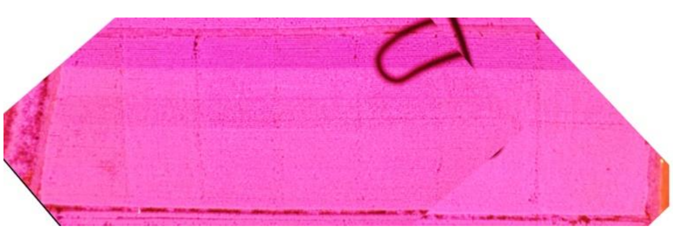


Fig. 9. Relation between SPAD Measured on August 30 2017 and Reflectance at 550 nm on August 28 2017.

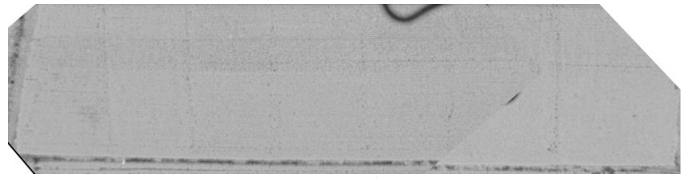
In this test, it was found that the 800 nm wavelength in the near-infrared region may be able to predict protein content and yield. If it can be predicted a little earlier, in early August, it is also possible to control by fertilization Drone based NIR camera data of the field No. 1 to 7 is acquired. NIR image is shown in Fig. 10. from the fields A to K correspond to the field No. 1 to 7. The fields A, B correspond to the field No. 1, the field C correspond to the field No. 2, the fields D, E are corresponding to the field No. 3, the field F is corresponding to the field No. 4, the fields G, H are corresponding to the field No. 5, the field I correspond to the field No. 6, the fields J, K are corresponding to the field No. 7, respectively.

No fertilizer	Slow Release Fertilizer	High Yield Fertilizer	Standard Fertilizer	High Yield Fertilizer	Standard Fertilizer	Slow Release Fertilizer

K	J	I	H	G	F	E	D	C	B	A
0.431	0.418	0.447	0.507	0.554	0.499	0.519	0.506	0.535	0.554	0.570



(a)Acquired NIR image



(b)Estimated reflectance

Fig. 10. Drone derived NIR Image Derived NIR Filter Attached Camera from Acquired on September 19 2017.

The spectral reflectance of the field A to K is shown in Fig. 11.

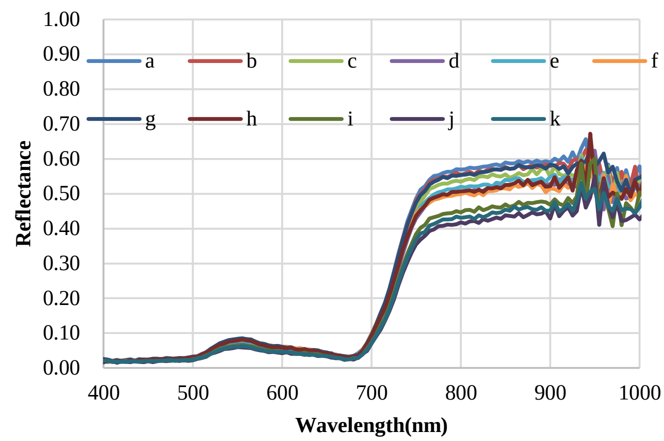


Fig. 11. Measured Reflectance on September 19 2017.

Then, regressive analysis between the measured protein content and the measured reflectance at 800 nm is carried out. Fig. 12 shows the result from the analysis. R^2 value of the regression is more than 0.45. Therefore, it is possible to estimate protein content in rice crops using the measured reflectance of rice leaves at 800 nm (NIR).

That is the same thing for the harvest amount estimation. Fig. 13 shows the results from the regressive analysis between measured harvest amount and the measured reflectance of rice leaves at 800 nm (NIR), R^2 value is not so high though.

Furthermore, Fig. 14 shows relation between SPAD measured on Aug.30 2017 and reflectance at 800 nm on September 19 2017.

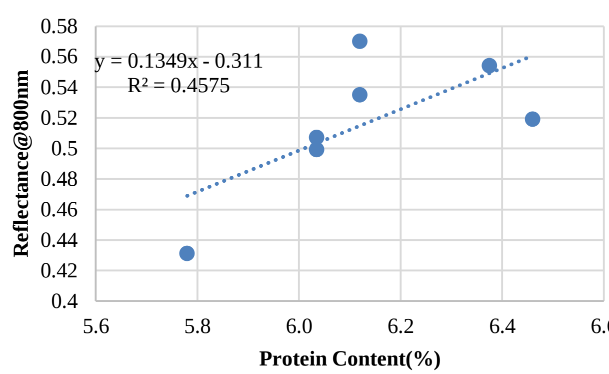


Fig. 12. Relation between Protein Content and Reflectance at 800nm(September 19 2017).

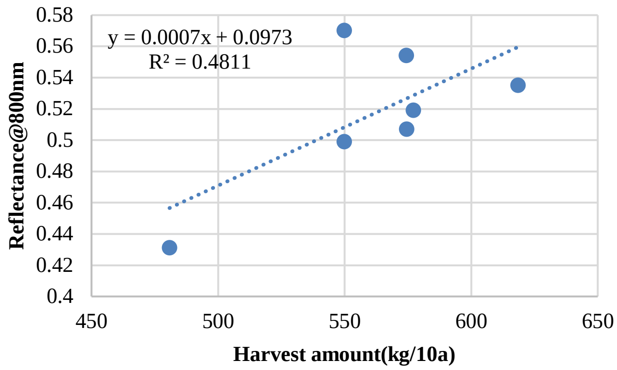


Fig. 13. Relation between Harvest Amount and Reflectance at 800nm(September 19 2017).

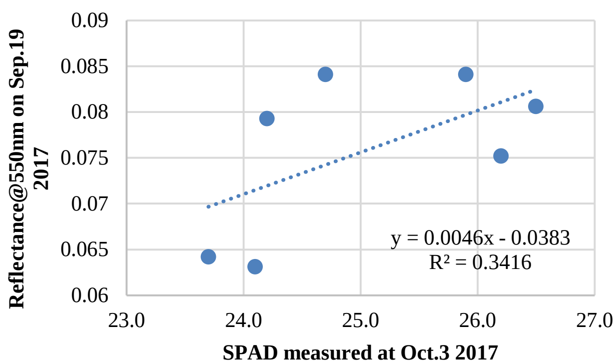


Fig. 14. Relation between SAPD Measured on October 3 2017 and Reflectance at 550nm on September 19 2017.

IV. Conclusion

The proposed Artificial Intelligence: AI based fertilizer control for improvement of rice quality and harvest amount with intelligent drone based rice field monitoring system dose work for increasing harvested rice crop quality and harvest amount with minimizing the required fertilizer. Through experiments at the rice paddy fields which is situated at Saga Prefectural Research Institute of Agriculture: SPRIA in Saga city, Japan, it is found that the proposed system allows control rice crop quality and harvest amount by changing fertilizer type and supply amount. In this test, it was found that the 800 nm wavelength in the near-infrared region may be able to predict protein content and yield. If it can be predicted a little earlier, in early August, it is also possible to control by fertilization.

Also, it is found that SPAD value which indicates chlorophyll concentration (related to rice crop quality) of rice leaves can be estimated with the measured reflectance of rice leaves at 550 nm. Since the relationship between SPAD value and protein content is SPAD value of 8/30, $R^2 = 0.63$ (protein), $R^2 = 0.35$ (yield), so is not it equivalent to 800 nm.

Further research works are required for improvement of the prediction accuracy of rice crop quality and harvest amount. Also, cost performance evaluation is required for fertilizer managements.

Acknowledgment

The author would like to thank Mr. Takashi Higuchi of Saga University for his effort to conduct the experiments.

References

[1] J.T.Compton, Red and photographic infrared linear combinations for monitoring vegetation, Journal of Remote Sensing of Environment, 8, 127-150, 1979.

[2] C.Wiegand, M.Shibayama, and Y.Yamagata, Spectral observation for estimating the growth and yield of rice, Journal of Crop Science, 58, 4, 673-683, 1989.

[3] Kohei Arai, Method for estimation of grow index of tealeaves based on Bi-Directional reflectance function:BRDF measurements with ground based netwrok cameras, International Journal of Applied Science, 2, 2, 52-62, 2011.

[4] Kohei Arai, Wireless sensor network for tea estate monitoring in complementally usage with Earth observation satellite imagery data based on Geographic Information System(GIS), International Journal of Ubiquitous Computing, 1, 2, 12-21, 2011.

[5] Kohei Arai, Method for estimation of total nitrogen and fiber contents in tealeaves with grond based network cameras, International Journal of Applied Science, 2, 2, 21-30, 2011.

[6] Kohei Arai, Method for estimation of damage grade and damaged paddy field areas sue to salt containing sea breeze with typhoon using remote sensing imagery data, International Journal of Applied Science,2,3,84-92, 2011.

[7] Kohei Arai, Monte Carlo ray tracing simulation for bi-directional reflectance distribution function and grow index of tealeaves estimation, International Journal of Research and Reviews on Computer Science, 2, 6, 1313-1318, 2011.

[8] K.Arai, Fractal model based tea tree and tealeaves model for estimation of well opened tealeaf ratio which is useful to determine tealeaf harvesting timing, International Journal of Research and Review on Computer Science, 3, 3, 1628-1632, 2012.

[9] K.Arai, H.Miyazaki, M.Akaishi, Determination of harvesting timing of tealeaves with visible and near infrared cameradata and its application to tea tree vitality assessment, Journal of Japanese Society of Photogrammetry and Remote Sensing, 51, 1, 38-45, 2012

[10] Kohei Arai, Osamu Shigetomi, Yuko Miura, Hideaki Munemoto, Rice crop field monitoring system with radio controlled DRONE based near infrared cameras through nitrogen content estimation and its distribution monitoring, International Journal of Advanced Research in Artificial Intelligence, 2, 3, 26-37, 2013

[11] Kohei Arai, Rice crop quality evaluation method through regressive analysis between nitrogen content and near infrared reflectance of rice leaves measured from near field radio controlled DRONE, International Journal of Advanced Research in Artificial Intelligence, 2, 5, 1-6, 2013.

[12] Kohei Arai, Masanori Sakashita, Osamu Shigetomi, Yuko Miura, Estimation of protein content in rice crop and nitrogen content in rice leaves through regressive analysis with NDVI derived from camera mounted radio-control DRONE, International Journal of Advanced Research in Artificial Intelligence, 3, 3, 7-14, 2014.

[13] Kohei Arai, Masanori Sakashita, Osamu Shigetomi, Yuko Miura, Relation between rice crop quality (protein content) and fertilizer amount as well as rice stump density derived from DRONE data, International Journal of Advanced Research on Artificial Intelligence, 4, 7, 29-34, 2015.

[14] Kohei Arai, Masanori Sakashita, Osamu Shigetomi, Yuko Miura, Estimation of Rice Crop Quality and Harvest Amount from DRONE Mounted NIR Camera Data and Remote Sensing Satellite Data, International Journal of Advanced Research on Artificial Intelligence, 4, 10, 16-22, 2015.

[15] Kohei Arai, Gondoh, Miura, Shigetomi, Effect of Stump density, Fertilizer on Rice Crop Quality and Harvest Amount in 2015 Investigated with DRONE mounted NIR Camera Data, International journal of Engineering Science and research Technology, 2, 2, 1-7, 2016

[16] Kohei Arai, Kenji Gondoh, Osamu Shigetomi, Yuko Miura, Method for NIR Reflectance Estimation with Visible Camera Data Bsed on

Regression for NDVI Estimation and Its Application for Insect Damage Detection of Rice Paddy Fields, International Journal of Advanced Research on Artificial Intelligence, 5, 11, 17-22, 2016.

AUTHOR'S PROFILE

Kohei Aarai He received BS, MS and PhD degrees in 1972, 1974 and 1982, respectively. He was with The Institute for Industrial Science and Technology of the University of Tokyo from April 1974 to December 1978 and also was with National Space Development Agency of Japan from January, 1979 to March, 1990. During from 1985 to 1987, he was with Canada Centre for Remote Sensing as a Post Doctoral Fellow of National Science and Engineering Research Council of Canada. He moved to Saga University as a Professor in Department of Information Science on April 1990. He was a councilor for the Aeronautics and Space related to the Technology Committee of the Ministry of Science and Technology during from 1998 to 2000. He was a councilor of Saga University for 2002 and 2003. He also was an executive councilor for the Remote Sensing Society of Japan for 2003 to 2005. He is an Adjunct Professor of University of Arizona, USA since 1998. He also is Vice Chairman of the Commission-A of ICSU/COSPAR since 2008. He wrote 30 books and published 500 journal papers.

Determination of Weighting Assessment on DREAD Model using Profile Matching

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***Abstract*—*Web* application creators often get lack of understanding of security threats that can occur in applications that are made, while security threats can create new problems that are more complex. These security threats will pose risks and can even result in large losses. Determining the risk ratings on a *web* application software development team is still experiencing problem or debate. The problem which occurs is that not all of the team members agree on the risk rating assessment process. This problem is caused by the differences in opinions and assumptions of the team members about threats and the fact that the assessor has different types of expertise, DREAD model places each expert in the same position. It means that there are no differences in weight at the time of assessment. DREAD stands for five aspects which are related to security threats in *web* applications. They are D (*Potential Damage*), R (*Reproducibility*), E (*Exploitability*), A (*Affected User*), and D (*Discoverability*). The proposal gives weight to the assessor by using profile matching method to produce an assessment involving assessors with different types of expertise, weighting on each assessor is according to their relevance to the assessed aspects, and rating on the type of expertise is according to the aspects assessed for the DREAD model. The result of the study shows that the proposed method can produce the weight closeness of the assessment to the target.**

Keywords*—*DREAD; risk; assessment; profile matching

I. Introduction

The application which is used by agencies and companies is currently experiencing rapid progress. Applications by using the *web* are developed from small to large companies. At present, almost all agencies/companies use *web* technology to complete the work's needs. Web technology can be developed according to user needs and become more modern at a lower cost to make it more efficient. The development of *web* technology can overcome various problems such as interoperability problems, it also can be used in several different platforms, and can connect multiple databases with different DBMS. Although *web* application is so important, *web* applications also have a risk to security threats [1].

Web application makers often get lack understanding of security threats that can occur in the application that is made, while security threats can create new problems that are more complex. Security threats that can be categorized as input validation, authorization, authentication, cryptography, exception management, configuration management, session management, sensitive data, parameter manipulation, audit, and logging. These security threats will pose risks and can cause many problems, and can even lead to large losses. In identifying the risks, there are several factors needed to consider, such as the extent to which these risks are exploited and how much damage will occur. [2]

The determination of risk ratings on a web application software development team is still experiencing problems or debates. The problem that occurs is that the team members do not all agree on the risk rating assessment process. This problem is caused by the fact that team members have different opinions and assumptions about threats [3]. These problems are in line with [4] the similarity of the experts which can be used in group decision making that can provide comprehensive information from all experts who have different and subjective.opinion.

Weighting is part of the way for decision making in a process to produce alternative decisions through assessment of parameters, criteria, and scoring [5]. Weights can be given to attributes such as parameters, criteria, experts or decision-making actors [6]. The weighting process can be done in 2 (two) ways. They are the process of weighting directly and indirectly. Direct weighting gives direct weight or percentage value based on knowledge about the importance of parameters and criteria used. Meanwhile, indirect weighting generally uses analytical methods with computation to produce weight values [7].

Based on the results of a preliminary study, it is known that the application of the DREAD model still has weaknesses. The DREAD model can be applied to assessments by several assessors with the same or different types of expertise. The problem is that in the event which the assessor has a different type of expertise, DREAD model places each expert in the same position, and it means that there is no difference on weight at the time of assessment weighting. The weighting model proposed in this study uses *profile matching* to get ranking from the assessor.

II. DREAD Model

DREAD model is a model which is developed by Microsoft, and it is used to calculate risk and generate risk ranking information for a threat that occurs. DREAD stands for five aspects related to security threats in web applications, namely D (*Damage Potential*), R (*Reproducibility*), E (*Exploitability*), A (*Affected User*), and D (*Discoverability*).

Some points that need to be considered which are related to the extension of DREAD and asking the following questions are such as [3]:

1) Damage potential: How great is the damage if the vulnerability is exploited?

2) Reproducibility: How easy is it to reproduce the attack?

3) Exploitability: How easy is it to launch an attack?

4) Affected users: As a rough percentage, how many users are affected?

5) Discoverability: How easy is it to find the vulnerability?

Determination of the level of risk in the DREAD model can be calculated by the formula:

$$Risk\_Level = \frac{(D + R + E + A + D)}{5}$$

Therefore, the value of D, R, E, A, and D is maximum three the level of threat using the rating, can be seen in TABLE I.

TABLE I. RATING OF RISK ASSESSMENT

No	Range Assessment	Rating	Risk Description
1	5 to 7	3	Low
2	8 to 11	2	Medium
3	12 to 15	1	High

Source: *Improving Web Application Security* [3]

Generally, the DREAD model consists of three important stages, and they are such as identification of threats, documentation of threats, and determination of threat levels [3].

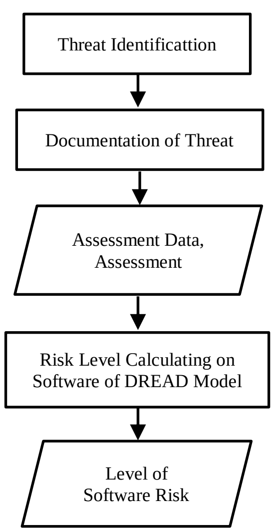


Fig. 1. DREAD model [3]

The examples of applying DREAD model is carried out by [1] in GWIS (*Geospatial Weather Information System*) system. The DREAD model has also been developed and implemented into a fuzzy concept for risk rating determination, namely by transforming ordinal ranks on several security parameters into numerical value ratings [8].

III. PROFILE MATCHING

Profile Matching is a decision-making mechanism to assume that there is an ideal level of predictor variables that must be done by parameters, not in static criteria [9]. In the profile matching process, the outline of the process of comparing individual competencies into aspects that can be known for differences in competencies is called gap [10] [11]. The smaller of the gap produces a large value weight, and it means that it will get a better chance to occupy the top position. In analyzing the data according to specific targets included; the method of matching profiles performs the method, in which the process is first to determine the competencies needed by the data. In a profile matching process, it describes the process of comparison between individual competencies and aspects that can be identified for both differences.

Profile Matching algorithm is divided into several steps:

- Weighting Aspects and Sub Aspects
- Determine the goal
- Weighting the gap
- Rating using the weight of aspect and score of the gap

A gap is a difference between the aspect value and the target value. Gaps can be obtained by doing this formula.

$$\text{Gap= Aspect Value} - \text{Target Value} \quad (1)$$

Scoring the gap = to score the gap, so that gap = 0 will weight 3, a maximum gap will have a score of 1.

IV. RESEARCH METHODOLOGY

This study takes a sample in one of the Universities in Samarinda, East Kalimantan. The steps in the study are such as:

1) Identify how many assessors who conduct assessments (n = number of assessors)

2) Identifying the type of expertise

3) Collection of assessment data based on expert/assessor analysis. The data used is academic management data in each university that is sampled with adjusted rules with ten threat categories.

4) Determining the weight of each assessor by using the stages of the profile matching method.

5) The next stage is analysis according to data obtained from experts/assessors and obtained data comparison between one expert and another expert based on established rules.

V. Proposed Determination of Assessment

In this study, the assessment is developed from the DREAD model, so that each assessor with different types of expertise will get an assessment weight that is adjusted to the aspect which is assessed. In the developed model, the assessor with the most relevant type of expertise with the aspect assessed will be given the highest weight. Otherwise, the assessor with the type of expertise that is least relevant to the aspect evaluated will be given the lowest weight. Meanwhile, the assessor with other kinds of knowledge is given appropriate weights on the level of relevance to the assessed aspect. The aspects assessed in the DREAD model which is developed include ten categories in which each category consists of predetermined variables, as a whole as many as 37 variables. For each variable is given in the form of rating categories such as high, medium, or low.

The proposal for determining the weight of each assessor which is carried out in the research is described in the form of these following categories, such as:

1) The same weight of assessor is formulated:

$$Wi = {}^{1}/_{n} \quad (4)$$

Description:

Wi = The weight of assessor -i, in which i= 1,2,.., n

n = number of assessors

2) Different weight of assessor is formulated:

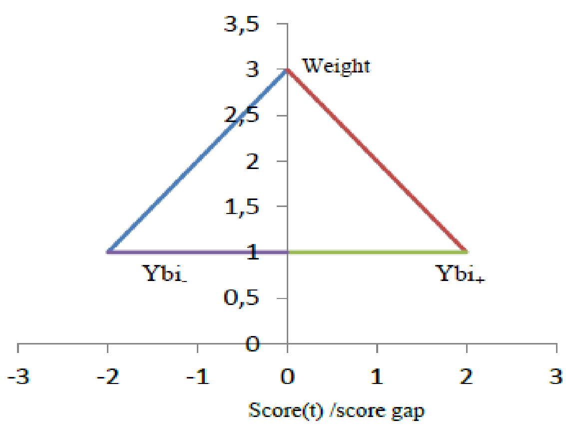
$$Wi = W_i' \quad (5)$$

Description:

Wi = The weight of assessor -i, in which i= 1,2,.., n

$W_1', W_2', W_3', \dots, W_n'$ = Weight of 1,2,3,.., n

Gap assessment can be calculated by using the formula below with the formula of graph 1.



Graph 1. Determination of weight

Determining the score (t) at min x <= t <=0 is determined by the formula:

$$score(t) = \frac{(t - \min x)}{(-(\min x))}.(Ymaks - Ybi_-) + Ybi_- \quad (6)$$

While, the determination of the score (t) at 0 <= t <= max x can be formulated as:

$$score(t) = \frac{(t)}{(max\ x)}.(Ybi_+ - Ymaks) + Ymaks \quad (7)$$

Description:

score (t) = weight/ score

t = value at gap / difference

min x = the smallest value in the gap (negative / x negative difference)

max x = the biggest value on the gap (positive / x positive difference)

Ymaks = the highest value on the assessment score

Ybi_+ = lower limit Y on t positive

Ybi_- = lower limit Y at t negative

Each assessor (Ni) calculated the number of DREAD which is calculated in the form of:

$$DTot_i = D_i + R_i + E_i + A_i + D_i \quad (8)$$

Description:

$DTot_i$ = Sum of DREAD with index i and i= 1,2,.., n

D_i, R_i, E_i, A_i, D_i = the value on D,R,E,A,D with index i and i= 1,2,3,.., n

The score of each assessor is divided into 2 (two), such as:

3) Scores with the same weight are formulated:

$$WSi = \frac{1}{n}.DTot_i \quad (9)$$

Description:

WS_i = score with the same weight from each assessor

4) Scores with the different weight are formulated:

$$WDi = W_i'.DTot_i \quad (10)$$

Description:

WD_i = Scores with different weights are formulated

VI. Result and Discussion

The results of the study are presented continually in TABLE II to TABLE V as follows:

TABLE II. The Expert who Assessed

No	Code	Expertise
1	P1	Networking
2	P2	Hardware
3	P3	Programmer
4	P4	Database
5	P5	Database

In this study, the assessors or experts who assessed are 5 people. The experts who assess the academic information system are according to their respective expertise. Appraisal expertise can be seen in TABLE II which is consisting of experts given P1 to P5 codes. In this study, two experts are the same in code P4 and P5, and they are experts in the field of the database. The similarity of some assessment expertise proves that the assessment of the academic information system in determining the expert as an assessor is objective, and in which it means that the number of experts obtained can be an assessor in this study.

Based on expert judgment, a calculation with the profile matching method obtained results from the weight of each expert which is presented in TABLE III.

TABLE III. EXPERT WEIGHTS BASED ON CATEGORY

No	Category	Expert				
		P1	P2	P3	P4	P5
1	Input validation	21.3%	19.1%	23.4%	19.1%	17.0%
2	Authentication	19.4%	17.7%	19.4%	21.0%	22.6%
3	Authorization	22.9%	20.8%	16.7%	18.8%	20.8%
4	Configuration management	25.5%	19.1%	21.3%	14.9%	19.1%
5	Sensitive data	20.6%	14.7%	17.6%	20.6%	26.5%
6	Session management	18.5%	21.5%	24.6%	18.5%	16.9%
7	Cryptography	21.9%	18.8%	15.6%	25.0%	18.8%
8	Parameter manipulation	22.7%	13.6%	22.7%	22.7%	18.2%
9	Exception management	21.6%	18.9%	16.2%	18.9%	24.3%
10	Auditing and logging	21.1%	15.8%	21.1%	26.3%	15.8%

Based on TABLE III, it can be explained that the highest weight of proximity between each category varies in each expert. The highest weight obtained in all categories in each expert in the range of 22% to 26%, while the lowest weight in the range of 13% to 17%. The highest expert weight of each category is presented in TABLE IV:

TABLE IV. THE HIGHEST EXPERT WEIGHT OF EACH CATEGORY

No	Category	Expert	Weight
1	Input validation	P3	23.4%
2	Authentication	P5	22.6%
3	Authorization	P1	22.9%
4	Configuration management	P1	25.5%
5	Sensitive data	P5	26.5%
6	Session management	P3	24.6%
7	Cryptography	P4	25.0%
8	Parameter manipulation	P1, P3, P4	22.7%
9	Exception management	P5	24.3%
10	Auditing and logging	P4	26.3%

From TABLE IV, it can be concluded that the highest weight of the expert judgment on the sequential target is such as: in the input validation category, the highest weight is located in the programming, database authentication, network expert authorization, network expert configuration management, sensitive database expert, session management programming expert, cryptography database expert. On the parameters, the highest manipulation weight is owned by network experts, programmers and it means that the closeness of the assessment of 3 experts on the target has the same weight value of 22.7%, for the highest category of exception management weight in database experts while in the Auditing and logging category lies in the database expert.

The expert weight which is obtained in each category in TABLE III is used in the calculation into the DREAD model. The calculation result that is according to the expert weights obtained result which is presented in TABLE V:

TABLE V. THE RESULT OF DREAD VALUE ACCORDING TO EXPERT WEIGHT

No	Category	Dp	R	E	A	D	SUM	Level Risk
1	Input validation	2.55	2.36	2.62	2.23	2.43	12.19	High
2	Authentication	2.23	2.58	3.00	2.58	1.63	12.02	High
3	Authorization	1.83	2.60	2.25	1.88	2.38	10.94	Medium
4	Configuration management	1.66	2.02	2.02	1.85	2.11	9.66	Medium
5	Sensitive data	2.00	2.41	2.62	2.59	2.82	12.44	High
6	Session management	2.29	2.40	2.00	2.40	1.58	10.68	Medium
7	Cryptography	1.75	1.75	2.59	1.84	1.56	9.50	Medium
8	Parameter manipulation	1.36	1.36	1.64	2.05	2.00	8.41	Medium
9	Exception management	2.43	2.41	1.65	2.00	2.57	11.05	High
10	Auditing and logging	1.68	2.47	1.16	2.00	2.16	9.47	Medium
						Avg	10.64	Medium

From TABLE V, it can be explained that high risk lies in the category of input validation, authentication, sensitive data and exception management with successive values of 12.19, 12.02, 12.44 and 11.05 while for other categories the level of risk is in the medium category. For the average value of all categories in the assessment of web applications or software, this is 10.64 including moderate risk.

VII. CONCLUSION

Based on the result of the trials which have been done, the highest rank in each category can be occupied by more than one expert, this indicated that the proximity of the expert judgment to the target is equal. Profile matching method can be used as an alternative to finding out the weight of the assessor in the assessment of DREAD model.

Meanwhile, the DREAD value after being calculated with the appraisal weight to reach the highest value or high risk contained in the input validation category with a value of 12.19, authentication with a value of 12.02, sensitive data with a value of 12.44 and exception management with a value of 11.05. For the overall assessment with the DREAD model is known that web applications or software are in moderate risk with a value of 10.58. so it can be said that the application that is applied can still be used with the main priority of improvement or full attention in the category of input validation, authentication, sensitive data, exception management.

ACKNOWLEDGMENTS

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REFERENCES

[1] K. R. Mohan Rao, and D. Pant, 2010, "A threat risk modeling framework for Geospatial Weather Information System (GWIS): a DREAD based study," (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 1, No. 3, September 2010

[2] D. Suprihanto and R. Wardoyo, 2017, "Analysis of Computational Time on DREAD Model", International Journal of Computer Engineering In Research Trends, Volume 4, Issue 2, pp. 53-56.

[3] J.D Meier, A. Mackman, S. Vasireddy, M. Dunner, S. Escamilla, and A. Murukan, "Improving Web Application Security: Threats and Countermeasures," Microsoft Corporation. 2003.

[4] W. Lu, C. Liang, and Y. Ding, "Experts Based on Evidence Similarity in Group Decision-making," in 4th International Conference on Wireless Communications, Networking and Mobile Computing, pp.1–4, 2008.

[5] R.R. Yager, "Uncertainty modeling and decision support," *Reliability Engineering & System Safety*, 85(1-3), pp.341–354, 2004.

[6] L. Garc, "Weighting Individual Opinions in Group Decision Making," pp.92–103, 2007.

[7] Z. Wang, "An Adjustment Method of Experts Weights in Group Decision," pp.1–5, 2010.

[8] A.A Singh and K.S Singh, "Network Threat Ratings in Conventional DREAD Model Using Fuzzy Logic," IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 1, No 3, January 2012 ISSN (Online): 1694-0814

[9] Z. Tharo, and A.P.U Siahaan, "Profile Matching in Solving Rank Problem," *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE).Volume 11, Issue 5, Ver. I (Sep.-Oct .2016), PP 73-76, e-ISSN: 2278-2834,p- ISSN: 2278-8735*

[10] D. J. Power, "Evaluation: From Precision, Recall and F-Measure to ROC, Informedness, Markedness & Correlation," Journal of Machine Learning Technologies, pp. 37-63, 2011.

[11] E. Turban, "Decision Support Systems and Intelligent Systems," New Jersey: Pearson Education, 2005.

Dynamic Weight Dropping Policy to Improve High-Priority Message Delivery Delay in Vehicular Delay-Tolerant Network

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***Abstract*—Vehicular Delay-Tolerant Network (VDTN) is a special case of Delay-Tolerant Network (DTN) in which connectivity is provided by movement of vehicles with traffic prioritization to meet the requirements of different applications. Due to high node mobility, short contact time, intermittent connectivity, VDTNs use multi-copy routing protocols to increase message delivery rates and reduce the delay. However due to limited resources (bandwidth and storage capacity), these protocols cause the rapid buffer overflow and therefore the degradation of overall network performance. In this paper, we propose a buffer drop policy based on message weight by including traffic prioritization to improve the high priority messages delivery delay. Thus, the memory is subdivided into a high-weight queue and a low-weight queue. When the buffer is overflowing, and a new message arrives, the algorithm determines the message to be dropped in the queues considering that the current node is the destination of the message, the position of the current node with respect to the destination of the message and the age of the messages in the network.**

Keywords—Vehicular delay-tolerant network; dropping policies; traffic differentiation; message weight; high priority message

I. Introduction

Delay-Tolerant Network (DTN) is an environment characterized by intermittent connection, long or variable delays, asymmetric data rates, and high message loss rates [1, 2].

The Vehicular Delay-Tolerant Network (VDTN) is a special case of DTN in which connectivity is provided by nodes (vehicles) with high mobility. The combination of this high mobility and the finite bandwidth, energy constraints and short radio transmission range, causes the short contact duration and intermittent connectivity [3,4]. As a result, to solve the intermittent connectivity problem, vehicles in the VDTN, like the DTN, use the Store-Cary-and-Forward (SCF) mechanism. In addition, to increase delivery rate and reduce delay, VDTNs use multi-copy routing protocols [5-8] that replicate messages across all nodes in the network. However, when the environment is heavily constrained in terms of resources, these excessive replications cause rapid buffer congestion those results in the degradation of overall network performance. Therefore it is important to design buffer scheduling and abort strategies in the VDTN.

VDTNs are used in several areas such as road safety, road traffic management, commercial information dissemination, rural connectivity and as communication media for disaster areas [3,4]. As a result, in order to support different applications with different requirements in terms of delivery probability and delivery time, the algorithms take into account three traffic priority classes: low priority for bulk messages, the average priority is normal messages and high priority for expedited messages. However, in order to avoid the resources monopolization by high priority messages at the expense of lower priority messages and to improve the delivery rate of these messages, buffer management strategies propose a message weight metric that does not take into account the priority class of service (CoS) required for VDTN. Therefore, all messages have the same delivery time while the high priority message requires a low delivery delay. As a result, it is necessary to improve the high priority messages delivery delay.

Thus, in this article, we propose a buffer management strategy based on the messages weight in the buffer which not only increases the messages delivery rate whatever the priority of the message but reduces the high priority messages delivery delay. In addition, we use the PRoPHET [8] routing protocol in this study.

The rest of the article is thus organized. Section 2 presents the related work. Section 3 presents the PRoPHET routing protocol. The buffer management strategy is described in Section 4. Section 5 presents the discussion. The conclusion and perspectives are presented in Section 6.

II. Related Work

As mentioned above, dropping and scheduling buffer policies are needed to increase the delivery rate, reduce delivery delay, and reduce network overhead. In this section, we present work related to the proposed management policy.

Soares and al [9] propose a buffer management system that classifies the messages into three separate queues of high priority, medium priority and low priority messages in order to consider the priority of the service classes. When the buffer becomes congested, the abort strategy removes the low time-to-live (TTL) message from the priority class corresponding to the priority of the incoming message. In addition, the scheduling strategy is based on Custom Service Time (CST), which assigns messages from each priority class based on a fixed percentage of custom time. This strategy avoids the monopolization of resources by high priority messages. However, it reduces the delivery rate of high priority messages.

Penurkar M. R. et al [10], propose a message dropping algorithm based on the message TTL and the messages priority. During this drop policy, the general messages with low-priority are first deleted according to their TTL increasing until TTL threshold. If this space created by deleting these messages is insufficient, then the traffic messages with middle-priority are in turn deleted from their increasing TTL to the TTL threshold. This policy repeats until the high-priority accident message can be inserted into the buffer. This policy despite the fact that it removes old messages of lower priority to reduce the delay and increase the rate of delivery there may be a network overhead caused by the increasing number of old high-priority messages.

More R. A. and Penurkar M. R [11] propose a scheduling policy that transfers messages from priority classes according to the round-robin strategy. In addition, during the drop policy, the low TTL message is first dropped. However, when two messages have the same TTL value, the lower priority message is first dropped. This policy reduces network overhead by removing low TTL messages.

Sadreddini Z. and Afshord in [12], propose General Purpose Buffer Management (GPBM) based on a Multi Criteria Decision Making (MCDM). Thus, to insert a high priority message into a congested buffer, the weighted sum model is used to drop the highest score message. This strategy increases the delivery rate and reduces the delay. However, the determination of the weight of the criteria is not indicated.

The authors in [13] proposed a buffer management policy called WBD (Weight Based Drop Policy) based on local network information. In this article, the message weight is calculated based on the properties of the message, which are its remaining TTL, size, buffer duration, number of hops, and number of replications. The policy divides messages in the node into a high-weight queue and a low-weight queue according to the message weight in the node. When buffer overflows happen, the policy drops the messages in the high-weight queue to receive the new message. If after dropping all messages in the high-weight queue the new message can't be inserted, then the new message will be ignored in case the current node is not the destination of the message. However, if the current node is the destination of the message, then the messages of the low-weight queue are dropped according to their increasing TTL until the new message is inserted. This strategy has advantages that include protecting recent network messages in the low-weight queue, reducing network overhead by deleting messages in the high-weight queue. However, this strategy does not take into account the hierarchy of the messages on the one hand and on the other hand new messages are ignored despite the fact that they can be inserted in the node by deleting messages from the low weight queue.

Wang H. et al [14] propose a buffer management system called NWBBMP (Novel Weight-Based Buffer Management Policy) that divides messages in the buffer into a queue of priority messages consists of recent messages in the buffer that can't be dropped, a low-weight queue and a high-weight queue. In addition, the system combines the Weight Based Drop Policy (WBD) [13] and OBM (Optimal Buffer Management) policies [15] to drop messages from the high-weight queue and messages from the low-weight queue on whether or not the current node is the message destination to improve network performance. This strategy based on the global information of the network whose acquisition is difficult. However, it has advantages that include protecting recent messages in the buffer, reducing delay, reducing network overhead, and increasing the delivery rate. However, this strategy does not take into account the hierarchy of messages.

Based on the analysis of the strategies above, combining the benefits and making improvements, we propose a new buffer management system. This system is based on the local network information and takes into account the priority class of the message. In the next section, we present the PRoPHET routing protocol used in this study.

III. PROPHET ROUTING PROTOCOL

PRoPHET (Probabilistic Routing Protocol using History of Encounters and Transitivity) [8] is a probabilistic routing protocol that uses the node's encounter history and transitivity to determine the best relay node by calculating the delivery predictability of the message, *P (a, b)*, where *a* is the node carrying the message and *b* is the destination. From the frequent node encounters, the node calculates the probability of delivery based on a high probability of meeting again in the future. The delivery probability is given by equation (1).

$$P_{(a,b)} = P_{(a,b)old} + (1 - P_{(a,b)old}) \times P_{init} \tag{1}$$

Where $P_{(a, b)}$ is the encounter probability of the nodes a and b, $P_{(a, b)old}$ is the old probability and P_{int} is the initial probability.

In addition, PRoPHET uses aging that describes the fact that a node with a large time interval of encounters should not be encountered in the future.

As a result, this reduces the probability value as a function of the time interval and the aging constant. The aging constant γ determines the reduction ratio and is represented as in equation (2).

$$P_{(a,b)} = P_{(a,b)old} \times \gamma^{k} \tag{2}$$

Where k represents the number of time slots between the nodes encountered.

In addition, PRoPHET uses the transitivity which describes the fact that the node C is the best destination of the node A if the node A has frequently met the node B and the node B has frequently met the node C. This transitivity is described by the equation 3.

$$P_{(a,c)} = P_{(a,c)old} + (1 - P_{(a,c)old}) \times P_{(a,b)} \times P_{(b,c)} \times \beta \qquad (3)$$

Where β is the transitivity factor used to bound the probability between three nodes A, B and C.

In general, PROPHET routing considering tradeoffs between its performance in terms of delivery ratio, delay, and node resource limitations in terms of energy and storage.

The following section presents the proposed buffer management policy.

IV. Proposed Buffer Management Policy

This section first introduces the preliminaries used to develop our buffer management strategy, then the distribution of messages in the queues and finally the details of the proposed policy.

A. *Preliminaries*

VDTN is a network characterized by a high mobility of vehicles. This high mobility results in short contact times, intermittent connectivity, and frequent changes in the topology of the vehicular network. Therefore, the vehicle mobility model has a direct impact on the message transmission opportunities and the vehicles inter-contact time of the vehicles.

In this paper, we assume that the number of vehicles follows a Poisson distribution of parameter λ [16]. Thus the inter-contact time follows an exponential distribution of parameter λ with λ = 1/E[X] where E[X] is the average encounter time. In addition, we assume that message transmission occurs when the vehicles are within communication range of each other and all vehicles have the same limited size of the buffer.

In this study, we assume that an incoming high priority message is recent in the network than another message in the low-weight queue if the sum of its hop count and its number of replications is less than the sum of the hop count and the number of replications of the new high priority message given by (4).

$$Hc_M + Rc_M < Hc_i + Rc_i \qquad (4)$$

Where Hc_M and Rc_M are respectively the hop count and replication numbers of the incoming high priority message. And Hc_i and Rc_i are respectively the numbers of hops and replications of a message in the low-weight queue.

Furthermore, in this study, in addition to the predictability of delivery given by PRoPHET, we use the position and direction of a node given in [17].

Let $\overrightarrow{V_M}$, the velocity vector of a node M moving or not towards the destination D. The angle θ given by the equation (5) allows to determine if M moves or not towards the destination D.

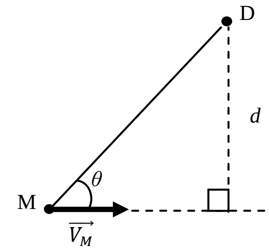

Fig. 1. Moving a Node.

$$\theta = \cos^{-1}\left(\frac{\overrightarrow{MD} \times \vec{V}_M}{\left|\overrightarrow{MD}\right| \times \left|\overrightarrow{V_M}\right|}\right) \qquad (5)$$

Thus, when the angle $\theta < 90°$, the node moves to the destination. And the expected minimum distance d_{min} is given by equation (6).

$$d_{\min} = \min\{d(M;D)\} = \sin\theta \times \left|\overrightarrow{MD}\right| \qquad (6)$$

Fig. 1 below illustrates the displacement of a node relative to the destination.

In our study, among the multitude of candidate neighbor nodes, the node with the highest predictability of delivery and located at a distance less than or equal to the minimum distance to the destination is defined as the node closest to the destination.

In other words, a node A which has the greater delivery predictability with respect to another node B is far from the destination if its distance to the destination is greater than the minimum distance. The following equations give the greater delivery predictability and position of the node relative to the destination. Thus, we have:

$$P(A;D) > P(B;D) \qquad (7)$$

The node is far from the destination if

$$d(A;D) > d_{\min} \qquad (8)$$

The node is close to the destination if

$$d(A;D) \le d_{\min} \qquad (9)$$

B. *Messages Classification in Queues*

As in the literature [13], this paper admits in each node the division of the messages in the buffer into a low-weight queue and a high-weight queue as shown in fig. 2.

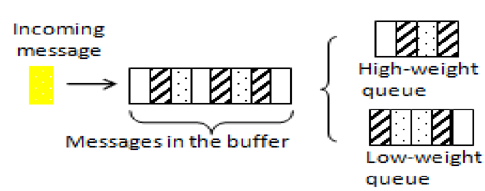

Fig. 2. Buffer Architecture.

The low-weight queue and the high-weight queue are defined according to [14]. Thus, if the message weight is greater than the average message weight in the buffer, then this message is placed in the high-weight queue. Otherwise, this message is placed in the low-weight queue. The message weight is given by equation (10).

$$\omega_i = Hc_i + Rc_i + \frac{1}{T_i} + \frac{1}{S_i} + \frac{1}{TTL_i} + \frac{1}{P_i} \tag{10}$$

Where Hc_i is hop count, Rc_i is the replication count, T_i is the message buffer time, S_i is the size, TTL_i is the remaining TTL and P_i is the message priority.

The average messages weight in the buffer is given by equation (11).

$$\bar{\omega}_M = \frac{1}{n(t)} \sum_{i=1}^{n(t)} \omega_i \tag{11}$$

Where $n(t)$ is the amount of all messages in the buffer at time t.

C. Operation of the Propose Drop Policy

In this model, we first check if the size of the free space (FS) is larger than the size of the new message. Thus, if this is the case, then the new message is inserted according to its weight in the corresponding queue if the current node is or is not the destination of the message.

Moreover, if the FS is insufficient, then the drop policy is applied taking into account that the current node is an intermediate node or is the destination of the message. In addition, when the current node is an intermediate node, the drop policy is applied taking into account the priority of the incoming message and the position of the current node with respect to the destination.

Thus, if the current node is the destination of the message, and if the sum of the size of the FS and the space occupied by the messages of the high-weight queue (HWQ) is greater than the size of the incoming message, then the messages of the HWQ are deleted according to their decreasing weight. And the new message is inserted. However, if two HWQ messages have the same weight, then the lower priority message is dropped first. However, if this sum is smaller than the size of the incoming message, then the messages of the low-weight queue (LWQ) are dropped according to the decreasing TTL (TTL Time-To-Live) until the new message is inserted. However, if two LWQ messages have the same TTL, then the lower priority message is dropped first.

On the other hand, if the current node is an intermediate node that is not closest to the destination, and if the sum of the size of the FS and the space occupied by the HWQ messages is greater than the incoming message size, then the HWQ messages are dropped according to the decreasing weight. However, if this sum is less than the size of the incoming high-priority message, and the high-priority message is recent than the LWQ message, then the LWQ message must be dropped. And insert the high- priority message. However, in each case, if two messages have the same value of the characteristic, then the lower priority message is first dropped. The Flow chart of the proposed policy is illustrated in Fig. 3.

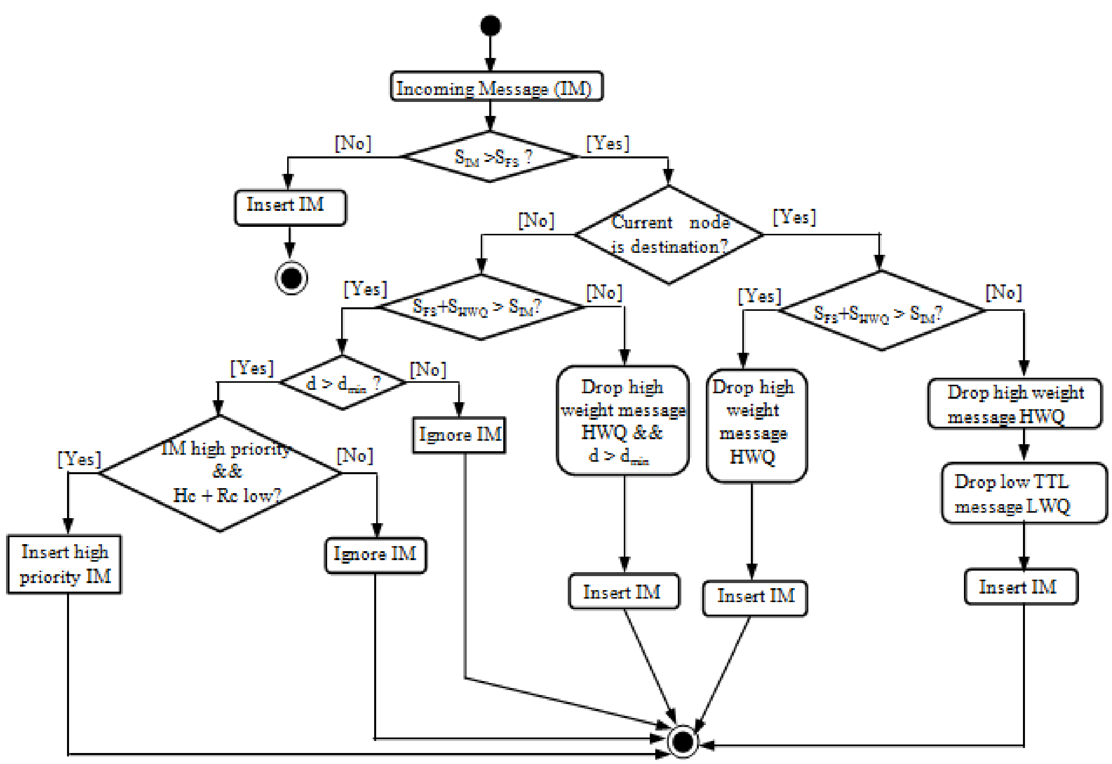

Fig. 3. The Flow Chart of the Proposed Policy.

V. Discussion

The dissemination of high priority messages in the VDTNs is generally done using the size of the message, its time-to-live, its priority or its number of forwarding. In our case, we are interested in reducing the delay of delivery of high priority message taking into account the local information of the network grouped in the expression of the message weight, the position of the current node and using Prophet routing protocol.

A message of high priority has its size which is between 750KB and 1, 5MB on the one hand and on the other hand the value of the priority P = 3. A medium priority message has its size between 250KB and 750KB on the one hand and on the other hand the priority value is P = 2. A low priority message has a size between 100 KB and 250 KB on the one hand and on the other hand the priority value is P = 1. [12]

Assuming the values the values of hop count, the replication count, the message buffer time and the time-to-live present in the weight expression are identical for each of the priority classes, then the high priority message has the smallest weight value. Therefore, the high priority message is first forwarded. Thus, its delivery delay is lower than that of the lower priorities.

In addition, the model favors the insertion of a higher priority message that is newer than the messages of the low-weight queue when the current node is not the destination of the message in order to increase not only the rate delivery but also to reduce the delivery delay of the high priority message with respect to the lower priority messages.

Moreover, if the different strategies do not take into account the position of the current node with respect to the destination, any message whose node will be close to the destination can be dropped. Therefore, this will cause an increase in the delivery delay of the messages and in particular the high priority message.

However, in our model, when the current node is an intermediate node, and deciding to delete a message in this node that is far from the destination, the delivery time of all messages decreases. Since the high priority message has the smallest weight, its delivery delay will be even smaller.

VI. Conclusion

In this article, we analyzed several buffer management policies to propose an algorithm to improve the delivery delay of high priority messages by using the local network information and the priority class of service. Thus, the proposed algorithm drops the message in the low-weight queue and high-weight queue depending on whether or not the current node is the destination of the new message, depending on whether the intermediate node is not the destination closest node and the age of the message. The high priority message is forwarded well before the lower priority messages.

Our work is of course opened. In the future, we plan to analyze the behavior of this model using other routing protocols such as the epidemic protocol and the Spray and Wait protocol.

References

[1] CAO, Yue and SUN, Zhili. Routing in delay/disruption tolerant networks: A taxonomy, survey and challenges. *IEEE Communications surveys & tutorials*, 2013, vol. 15, no 2, p. 654-677.

[2] ATHANASIOS, V. V., ZHANG, Y., et SPYROPOULOS, T. V. Delay tolerant networks: Protocols and applications. *Wireless Networks and Mobile Communications. Boca Raton, FL*, 2011, vol. 33487..

[3] DE JESUS, Vasco Nuno da Gama, RODRIGUES, Joel José Puga Coelho, FERREIRA, Paulo Salvador, *et al*. Improvement of messages delivery time on vehicular delay-tolerant networks. In : *Parallel Processing Workshops, 2009. ICPPW'09. International Conference on*. IEEE, 2009. p. 344-349.

[4] SOARES, Vasco NGJ, FARAHMAND, Farid, et RODRIGUES, Joel JPC. Scheduling and drop policies for traffic differentiation on vehicular delay-tolerant networks. In : *Software, Telecommunications & Computer Networks, 2009. SoftCOM 2009. 17th International Conference on*. IEEE, 2009. p. 353-357.

[5] VAHDAT, Amin, BECKER, David, *and al.* Epidemic routing for partially connected ad hoc networks Duke University, Technical Report CS-2000-06, April, 2000.

[6] T. Spyropoulos, K. Psounis, and C. S. Raghavendra, "Spray and Wait: An Efficient Routing Scheme for Intermittently Connected Mobile Networks," in ACM SIGCOMM 2005 - Workshop on Delay Tolerant Networking and Related Networks (WDTN-05), Philadelphia, PA, USA, August 22-26, 2005.

[7] J. Burgess, B. Gallagher, D. Jensen and B. Levine, "MaxProp: Routing for Vehicle-Based Disruption-Tolerant Networks," in INFOCOM 2006 - The 25th IEEE International Conference on Computer Communications, Barcelona, Catalunya, Spain, April 23-29, 2006, pp. 1-11

[8] LINDGREN, Anders, DORIA, Avri, and SCHELEN, Olov. Probabilistic routing in intermittently connected networks. In : *Service assurance with partial and intermittent resources*. Springer, Berlin, Heidelberg, 2004. p. 239-254.

[9] SOARES, Vasco NGJ, FARAHMAND, Farid, and RODRIGUES, Joel JPC. Traffic differentiation support in vehicular delay-tolerant networks. *Telecommunication Systems*, 2011, vol. 48, no 1-2, p. 151-162.

[10] PENURKAR, Milind et GAJIPARA, Aditi. Scheduling and Dropping Policies in Vehicular Delay Tolerant Network. *International Journal of Engineering and Science (IJES)*, 2013.

[11] More R. A. and Penurkar M. R. "Scheduling and Dropping Policies in Delay Tolerant Network". International Advanced Research Journal in Science, Engineering and Technology Vol. 2, Issue 10, October 2015

[12] SADREDDINI, Zhaleh et AFSHORD, Masumeh Marzaei. Impact de l'utilisation de plusieurs critères pour la gestion des tampons dans les réseaux tolérants au retard des véhicules. *Journal mondial des sciences appliquées* , 2013, vol. 22, no 9, p. 1204-1209.

[13] S. Rashid, Q. Ayub, and A. H. Abdullah. Reactive weight based buffer management policy for DTN routing protocols. Wireless Personal Communications, 80(3):993{1010, 2015.

[14] WANG, Hezhe, WANG, Huiqiang, FENG, Guangsheng, *and al* .NWBBMP: a novel weight-based buffer management policy for DTN routing protocols. *Peer-to-Peer Networking and Applications*, 2018, vol. 11, no 5, p. 917-923.

[15] KRIFA, Amir, BARAKAT, Chadi, et SPYROPOULOS, Thrasyvoulos. Optimal buffer management policies for delay tolerant networks. In : *Sensor, Mesh and Ad Hoc Communications and Networks, 2008. SECON'08. 5th Annual IEEE Communications Society Conference on*. IEEE, 2008. p. 260-268.

[16] WISITPONGPHAN, Nawaporn, BAI, Fan, MUDALIGE, Priyantha, *et al*. Routing in sparse vehicular ad hoc wireless networks. *IEEE journal on Selected Areas in Communications*, 2007, vol. 25, no 8.

[17] BAROOTKAR, Marziyeh, RAHBAR, Akbar Ghaffarpour, et SABAEI, Masoud. LDAOR-Location and Direction Aware Opportunistic Routing in Vehicular Ad hoc Networks. *Journal of Telecommunications and Information Technology*, 2016.

Normalization of Unstructured and Informal Text in Sentiment Analysis

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***Abstract*—Sentiment Analysis is problem of natural language processing which deals with the extraction and analysis of public sentiments shared about target entities over microbloging websites. This field has gained great attention due to the huge availability of decision making textual contents. Sentiment Analysis has enormous application areas such as; Market Analysis, Service Analysis, Showbiz analysis, Movies, sports and even the popularity and acceptance rate of political policies can also be predicted via sentiment analysis systems. Although tremendous volume of opinionative text is available but it is unstructured and noisy due to which sentiment classifiers can't achieve good outcomes. Normalization is the process used to clean noise from unstructured text for sentiment analysis. In this study we have proposed a mechanism for the normalization of informal and unstructured text. Proposed mechanism is comprised of four essential phases; Noise Reduction, Part of Speech Tagging, Stop Word Removal stemming and Lemmatization. Numerous experiments are performed on twitter data set with unsupervised lexicons and dictionaries. Python and Natural language toolkit is used for performing all four essential steps. This study demonstrates that utilization and normalization of informal tokens in tweets improved the overall classification accuracy from 75.42 to 82.357.**

Keywords—Informal; normalization; opinion mining; roman; sentiment analysis; text preprocessing

I. Introduction

Text Mining is computer assisted process introduced to help business organizations by providing effective decision making answers and future trends. Text Mining is the method of mining high quality information from text using patterns with additional knowledge of linguistic rules. Text Mining fulfils the needs of government, research and business e.g. E-discovery, Scientific Discovery and National Security [1]. The extraction and recognition of pattern is performed through the intersection of Machine Learning, Artificial Intelligence and Database system [2]. The Social sites are used widely for socio communication like Blogs and Microblogs. Blogs are utilized for publishing articles, news, or any other topic that is of interest. Mostly organization like Exact, Themovieblog, ESOMAR (European Society for Opinion and Market Research), AAPOR (American Association for Public Opinion Research) and individuals have their own blogs for communication. Blogging sites provide immediate feedback of reviewers about their products, articles and publications. On the other hand, the sites that allow short text for chatting, communication, exchanging views about their interests are considered as Microblogs. These sites allow the posting of short text and messages. Microblogs are designed for expressing real world actions in an instant environment. The common characteristics of microbloging sites are: (i) Short Text (ii) Instant Messaging (iii) Pictorial symbols (iv) Slang terms (v) Real time [3]. The well-known microbloging sites are Tumblr, Plurk, Friendfeed and Twitter. Twitter is the most popular microbloging site that allows its users to publish short messages (tweets) for communication. The emergence of social media sites has changed the public communication style so the research directions are shifted from information retrieval to "Opinion Mining". Online users share bulk of opinionative information over these social networking websites so observers and analysts are taking advantage of these available information by collecting and summarizing concerned opinionative information for the sake of monitoring authors' moods about their launched products, services and even political policies for better decision making. Socio Monitoring is performed by means of Sentiment Analysis and Opinion Mining. Sentiment Analysis or Opinion Mining is the novel field of text classification and problem of Natural Language Processing. Opinion Mining is the computational study of public sentiments, feelings and opinions shared in the form of text over social media sites. Extracting public opinions from user generated content is not a big matter instead the identification, summarization and strength of opinions about desired entity is the challenging task. Efficient classification of opinions requires knowledge of machine learning and classification algorithm with appropriate linguistic rules. The rapid growth of socio communication devices and channels produced newer challenges for observers and analysts. Online users publish their views and opinions in distinctive and informal way which is not directly translatable for machine learning system. Additionally they adopt acronyms, emotion icons and other microbloging features for communication. Sentiment Analysis task can't be performed directly on these published reviews instead it requires massive effort of input text preparation. In past numerous experiments have been performed for text normalization and preprocessing. Text Normalization is task of data mining in which text is cleaned from undesired tags and symbols. Normalization (a.k.a. preprocessing) is process of cleaning user generated text for analysis and prediction [4]. One can't extract actual opinion without assessing opinionative text precisely so quality of decision directly depends on the quality of text. In past preprocessing is performed via many different supervised [5], semi supervised [6] and unsupervised [7] methods. Sentiment Analysis is applicable in almost every field of life. In this research we have decided to normalize user generated contents in political domain for making valuable dataset for the sake of analysis. We have offered a mechanism in which text is cleaned using four key steps; Noise Reduction, Part of Speech Tagging, Stop Word Removal, Stemming & Lemmatization. Python Natural language toolkit is used for performing all four necessary steps. This study demonstrates that utilization and normalization of informal tokens in tweet can improve the overall classification accuracy. The rest of article is comprised of; Section 2 presents related work, section 3 method, section 4 results and discussion and section 5 presents Conclusion and Future work.

II. Related Work

The increasing growth of electronic document on World Wide Web has changed the way of analysis dramatically. The social media is growing rapidly due to the availability of millions of online user generated opinionative contents on social sites. The expressed views and suggestions are considered as sentiments and opinions. These sentiments are mined for better decision making and also for the purpose of analysis and evaluation. Sentiment Analysis or Opinion Mining is the computational study of public moods. Dave el al [8] in 2003 used the term "Opinion Mining" for the first time. Opinion mining or sentiment analysis is the problem of NLP. Sentiment analysis on twitter is new and challenging area, reasonable efforts have already been done in this area but due to increasing ratio of online users this research area is rising day by day for analyzing various entities but the quality of text is big issue for observers and analysts.

Sentiment Analysis for politics is the hot topic, in past a lot of work has been done on predicting elections or political events. In fact Microbloging sites are becoming the most popular platform for political arena [9]. The use of internet was limited to exchange of information with each other before the election of USA in 2008 but it was changed dramatically when Barack Obama started his campaign on social media [10]. It was the first political campaign ran on social media. The social media became one of the most valuable source for political conversation after that campaign. Kim,D [11] investigated that Twitter was highly focused for seeking political information during the Korean Election 2010. Gaffney [12] tracked the #IranElection hashtag for studying the use of microbloging sites more specifically twitter during 2009 Iran election, due to maximum usage of twitter the maintenance of twitter was stopped at one stage on the order of US state department [13]. Political incumbents and challengers used twitter for political benefits during the US midterm elections held in 2010 [14]. Although there exist many systems for the extraction of public sentiment but informal nature of text is big hurdle for all of them. Cleaning or normalizing opinionative text is challenging issue of sentiment analysis. In last few years data cleaning and preprocessing is viewed as an important action and topic of research, as various supervised and unsupervised methods have been experimented for number of domains for analysis purpose. Hariharakrishnan, J. et al [15] reviewed numerous techniques of text preprocessing and highlighted the significance and multi-aspects of preprocessing such as Noise reduction, outlier identification, and inconsistent data. They raised a very logical point that most of the experiments for text preprocessing are performed either in data collection phase or for homogeneous data. There is lack of efforts for heterogeneous text preprocessing and also there is no such system which detect and clean data during classification. They are planning to develop a hybrid system for cleaning homogenous data in different situations. Haddi, E et al [16] explored the significance of text preprocessing for extracting public opinions from social media contents. They performed various experiments over movie reviews dataset with supervised algorithm and concluded that SVM significantly achieved better accuracy in comparison with other algorithms. They used three different features like Feature Presence (FP), Feature Frequency (FF) and Term Frequency Inverse Document Frequency (TF-IDF) and achieved 93 % of overall accuracy. They stated that sentiment analysis is harder problem and one can't achieve promising outcomes without cleaning text. Singh, T. et al [17] proposed a system for efficient preprocessing of text for twitter sentiment analysis. They actually explored the importance of slang words in sentiment analysis by combining these with existing features. Various experiments are performed in which SVM was used as base classifier. Their results demonstrate that proposed system achieved promising outcomes with the combination of conditional random field with n-grams. They achieved 94 % of average accuracy after normalization of text. Hemalatha, I. et al [18] offered a three step preprocessing strategy in which they removed URL as first step, Special and repeated characters are removed in second step while third step was introduced to remove question words. They claimed that with this preprocessing algorithm one can easily perform sentiment analysis with any machine learning algorithm. Angiani, G. et al [19] compared various existing machine learning methods for text preprocessing and stated that appropriate preprocessing can improve and gain the valuable information knowledge from available text. They evaluated the performance of numerous preprocessing strategies over twitter data and concluded that using a dictionary is not a useful idea for upgrading the classification performance. Additionally, they suggested that combining different preprocessing filters can positively improve the classification accuracy. Although sentiments and opinions are mined and analyzed in English like languages but it is observed that opinionative contents in other languages are also available at high rate over social networking websites. Duwairi, R. & El-Orfali,M [20] presented their work for Arabic text in which they investigated Arabic text from three perspective; first one is the multi-aspect of text representation such as significant role of stemming n-gram and features correlation for Arabic language. Secondly the performance of three existing machine learning classifiers; NB, SVM and K-NN was examined and the last perspective was to analyses the impact of different characteristics of dataset over sentiment analysis whereas experiments were performed on two datasets; Manually compiled dataset for politics and existing corpus of movie reviews. Their results demonstrate that Naïve Bayes classifier outperforms the other two on both domains (Politics and Movies) by achieving 96.6% and 85.7% accuracy respectively. They stated that preprocessing and behavior of dataset has great impact on sentiment analysis accuracy. Dos Santos & Ladeira, M [21] performed experiments on Portuguese reviews for presenting the role of text preprocessing in sentiment analysis.

Additionally this research presented a large corpus of 759 thousands reviews as their contribution. They concluded that text preprocessing has insignificant role in text classification and sentiment analysis. They stated that accuracy and performance of sentiment analysis systems depends on the nature of datasets and sentences/reviews used in the dataset because sometimes preprocessing lower the accuracy by removing the valuable and necessary information from target text. Toman, M [22] proposed a lemmatization system which uses multilingual semantic thesaurus Eurowordnet. They evaluated the performance of proposed system on two different corpora. Their findings suggest that the proposed system achieved promising outcomes and they concluded that conversion of inflected forms into their roots does not affect the classification accuracy while on the other hand Christopher, D.M et al. [23] stated that stemming lowers the precision. Dařena, F., & Žižka, J. [24] reviewed the existing preprocessing methods and application for non-standard short text and unfold several informative patterns. They stated that smaller datasets are inappropriate and produces inefficient outcomes. Additionally, this study explored that preprocessing results highly based on the language of data and algorithm. The positive point about preprocessing is that it reduces dictionary size of data collection. Noise and unclear data is not the issue of English language but all languages used over internet based social media require preprocessing of text. Infact preprocessing experiments are performed for almost all human languages; Arabic, French, Hindi, Chinese, Japanese and Turkish. Hidayatullah, A. F et al [25] experimented with Indonesian language in order to clean the text more specifically tweets for further analysis. They divided these experiments into two parts; common preprocessing and specific preprocessing. Their results demonstrate that they achieve good results with specific text preprocessing tasks. Additionally, they suggested preprocessing process can be improved by introducing novel algorithms and system for automatic recognition of non-standard words. The rapid advent in web came with newer communication indicators such as # tags, @ tags and emotion icons. Ignoring such symbols during preprocessing can affect the quality of dataset. One can't directly remove meaningful punctuations during preprocessing, because meaningful punctuation (Emoticons) convey opinion towards target entities. Wegrzyn-Wolska, K et al [26] compared three emoticon's preprocessing methods; Emotion deletion (emodel), emoticons 2-values translation (emo2label) and emoticon explanation (emo2explanation). Emoticon weight lexicon was used with Naïve Bayes Classier in order to assess the effect of emotion icons. They concluded that emotion icons act as verbal indicator of sentiment and can enhance the sentiment analysis accuracy. They achieved 78% of average accuracy with Naïve Bayes Classifier. Gull, R et al [27] proposed an approach for the analysis of qualitative and quantitative data in specified time. They transformed the extracted text into structured format and prepared politics dataset for the analysis of political party using linguistic features and classifiers. Two classifiers Naïve Bayes and SVM are employed and they concluded that SVM produced better outcomes. In future, they are planning to analyze multilingual text. Stemming is one the key phase of preprocessing because identifying and converting inflected forms of opinionative terms may increase quality of dataset. Arjun et al. [28] compared two stemming techniques; Porter's and Krovetz algorithm. Their findings suggested that both algorithms have few limitations in some specific scenario Porter's algorithm [29] is context based and also it leads to large degree of conversion whereas Krovetz algorithm [30] produced inefficient results with large datasets. In past, preprocessing is performed in a sequential manner using a pipeline of preliminary tasks but there exist few systems which utilizes unified phase for all essential tasks. Clark, A [31] came with the design and implementation tool for the preprocessing of noisy corpora. He coped with typographical errors, white space issue using trainable stochastic transducer model over 100 million word corpus of Usenet news. He stated that preprocessing process can be improved by merging various models for sort of typographical errors. Bao, Y et al [32] explored the significance of text preprocessing for twitter sentiment Analysis. They unfolded the impact of URLs, Negation, repeated letters, stemming and Lemmatization. The experiments were performed on Stanford twitter dataset. Their findings show that handling URLs, negations and repeated characters can improve accuracy while on the other hand stemming and lemmatization decreases the classification accuracy. They achieved an average 85.5 % accuracy with original feature space. Petz, G et al. [33] compared various existing preprocessing techniques for sentiment analysis in real world situations. They stated that to achieve satisfactory outcomes three tasks of preprocessing are essentials; sentence tokenization, replacement of slang symbols and stemming of inflected forms. They achieved 83.42 % of average F1-score for eight different techniques. Krouska, A et al. [34] reviewed the recent research of text preprocessing and sentiment analysis. They revealed the in-depth analysis of preprocessing techniques by performing various experiments over manually compiled twitter dataset and stated that appropriate feature selection and proper representation can improve classification accuracy positively. They compared four key classifiers NB, SVM, KNN and C4.5 over three different datasets OMD, HCR and STS-Gold. Raza, A et al [35] reported that modern linguistic style has number of variant features such as use of romans, slangs, Urdu language terms and sentences for expressing their likes, dislikes about hundreds of real world entities. Additionally, system of one domain and language is inapplicable over other languages and domains. Therefore, Text normalization is important to cope with many tasks such as Plagiarism Detection, pattern discovery, Sentence Recognition, Topic Modelling and information retrieval. Liu, B. and Zhang, L [36] demonstrated that sentiment analysis is performed at three granularity levels; document, sentence and phrase level. Previous research showed that document level sentiment analysis has gained much focus as in past [37, 38] performed document level sentiment analysis using minimum cuts algorithm. Kian, K.D et al [39] performed preprocessing experiments to determine the qualitative difference among high and low agreement data. Raza, Raza, A et al [40] used preprocessing and lexicon based sentiment analysis system to capture public opinion shared about political protest over twitter. They stated that effective preprocessing can enhance the classification accuracy. Yu et al [41] proposed a system for sentence level subjectivity classification. In this research we have proposed a mechanism for text preprocessing at sentence level for sentiment analysis of political contents using existing and manually built dictionaries and lexicons.

III. Methodology

Sentiment Analysis is process of acquiring users sentiments shared on social networking websites. There exists two main methods of assigning polarities to public sentiments; Supervised & Unsupervised. Whatever the method is used for sentiment analysis it always needs quality text in decision making process.

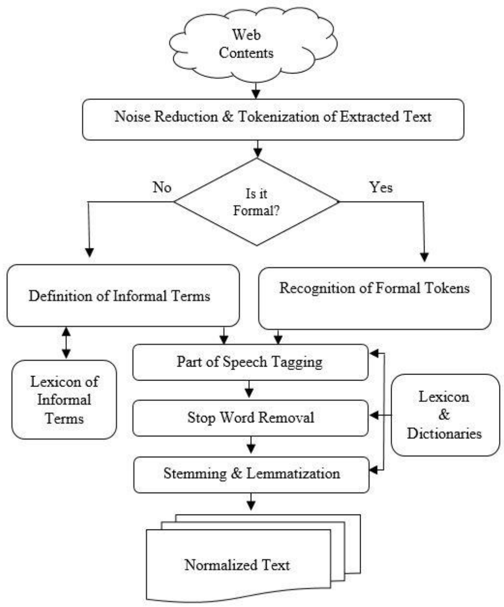

Fig. 1. Mechanism for Normalization of Informal Text.

Today socio sites produce numerous challenges for gathering quality text. In this research a mechanism is proposed for the normalization of user generated opinionative contents in order to perform optimized analysis. Proposed mechanism is comprised of following essential phases as depicted above in Fig. 1.

A. Normalization

Normalization in sentiment analysis is referred as the process of cleaning or removing irrelevant data from a huge collection of extracted data. The extracted data is full of noise containing URLs, tags, links etc. Data preprocessing is performed to remove such noise from extracted text to make it more clear and consistent. In every text mining process data must be preprocessed before going to analysis phase, so we preprocessed the extracted data for further processing. The URLs and tags are removed from extracted data; generally these URLs have no use in sentiment analysis process. Following tasks are involved in text preprocessing process:

B. Noise Reduction

The text extracted from social media sites is full of noise. This text contains URLs, Symbols, undesired punctuations and some special communication symbols i.e. @, RT and < > etc. These symbols and tags have no role in sentiment classification tasks so all such kind of punctuations must be eliminated before mining and analysis. In this phase of preprocessing we removed these undesired symbols and tags using HTML parser.

C. Definition of Informal Tokens

In past extracted text is preprocessed using English repositories but it is observed that today social sites have provided bulk of opinionative data in informal style and words of other language too, so in order to capture opinion from numerous geographical areas there is a dire need to collect and summarize opinion of different styles (formal & Informal) and format. Twitter and other microbloging services allow users to share short informal slangy terms which are not easily detectable for machine and sometimes even for a human reader. So in this study we have captured non-English opinionative words used in English sentences for the sake of efficient sentiment analysis. We first detected all the slang terms and then proper definition is assigned to each extracted token using manually compiled list of slangs and non-standard terms. Slangs refer to misspell English language opinionative terms whereas non-standard used to represent Roman Urdu terms shared in English sentences for expressing positivity and negativity about concerned entity. A list of Roman Urdu opinionative terms is created for effective identification of both slang and non-standard terms. Python Natural Language Toolkit is used for cleaning formal and informal opinionative tokens.

D. Part of Speech Tagging

The noise free text is passed to part of speech tagging phase for labeling appropriate parts of speech tags to each target token. Part of Speech (POS) Tagging is the process of assigning parts of speech to each desired term. In this research tokenized text is labeled according to grammatical nature i.e. adjective, verb, adverb and noun etc. we use python NLTK for assigning part of speech tags to extracted text.

E. Stop Word Removal

The words having high frequency or most frequently used terms are considered as stop words like "for" "the" "a" etc. In sentiment Analysis, stop words are removed to obtain more concise and desired text for analysis. So we removed all such stop words from extracted data by providing tokens to python NLTK. Python NLTK [42] is a collection of built-in libraries and software for Natural Language Processing. A corpus having list of words of various language is the part of python NLTK so stop words from extracted text is removed through the utilization of corpus with Python NLTK.

F. Stemming and Lemmatization

The process of reducing all the terms with the same stem to a common form is named as stemming; a stem is a root form. For example the stem for the words "fishing", "fished", "fisher" is "Fish" while lemmatization is the process of removing inflectional endings and replacing this inflected word with a base word, and the module used for this process is known as Lemmatizer; the Lemmatizer uses an additional dictionary to replace the inflected forms into its base form. As in stemming the terms "begging" "beggar" "beginning" will be replaced with the terms "beg" while in lemmatization these terms will be replaced with terms "beg" , "beg" and "begin" respectively. The output generated by Lemmatizer is more accurate as compared to that of stemmer. So we replaced all the inflected form to their base form by using python NLTK Lemmatizer. The Python NLTK Lemmatizer uses WordNet database for finding lemmas of inflected terms. The canonical form of the word is known as lemma.

The preprocessed text is saved in separate file as dataset for classification and analysis. We have evaluated the effectiveness of our preprocessed text using existing classification technique.

IV. Results and Discussion

To evaluate the effectiveness of proposed mechanism comprehensive experiments are performed on twitter data about Pakistan Political Parties and Leaders. The data is extracted about Pakistan politics from publically available reviews of twitter using twitter APIs. Manual annotation is performed to assign polar classes to each extracted tweet so a set of 1400 tweets in which 700 positive whereas other 700 negative are labelled as benchmark in order to evaluate the performance of preprocessing mechanism. Table I. shows the statistics for positive & negative tweets for both formal & informal opinions.

All the necessary steps of normalization mentioned in section 3 are performed using Python natural language toolkit. This study presents a novel mechanism of text normalization in the classification of informal opinion bearing text. In past there exist many methods for text normalization but still there is sufficient gap for improvement so we proposed a mechanism which detect all the opinionative feature in preprocessing phase. Table.II presents the opinionative features which are considered in this study just to increase the classification accuracy.

TABLE I. Human Annotated Dataset of Formal and Informal Opinionative Tweets

MANUALLY LABELED OPINION	**POSITIVE**	**NEGATIVE**
FORMAL OPINION	500	500
INFORMAL OPINION	200	200

TABLE II. Formal and Informal Opinionative Features

S.NO.	**OPINION FEATURES**	**NATURE**	**DEFINITION**
1	**f1:** Adjective	Formal	Qualifying Word: A word that shows the quality of an entity
2	**f2:** Verb	Formal	Action: A word that shows some action on an entity
3	**f3:** Adverb	Formal	An adverb is a word that emphasis an adjective, verb.
4	**f4:** Slangs & Acronyms	Informal	Informal opinionative words that are left misspelled intentionally in some particular context.
5	**f5:** Roman Urdu Terms	Informal	Writing Urdu script with English letter according to its appropriate pronunciation.
6	**f6:** Emoticon	Symbolic	Punctuations and combination of characters used to show facial expressions.

This section presents the experimental findings of proposed mechanism. In order to underline the impact of preprocessing we have presented precision, recall, f-measure & accuracy of tweets collection for both formal and informal opinion bearing terms. We have computed precision, recall f-measure separately for both terms just to emphasize the effectiveness of handling informal opinions in sentiment analysis.

A. Precision

Precision is actually the fraction between retrieved and relevant instances as shown below in equation 1.

$$\text{Precision} = \frac{TP}{TP+FP} \tag{1}$$

Whereas TP is used for True Positive, FP is for False Positive. TN shows True negative and FN is for False Negative. In this study we used these terms for specifying the following criteria, TP: Correctly identified as positive by the proposed framework, FP: Incorrectly identified as positive. Similarly, for negative, TN is for correctly identified as negative while FN shows the terms which are incorrectly identified as negative.

Precision for **formal** positive instances:

$$\frac{TP}{TP+FP} = \frac{396}{486} = 81.31\%$$

Precision for **formal** negative instances:

$$\frac{TN}{TN+FN} = \frac{409}{513} = 79.72\%$$

The precision for informal positive and negative tweets is as follow;

Precision for **informal** positive instances:

$$\frac{TP}{TP+FP} = \frac{186}{224} = 83.03\%$$

Precision for **informal** negative instances:

$$\frac{TN}{TN+FN} = \frac{162}{176} = 92.04\%$$

Similarly, precision for both formal & informal positive and negative tweets is described as below;

Precision for **both** formal & informal positive instances:

$$\frac{TP}{TP+FP} = \frac{582}{711} = 81.85\%$$

Precision for **both** formal & informal negative instances:

$$\frac{TN}{TN+FN} = \frac{571}{689} = 82.87\%$$

B. Recall

Recall is used to find the numbers of relevant from retrieved instances as shown below in eq.2.

$$\text{Recall} = \frac{TP}{TP+FN} \tag{2}$$

Recall for formal positive & negative tweets is presented as follow;

Recall for **formal** positive instances:

$\frac{TP}{TP+FN} = \frac{396}{500} = 79.2\%$

Recall for **formal** negative instances:

$\frac{TN}{TN+FP} = \frac{409}{500} = 81.8\%$

Recall for informal positive & negative tweets is shown below;

Recall for **informal** positive instances:

$\frac{TP}{TP+FN} = \frac{186}{200} = 93\%$

Recall for **informal** negative instances:

$\frac{TN}{TN+FP} = \frac{162}{200} = 81\%$

Similarly, recall for both formal & informal positive & negative tweets is shown below;

Recall for **both** formal & informal positive instances:

$\frac{TP}{TP+FP} = \frac{582}{700} = 83.14\%$

Recall for **both** formal & informal negative instances:

$\frac{TN}{TN+FN} = \frac{571}{700} = 81.57\%$

C. *F-Measure*

F-Measure is also a statistical analysis used in binary classification. It is used to measure the accuracy by considering both precision and recall as shown below in eq.3.

$$\mathrm{F-Measure} = \frac{2(Precision * Recall)}{Precision + Recall} \quad (3)$$

$$\mathrm{F-Measure\ (Positive)} = \frac{2(81.85 * 83.14)}{81.85 + 83.14} = 82.489\%$$

$$\mathrm{F-Measure\ (Negative)} = \frac{2(82.87 * 81.57)}{82.87 + 81.57} = \frac{2(6759.70)}{164.44} = 82.21\%$$

D. *Accuracy*

The accuracy is the degree of correctness; Mathematical representation of accuracy is shown below in eq. 4.

$$\mathrm{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (4)$$

$$\mathrm{Accuracy} = \frac{582+571}{582+571 + 129+118} = 82.357\%$$

It is observed that out of 1153 opinionative tweets 1054 tweets are identified as opinionative with formal and informal opinion bearing words whereas rest of the opinionative tweets are identified using informal tokens only, where no single formal opinionative token was present which increases accuracy up to 6.937 from 75.42 to 82.357. Table III shows a subset of tweets collection which are marked as opinionative with formal and informal opinion.

TABLE III. OPINIONATIVE TWEETS HAVING BOTH FORMAL & INFORMAL FEATURES

S. No	OPINIONATIVE TWEETS	OPINION FEATURES	LABEL
2	Riaz has bribed many politicians but he must know he can never bribe me: PTI chief	F2	Positive
3	Once a drbari always darbari	F5	Negative
4	Patwari (zehni ghulam), darbari and bhikari All are in shock That what happened to us.	F2, F5	Negative
5	Chal patwari get lost...	F4, F5	Negative
6	Aala to good zbrdst	F1, F5	Positive
7	Fucking Daghi :-P	F2, F5	Negative
8	That's great janbaz 👍 #Bilawal	F1, F5, F6	Positive
9	Wah,,bahut aala,,,pti linked offshore companies are neat and clean like imran niazi,,,, hahahaha	F1, F4, F5	Positive
10	I have seen KPK hospitals , they are better than Punjab hospitals, 1000 times better and i am a doctor also i know better than you Mr brainless Patwari	F1, F5	Positive

E. *Confusion Matrix*

Confusion Matrix or Contingency Table is used for the evaluation of proposed system. Confusion Matrix is actually a two dimensional array which is used to visualize the performance of proposed mechanism. Table IV shows the confusion matrix of experimental results. In which rows show the number of manually annotated instances whereas columns show the machine/system annotated instances.

TABLE IV. CONFUSION MATRIX OF FORMAL AND INFORMAL OPINIONATIVE TERMS

POLARITY CLASS LABELS FOR FORMAL & INFORMAL OPINIONATIVE TERMS			MACHINE ANNOTATED LABELS		
			Positive	**Negative**	**TOTAL**
Formal opinion	**HUMAN ANNOTATED**	Positive	396 (TP)	104 (FN)	500
		Negative	91 (FP)	409 (TN)	500
		TOTAL	487	513	1000
Informal opinion		**CLASS LABELS**	**Positive**	**Negative**	**TOTAL**
		Positive	186 (TP)	14 (FN)	200
		Negative	38 (FP)	162 (TN)	200
		TOTAL	224	176	400
Formal & informal opinions		**CLASS LABELS**	**Positive**	**Negative**	**TOTAL**
		Positive	582 (TP)	118 (FN)	700
		Negative	129 (FP)	571 (TN)	700
		TOTAL	711	689	1400

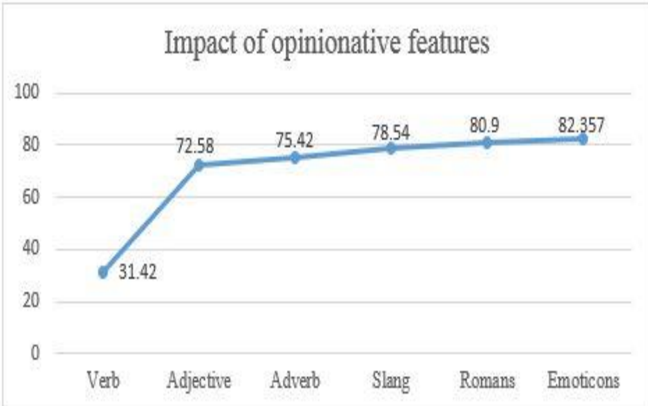

Fig. 2. Impact of Opinionative Features.

In above table, vertical representations of positive and negative instances show the outcomes of machine whereas horizontal instances indicate manually labeled instances. We have decomposed whole data set into formal and informal so here in Table.4 ternary confusion matrix is shown in order to provide clear picture of informal opinions. Third &last confusion matrix shows the overall results of both formal & informal opinions in which machine labeled 711 opinionative tweets as positive while 689 are marked as negative with accuracy of 81.9 and 82.85 respectively. As in this preprocessing mechanism six opinionative features are considered as shown in table.2. Experimental results demonstrate that all these features have great impact on real world results. Fig.2 shows that few of them has increased the classification accuracy dramatically.

Fig.2 shows that all considered features have increased the average accuracy of sentiment analysis. If we consider only verbs from whole collection the accuracy was noticed as 31.42, and for verb and adjectives, accuracy is jumped to 72.58 and similarly for all features the overall accuracy is achieved as 82.357 which shows significant contribution in sentiment analysis.

Table.V shows the comparative results of proposed preprocessing mechanism, it is noticed that proposed system outperformed the existing systems by achieving an average precision, recall and accuracy of 81.9%, 82.35%, and 82.357% respectively.

TABLE V. COMPARATIVE ANALYSIS OF PROPOSED PREPROCESSING MECHANISM

STUDIES	PRECISION	RECALL	ACCURACY
Pang, B et al. [37]	**83%**	80.58%	81.5%
Haddi, E [43]	63%	60%	60% lexical
Etaiwi, W et al. [44]	51.8%	74.9%	72.96%
Proposed	81.9%	**82.35%**	**82.357%**

V. CONCLUSION AND FUTURE WORK

Sentiment Analysis is computational study of user's opinion about real world entities. Analysis are performed on publically available data over social media sites. Machine Learning algorithms need a well formed quality dataset for analysis so publically available text is first normalized in order to achieve decision making results. One can't mine public opinions accurately without inputting meaningful instances. In fact, quality of analysis directly depends on the size and nature of input data. This research proposes a novel mechanism for normalization of publically available opinionative data for the sake of sentiment analysis. Text normalization is not just a single step, Infact it is the process of performing a flow of essential actions sequentially i.e. Tokenization, Stop word removal, Part of Speech Tagging, Stemming and Lemmatization. In this study we have considered six opinion bearing indicators; Verb, Adjective, Adverb, Slang, Roman Urdu terms and Emoticon as classification attributes. In past, non-standard and unstructured terms are handled at classification phase which sometimes lowers the classification accuracy so in order to overcome this deficiency proposed study provides a proper definition to each extracted informal & non-standard terms at normalization phase. Twitter data is first crawled using twitter APIs and then separate file is generated for performing normalization tasks. The normalization steps namely; Noise reduction, informal definition, parts of speech tagging, stemming and lemmatization are performed in incremental manners. To evaluate the results of proposed mechanism experiments are performed on manually annotated collection of 1400 tweets equally distributed for positive and negative opinion bearing instances. Experimental results demonstrate that informal opinions have great impact on the classification accuracy as we achieved 82.357% accuracy with an increment of 6.937%. Proposed mechanism is robust and can be applied at multidimensional domains. We must encourage future researchers to experiment with novel opinionative features to provide quality datasets for many real world entities.

REFERENCES

[1] Glass, K. and Colbaugh, R., 2012. Estimating the sentiment of social media content for security informatics applications. Security Informatics (a springer open jouranl), Vol. 1, Issue 1.pp 1-16

[2] Lahoti, A.A., 2014. Data Mining Technique its Needs and Using Applications. , IJCSMC Vol. 3.Issue. 4, pp.572-579.

[3] Kumar, A. & Sebastian, T.M., 2012. Sentiment Analysis: A Perspective on its Past, Present and Future.International Journal of Intelligent Systems and Applications, Vol. 4. Issue.10. pp1-14.

[4] Jianqiang, Z. and Xiaolin, G., 2017. Comparison Research on Text Pre-processing Methods on Twitter Sentiment Analysis. IEEE Access, 5, pp.2870-2879.

[5] Kotsiantis, S.B., Kanellopoulos, D. and Pintelas, P.E., 2006. Data preprocessing for supervised leaning. International Journal of Computer Science, 1(2), pp.111-117.

[6] Xiang, B. and Zhou, L., 2014. Improving twitter sentiment analysis with topic-based mixture modeling and semi-supervised training. In Proceedings of the 52nd Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers) (Vol. 2, pp. 434-439).

[7] Karl, M., Bayer, J. and van der Smagt, P., 2016. Unsupervised preprocessing for Tactile Data.

[8] Dave, K. et al., 2003. Mining the peanut gallery: Opinion extraction and semantic classification of product reviews. Proceedings of the 12th

international conference on World Wide Web, pp.519–528. New York, NY, USA.

[9] Tumasjan, A., Sprenger, T.O., Sandner, P.G. and Welpe, I.M., 2011. Election forecasts with Twitter: How 140 characters reflect the political landscape. Social science computer review, 29(4), pp.402-418.

[10] Anderson, D., 2009. How has Web 2.0 reshaped the presidential campaign in the United States? In Proceedings of the WebSci'09: Society On-Line, 18-20 March 2009, Athens, Greece.

[11] Kim, D., 2011. Tweeting politics: Examining the motivations for Twitter use and the impact on political participation. In 61st Annual Conference of the International Communication Association.

[12] Gaffney, D., 2010. iran Election : Quantifying Online Activism. Analysis, (pp.1-8). Web Science Conf. 2010, April 26-27, 2010, Raleigh, NC, USA.

[13] Pleming, S., 2009. US State Department speaks to Twitter over Iran. Reuters, June, 16.

[14] Cozma, R. and Chen, K., 2011, May. Congressional Candidates' Use of Twitter During the 2010 Midterm Elections: A Wasted Opportunity?. In 61st Annual Conference of the International communication association.

[15] Hariharakrishnan, J., Mohanavalli, S. and Kumar, K.S., 2017, January. Survey of pre-processing techniques for mining big data. In Computer, Communication and Signal Processing (ICCCSP), 2017 International Conference on (pp. 1-5). IEEE.

[16] Haddi, E., Liu, X. and Shi, Y., 2013. The role of text pre-processing in sentiment analysis. Procedia Computer Science, 17, pp.26-32.

[17] Singh, T. and Kumari, M., 2016. Role of Text Pre-processing in Twitter Sentiment Analysis. Procedia Computer Science, 89, pp.549-554.

[18] Hemalatha, I., Varma, G.S. and Govardhan, A., 2012. Preprocessing the informal text for efficient sentiment analysis. International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), 1(2), pp.58-61.

[19] Angiani, G., Ferrari, L., Fontanini, T., Fornacciari, P., Iotti, E., Magliani, F. and Manicardi, S., 2016. A Comparison between Preprocessing Techniques for Sentiment Analysis in Twitter. In KDWeb.

[20] Duwairi, R. and El-Orfali, M., 2014. A study of the effects of preprocessing strategies on sentiment analysis for Arabic text. Journal of Information Science, 40(4), pp.501-513.

[21] Dos Santos, F.L. and Ladeira, M., 2014, October. The role of text pre-processing in opinion mining on a social media language dataset. In Intelligent Systems (BRACIS), 2014 Brazilian Conference on (pp. 50-54). IEEE.

[22] Toman M, Tesar R, Jezek K. Influence of word normalization on text classification. Proceedings of InSciT. 2006 Oct 25;4:354-8.

[23] Christopher, D.M., Prabhakar, R. and Hinrich, S.C.H.Ü.T.Z.E., 2008. Introduction to information retrieval. An Introduction To Information Retrieval, 151, p.177.

[24] Dařena, F. and Žižka, J., 2015. Interdependence of text mining quality and the input data preprocessing. In Artificial Intelligence Perspectives and Applications (pp. 141-150). Springer, Cham.

[25] Hidayatullah, A.F. and Ma'arif, M.R., 2017, January. Pre-processing Tasks in Indonesian Twitter Messages. In Journal of Physics: Conference Series (Vol. 801, No. 1, p. 012072). IOP Publishing.

[26] Wegrzyn-Wolska, K., Bougueroua, L., Yu, H. and Zhong, J., EXPLORE THE EFFECTS OF EMOTICONS ON TWITTER SENTIMENT ANALYSIS. Computer Science & Information Technology, p.65.

[27] Gull, R., Shoaib, U., Rasheed, S., Abid, W. and Zahoor, B., 2016. Pre Processing of Twitter's Data for Opinion Mining in Political Context. Procedia Computer Science, 96, pp.1560-1570.

[28] Arjun Srinivas Nayak , Ananthu P Kanive , Naveen Chandavekar, Bala subramani R. ,2016. Survey on Pre-Processing Techniques for Text Mining. International Journal of Engineering and Computer Science. 5(6),pp. 16875-16879.

[29] Moral, C., de Antonio, A., Imbert, R. and Ramírez, J., 2014. A survey of stemming algorithms in information retrieval. Information Research: An International Electronic Journal, 19(1), p.n1.

[30] Ramasubramanian, C. and Ramya, R., 2013. Effective pre-processing activities in text mining using improved porter's stemming algorithm. International Journal of Advanced Research in Computer and Communication Engineering, 2(12), pp.4536-8.

[31] Clark, A., 2003, March. Pre-processing very noisy text. In Proc. of Workshop on Shallow Processing of Large Corpora(pp. 12-22).

[32] Bao, Y., Quan, C., Wang, L. and Ren, F., 2014, August. The role of pre-processing in twitter sentiment analysis. In International Conference on Intelligent Computing (pp. 615-624). Springer, Cham.

[33] Petz, G., Karpowicz, M., Fürschuß, H., Auinger, A., Winkler, S., Schaller, S. and Holzinger, A., 2012. On text preprocessing for opinion mining outside of laboratory environments. Active media technology, pp.618-629.

[34] Krouska, A., Troussas, C. and Virvou, M., 2016, July. The effect of preprocessing techniques on Twitter sentiment analysis. In Information, Intelligence, Systems & Applications (IISA), 2016 7th International Conference on (pp. 1-5). IEEE.

[35] Raza, A.A., Habib, A., Ashraf, J. and Javed, M., 2017. A Review on Urdu Language Parsing. INTERNATIONAL JOURNAL OF ADVANCED COMPUTER SCIENCE AND APPLICATIONS, 8(4), pp.93-97.

[36] Liu, B. and Zhang, L., 2012. A survey of opinion mining and sentiment analysis. In Mining text data (pp. 415-463). Springer US.

[37] Pang, B., Lee, L. and Vaithyanathan, S., 2002, July. Thumbs up?: sentiment classification using machine learning techniques. In Proceedings of the ACL-02 conference on Empirical methods in natural language processing-Volume 10(pp. 79-86). Association for Computational Linguistics.

[38] Pang, B. and Lee, L., 2004, July. A sentimental education: Sentiment analysis using subjectivity summarization based on minimum cuts. In Proceedings of the 42nd annual meeting on Association for Computational Linguistics (p. 271). Association for Computational Linguistics.

[39] Kenyon-Dean, K., Ahmed, E., Fujimoto, S., Georges-Filteau, J., Glasz, C., Kaur, B., Lalande, A., Bhanderi, S., Belfer, R., Kanagasabai, N. and Sarrazingendron, R., 2018. Sentiment Analysis: It's Complicated!. In Proceedings of the 2018 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long Papers) (Vol. 1, pp. 1886-1895).

[40] Raza, A.A., Habib, A., Ashraf, J. and Javed, M., 2018. Semantic Orientation Based Decision Making Framework for Big Data Analysis of Sporadic News Events. Journal of Grid Computing, pp.1-17.

[41] Yu, H. and Hatzivassiloglou, V., 2003, July. Towards answering opinion questions: Separating facts from opinions and identifying the polarity of opinion sentences. In Proceedings of the 2003 conference on Empirical methods in natural language processing (pp. 129-136). Association for Computational Linguistics.

[42] Maynard, D. & Funk, A., 2012. Automatic Detection of Political Opinions in Tweets. In CEUR Workshop Proceedings. pp. 88–99, Venezia, Italy.

[43] Haddi, E., 2015. Sentiment analysis: text, pre-processing, reader views and cross domains (Doctoral dissertation, Brunel University London).

[44] Etaiwi, W. and Naymat, G., 2017. The Impact of applying Different Preprocessing Steps on Review Spam Detection. Procedia Computer Science, 113, pp.273-279.

Development of Purchasing Module for Agriculture E-Commerce using Dynamic System Development Model

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***Abstract*—Trading model has been changing since the vast implementation of Information and Communication Technology in every sector. This model is known as e-Commerce. Unlikely, there is still limited company which specifically trades agriculture product. Agriculture e-Commerce is known as a platform to buy and sell some agriculture products. Agriculture e-commerce has important role to support economic development and market expansion for farmers in particular and people in rural areas in general. There is still limited access and provider which buy and sell agriculture product to farmer and its farmer representative. Therefore, this research develops specific agriculture e-commerce. There are two main modules for agriculture e-commerce, purchasing and buying module. On this article, we acknowledge to develop the first module, which is purchasing module. Purchasing module was developed using Dynamic System Development Method (DSDM). Development phase includes feasibility study, business study, functional model iteration, and design and build model iteration. At the end of the phase, testing is conducted. The result of this study is the prototype of agriculture e-Commerce product with predefined functions. Purchasing module of the system depicts the opportunity for farmer to buy the tools and materials. This system has two main functions: purchasing system management and reporting management. System testing also was conducted to test the system.**

Keywords*—Agricultural e-commerce; dynamic system development method; DSDM; purchase module

I. Introduction

Purchasing and Selling are two main processes of trading business, goods and services. In the era of industry revolution 4.0, there is a change in the trading business model. In the conventional model, buyer and seller meet directly face to face. Nowadays, there is a shifting to become trading model based on Information and Communication Technology (ICT). This trading model is known as e-commerce. E-Commerce is a trading model, including purchasing, selling, and exchanging goods, services, and information through computer network and internet [1].

E-Commerce business model evolves rapidly in some countries in the world. This business model offers some advantages, either for seller and buyer. Two e-Commerce advantages are: (1) e-Commerce is able to decrease company operational costs; (2) Buyers can save time in shopping and get flexibility at certain levels in shopping [2]. However, e-Commerce business model have not reached agriculture sector, especially in developing countries such as Indonesia. There are some e-Commerce companies, such as Lazada, Tokopedia, Elevania, and OLX. Among those e-Commerce companies, there is none of e-Commerce companies which focus on selling agriculture product. Thus, in this research, researcher developed an e-Commerce system which sells agriculture tools, materials, and products specifically.

System development uses Dynamic System Development Model (DSDM). The usage of this method is based on the advantages of DSDM as agile development models [3]. This model tries to look for equilibrium process so the model is able to work in dynamic environment. Dynamic environment usually involves requirement changes. This model suppresses the control mechanism in customer feedback to ensure a high level of customer satisfaction [4].

Agriculture e-Commerce system contains two main module, purchasing module and selling module. This article discusses development of purchasing module as part of Agriculture e-Commerce system. Purchasing module was developed intended for buyer of agriculture products offered. This system is developed using PHP and HTML5 and database engine MySQL. Purchasing module user are buyers. This module has some functions, including goods selection, discussion with sellers, and buying directly using system.

II. Literature Review

A. Dynamic System Development Metohod (DSDM)

Dynamic System Development Method is one of agile methodology that is used to develop software. Dynamic System Development Method (DSDM) is a method that has been developed based on software development success experience. This method is an improvement method for Rapid Application Development (RAD). This method is flexible and practical for software project management [5][6][7].

DSDM has 4 basic philosophies: (1) Development process is a team work. This process is a combination between customer knowledge about business process and business requirement and IT staff professional; (2) good quality demands suitability with good technical skills; (3) Development process can be incremental means that not everything can be done; and (4) The diminution of the law of increasing returns means that resources must be used to develop features that are most valuable to the business [5].

DSDM has 9 important principles: (1) User active participation is an important part and needed for system development; (2) Development team should have authority to take decision; (3) Focusing on product completion periodically; (4) Suitability with business is a product acceptance criteria; (5) Development is an iterative and mandatory incremental process; (6) All changes in the development process must be reversible, which means that changes do not affect the cycle, system, and environment; (7) It is needed to define system "high level"; (8) System testing is a life cycle integrated part; and (9) Collaborative and Cooperative Approach is used in this method [8].

DSDM system development is called "The three pizzas and a cheese". The three pizzas are DSDM three main stages, Functional Model Iteration, Design and Build Iteration, and Implementation. Meanwhile, "a cheese" is 2 initial stages software development process, Feasibility and Business Study. The DSDM Software Development Process can be seen in Fig.1.

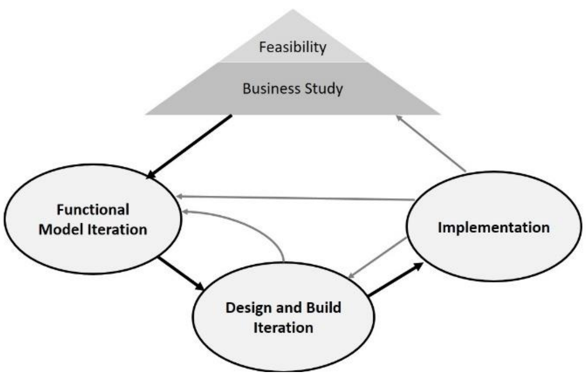

Fig. 1. Dynamic System Development Method.

Figure 1 shows Dynamic System Development Method diagram. It is shown that there are 3 main stages and 2 initial stages for software development. 2 Initial Stages are Feasibility study and Business study. Those 2 initial stages should be conducted before the main stages. 3 main stages are Functional Model Iteration, Design and build iteration, and Implementation. Functional Model Iteration consists of 4 main sub stages: (1) Create functional prototype; (2) Agree schedule; (3) Identify functional prototype; and (4) Review prototype. Design and build iteration is the next stage after Functional Model Iteration and consists of four sub-stages: (1) Identify design prototypes; (2) Agree schedule; (3) Create design prototypes; (4) Review design prototypes. And the last stages is the implementation which has 4 sub-stages: (1) Review Business; (2) User approved and user guidelines; (3) Train user; and (4) Implement.

B. Agriculture e-Commerce

Agriculture e-Commerce is an e-Commerce implementation for agriculture sector. In particular, agriculture e-Commerce involves internet usage, including mobile phone to provide information and bring together supply and demand in Agriculture sector. In the farmer's point of view, e-Commerce is selling and buying activity for agriculture product by using internet [9].

Agriculture e-Commerce is important to be developed since this system is needed to: 1) grow economic development in agriculture sector; 2) accelerate agriculture information flow; 3) spread market for agriculture sector; 4) promote industrialization process for agriculture [10]. There is some models to implement agriculture e-Commerce, including Business to Business (B2B), Farmer to Customer (F2C), Farmer To Association To Business (F2A2B), Online to Offline (O2O), Business to Business to Customer (B2B2C), Peasants to Customer to Business (P2C2B), and Peasants to Government to Business (P2G2B) [9][10]

China and India as agricultural country have started to develop agriculture e-Commerce. There is similarity for two e-Commerce business model. China and India involves e-business farmers, organization, and company as an integrated agriculture e-Commerce [11]. Therefore, there is a different in its implementation: 1) initiative e-Commerce implementation in India is aimed to cut production and buying cost, while in China is to increase farmer's revenue; 2) Agriculture e-Commerce business model in India to facilitate farmer to buy land and daily need through e-business mobile. On the other hand, China agriculture e-Commerce business model to ensure farmer's comfortable to sell agriculture product using PC and internet network; 3) Government has direct and special role in India, while China government only provides macroeconomic guidance or indirect regulation through finance, tax, law, and indirect participation in the market; and 4) Agriculture e-Commerce in Indonesia focuses on cheap goods and similar form of technology and electronics. Meanwhile, China Agriculture e-Commerce supports good quality products and more mature and multiform business model platforms [11]

During the development and implementation of agriculture e-Commerce, there are some problems that should be faced: 1) Low level of agriculture informatization; 2) Rural society's knowledge to use e-Commerce is still limited; 3) Less knowledge to optimize e-Commerce benefit; 4) Incomplete e-Commerce environment; 5) Various agriculture product characteristics; 6) Limited internet access; and 7) Agriculture practitioner lack of skill in using technology [9]. Thus, there are some considerations to develop and implement agriculture e-Commerce: 1) Integration of required information resources; 2) e-Commerce should focus on area development; 3) The need of strengthening the logistics and distribution system; 4) The need of strategy to boost farmer's and customer's profit [10]. Agriculture e-Commerce is important to raise rural society economic development. Perception, awareness, and obstacles are the most important things to implement agriculture e-Commerce. Perception relates with obstacles, while awareness relates with perception and obstacles. Farmer awareness and infrastructure support play important role in successful implementation of agriculture e-Commerce [12].

Institute of Research and Community Service Duta Wacana Christian University (DWCU) and Informatic Department DWCU.

III. RESEARCH METODOLOGY

This study use Dynamic System Development Method (DSDM). There are 5 main stages in development process of purchasing module: 1) feasibility study; 2) business study; 3) functional model iteration; 4) design and build iteration; and 5) implementation. This study is only up to the fourth stage, namely design and built iteration.

A. Feasibility Study

This is the first stage in developing agriculture e-Commerce. In this stage, it is identified some problems that for research background. There is no e-Commerce that particularly provides agriculture tools, materials, and product. This system has important roles in expanding the market for trading agricultural product that will provide bargaining power for farmers and actors involved in agricultural business.

Feasibility study also does some implementation eligibility assessment from resources availability, including development team and funding. Development team for agriculture e-Commerce consists of 6 persons as analyst, designer, and code implementation. Other while, this project is funded by Institute of Research and Community Service Duta Wacana Christian University (DWCU) and Informatics Department DWCU. Based on resources availability, agriculture e-commerce is considered worthy to be executed.

B. Business Study

Business study is the second stage to analyze business process relate to the system to be developed. Development of agriculture e-commerce is a stage that is already planned for Integrated Agriculture Information System (IAIS). IAIS is a study project has been conducting since 2015 and will continue until 2022. Agriculture e-commerce development is stated in developed IAIS blueprint [13][14][15]. Agriculture e-Commerce development in accordance with IAIS business motivation: development of architecture and application for IAIS. This goal has 3 objectives: 1) Blueprint strategy for system development; 2) Availability of IT infrastructure; 3) Development of Agriculture Information Systems and Knowledge Based Systems [15].

C. Functional Model Iteration

Functional Model Iteration is an iterative stage that is conducted to do modelling for system functionalities. Specifically, this step is to model functionalities in purchasing module of agriculture e-Commerce. There are two main functions: 1) Purchasing transaction management; 2) Reporting management. Those two functions are mapped and shown in table 1 below:

TABLE I. MODUL FUNCTIONALITY MAPPING

Functional Model	Module
Purchasing Transaction Management	Buyer Login
	Material, Tools, and Product searching
	Material, Tools, and Product Purchasing
	Payment
	Payment Verification
Reporting Management	Seller Reporting
	Admin Reporting

D. Design and Build Iteration

This is the fourth stage in development process. Purchasing module design includes use case diagram design, database design using ER Diagram, activity diagram, sequence diagram, and interface design.

Use case diagram is used to give some explanations of each user's role and functionalities. Purchasing module has two main actors: Buyer and Administrator. Use case diagram is show in figure 2 below.

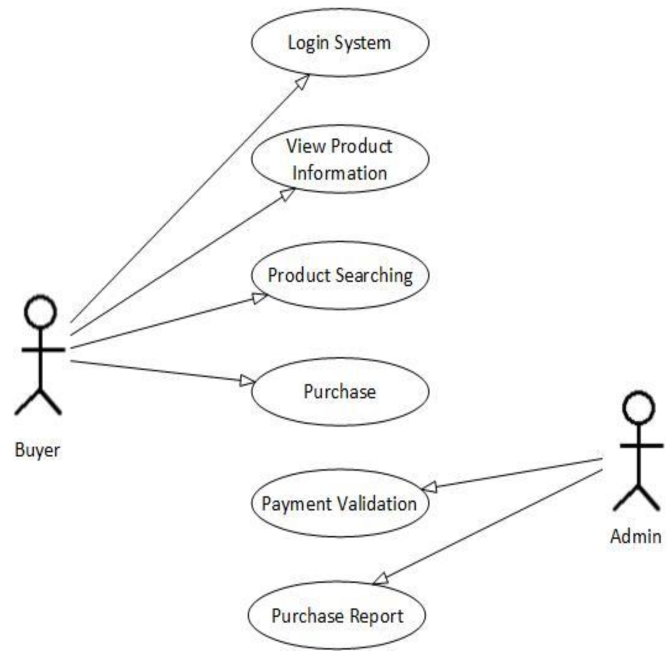

Fig. 2. Purchasing Module Use Case Diagram.

Figure 2 shows that there are two main actors: buyer and system administrator. Each user has its use cases. Buyer is able to 1) login to system; 2) material, tool, and product searching; 3) see information related to the product offered; 4) buying agricultural material, tools, and product; and 5) processing payment. On the other hand, system administrator is able to validating payment and generates purchasing report.

Database design of purchasing module was designed using Entity Relationship Diagram. This process uses Logical Data Modelling. There are 8 steps in the modelling: 1) identify main entities; 2) depiction of entity relationship; 3) defining primary and secondary key; 4) defining foreign key; 5) business rules definition; 6) non-key attribute addition; 7) validating normalization rules; 8) data dictionary creation. There are 12 entities in e-commerce database. The followings are relation scheme:

- Master_detail_user (ID_User Primary Key),
- Master_kategori(ID_Kategori Primary Key),
- Master_user_kat(ID_kategori, ID_user Both are Foreign Key from table master_kategori and master_detail_user),
- Master_user(ID_User Primary Key),

- Master_Produk_Tani(ID_Produk Primary Key),
- Master_Spesies_tanaman(ID_Spesies Primary Key),
- Master_Kategori_Produk(ID_Kategori Foreign Key from table Master_kategori),
- Master_alat_tani(Id_Alat Primary Key, ID_Kategori Foreign Key from master_kategori),
- Master_bahan_pertanian(ID_Bahan Primary Key, ID_Kategori Foreign Key from table Master_kategori),
- Trans_harga_produk(ID_Produk Foreign Key from Master_produk_tani, ID_User Foreign Key from Master_detail_user),
- Trans_permintaan(ID_Permintaan Primary Key, ID_User Foreign Key from Master_detail_user, ID_Penawaran Foreign Key),
- Trans_penawaran_prod_tani(ID_Penawaran Foreign Key, ID_User Foreign Key from Master_detail_user).

Complete figure of Database design can be seen in Figure 3.

The next modelling is activity diagram. There are three main processes: 1) login process; 2) purchasing process; and 3) report generating process. Activity diagram of each process can be seen in fig. 3 - 5.

Figure 4-5 shows activity diagram of each main activities. Fig. 4 shows activity for login process. User should have an account to login. If there is no account, user should register it through the website. Administrator will verify new user registration. An email is able only once to be used to register the new user and will be active in a day.

Figure 5 shows activity diagram to order agriculture tools, materials, and product. To order, user should have an account. User should pay the order to website administrator. System administrator will verify the payment. If it is success, system administrator will forward the order to the seller and change the status to indicate that the order is already paid. Seller will sent the order to the buyer if it is ready.

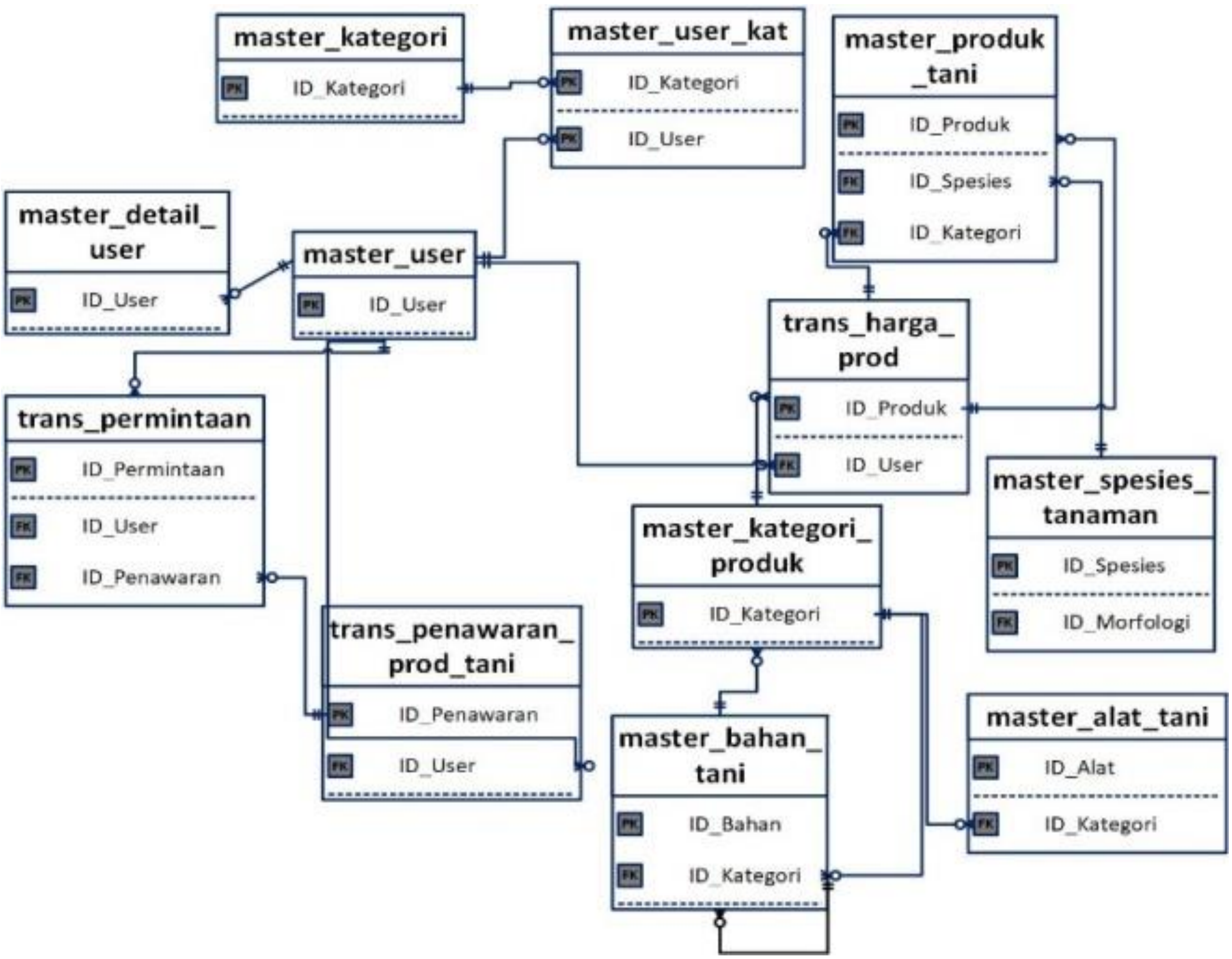

Fig. 3. Entity Relationship Diagram Purchasing Module.

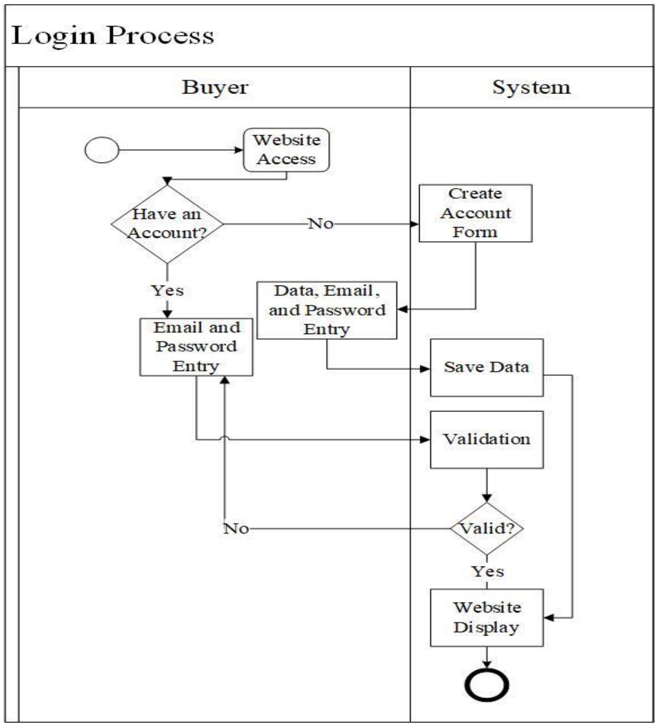

Fig. 4. Activity Diagram Login Process.

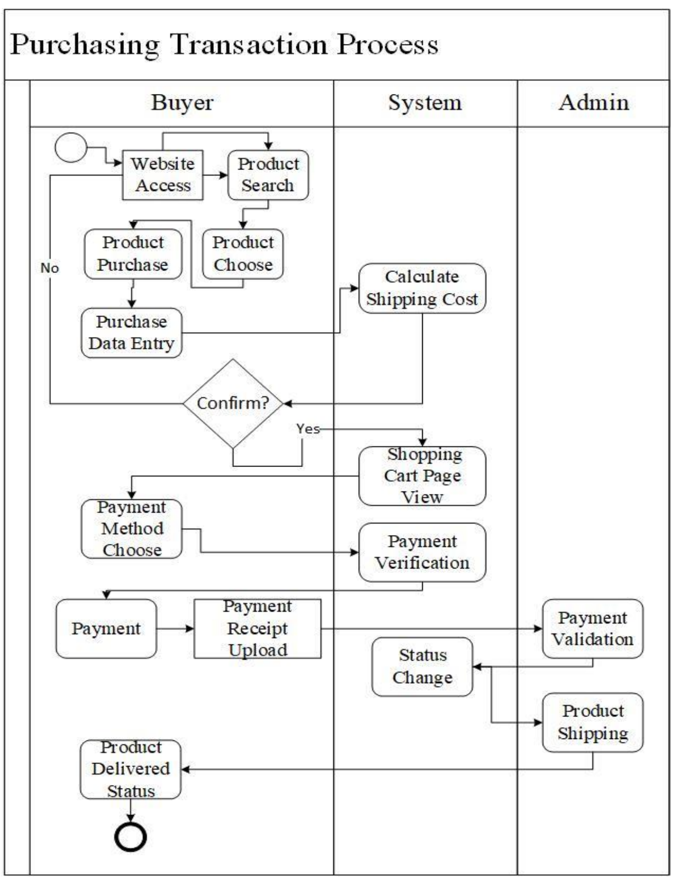

Fig. 5. Activity Diagram Purchasing Transaction.

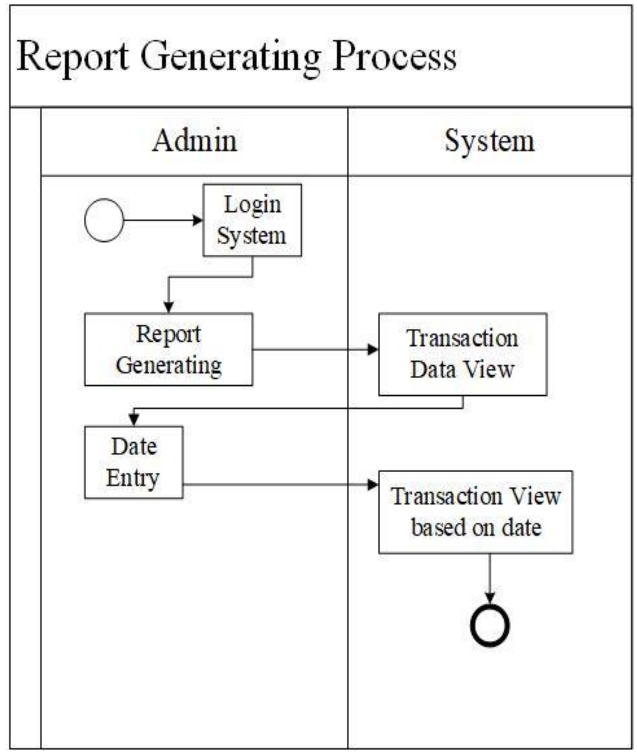

Fig. 6. Activity Diagram Report Generating.

Figure 6, shows activity diagram to manage report. User should determine and enter the specific date for report. The system will generate the desired report.

Sequence diagram is the diagram to describe the interaction between object and system. There are 6 sequence diagrams for purchase module: 1) user login sequence diagram; 2) see item information; 3) search specific item; 4) purchase item; 5) payment verification; and 6) generate report. Sequence diagram of six main activities are shown in fig. 6 - 11.

The first sequence diagram is user login (fig. 7). This diagram shows the process of login user. User input id and password, after that system will check user id and password on user data. If data conform then user will be directed to purchasing page. In purchasing page, user can search product as shown in fig. 8. User can click the product to see information detail. Sequence diagram for viewing product detail can be seen in fig. 9. The steps that user should do for purchasing can be seen in fig. 10. The admin payment verification process can be seen in fig. 11. User admin can perform report by following the steps in the fig. 12.

After completing the database and process design for purchasing module, the next step is to design the user interface for purchasing module. There are 11 user interface design for purchasing module in agriculture e-Commerce. Those are home, user login, user registration, product detail, shopping transaction, shopping cart, payment form, user profile detail, admin dashboard page, payment verification, and reporting page.

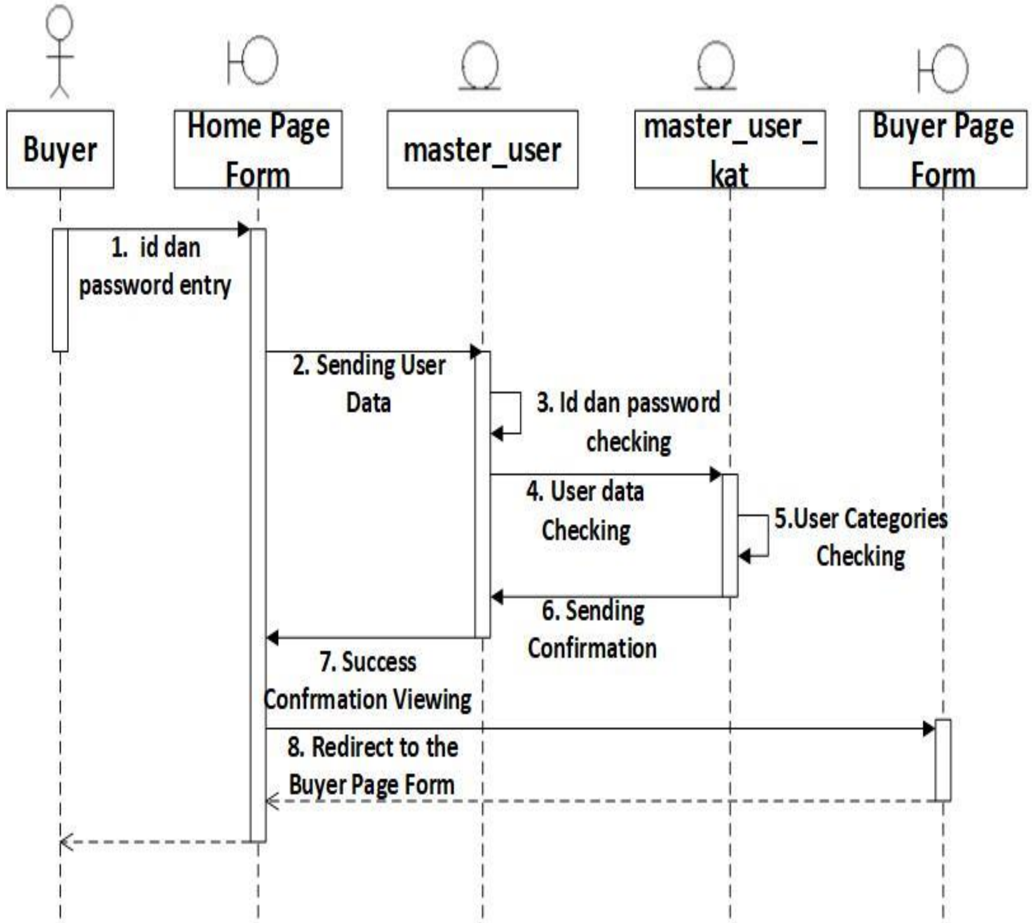

Fig. 7. Sequence Diagram User Login.

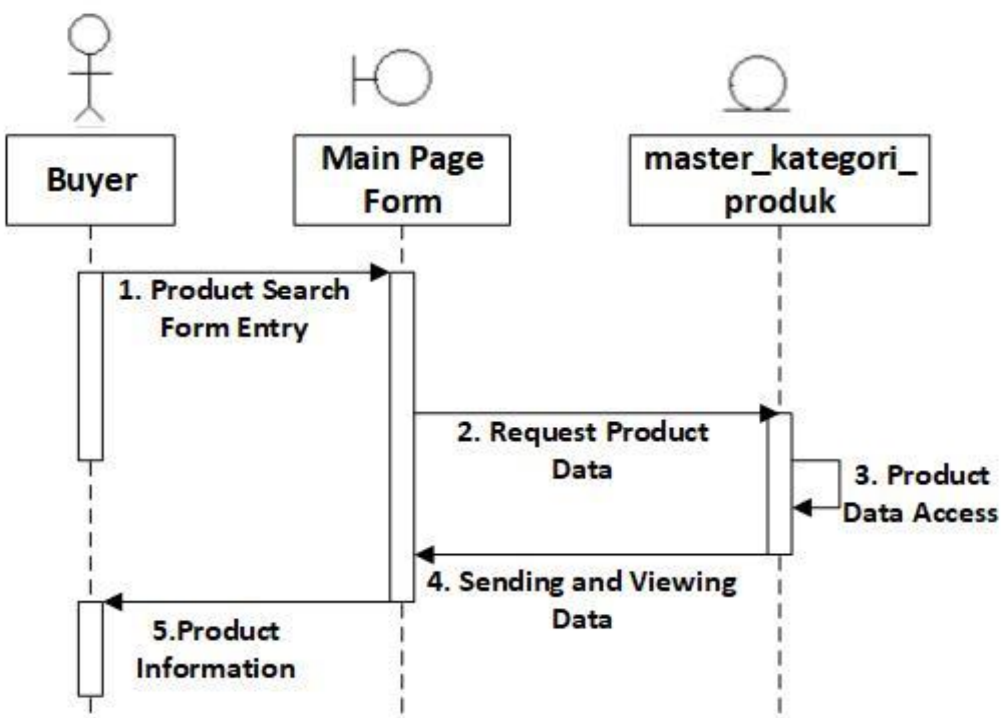

Fig. 8. Sequence Diagram Item Searching.

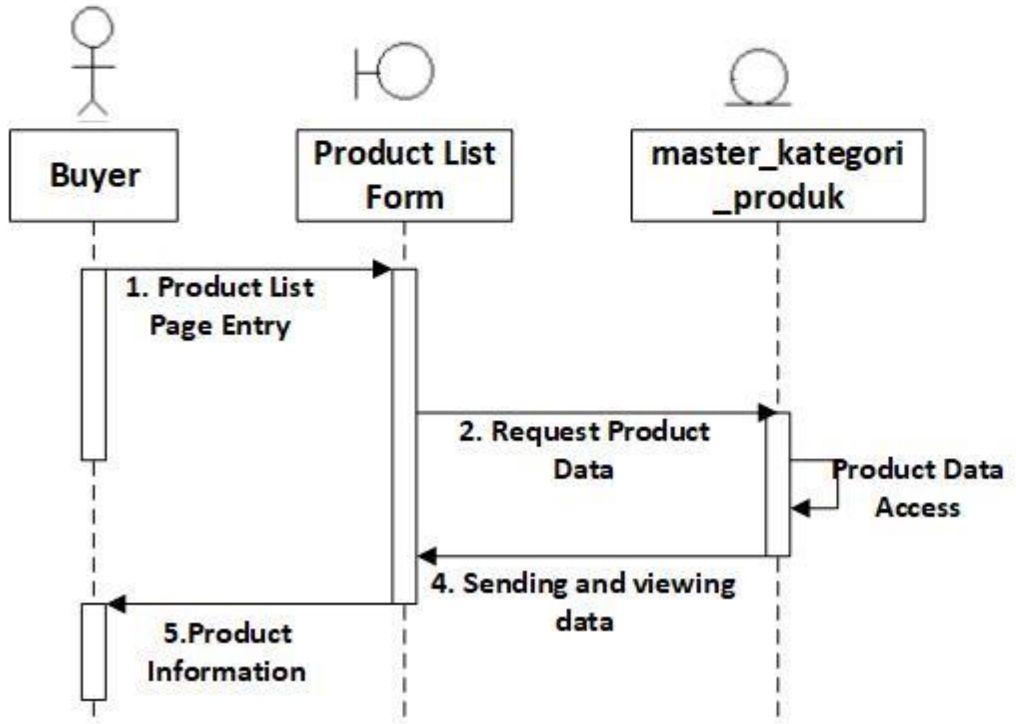

Fig. 9. Sequence Diagram Viewing Item Information.

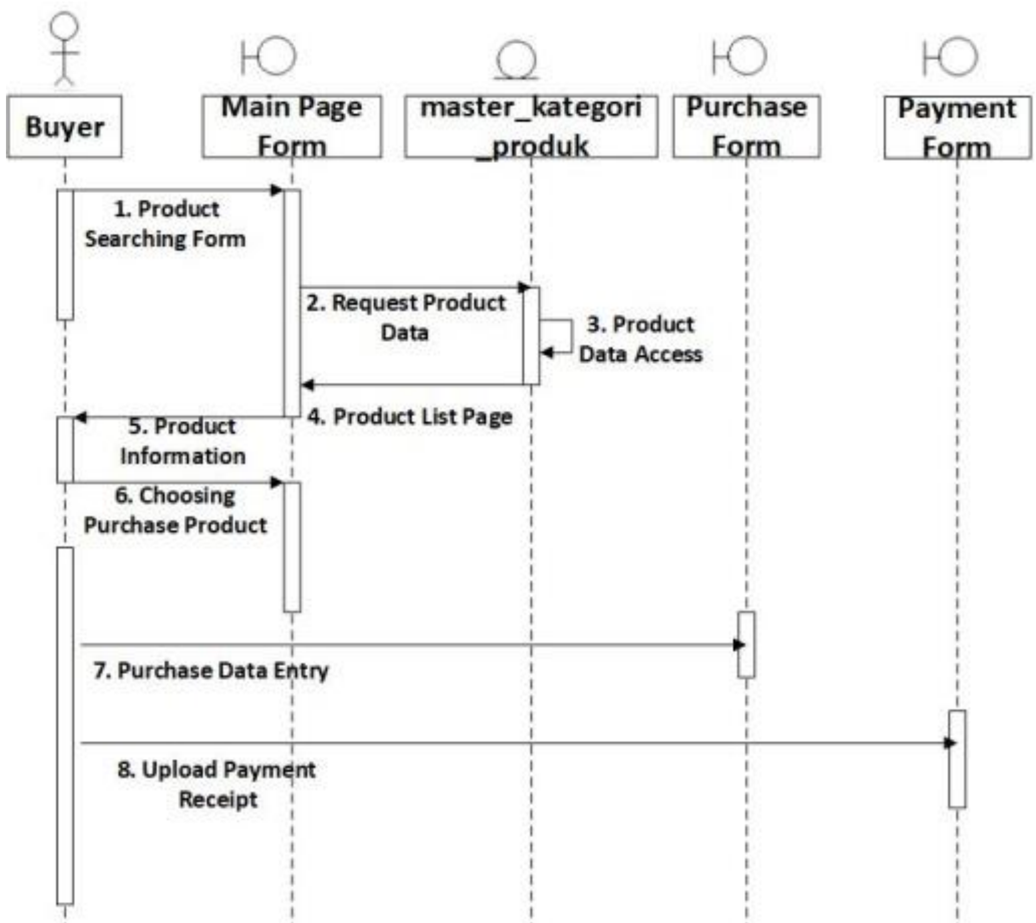

Fig. 10. Sequence Diagram Purchasing Item.

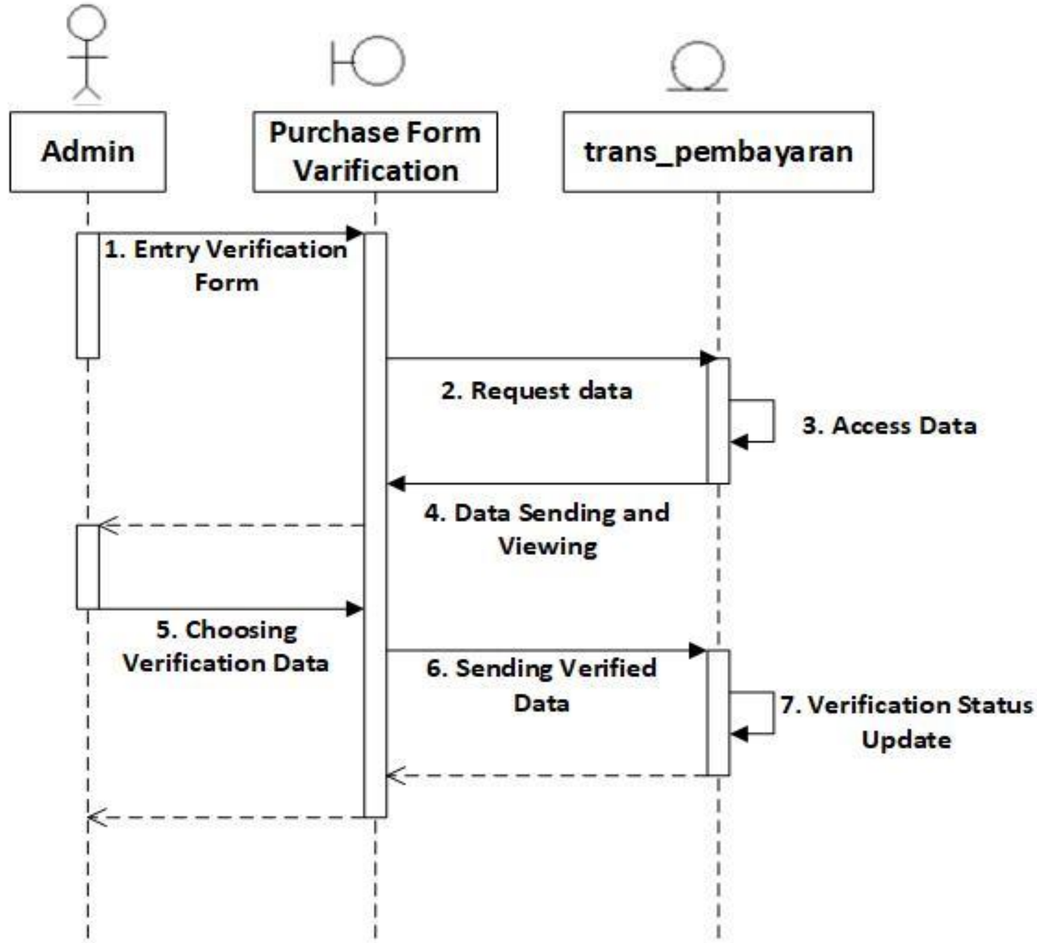

Fig. 11. Sequence Diagram Payment Verification.

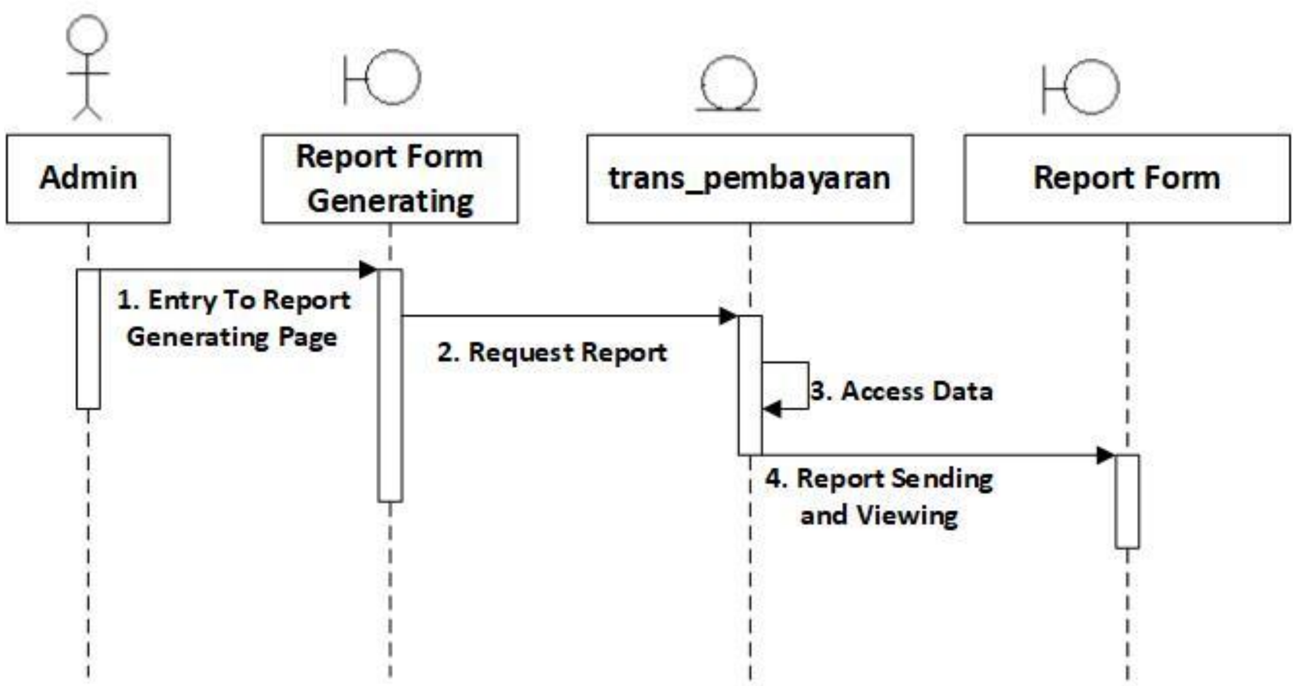

Fig. 12. Sequence Diagram Report Generating.

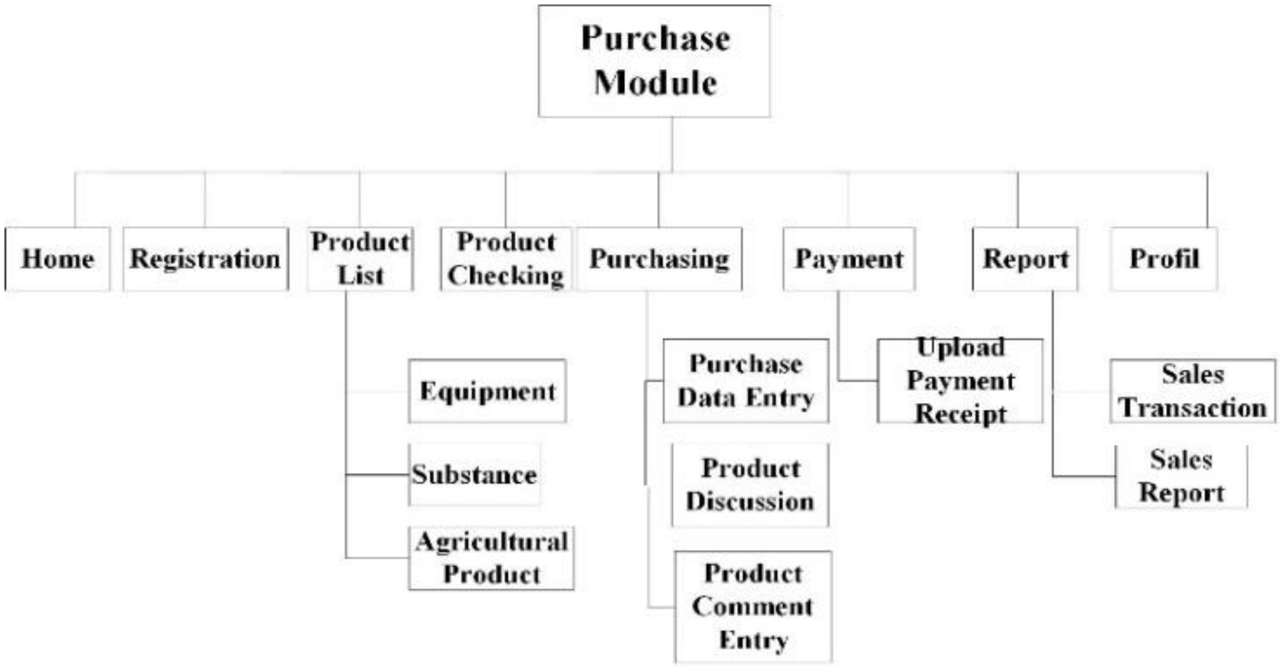

Fig. 13. Agriculture e-Commerce Purchasing Module Site Map.

IV. Implementation and Analysis

A. Purchasing Module Implementation

Agriculture e-Commerce purchasing module has this following sitemap, as shown in fig. 12.

Figure 13 shows purchasing module site map. Purchasing module has 8 main menu: home, registration, product information, product detail, purchasing module, payment, reporting, and user profile. Some of those menus has sub menu which bring user to get more detail information.

Figure 14 shows user login page for user authentication. User should have an account to login. If the user does not have an account, user should register it and the system administrator will verify the registration.

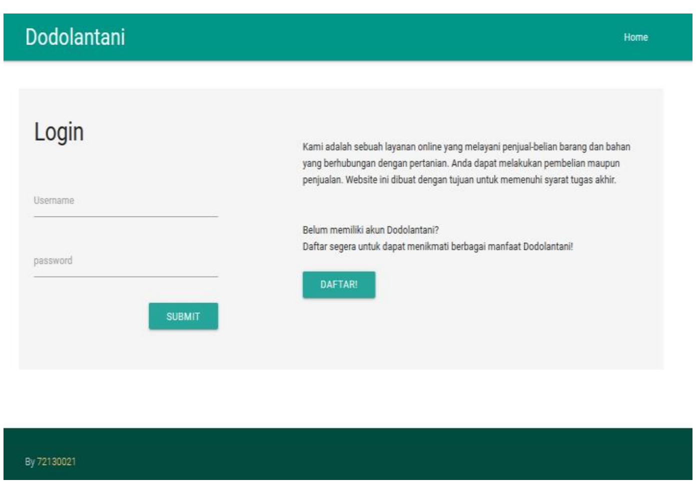

Fig. 14. User Login Page.

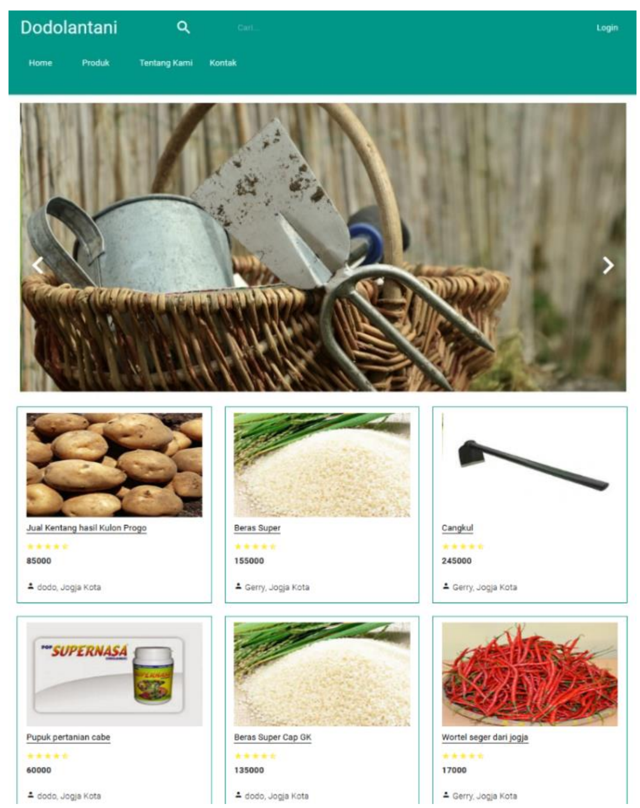

Fig. 15. Product Page.

Figure 15 shows the product page information. This page gives the product information, price, and the seller. User is able to see the detail information by clicking the product picture or product name.

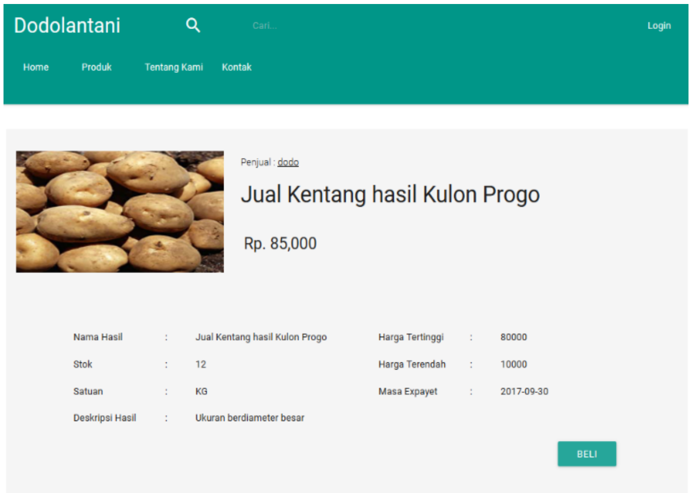

Fig. 16. Detail Product Page.

Figure 16 shows the product information detail. Product information, like unit, price, and product description, highest and lowest price are shown in this page. User is able to see the remaining stock available in this page.

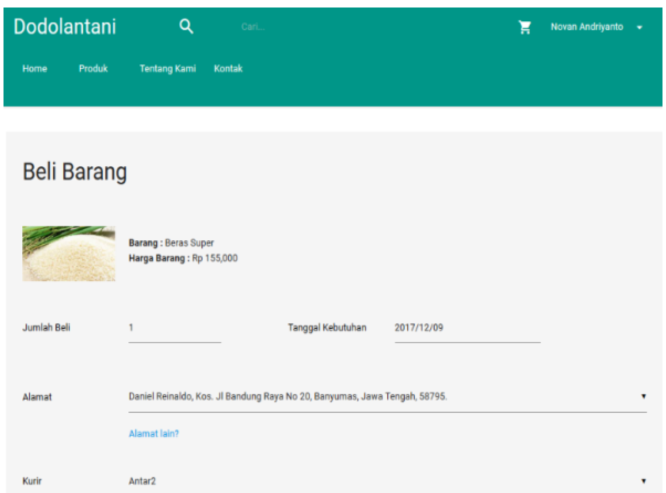

Fig. 17. Shopping Page.

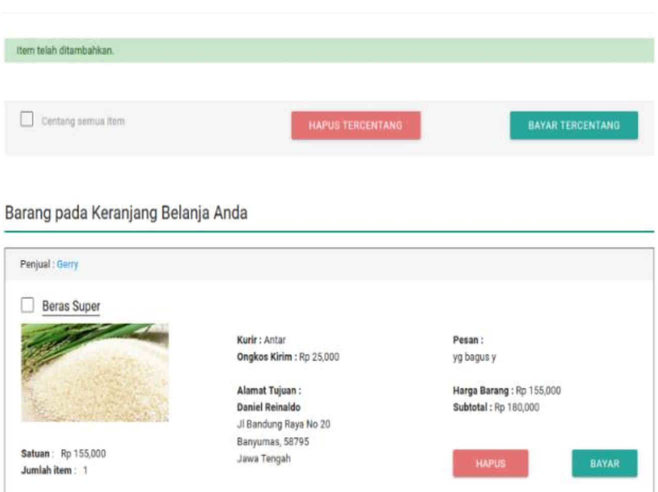

Fig. 18. Shopping Cart Page.

Figure 17 shows the shopping page. In this page, customer should entry quantity of product they eager to buy, requirement date, shipping address, and choose the appropriate courier services. After completing the purchasing process, the product goes to shopping cart. Shopping cart is shown in figure 17 below.

Figure 18 shows the shopping cart page. This page summarizes items that customer buys. Customer is able to delete the item if the customer wants to cancel the order. If customers are ready to pay, customer should press the payment button and the system will bring you to the payment page. Customer should pay via transfer to the stated amount. This e-commerce still has limitation in its payment process. It still has no cooperation with card merchant and banking.

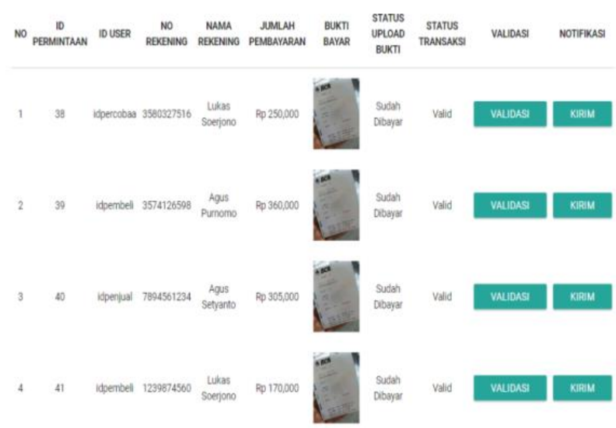

Fig. 19. Payment Validation Page.

After completing the transfer and payment process, customer should upload the transfer receipt. Figure 19 shows the admin validation page. Customer should entry the transfer amount. System administrator will verify the payment process by clicking the validation button. System administrator is also able to send the notification to the seller if the payment has been received.

B. System Testing

System testing is conducted after the development process finished. System testing is carried out to evaluate and ensure the program is working according to the functions that have been set. Module testing is carried out focusing on functional and system specification. This model is called Black Box. There are four functionalities specifications that is tested: system interface, basic functional system, system handling, and system security. The number of tests and the percentage of success for each test can been seen in table 2 below:

TABLE II. MODULE FUNCTIONALITY MAPPING

No	Testing Specification	Number of button or function	Number of test	Percentage of success
1.	System Interface	10 buttons	61	100
2.	System Basic Function	3 functions	40	100
3.	System Form Handle	3 entry form	12	100
4..	System Security	2 cases	6	100

Table II indicates the module functionality mapping results. It shows that percentage of success for the test is 100%. It means that functionality of purchasing module prototype works according to the requirement.

C. Advantage and Disadvantage Purchasing Module Analysis

There are some advantages of purchasing module for agriculture e-Commerce: 1) system has been equipped with product discussion. Through this feature, buyer is able to interact and communicate with seller about the product; 2) Information / reports as an output system is able to be saved in pdf format; and 3) this system is web based. It will help the seller to expand the market wider.

There are two disadvantages of purchasing module for agriculture e-Commerce: 1) System is not able to give limitation to product picture size; 2) System does not have product payment feature. It has no cooperation with financial institution.

D. Dynamic System Development Method (DSDM) Implementation Analysis

Dynamic System Development Method (DSDM) is implemented to continue the previous study. Two initial phases are feasibility and business study is implemented based on previous study. Functional model and design and build model iteration is implemented, either parallel or sequential. Parallel process is carried out for purchasing and selling module. Otherwise, integration module is conducted sequential after those two modules are successes to be implemented. Implementation of Dynamic System Development Method is suitable and flexible following dynamic changes experienced by the system development team.

V. Conclusion and Future Work

A. Conclusion

This study concludes that: 1) Dynamic System Development Method (DSDM) is successfully applied by perform two main steps, namely functional model iteration and design and build iteration incrementally. Meanwhile the first two steps, feasibility and business study are done by referring the result of previous research; 2) Purchasing module for agriculture e-Commerce has two main users: purchasing system management and reporting management; and 3) Testing results shows that module prototype runs well in according to defined functions.

B. Future Work

Future work that is going to be done is integrating purchasing and selling module, system usability testing, and implementation to the farmer community and agriculture industry.

Acknowledgment

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References

[1] E. Turban, D. King, J. Lee, T. Liang and D. Turban, Electronic Commerce : A Managerial and Social Network Perspective, Cham, Switzerland: Springer International Publishing AG, 2015.

[2] A. G. Khan, "Electronic Commerce: A Study on Benefits and Challenges in an Emerging Economy," *Global Journal of Management and Business Research: Beconomics and Commerce,* pp. 3-4, 2016.

[3] A. E. Chowdhury, A. Bhowmik, H. Hasan and M. S. Rahim, "Analysis of the Veracities of Industry Used Software Development Life Cycle Methodologies," *AIUB Journal of Science and Engineering (AJSE),* pp. Vol. 16; Issue 2; June; pp 1-8, 2017.

[4] M. Al-Zewairi, M. Biltawi, W. Etaiwi and A. Shaout, "Agile Software Development Methodologies:," *Journal of Computer and Communicat,* pp. Vol. 5; pp 74-97, 2017.

[5] J. Stapleton, DSDM Business Focused Development, Second Edition, Great Britain: Addison Wesley, Pearson Education, DSDM Consortium 2003.

[6] K. Slegten, "Dynamic Systems Development Method (DSDM)," 2016.

[7] Agile Business Consortium, "The DSDM Agile Project Framework (2014 Onwards)," 22 Januari 2018. [Online]. Available: https://www.agilebusiness.org/resources/dsdm-handbooks/the-dsdm-agile-project-framework-2014-onwards.

[8] B. J. Voigt, "Dynamic System Development Method," Departement of Information Technology University of Zurich, Zurich, 2004.

[9] J. Wang, X. Zhu and C. Zhang, "Models of China's E-Commerce in the Agricultural Sector : an Exploratory Study," *International Journal of U-ande-Service, Science and Technology,* vol. 9. No. 4, pp. pp. 389 - 400, 2016.

[10] J. Huiting, "Discussion on the Construction of Agricultural E-commerce Mode," in *International Conference on Ecanomic, Finance and Statistics (ICEFS),* Hongkong, 2017.

[11] M. Dong, "International Comparisons on Business model of agriculture e-commerce between India and China," in *International Conference on Industrial Economics System and Industrial Security Engineering (IEIS),* Sydney, Australia, 2016.

[12] R. Kalpana and N. Shibu, "ICT Usages with E-Commerce in Agricultural Practices," *Journal of Commerce and Management Studies,* vol. VIII, no. Special Issue 1(2), pp. 63-67, July 2017.

[13] R. Delima, H. B. Santoso and J. Purwadi, "Architecture Vision for Indonesian Integrated Agriculture Information Systems Using TOGAF Framework," in *International Conference of Informatics and Computing (ICIC),* Lombok; Indonesia, 2016.

[14] H. B. Santoso and R. Delima, "Stakeholder Definition and Analysis for Indonesian Integrated Agricultural Information Systems (IAIS)," in *Conference on Information Technology and Digital Application,* Yogyakarta, 2016.

[15] R. Delima, H. B. Santoso and J. Purwadi, "Business Architecture Developmnet for Integreted Agriculture Information System (IAIS) using TOGAF Framework," *Researchers World,* vol. VIII, no. 2(1), pp. pp 01-13, April 2017.

Formalization of UML Composite Structure using Colored Petri Nets

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***Abstract*—Design specification and requirement analysis, during development process involved in transformation of real world problems to software system are subjected to severe issues owing to involvement of semantics. Though, for design and specification of object-oriented systems, Unified Modeling Language (UML) is now recognized as standard language however, its structures have numerous drawbacks which include lack of semantics definition and unidentified deadlocks. The research work proposes a model to avoid deadlocks, specifically in composite structure of UML. Verification of system models by formal methods holds significance, particularly, at requirement specification and design level, to ensure the accuracy of models and high light the design problems before implementation. The paper proposes the rules that allow software engineers to formalize the behavior of UML 2.0 composite structure using Colored petri nets. Using these rules, the research shall analyze the correspondent Colored petri nets and conclude the properties of the original work flow, using theoretical outcomes in the Colored petri nets domain.**

Keywords*—*Design specification; UML (Unified Modeling Language); semantic; transformation; deadlocks

I. Introduction

Software engineering is facing multifarious challenges in the fields of design specification and requirement analysis owing to complications involved in system models' verification of real world thus rendering it a difficult task [1]. UML, governed by Open Group of Companies, is comparatively open standard, organized by the Open Management Group (OMG). It helps to make all important decisions of specification related to analysis, design and implementation. Though it is not visual programing, but its models are connected to a huge variety of programming languages [2]. It plays a vital role in design and implementation segment for building a software system. However, combination of a variety of object-oriented analysis and design methods into a single modeling language has inherited complicated issues [3]. Flaws in UML notation have invited the researchers to discover alternative methods for addressing the integration and compatibility issues with in order to allow an accurate and reliable design, modeling and development. UML has a set of standard symbols required for building objects and visualization of a software system, non-software systems and business modeling [4]. It has become a standard for designing and implementation of object-oriented system [5], even though its semantics are semi-formal and liable to chances of ambiguities in the system design. Issues related to Modeling a system by UML are as under:

- Due to the graphical notation of UML structure it has certain chances of errors.
- At the design level of software system, hidden semantics of UML diagram can cause ambiguities.
- Model described by UML diagram can lead to multiple understandings, thereby disabling receivers of the model to take the precise decision with respect to the diagram.

The capability of UML can be enhanced by connecting it with formal methods and design the system by describing semantic rules in a formal way [6] owing to following reasons: -

a) Formal methods provide high level guarantee and reliability for analyzing of models.

b) It helps in detection of errors and defects at an early stage to reduce the cost.

c) Formal methods allow the developer to check model mathematically and prove its validity by the integration of UML diagrams with formal notations resulting in reliable, complete and accurate modeling of the system [7] [8].

UML 2.0, comprising integrated models and diagrams was introduced after success of UML 1.x. It allows us to model the structure of a system before its implementation, however significant problems related to identification of "errors" and "deadlocks" in designing phase persist [9] thereby leaving chances of system failure after execution. This research aims at resolution of this problem by transforming composite structure, using formal methods. Composite structure diagram enables us a deep insight of the class so as to what is actually happening as well as relationship of nested classes [10]. Using Colored petri nets model for transformation process which is a mathematical modeling (formal verification) language used for systems which have complex behavior. Since Colored petri nets are a formal model so they do not carry any ambiguity and can be validated [11]. The prominent benefit of this language which compelled us to deviate from traditional UML to Colored petri nets model is that it identifies the 'Errors' and 'Deadlocks' in a system before execution [9]. This will help to evaluate the model at an early stage thereby reducing the cost, risk and time span [12]. In the past few years a lot of work gone into formalization of UML diagrams, however composite structure diagram has failed to attract any worthwhile strength of researchers in the field. By transforming composite structure using Colored petri nets model will try to attain much precise results, while proving the scenario using some rules and formulate a case study towards the end.

II. Related Work

A combination of Z notation and petri nets is proposed for designing safety critical systems. The part of construction cell is modeled and check its validity by safety interrelated properties [13]. A transformation from OCL (Object Constraint Language) into B is projected in [14]. Given transformation scheme is automatically derive to B except invariants of class. A UMC framework is present by the gatherings of UML state machine for the formal verification of concurrent systems. The formal model which is given in this system have transition having labels dually and uses logic to describe its properties comprising event-based and state-based logic. It allows user to see insights of a UML model to investigate behavioral aspects by visualization and model checking [15]. A framework of fuzzy logic is suggested to evaluate the compatibility of formalism on specific electronic commerce system. The evaluation of UML, Z notation, state charts, finite state machine (FSM) and Colored petri nets is carried out in combination with some domain by using the fuzzy logic structure and evaluation standards [16].

Raymond [17] shows the growing diversity of formal methods and mathematical models which plays a bridge role between “continuous” and “discrete” systems. A method is proposed by Than et al. [18] to formalize the syntax and semantics of UML state chart into Z notation, given semantics helps to elaborate the model consistency and assure its unambiguity and completeness. A formalization of higher order logic is presented based on arithmetic by using tool SPW (Signal Processing Work System) [19]. Akbarpour et al. uses the different rounding modes in fix point arithmetic like directed and even rounding modes. An analysis is performed to check the accuracy and basic arithmetic operations, multiplication, subtraction, addition and division.

Liu and Dong [20] give an algorithm to schedule the tasks executed in the finite set of memory, Input streams and code generated will be smaller in size as compared to previously used. Petri nets is used to do formal analysis and verification of the given algorithm. A simulation is projected by Hasan and Tahar [21] a higher order logic theorem for the analysis of critical parts and can give accurate results. A pair of probabilistic properties is also verified which was not evaluated by existing techniques. A methodology is offered to formalize some common diagrams of UML which are used in several phases of Z notation software development [22], a visual representation has been taken with this tool based approach by the formalization of UML diagrams. Derakhshandeh et al. [23] proposed a formal model for Access Control Policies (ACP) specification which have ability to express many ACPs, joining them in a unified model and also verifying conflicts among them.

Ma [24] presents the fuzzy extensions of ER/EER and UML models to manage a system at conceptual level. Some main notations have been prolonged and conforming the graphical notations, a formalization is performed by aiming on the basic concepts of class structure using simple case studies. A formal method is proposed based on mathematical mechanism to prove program correctness [25]. Algebra approach is used to improve the verification capability of the model which give the guarantee to provide error free model. Cunha et al. offered a method for transformation of UML sequence diagram to Petri nets to find out dead locks, errors and verifying liveness, reachability and safety of the model. This method is performed in an embedded control application, a sensory device which detect the object in the environment. A mathematical extension of OCL language is projected by cumulate its class library to deploy some mathematical notions including relations and functions [26]. Zhang and Liu [27] give a web-based service CCML (Cooperative Composition Modeling Language), is formalized by the formal verification method and also check its validity by proving a case study. A target fusion recognition method is proposed to check its reliability and validity based on the fuzzy sets and Petri nets under a complex environment which is also demonstrated by a simulation example [28]. UML activity model does not have firmly formal semantics, so it is hard to analyze them and activity model checking. An ontology-based method is presented for semantic checking of activity model which are divided into two parts dynamic semantics and static semantics [29].

III. Background

In this section a brief discussion has been presented about the composite structure diagram and Colored petri nets.

A. Composite Structure

In UML 2.0 many diagrams were introduced which comprises Activity diagram, Class diagram, Sequence Diagram, Communication diagram, Component diagram, Composite Structure diagram, State diagram, Agent based UML and so on so forth. Composite structure diagram shows the internal structure of a specific classifier just like component diagram. A huge range of the notation of component diagram can be supported by composite structure diagram as well. Where the component diagram shows the internal structure, on the other hand composite structure shows the specific functionality of the classifier to be executed. It has four main parts which includes class, connectors, ports and interfaces. Class shows all the information, and composite structure diagram assumes to be complete when class diagram is considered as the smallest class structure which declares the given composite structure [30].

A connector is providing the interface between two objects. It might be an object which represent the relationship or a value hold in the variable. The value which is hold by the variable is the other way to represent the association between two objects. A port is a source which suggest the functionality of composite structure without exposing the internal operations. The port is a small square notation which is drawn above the edge line of the boarder. The multiplicity of port and its parent name are written near to it. The ports are connected with required/provided interfaces like from/to the situation. The required/ provided interfaces are commonly show with the socket/ball notation. Each port is connected to its internal operation using connectors and these internal operations can be some code kept by the classifier. The composite structure diagram and associated structures uses and semantics are well defined in [31][32][33] while the concepts of composition are effectively defined in [34][35].

B. *Petri Nets*

Petri Nets is a formal mathematical modeling language which is introduced in 1962 by Carl Adam Petri. It is used to formalize the models before implementation to identify the errors and deadlocks hence it can be rectified. It has strong formalized modeling capability in various fields like computer science and system engineering. It gives us facility to provide the mathematical theory with pictorial representation for a dynamic system. Mathematical theory will draw a precise model and let us know the behavior of system. And the graphical system shows the model visuals and state changes of the system. The combination of these two aspects are the key reasons of petri nets success. It has been used in modeling of many event driven systems such as computer networks, work flows, communication systems, real time computing systems, manufacturing plants, logistic networks and command and control systems [36].

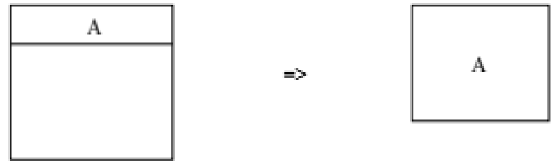
Petri nets are the directed split graph having transitions and places which are represented by the nodes. Transitions are the events which may be occur and it is denoted by the bars and places are the conditions denoted by circles. Petri nets are consisting of three main parts which include places, transitions and arcs. Arcs are directed from places to transition or transition to places. They will never connect from place to place or transition to transition. The arc which comes out from place to transition that place will called transition input place, and arc which connects from transition to place is called transition output place. In the diagram of a petri nets, places are denoted by circles, transition are by long narrow rectangle and arcs are symbolized by one-way arrow which represent the relation from place to transition and transition to place [37].

IV. Composite Structure to Colored Petri Nets Model Formalization Rules

In this segment, shown a briefly description about the transformation and formalization of some upper level operators which are offered in the UML2.0 composite structure into interactively equal Colored petri nets. For this purpose, here describe the semantics of operators, and explain how formalization will be accomplished. Furthermore, presented some outcomes by applying these concepts on a few demonstrative samples and also explain by a case study.

A. *Component*

In rule 1, shown the trivial case where component A is implies the existence of class A. Now show its obtained colored petri nets fig. 1.



Rule 1 UML Composite Structure.

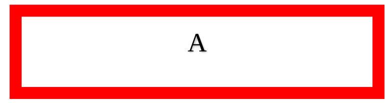
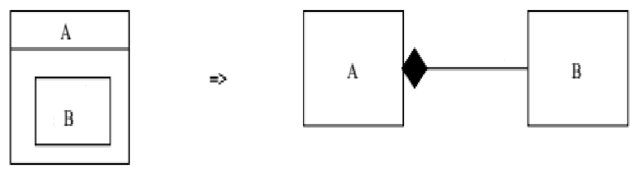


Fig. 1. Obtained CPN.

B. *Simple Composite Structure with Class into Component*

The case in rule 2 is denoted the situation of a simple composite structure A contains the B parts. This implies that class A having a sort of relationship with class B. When the relationship is executed, objects may communicate with each other by calling their operations. The part B is shown by solid rectangle with the composition of part A, though the relationship of A and B must be composite. A strong relationship shown by black diamond, which means that part B is life time owned by the parent object part A. Obtained CPN are shown in fig. 2.



Rule 2. UML Composite Structure.

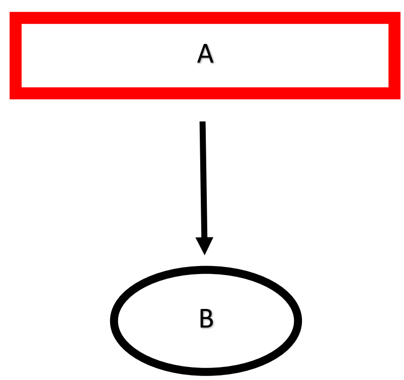
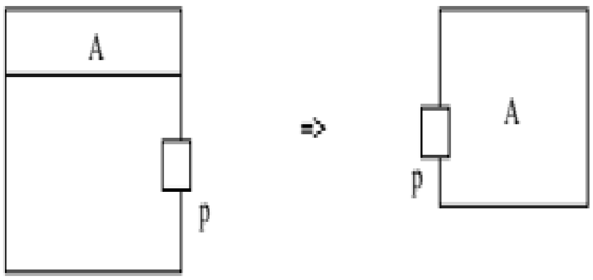


Fig. 2. Obtained CPN.

C. *Component with Port*

In composite structure a connection is made by port artifacts and signals send and receive via these ports. A trivial case of composite structure with port is shown in rule 3, which is also implied in class diagram. Connection between ports is termed as “wire”, elaborate that a communication is occur by a signal sent from “wire” to receive port. Obtained Colored petri nets are given in fig. 3.



Rule 3. UML Composite Structure.

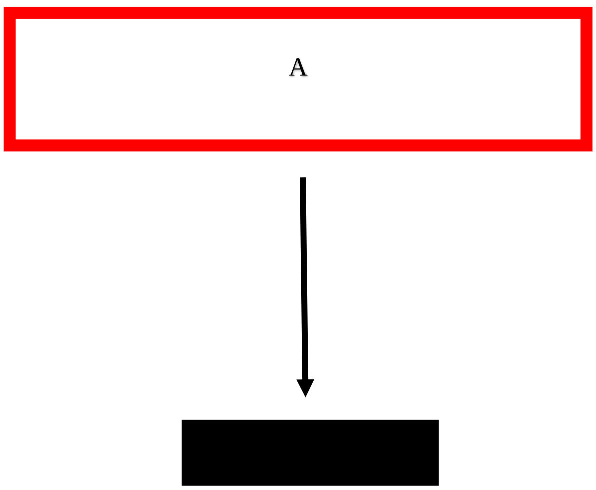
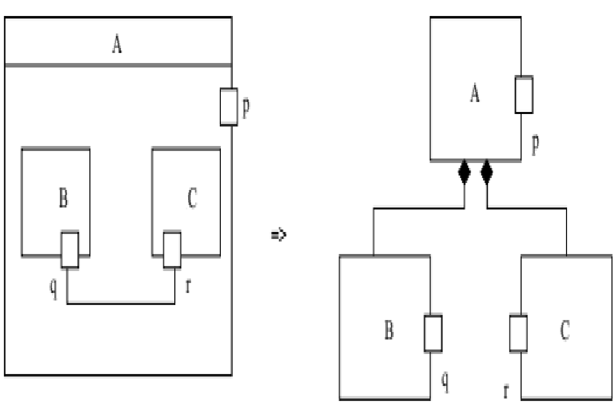


Fig. 3. Obtained CPN.

D. Two wired Ports

In this rule port p of A is by default visible and public to internal and external parts, although it is the parent class of B and C and port q and r visibility is internal and private because they are the child classes of A. Let us check its obtained CPN in fig. 4.



Rule 4. UML Composite Structure.

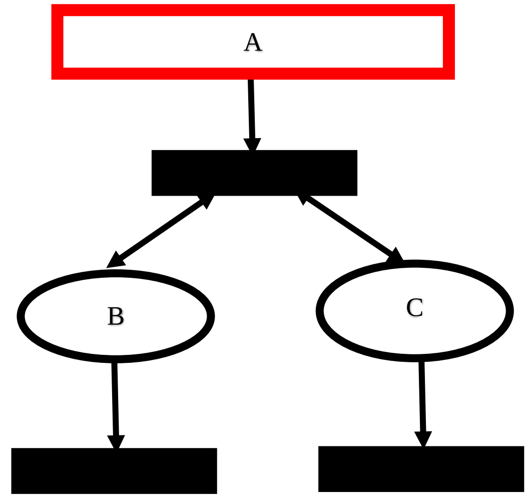
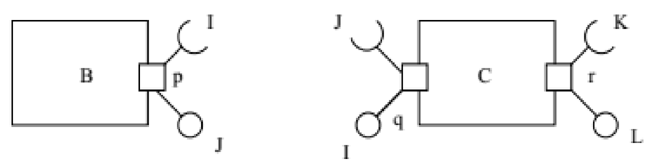


Fig. 4. Obtained CPN.

E. Various Interface Combination

If the interfaces are compatible, then two ports can communicate sensibly between required interface and provided interface. In rule 5 it is possible to establish connection in both directions for ports p and q as each either provided interface or required interface I and J. If connection for instance, between port p and port r are not sensibly connected to each other, no message will be understood and propagate with each other. And a meaningful communication will not take place as neither the required nor provided interface match. Obtained CPN are shown in fig. 5.



Rule 5. UML Composite Structure.

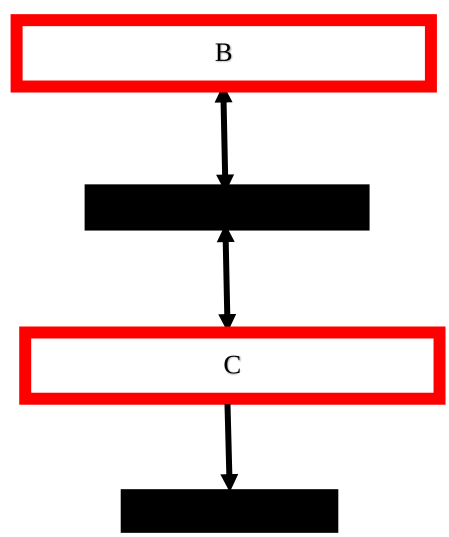


Fig. 5. Obtained CPN.

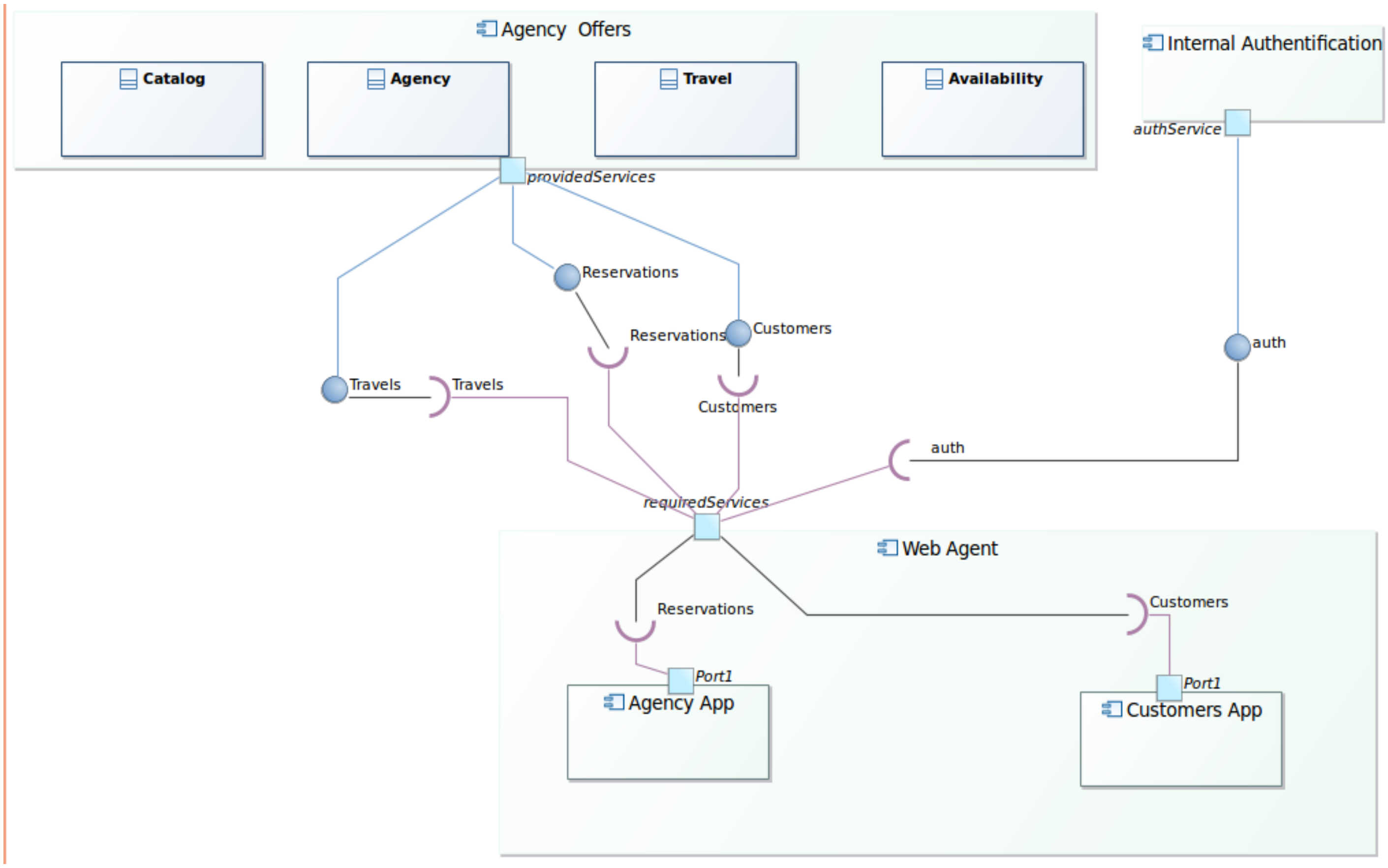


Fig. 6. Composite Structure Model of a Travel Agency.

The obtained petri nets elaborate the various connecting interfaces of a composite structure, where B is a class having both provided and required interface. After transition of class B, another interface connecting the class C with provided interface.

V. Case Study

By taking a real-world case study of a travel agency shown in fig. 6. We will prove the composite structure diagram by explaining each of its component. For this purpose, formalize a composite structure diagram into Colored petri nets model.

By taking a real-world case study of a travel agency formalization of composite structure will explain more clearly. In this case study proposed a structure of a travel agency that how it works with *Web Agent, Agency Offers* module and *Internal Authentification.* Furthermore, show the interactions between customer and agency also their relationship.

A. *Web Agent Module*

- There are two components to choose in the 'Web agent'.
- One is 'Customer app' for customer only and second is 'Agency app' for agency only.
- Each component has its connecting port with 'Required interfaces'.

The formalized web agent module is shown in fig. 9.

B. *Agency Offers Module*

- There are four classes to access in the 'Agency offers'.
- One is 'Catalog' for agency catalog information and second is 'Agency' for Agency detail.
- Third is 'Travel' for getting information about services of travelling and fourth is 'Availability' to check the availability of flights.
- Each class and component have its connecting port with 'Provided interfaces

The formalized agency offers module is shown in fig. 8.

C. *Internal Authentification*

- Before confirmation of flight an Internal Authentication of passenger is required after completing all formalities.

VI. Formalized Colored Petri Nets Model

A formalized colored petri nets model has been given below which shows the different operations performing in the model. In this model presented a web agent module taking the queries of the customer and forward it to the agency offers module and after internal authentification of the customer the process will place towards the final procedings. Fomalized model is shown in fig. 7.

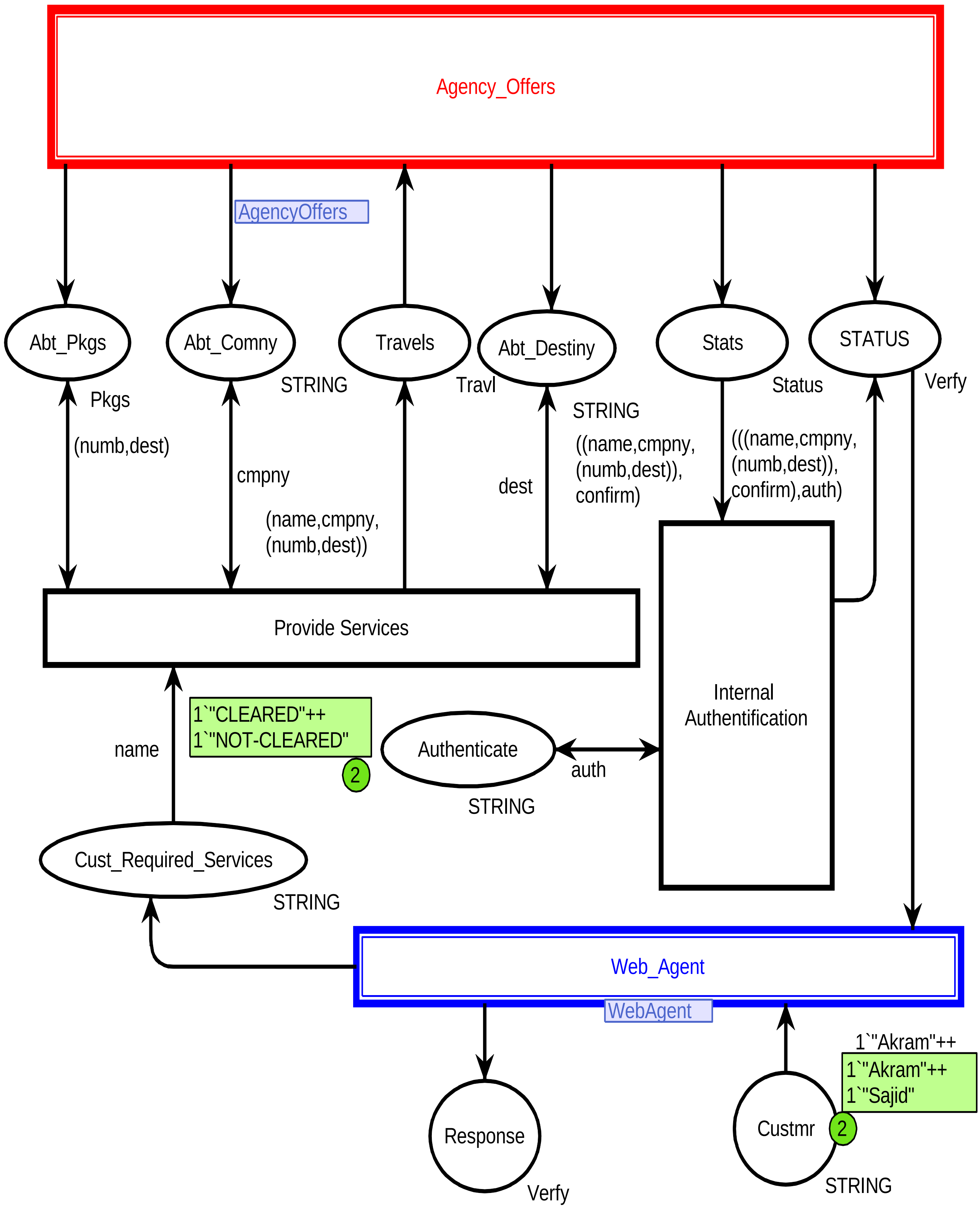


Fig. 7. The Agency Page – Architecture of CPN Model with Initial Marking M_0.

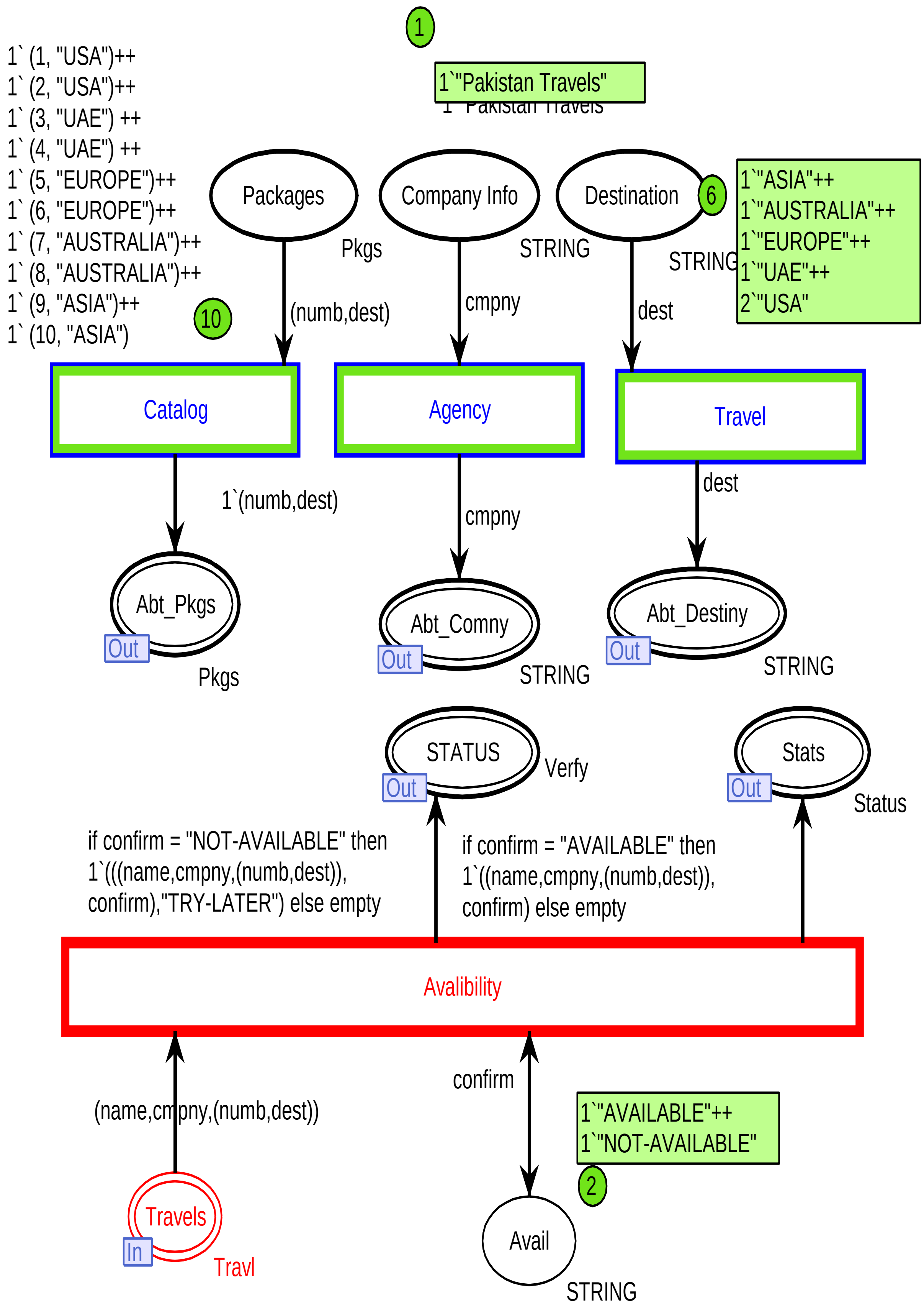


Fig. 8. The Agency Offers Module.

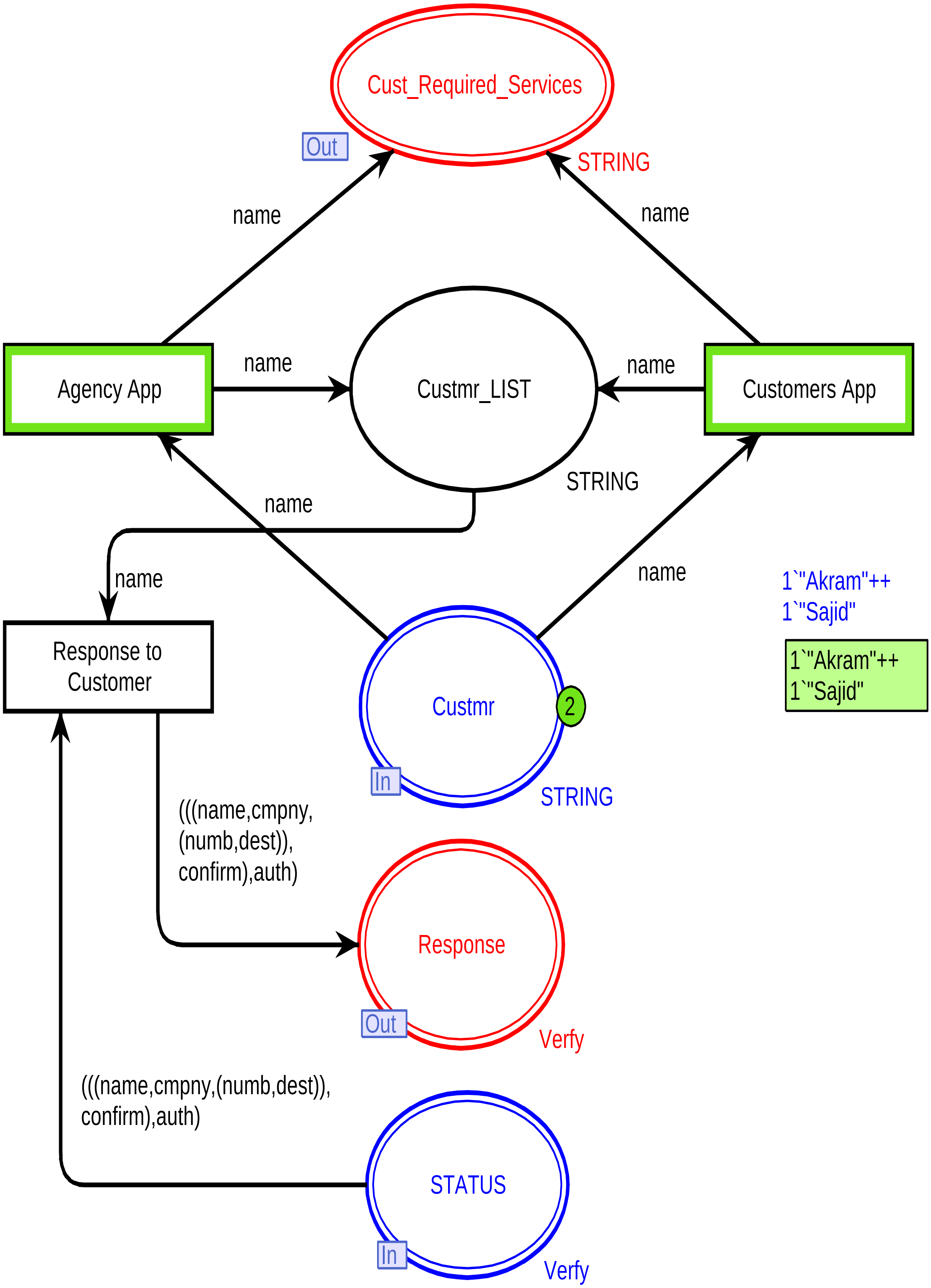


Fig. 9. The Web Agent Module.

VII. CPN Tools State Space Report

```
CPN Tools state space report for:
/cygdrive/F/2 AFTER PhD 23.4.2018/RESEARCH PAPERS/GC FSD PAPER/TicktingHier.cpn
Report generated: Sun May 13 13:56:09 2018


 Statistics
------------------------------------------------------------------------

  State Space
     Nodes:  20039
     Arcs:   99589
     Secs:   300
     Status: Partial

  Scc Graph
     Nodes:  20039
     Arcs:   99589
     Secs:   2


 Boundedness Properties
------------------------------------------------------------------------

  Best Integer Bounds
                             Upper      Lower
     Agency'Abt_Comny 1      1          0
     Agency'Abt_Destiny 1    5          0
     Agency'Abt_Pkgs 1       5          0
     Agency'Authenticate 1   2          2
     Agency'Cust_Required_Services 1
                             2          0
     Agency'Custmr 1         2          0
     Agency'Response 1       0          0
     Agency'STATUS 1         1          0
     Agency'Stats 1          1          0
     Agency'Travels 1        1          0
     AgencyOffers'Avail 1    2          2
     AgencyOffers'Company_Info 1
                             1          0
     AgencyOffers'Destination 1
                             6          1
     AgencyOffers'Packages 1 10         5
     WebAgent'Custmr_LIST 1  2          0

  Best Upper Multi-set Bounds
     Agency'Abt_Comny 1  1`"Pakistan Travels"
     Agency'Abt_Destiny 1
                         1`"ASIA"++
1`"AUSTRALIA"++
1`"EUROPE"++
1`"UAE"++
2`"USA"
     Agency'Abt_Pkgs 1   1`(1,"USA")++
1`(2,"USA")++
1`(3,"UAE")++
1`(4,"UAE")++
1`(5,"EUROPE")++
```

```
1`(6,"EUROPE")++
1`(7,"AUSTRALIA")++
1`(8,"AUSTRALIA")++
1`(9,"ASIA")++
1`(10,"ASIA")
     Agency'Authenticate 1
                         1`"CLEARED"++
1`"NOT-CLEARED"
     Agency'Cust_Required_Services 1
                         1`"Akram"++
1`"Sajid"
     Agency'Custmr 1     1`"Akram"++
1`"Sajid"
     Agency'Response 1   empty
     Agency'STATUS 1     1`((("Akram","Pakistan Travels",(2,"USA")),"NOT-
AVAILABLE"),"TRY-LATER")++
1`((("Akram","Pakistan Travels",(4,"UAE")),"NOT-AVAILABLE"),"TRY-LATER")++
1`((("Akram","Pakistan Travels",(5,"EUROPE")),"NOT-AVAILABLE"),"TRY-LATER")++
1`((("Akram","Pakistan Travels",(6,"EUROPE")),"NOT-AVAILABLE"),"TRY-LATER")++
1`((("Akram","Pakistan Travels",(7,"AUSTRALIA")),"NOT-AVAILABLE"),"TRY-LATER")++
1`((("Akram","Pakistan Travels",(10,"ASIA")),"NOT-AVAILABLE"),"TRY-LATER")
     Agency'Stats 1      1`(("Akram","Pakistan Travels",(2,"USA")),"AVAILABLE")++
1`(("Akram","Pakistan Travels",(4,"UAE")),"AVAILABLE")++
1`(("Akram","Pakistan Travels",(5,"EUROPE")),"AVAILABLE")++
1`(("Akram","Pakistan Travels",(6,"EUROPE")),"AVAILABLE")++
1`(("Akram","Pakistan Travels",(7,"AUSTRALIA")),"AVAILABLE")++
1`(("Akram","Pakistan Travels",(10,"ASIA")),"AVAILABLE")
     Agency'Travels 1    1`("Akram","Pakistan Travels",(1,"USA"))++
1`("Akram","Pakistan Travels",(2,"USA"))++
1`("Akram","Pakistan Travels",(3,"UAE"))++
1`("Akram","Pakistan Travels",(4,"UAE"))++
1`("Akram","Pakistan Travels",(5,"EUROPE"))++
1`("Akram","Pakistan Travels",(6,"EUROPE"))++
1`("Akram","Pakistan Travels",(7,"AUSTRALIA"))++
1`("Akram","Pakistan Travels",(8,"AUSTRALIA"))++
1`("Akram","Pakistan Travels",(9,"ASIA"))++
1`("Akram","Pakistan Travels",(10,"ASIA"))++
1`("Sajid","Pakistan Travels",(1,"USA"))++
1`("Sajid","Pakistan Travels",(2,"USA"))++
1`("Sajid","Pakistan Travels",(3,"UAE"))++
1`("Sajid","Pakistan Travels",(4,"UAE"))++
1`("Sajid","Pakistan Travels",(5,"EUROPE"))++
1`("Sajid","Pakistan Travels",(6,"EUROPE"))++
1`("Sajid","Pakistan Travels",(7,"AUSTRALIA"))++
1`("Sajid","Pakistan Travels",(8,"AUSTRALIA"))++
1`("Sajid","Pakistan Travels",(9,"ASIA"))++
1`("Sajid","Pakistan Travels",(10,"ASIA"))
     AgencyOffers'Avail 1
                         1`"AVAILABLE"++
1`"NOT-AVAILABLE"
     AgencyOffers'Company_Info 1
                         1`"Pakistan Travels"
     AgencyOffers'Destination 1
                         1`"ASIA"++
1`"AUSTRALIA"++
1`"EUROPE"++
1`"UAE"++
2`"USA"
```

```
     AgencyOffers'Packages 1
                         1`(1,"USA")++
1`(2,"USA")++
1`(3,"UAE")++
1`(4,"UAE")++
1`(5,"EUROPE")++
1`(6,"EUROPE")++
1`(7,"AUSTRALIA")++
1`(8,"AUSTRALIA")++
1`(9,"ASIA")++
1`(10,"ASIA")
     WebAgent'Custmr_LIST 1
                         1`"Akram"++
1`"Sajid"

  Best Lower Multi-set Bounds
     Agency'Abt_Comny 1  empty
     Agency'Abt_Destiny 1
                         empty
     Agency'Abt_Pkgs 1   empty
     Agency'Authenticate 1
                         1`"CLEARED"++
1`"NOT-CLEARED"
     Agency'Cust_Required_Services 1
                         empty
     Agency'Custmr 1     empty
     Agency'Response 1   empty
     Agency'STATUS 1     empty
     Agency'Stats 1      empty
     Agency'Travels 1    empty
     AgencyOffers'Avail 1
                         1`"AVAILABLE"++
1`"NOT-AVAILABLE"
     AgencyOffers'Company_Info 1
                         empty
     AgencyOffers'Destination 1
                         empty
     AgencyOffers'Packages 1
                         empty
     WebAgent'Custmr_LIST 1
                         empty


 Home Properties
------------------------------------------------------------------------

  Home Markings
     None


 Liveness Properties
------------------------------------------------------------------------

  Dead Markings
     13571 [9999,9998,9997,9996,9995,...]

  Dead Transition Instances
     Agency'Internal_Authentification 1
```

```
    WebAgent'Response_to_Customer 1

  Live Transition Instances
    None


 Fairness Properties
-----------------------------------------------------------------------
    No infinite occurrence sequences.
```

VIII. Conclusion

In this paper presented a bunch of rules and also perform a tool implementation to formalize the composite structure into equivalent colored petri nets. In UML 2.0, composite structure shows the internal structure of the classifier and give a deep insight view and cannot identify the errors and deadlocks with this. Proposed work explores the ways to identify the hidden errors and deadlocks at abstract level. This work is done with advance notation of petri nets, Colored petri nets gives more precise formalization. Hence the rules allow the formation of Colored Petri nets that shows various behavior of components in more accurate way.

References

[1] N. H. Ali, Z. Shukur and S. Idris, "A Design of an Assessment System for UML Class Diagram," International Conference on Computational Science and Applications, Kuala Lampur, 26-29 August 2007, pp. 539546.doi:10.1109/ICCSA.2007. 31.

[2] UML Distilled Third Edition June 2003, pp. 118.

[3] Review and analysis of the issues of Unified Modeling Language for Visualizing, Specifying, Constructing and Documenting the Artifacts of a Software-Intensive System by Dr.S.S.Riaz Ahamed (2009).

[4] A Critical Analysis and Treatment of Important UML Diagrams Enhancing Modeling Power by Fahad Alhumaidan (2012).

[5] K. E. Hamdy, M. A. Elsoud and A. M. El-Halawany, "UML-Web Engineering Framework for Modeling Web Application," Journal of Software Engineering, Vol. 5, No. 2, 2011, pp. 49-63. doi:10.3923/jse.2011.49.63.

[6] X. He, "Formalizing UML Class Diagrams: A Hierarchical Predicate Transition Net Approach," Proceedings of Twenty-Fourth Annual International Computer Software and Applications Conference, Taipei, 25-27 October 2000, pp. 217-222. doi:10.1109/CMPSAC.2000. 884721.

[7] M. Shroff and R. B. France, "Towards Formalization of UML Class Structures in Z," 21st International Conference on Computer Software and Applications, Washington DC, 1-15 August 1997, pp. 646-651.

[8] Formal methods by the institution of Engineering and Technology (2011), pp. 4.

[9] A. M. Mostafa, A. I. Manal, E. B. Hatem and E. M. Saad, "Toward a Formalization of UML2.0 Meta-Model Using Z Specifications," Proceedings of 8th ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing, Qingdao, 30 July-1 August 2007, pp. 694 701 doi:10.1109/SNPD. 2007.508.

[10] E. Cunha, M. Custodio, H. Rocha and R. Barreto, "Formal Verification of UML Sequence Diagrams in the Embedded Systems Context," Brazilian Symposium on Computing System Engineering (SBESC), 2011, pp. 39-45.

[11] Composite structure & Component diagrams by Greg Guyles csci5448 Prof. Anderson (2012).

[12] Transformation Of Uml Activity Diagrams Into Petri Nets For Verification Purposes by Bhawana Agarwal (2013).

[13] W. S. Changchien, J. J. Shen and T. Y. Lin, "A Preliminary Correctness Evaluation Model of Object-Oriented Software Based on UML," Journal of Applied Sciences, Vol. 2, No. 3, 2002, pp. 356-365. doi:10.3923/jas.2002.356.365.

[14] M. Heiner, and M. Heisel, "Modeling Safety Critical Systems with Z and Petri-Nets," Proceedings of International Conference on Computer Safety, Reliability and Security, Toulouse, 27-29 September 1999, pp. 361-374.

[15] Leading and J. Souquieres, "Integration of UML and B Specification Techniques: Systematic Transformation from OCL Expressions into B," Proceedings of 9th Asia-Pacific Software Engineering Conference, Gold Coast, 4-6 December 2002, p. 495.

[16] H. Beek, A. Fantechi, S. Gnesi and F. Mazzanti, "State/Event-Based Software Model Checking," Proceedings of 4th International Conference on Integrated Formal Methods, Canterbury, 4-7 April 2004, pp. 128-147.

[17] S. A. Ehikioya and B. Ola, "A Comparison of Formalisms for Electronic Commerce Systems," Proceedings of International Conference on Computational Cybernetics, Vienna, 30 August-1 September 2004, pp. 253-258. doi:10.1109/ICCCYB. 2004.1437721.

[18] T. B. Raymond, "Integrating Formal Methods by Unifying Abstractions," Springer, Berlin, 2004, pp. 441-460.

[19] X. Than, H. Miao and L. Liu, "Formalizing Semantics of UML Statecharts with Z," Proceedings of 4th International Conference on Computer & Information Technology, Wuhan, 14-16 September 2004, pp. 1116-1121. doi:10.1109/ CIT.2004.1357344.

[20] B. Akbarpour, S. Tahar and A. Dekdouk, "Formalization of Cadence SPW Fixed-Point Arithmetic in HOL," Formal Methods in System Design, Vol. 27, 2005, pp. 173-200.

[21] C. Liu and X. M. Dong, "An Improved Quasi-Static Scheduling Algorithm for Mixed Data-Control Embedded Software," Journal of Applied Sciences, Vol. 6, No. 7, 2006, pp. 1571-1575.

[22] O. Hasan and S. Tahar, "Verification of Probabilistic Properties in the HOL Theorem Prover," Proceedings of the 6th International Conference of Integrated Formal Methods, Oxford, 2-5 July 2007, pp. 333-352.

[23] S. Sengupta and S. Bhattacharya, "Formalization of UML Diagrams and Consistency Verification: A Z Notation Based Approach," Proceedings of India Software Engineering Conference, Hyderabad, 19-22 February 2008, pp. 151-152. doi:10.1145/ 1342211.1342248.

[24] Z. Derakhshandeh, B. T. Ladani and N. Nematbakhsh, "Modeling and Combining Access Control Policies Using Constrained Policy Graph (CPG)," Journal of Applied Sciences, Vol. 8, No. 20, 2008, pp. 3561-3571. doi:10.3923/jas.2008.3561.3571.

[25] Z. M. Ma, "Fuzzy Conceptual Information Modeling in UML Data Model," International Symposium on Computer Science and Computational Technology, Shanghai, 20-22 December 2008, pp. 331-334. doi:10.1109/ ISCSCT.2008.353.

[26] C. Yong, "Application of Wu's Method to Proving Total Correctness of Recursive Program," Information Technology Journal, Vol. 9, No. 7, 2010, pp. 1431-1439. doi:10.3923/ itj.2010.1431.1439.

[27] M. T. Bhiri, K. Mourad, M. Graiet and P. Aniorte, "UML/ OCL and Refinement," 18th IEEE International Conference and Workshops on Engineering of Computer-Based Systems, Las Vegas, 27-29 April 2011, pp. 14-158.

[28] X. G. Zhang and H. Liu, "Formal Verification for CCML Based Web Service Composition," Information Technology Journal, Vol. 10, No. 9, 2011, pp. 1692-1700. doi :10.3923/ itj.2011.1692.1700.

[29] Z. Shi, "Intelligent Target Fusion Recognition Based on Fuzzy Petri Nets," Information Technology Journal, Vol. 11, No. 4, 2012, pp. 500-503. doi:10.3923/itj.2012.500.503.

[30] Z. X. Wang, H. He, L. Chen and Y. Zhang, "Ontology Based Semantics Checking for UML Activity Model," Information Technology Journal, Vol. 11, No. 3, 2012, pp. 301-306. doi:10.3923/itj. 2012.301.306.

[31] McCarthy, J.: Circumscription - a form of non-monotonic reasoning. Artificial Intelligence 13 (1980) 27-39.

[32] Haugen, Ø., Møller-Pedersen, B., Weigert, T.: Structural modeling with uml 2.0, classes, interactions and state machines. In Lavagno, L., Martin, G., Selic, B., eds.: UML for Real, Design of Embedded Real-Time Systems. Kluwer AcademicPublishers (2004) 53-76.

[33] Bock, C.: Uml 2 composition model. Journal of Object Technology 3(10) (2004) 47-74.

[34] Hofmeister, C., Nord, R., Soni, D.: Applied Software Architecture. Addison-Wesley (1999) 0201325713.

[35] Bock, C., Odell, J.: A foundation for composition. Journal of Object Oriented Technology 7(6) (1994) 10-14.

[36] Odell, J.: Advanced Object-Oriented Analysis and Design Using UML. SIGS Reference Library. Cambridge (1998) 0-521-64819-X.

[37] Petri Nets for Dynamic Event-Driven System Modeling by Jiacun Wang, Department of Software Engineering, Monmouth University, West Long Branch, NJ 07764 (2012).

Tracking Systems as Thinging Machine: A Case Study of a Service Company

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***Abstract*—Object tracking systems play important roles in tracking moving objects and overcoming problems such as safety, security and other location-related applications. Problems arise from the difficulties in creating a well-defined and understandable description of tracking systems. Nowadays, describing such processes results in fragmental representation that most of the time leads to difficulties creating documentation. Additionally, once learned by assigned personnel, repeated tasks result in them continuing on autopilot in a way that often degrades their effectiveness. This paper proposes the modeling of tracking systems in terms of a new diagrammatic methodology to produce engineering-like schemata. The resultant diagrams can be used in documentation, explanation, communication, education and control.**

Keywords—Tracking systems; system documentation; system control; abstract machine; conceptual model; thinging

I. Introduction

Transportation is a crucial element in modern society. Transportation, here, refers to the physical movement of things. The Global Positioning System (GPS) plays important roles in tracking the movement of things and overcoming problems like safety, security and other location-related applications. From one perspective, it is claimed that GPS is "one of the most important inventions in the last 25 years" [1]. The use of GPS devices in positioning and tracking things has increased immensely in the past decades, and applications include mobility pattern recognition, vehicle navigation, fleet management and route tracking [2].

GPS technology is still relatively new, which raises many issues for potential users. It was originally designed for military application, and it combines satellite navigation systems that broadcast location information (e.g., latitude and longitude, speed, heading and altitude) across the Earth [2]. GPS usually requires at least four satellites to be on the visible horizon.

The focus of this paper is on vehicle-tracking systems. A typical system includes a mechanized device and software at an operational base to locate and monitor the position, timing and mobility of a vehicle. It utilizes a GPS receiver along with a Global System for Mobile Communications (GSM) modem to monitor the vehicle status in terms of time and position. GSM has become an accepted worldwide standard. Transmitting data in a GSM-supported modem is achieved by utilizing radio signals.

The base station is supplemented by products such as Google Maps and Bing Maps that provide maps using satellite imaging that shows objects indicating points of interest or line objects to show tracks. The interaction between a GSM modem and a GPS receiver is facilitated by a microcontroller [3].

The aim of this paper is to utilize a new diagrammatic language in producing a conceptual (non-technical) model of vehicle-tracking systems.

A. Conceptual Modeling

Thinking diagrammatically as a way of conceptualizing our world has been in existence from the moment the first cave-person picked up a soft "rock" and started making markings on the walls of his/her dwelling. As civilization progressed, humanity moved into recording our activities and learning via tablets, papyri and paper for posterity [4].

Modeling can take the form of abstraction, idealization and representations of what is observable from nature [4]. In software engineering, thing-oriented modeling is used to model a portion of reality through flow (abstract) machines [5]. We will utilize such a methodology in developing the conceptual model of vehicle-tracking systems.

B. Problem: Unsystemic Process Description

Problems of describing processes such as vehicle tracking arise from reported difficulties in creating a well-defined and understandable model of such processes [6]. Modeling is a way to visualize processes to give maximum efficiency, regardless of complexity [7]. Currently, processes are fragmental, nameless and invisible phenomena that most of the time result in difficulties creating documented descriptions [8]. Additionally, most organizations have repeated tasks that, once learned, continue on autopilot and, as they are passed on from one employee to another, often degrade in their effectiveness. "These businesses seldom diagram their processes, as they often lack the knowledge, understanding and willingness to invest the time and effort, or a combination of these" [9]. However, different types of unsystemic (neither uniformed nor holistic in the sense of applying to parts and the whole of a system) diagrams are utilized in process descriptions.

The following provides sample diagrams used in detailing tracking systems. Bharati and Fernandes [3] described a tracking system where a microcontroller is linked to the GPS. The data are received by the GPS receiver from satellites, and data are processed and sent to the GSM modem. On the user end, a GSM-enabled device acts as the GSM modem connected serially to the microcontroller. Such a process is depicted in Fig. 1. Verma et al. [10] used flowcharts in describing their tracking system, as shown in Fig. 2. Manual pictures (e.g., satellite images, a human figure on a computer screen, a car or a network tower) are also used in explaining the architecture of a GPS vehicle-tracking system (see [11]). ER, UML and DFD are also used in this context (e.g., see Fig. 3 [12]). Benrouyne [13] utilized UML use cases. We will model use cases using our diagrammatic language in section 3.

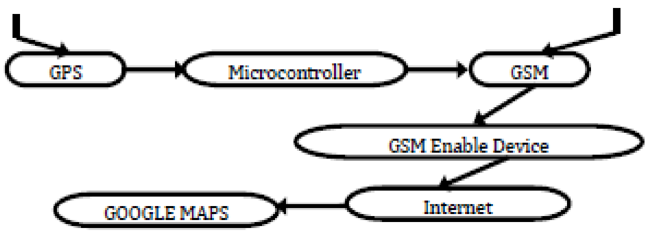

Fig. 1. Block Diagram Illustrating the Concept (Adapted from [3]).

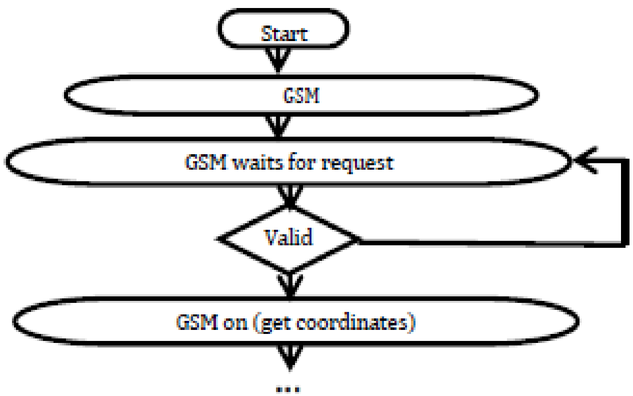

Fig. 2. Flowchart of a Tracking System (Adapted from [10]).

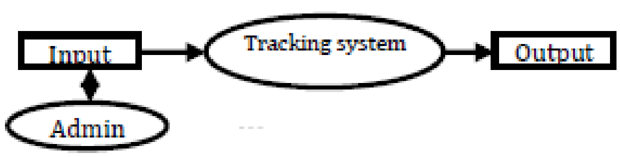

Fig. 3. Level-0 of Describing a Tracking System (Adapted from [12]).

C. *Proposed Method of Description*

This paper proposes modeling tracking systems in terms of a new methodology that diagrams such a process to produce engineering-like schematization. The resultant illustrations can be used in documentation, explanation, education and control. Specifically, we focus on vehicle-tracking systems that aim at locating and monitoring vehicles, thus enabling an agency to observe activities related to its fleet of vehicles (e.g., sending alerts, providing security and finding paths to a particular destination). We utilize a new diagrammatic language, called the thinging machine (TM)—also called the flowthing machine (FM)—which will be reviewed briefly in the next section [14-20] as a foundation for describing a tracking system. The limited number of notions used in the TM and its all-inclusive description that encompasses the cyber–physical system make TM attractive for modeling tracking systems. Section 3 applied this methodology to an example in the literature that uses UML for this purpose. Section 4 discusses the notion of tracking and monitoring in the context of TM. Section 5 develops a TM model for an operational tracking system in Kuwait.

II. Thinging Machine (TM)

Drawing on Deleuze and Guattari [21], Bryant [22] declared, “All objects can be understood as machines.” TM modeling utilizes an *abstract thinging machine* (hereafter, *machine*) with five stages of thinging, as shown diagrammatically in Fig. 4.

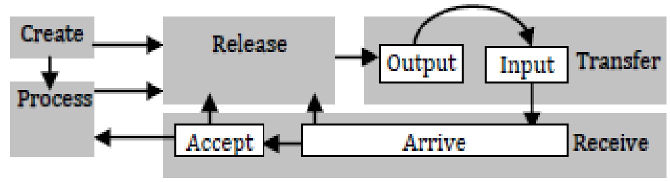

Fig. 4. Thinging Machine.

In philosophy, *thinging* refers to “defining a boundary around some portion of reality, separating it from everything else, and then labeling that portion of reality with a name” [23]. TM modifies the notion of thinging attributed to Heidegger [24] through applying it to the life cycle of a thing and not to its ontological feature. In TM, a thing is created, processed, released, received and transferred as will be described next. Moreover, in TM, a thing may not have a name as mentioned above, but it is distinguishable in some way. This distinguishability installs it as a thing in a system (machine). For example, the thing we now call *oxygen* had been described (created in the human knowledge system) prior to its discovery in 1774 when Priestley called it “dephlogisticated air” and did not recognize it as a chemical element. The name *oxygen* was given in 1777 as a chemical element in the chemical system.

In TM, a system (machine) has (created in it) a thing only if it “knows” (becomes aware or experiences) the thing. This is a phenomenological view projected over systems. In phenomenology, things are given to us through sight, touch, taste or smell, but in TM things are given *to the system* by machines, otherwise the things do not appear at all (in the system). In TM, the system is a grand machine—a machine that is not contained in a machine. *Creation* in a machine is not a thing, but rather a process that provides the machine (and the system) with new things.

According to Heidegger [24], to understand the thingness of things, one needs to reflect on how thinging expresses the way a “thing *things*” (i.e., “gathering,” uniting or tying together its constituents, just as a bridge makes an environment [banks, stream and landscape] into a unified whole). From slightly different perspectives, saying thinging and things *thing* (verb) refers to actualization (manifestation), existence, being known or recognized, possession of being, being present, being there, being an entity (a creature), appearance or the opposite of nothingness. According to [25], Heidegger’s view can however be seen as a tentative way of examining the nature of entities, a way that can make sense. An artefact that is manufactured instrumentally, without social objectives or considering material/spatial agency, may have different qualities than a space or artefact produced under the opposite circumstances.

In TM, a strong association exists between systems and their models. A system is defined through a model. We view a system as an assemblage of things and machines. In simple words, as will be exemplified later, it is a web of (abstract) machines represented as a diagram (the grand machine). A machine can *thing* (i.e., creates, process, receive, transfer and/or release other things). These operations (i.e., thing or create, process, receive, transfer and release) are represented within an abstract Thinging Machine (TM) as shown in Fig. 5.

The starting phase of development in a system's life cycle includes collecting information in order to construct a conceptualization blueprint of it. This conceptualization is intended to give an adequate description of the system (machine) boundaries so that needs, scope and constraints are taken into consideration in building the overall system description that conceives it in its entirety. This paper diagrammatically describes a sample tracking system based on the notion of the verbs *to thing* and *thinging*.

A machine things (verb): (i.e., creates, processes, receives, releases and transfers things). It handles things and is itself a thing that is handled by other machines. The TM model is a grand thing/machine that forms the thinging of a system. Thinging here refers to the creation, processing, receiving, releasing and/or transferring of the system (grand machine) or any of its sub-machines.

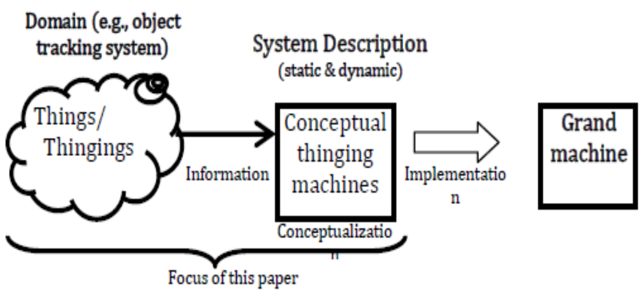

Fig. 5. The Aim is to Capture Things/Thinging in the Form of a Grand Diagram.

The stages in the machine can be briefly described as follows.

Arrive: A thing flows to a new machine (e.g., packets arrive at a buffer in a router).

Accept: A thing enters a machine; for simplification purposes, we assume that all arriving things are accepted; hence, we can combine Arrive and Accept into a **Receive** stage.

Release: A thing is marked as ready to be transferred outside the machine (e.g., in an airport, passengers wait to board after passport clearance).

Process (change): A thing changes its form but not its identity (e.g., a number changes from binary to hexadecimal).

Create: A new thing is born in a machine (e.g., a logic deduction system deduces a conclusion).

Transfer: A thing is inputted or outputted in/out of a machine.

TM includes one additional notation, triggering (denoted by dashed arrow), that initiates one flow from another.

III. EXAMPLE

Benrouyne [13] used UML in the analysis phase to identify and organize the requirements of an anti-theft vehicle-tracking system. Fig. 6 represents the use case diagram of the different actors of the system including the end user, the administrator and the GPS tracker. Some of the use cases are given as follows [13]:

1) The user or administrator enters the login username and password.

2) The user or administrator is logged in the system.

3) The user starts this use case by clicking on *create account* on the menu.

4) The user provides a valid International Mobile Equipment Identity (IMEI) of a GPS tracker.

5) The user fills the required fields of the creation form of the desired account.

6) The end user selects a view of the vehicle's current location.

7) Live positioning of the vehicle is displayed as the vehicle moves.

8) The user enters an alert radius.

9) The user selects the "enable proximity alerts" button.

10) The proximity alert is set and enabled.

11) A confirmation message pops up.

12) The user presses "confirm" to enable proximity alters.

13) An alert radius is displayed on the map.

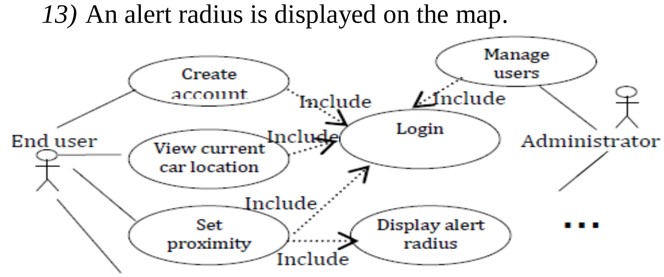

Fig. 6. Use Cases (Adapted from [13]).

D. Static Representation

Fig. 7 shows the TM static representation of some of these use cases. For simplicity sake, boxes are removed. In Fig. 7, first the user creates a request to login supported by the account name and password (circle 1). The request flows (2) to the system where it is processed. If it is valid (3), then a session is opened (4) and displayed to the user (5). The user requests an account for the tracking system (6). After processing the request (7), the system asks the user to send the IMEI and other requested information (8). The user sends the requested data (9). The system processes the standard vehicle-tracking menu (interface; 10) and downloads it to the user (11).

Now the user is able to use the vehicle-tracking system. He/she selects from a menu (12; e.g., current vehicle location), and such a choice flows to the system where the current vehicle location is processed (13) and triggers the creation of a map (14) that flows to the user (15).

We assume that the user has the tracking system menu available to him/her (16). He/she opts to create an alert radius. This is transferred to the system to be processed (17) and causes the creation of the alert (18) and setting it (20), and then a confirmation message is sent to the user (21). The user signals that the alert is enabled (22), and processing this signal creates an alert map (23).

E. Dynamic Representation

Now, using the static description in Fig. 7, we identify different meaningful events to be used to build a certain sequence of events. An event in TM is a machine that includes at least three submachines: time, region and the event itself. For example, the *log in to the system* event is modeled as shown in Fig. 8. The region is the space where the event occurs (sub-diagram of the static description in Fig. 7). Accordingly, we identify the following events (see Fig. 9) in the static description as follows:

Event 1 (E_1): Logging in with username and password.

Event 2 (E_2): Opening a session.

Event 3 (E_3): Requesting an account in the vehicle-tracking system.

Event 4 (E_4): Requesting IMEI and other information.

Event 5 (E_5): IMEI and other information are received.

Event 6 (E_6): Displaying the tracking system menu.

Event 7 (E_7): Selecting current vehicle location.

Event 8 (E_8): Finding the latest vehicle coordinates and constructing a map that is displayed.

Event 9 (E_9): Selecting alert radius.

Event 10 (E_{10}): Creating proximity alert, setting it and sending a confirmation message.

Event 11 (E_{11}): The alert is enabled.

Event 12 (E_{12}): Alert map is displayed.

We assume that the events are not independent of each other; hence, Fig. 10 shows the chronology of these events.

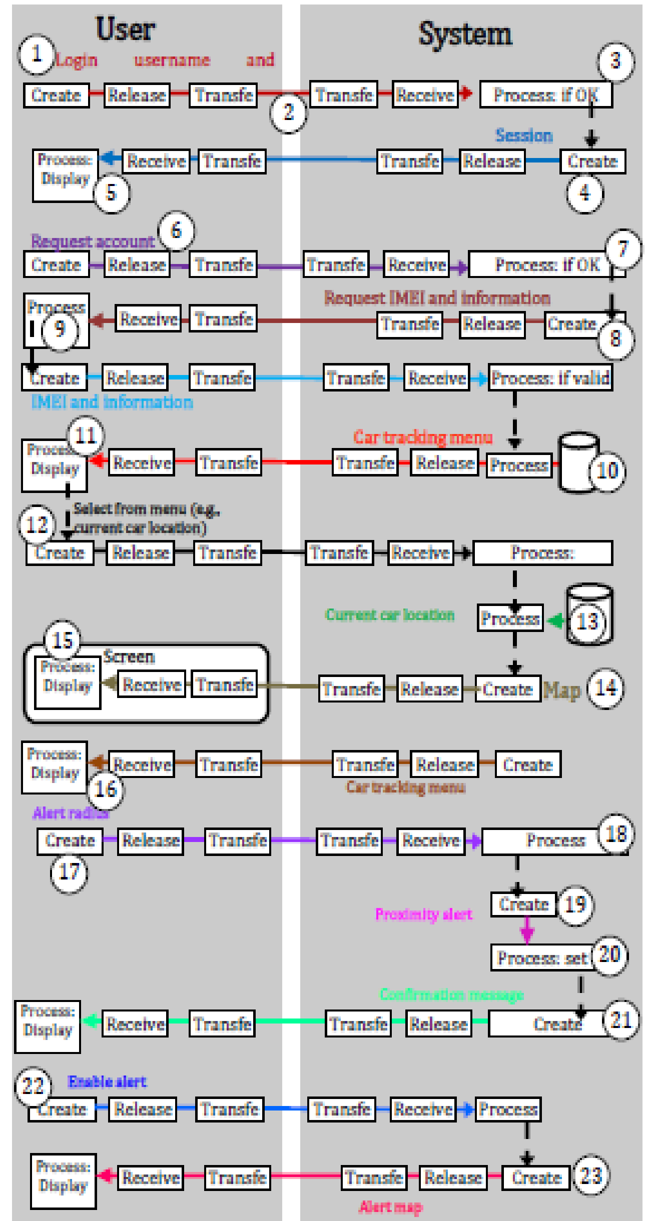

Fig. 7. Partial TM Representation of an Anti-Theft Car-Tracking System.

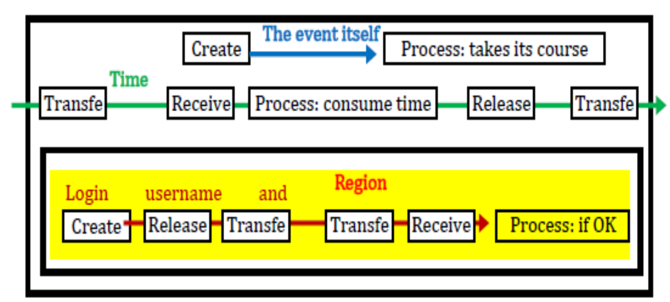

Fig. 8. Description of Event Machine.

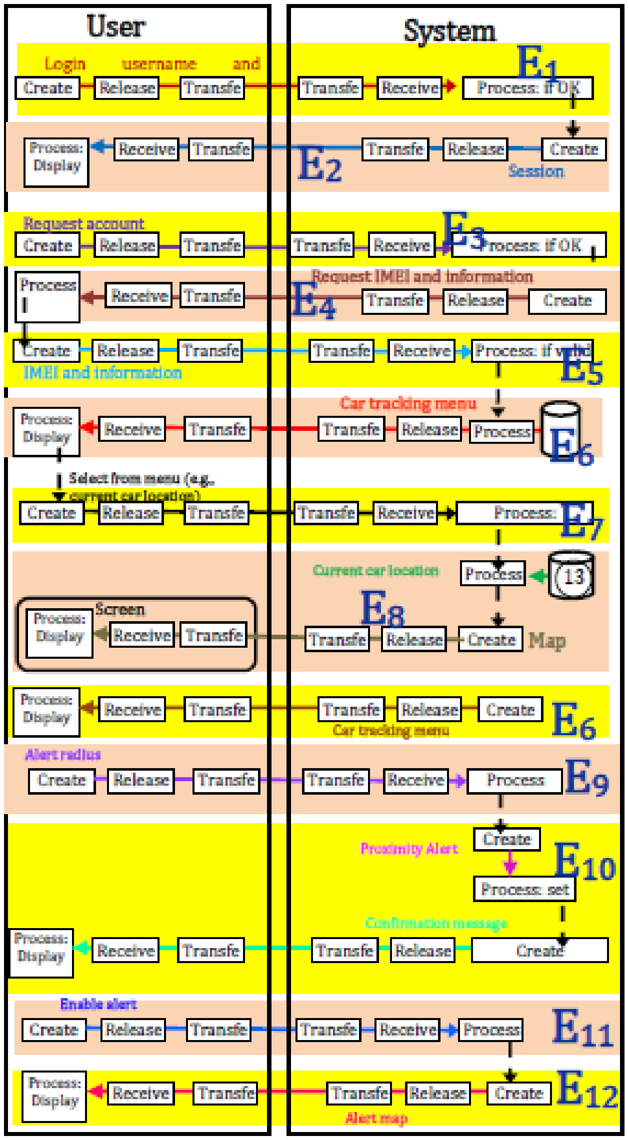

Fig. 9. Events on the static description of the tracking system.

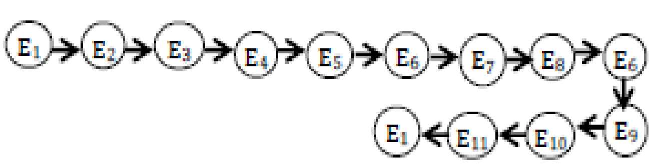

Fig. 10. The chronology of events in Fig. 9.

IV. TRACKING: DEFINITION AND REVIEW

The dictionary meaning of *tracking* refers to following the trail or movements of something, typically to find it or note its course. Tracking may also be capable of providing monitoring. Monitoring denotes collecting and processing data about a system to check the progress of something over a period of time. A tracking system involves collecting, processing, aggregating and displaying real-time quantitative data.

Tracking is used in monitoring enterprise elements that are processed and presented in an understandable format. Such a reporting process helps an administrator understand the performance, current status of work and what is normal in the enterprise. With data from reports, an administrator can make informed decisions for capacity planning, maintenance, troubleshooting and security. Although reporting helps one to understand what is normal and the current status of an enterprise, alerts help administrators to identify possible issues related to performance and security and to assess potential problems. All of this is applied to tracking systems.

Fig. 11 shows a general picture of tracking and monitoring from the TM point of view. Feedback can easily be added to such a picture to facilitate control. This is also applied to any tracking system.

A great deal of the research and a body of commercial studies report the classification and limitations of tracking systems (see surveys in [26-28]). These studies include methodological studies that evaluate the reliability of GPS-based traffic data, technical studies that outline the general procedure for processing GPS tracking data and related issues and practical studies that investigate the influence of road network conditions (e.g., density) to find an optimal location. Specifically, since the 1990s, many have studied the routes of vehicles [26] [29-30], the travel pattern and prediction of human mobility [31-32] and environment control [33]. Leduc [34] discussed the potentials related to new GPS technologies. Spek et al. [35] examined the GPS potential applications of spatial-temporal data, thus adding new knowledge to urban studies. Additionally, considerable effort has been involved in processing and analyzing collected data (e.g., achieving precision instantaneously) [2]. In this paper, we are not concerned with the data aspect of a vehicle-tracking system; rather, we focus on the issue of providing visualization of the entire system.

Accordingly, no literature directly relates to our study, but some works have used diagrammatic languages such as UML in describing systems without explicating targeting the modeling topic. To demonstrate the feasibility of applying TM in a tracking system, we next model an actual tracking company in Kuwait.

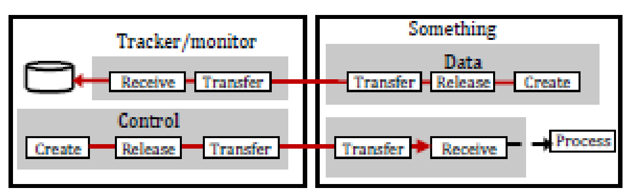

Fig. 11. TM Definition of a Tracking/Monitoring/Control System.

V. CASE STUDY IN KUWAIT

Currently, any tracking process in Kuwait is monitored by a local authority known as the Communication and Information Technology Regulatory Authority (CITRA). Kuwait law prohibits private installation of vehicle trackers due to privacy issues; therefore, any installation of GPS trackers should be on a corporate level. Any provider of tracking services must register with CITRA. Every imported device must also be registered in CITRA records.

The current problem is that no clear understanding and standard documentation and regulations exist for the tracking process. This makes it difficult for service providers to present and manage the process for multiple clients with different needs and requirements. It creates an obstacle to fulfilling the utilization and growth of such services.

We take a current working company as a case study from the point of view of how the company describes and documents its tracking system. Of course, the implication is that TM can be used for any tracking system in the world.

A. *Description of Current System*

The current system of tracking vehicles requires installing a tracking device within each vehicle and an underlying infrastructure of servers. The system involves the following:

- A black box tracking device that is installed inside the vehicle to be tracked;
- A tracking server that is responsible for managing and communicating with the device;
- A tracking system that contains an interface to view data and to control the device.

No official documentation of this process exits, but it is understood by the workers in the company. Accordingly, a new employee receives an oral description of the system during his/her training period.

B. *TM Model of the Static Model*

Fig. 12 shows the current system of tracking a fleet of vehicles by installing a tracking device within each vehicle. It is divided into sub-processes as follows:

1) Gathering data from the vehicle: In the diagram in Fig. 12, vehicle data flows from the vehicle (circle 1 in the diagram) to the tracking device (2) and includes the following:

Ignition Status: The engine is ON or OFF (3).

Speed: The current speed (4).

Temperature: The current temperature (5).

Acceleration: The current acceleration (6).

All data flow to become part of a message that is sent to the tracking server, as will be described.

2) Acquiring GPS location: The tracking device simultaneously receives data from four satellites using an antenna (7) that obtains navigation data from the satellites (8) through a receptor (9). The data are processed (10) to trigger (11) the generation of the coordinates (12) of the location of the vehicle that flow to become part of the message.

Fig. 12 may look complex. However, note that the TM description forms the base for different levels of representation of the system. For example, if we want to discuss different components of the system and the flow among them regardless of the role of a machine (components)—whether it generates, processes or transports things—we can remove the stages of machines, thus cutting the size of the diagram by more than half of its size, as shown in Fig. 13.

Continuing with the description in Fig. 12, the next process is as follows:

3) Data processing and message creation: The tracking device receives the readings (i.e., (3), (4), (5) and (6) in Fig. 12) from the vehicle and from the antenna (12), then the device records its clock time (13) and its device ID (14) and all these data are processed (15) to construct a message (16). After saving a copy of the message (17), the message flows to the tracking server (18).

4) Message entering the tracking server: The message is transferred via a GPRS connection to the tracking server (18) where a copy is stored (19), and the message is processed in the server (20) to create a formatted message (21) that flows to the tracking system (22). The tracking system is a web application (website) that is accessed by users/operators though a web browser and managed by the tracking server.

5) Message processing in the tracking system: In the tracking system, the message is defragmented to its original fields of data: temperature (23), speed (24), acceleration (25), clock time (26), ignition status (27), coordinates (28) and ID (29). Each type of data is handled independently by the tracking system as follows:

a) Generate alerts: If

- Temperature is outside two fixed temperature ranges (30),
- Speed exceeds fixed speed limit (31), and/or
- Acceleration exceeds a fixed G-Force value (32).
- Then, corresponding alerts (33), (34) and (35) are created and displayed on the interface (36) and transferred to the driver (37).

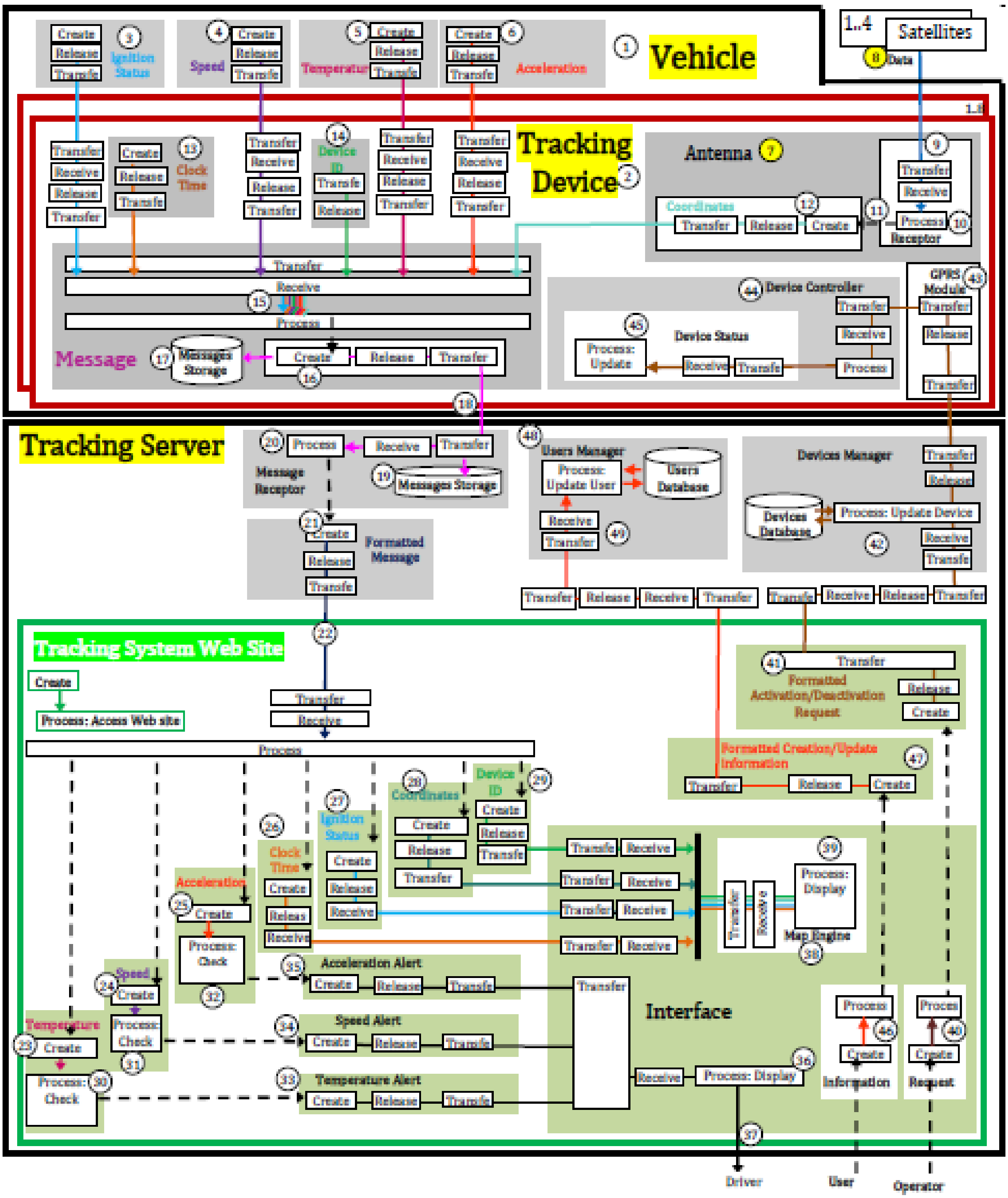

Fig. 12. TM Static Description of the Tracking System.

b) Plotting updates on a map: For the purpose of plotting updates on a map, clock time (26), ignition status (27), coordinates (28) and device ID (29) are supplied to the map engine (38) to plot the corresponding update on a map displayed (39) on the interface.

c) Other activities: These activities involve sending requests from the user to the server as follows:

- *Device Activation/Deactivation Request*: The operator (40) initiates a request via the interface using a tracking device ID to activate or deactivate the device. The request is formatted by the tracking system (41) and sent to the device manager (42) in the server where the record of the device is updated with the new status. Additionally, the request is sent via a GPRS (43) connection to the corresponding device controller (44) to update the status of the device (45).
- *User Creates/Updates Information*: The user/controller can supply the interface with information and privileges to be created and updated (46). The information is formatted (47) and flows to the user manager in the tracking server (48) to update the user database (49) either by creating a new record or updating an existing record.

C. *Description of the Dynamic System*

Now, based on the static description, we develop the set of meaningful events in the tracking system in Fig. 12. These events are as follows (see Fig. 14):

Event 1 (E_1): Parameters are originated from the vehicle.
Event 2 (E_2): The tracking device creates data.
Event 3 (E_3): Satellites send data.
Event 4 (E_4): Satellite data are received.
Event 5 (E_5): Coordinates are calculated.
Event 6 (E_6): Tracking device message is created.
Event 7 (E_7): Tracking message arrives to the server.
Event 8 (E_8): The data of the message are formatted.
Event 9 (E_9): The tracking system is operational.
Event 10 (E_{10}): The message arrives to the tracking system.
Event 11 (E_{11}): Time, ignition status, coordinates and device ID are used by the map engine.
Event 12 (E_{12}): Temperature, speed and acceleration generate alerts that are displayed and sent to the driver.
Event 13 (E_{13}): The user feeds new user information.
Event 14 (E_{14}): The operator requests updating the device status.
Event 15 (E_{15}): The server updates new information.
Event 16 (E_{16}): The server receives the operator's request to update device status.
Event 17 (E_{17}): The device receives the new status.
Event 18 (E_{18}): The device updates the status.

Fig. 15 shows the chronology of events in Fig. 14.

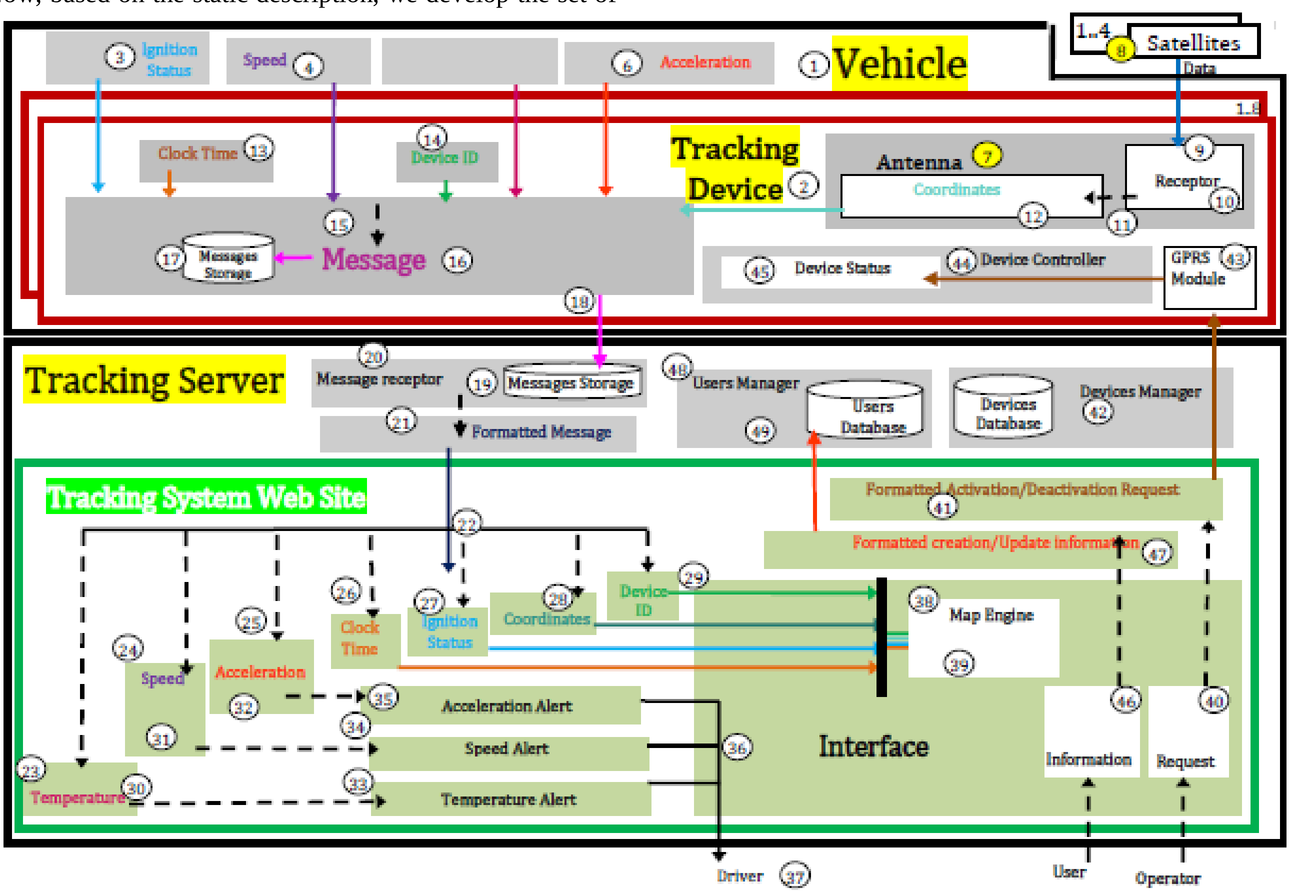

Fig. 13. Simplification of the TM Static Description of the Tracking System Shown in Fig. 12.

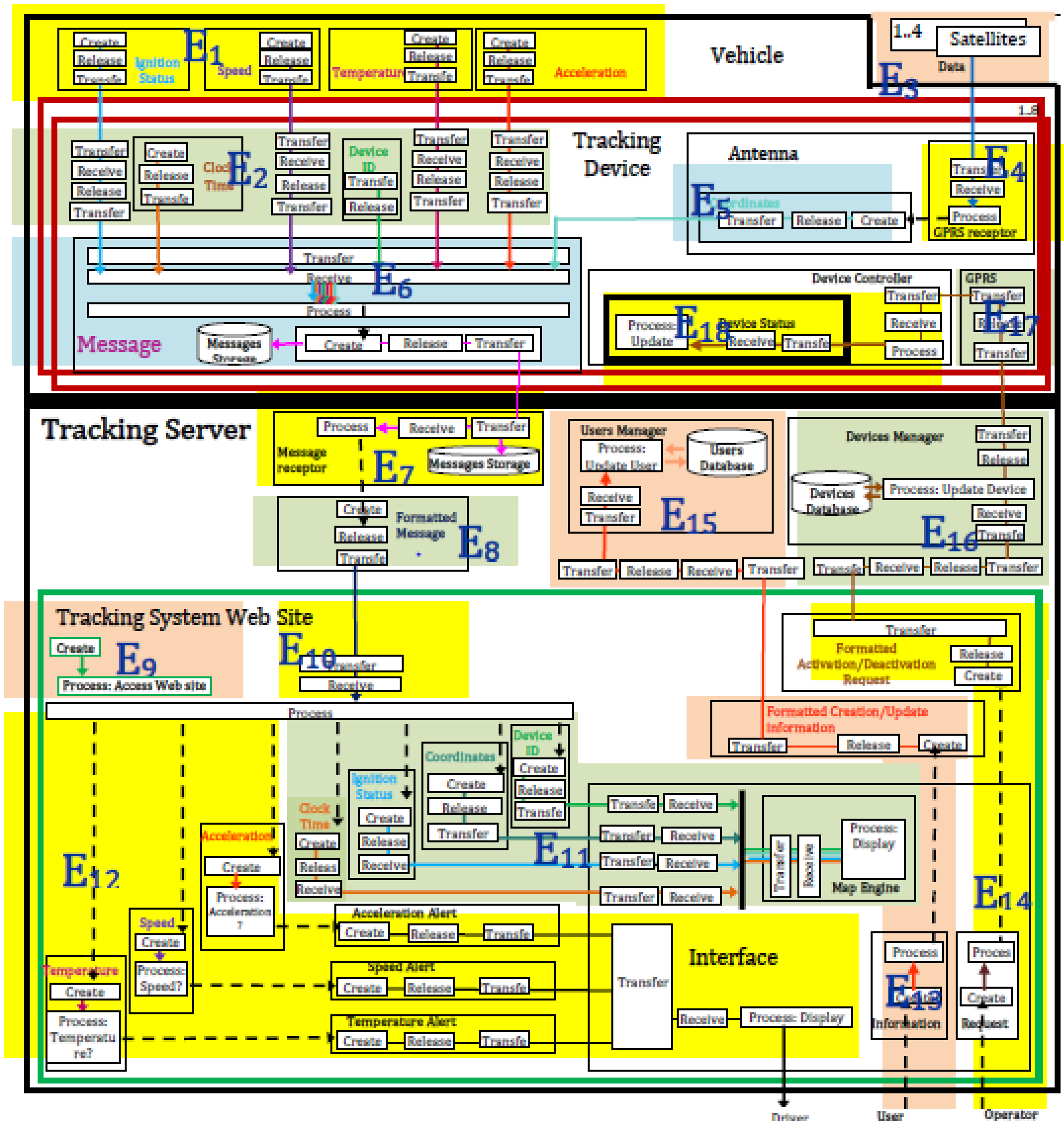

Fig. 14. The Events of the Tracking System.

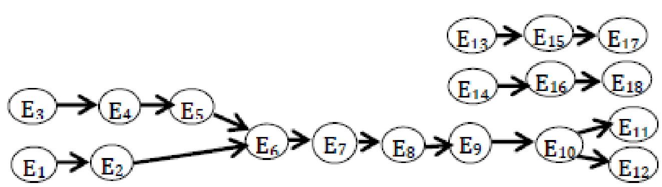

Fig. 15. The Chronology of Events in Fig. 14.

VI. Conclusion

We proposed using a new modeling technique, TM, to describe a tracking system systematically. Using the TM modeling technique as a documentation tool is a promising field that needs further in-depth exploration to develop appropriate diagramming tools.

The TM diagrams may look complex; however, as previously described, they can be simplified by lumping the details together or consolidating stages. Nevertheless, the underlying TM schema remains a reference for any simplified representation or other uses such as analysis and documentation. Many issues remain to be clarified; however, this paper demonstrates the potential feasibility of this documentation approach, which can be utilized in technical manuals.

The tracking system described in the previous TM diagrams is a viable general solution for tracking by itself; however, it can be the foundation for building larger and more sophisticated advanced fleet management and optimization systems. An example of such utilization would be a customized system dedicated to managing public transportation. Such a system uses the TM modeling methodology to integrate equipment and to facilitate the management and logistical operations for public transportation.

An RFID passenger counter can be integrated with the tracking server through the tracking device to automate the billing and accounting, or fatigue-detecting cameras managed by the tracking device can be used.

Another utilization of the TM model is managing a fleet of self-driving vehicles. In this model, the driver element is eliminated, but instead the tracking device monitors the vehicle. Security checks are done to make sure a vehicle is acting according to its intended driving pattern. The TM model can be applied to ethical guidelines with respect to the three laws of robotics:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given to it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

Additional controls that can be modeled include continuously assigning the tracking device to check that all the vehicle functionalities are at an acceptable condition. If a problem is detected, the device triggers the movement of the vehicle to the nearest workshop that can solve the detected problem.

References

[1] J. Haywood Rolling Jr., "Art + design practice as Global Positioning System," Art Ed., vol. 70, no. 6, pp. 4-6, 2017. doi:10.1080/00043125.2017.1361756

[2] X. Zhao, "Road network and GPS tracking with data processing and quality assessment," [thesis], Dalarna University, Sweden, 2015. ISBN: 978-91-89020-92-4

[3] B. Wukkadada and A. Fernandes, "Vehicle tracking system using GSM and GPS technologies," IOSR J. of Comp. Eng., pp. 05-08, August 2005. http://www.iosrjournals.org/iosr-jce/pages/Conf-16055-vol-1.htm

[4] C. A. L. Lee, "The science and art of the diagrams: culturing physics and mathematics, part 2," [blog post], Sci. Am., April 2013. http://blogs.scientificamerican.com/guest-blog/the-science-and-art-of-diagramming-culturing-life-and-chemical-sciences-part-ii/

[5] S. Al-Fedaghi and M. Almutairy, "Applying thing-oriented modeling and patterns," Int. J. Software Eng. and Its Apps., vol. 10, no. 4, pp. 143–160, 2016.

[6] S. Al-Fedaghi and H. Almutairi, "Diagramming language for process documentation," 15th Int. Conf. on Applied Comp, 2018, Budapest, Hungary, 21-23 October, 2018.

[7] J. Bal, "Process analysis tools for process improvement," The TQM Magazine, vol. 10, pp. 342–354, 1998.

[8] M. Ene and C. Persson, "The process of process documentation: A case study at Volvo IT" [thesis], School of Economics and Commercial Law, University of Gothenburg, Department of Informatics, June 2005.

[9] S. Aschwanden-Granfelt, "Process flow documentation: A flowchart guide for micro & small business," [thesis], April 2007.

[10] P. Verma and J. S. Bhatia, "Design and development of GPS-GSM based tracking system with Google Map based monitoring," Int. J. of Comp. Sci., Eng. and App., vol. 3, no. 3, June 2013.

[11] S. Mohol, A. Pavanikar, and G. Dhage, "GPS vehicle tracking system," Int. J. of Emerging Eng. Research and Tech., vol. 2, no. 7, pp. 71–75, October 2014.

[12] K. Swapna, K. Priyanka, V. Navyasree, "Student tracking system," February 10, 2016. https://www.slideshare.net/NavyasriVeluri/student-tracking-system-58078698

[13] S. Benrouyne, "Car tracking anti-theft system, school of science and engineering," Al Akhawayn University, Morocco, April 2015. http://www.aui.ma/sse-capstone.../pdf/CAR-TRACKING-ANTI-THEFT-SYSTEM.pdf

[14] S. Al-Fedaghi, "Thinging for software engineers," Int. J. Comp. Sci. and Info. Sec., vol. 16, no. 7, July 2018.

[15] S. Al-Fedaghi, "Flow-based enterprise process modeling," Int. J. Database Theory and App., vol. 6, no. 3, pp. 59–70, 2013.

[16] S. Al-Fedaghi, "A method for modeling and facilitating understanding of user requirements in software development," J. Next Gen. Info. Tech., vol. 4, no. 3, pp. 30–38, 2013.

[17] S. Al-Fedaghi, "Software engineering interpretation of information processing regulations," IEEE 32nd Annual Int. Computer Software and Applications Conf., Turku, Finland, July 28–August 1, 2008.

[18] S. Al-Fedaghi, "Crossing privacy, information, and ethics," 17th Int. Conf. Info. Resources Management Ass., Washington, DC, USA, May 21-24, 2006. [Republished in Emerging Trends and Challenges in Info. Tech. Management, M. Khosrow-Pour (ed.), Hershey, PA: IGI Publishing, 2006.]

[19] S. Al-Fedaghi, "Diagrammatic modeling language for conceptual design of technical systems: A way to achieve creativity," Int. Review Auto. Control, vol. 9, no. 4, 2016.

[20] S. Al-Fedaghi, "Toward a philosophy of data for database systems design," Int. J. Database Theory and App., vol. 9, no. 10, 2016.

[21] G. Deleuze and F. Guattari, "Anti-Oedipus: Capitalism and schizophrenia." Minneapolis, MN: University of Minnesota Press, 1983.

[22] L. R. Bryant, "Towards a machine-oriented aesthetics: On the power of art," The Matter of Contradiction Conf., Limousin, France, 2012.

[23] J. Carreira, "Philosophy is not a luxury," [blog post], March 2, 2011. https://philosophyisnotaluxury.com/2011/03/02/to-thing-a-new-verb/

[24] M. Heidegger, "The thing," in Poetry, Language, Thought, A. Hofstadter, Trans., pp. 161–184, New York: Harper & Row, 1975.

[25] H. Frichot, "Architecture + Philosophy research seminar," Critical Studies in Architecture, Philosophies Blog, https://philosophiesresarc.net/

[26] R. Zito, G. d'Este, and M. A. Taylor, "Global positioning systems in the time domain: How useful a tool for intelligent vehicle-highway systems?" Transportation Research Part C: Emerging Technologies, vol. 3, no. 4, pp. 193–209, 1995.

[27] I. Skog and P. Handel, "In-car positioning and navigation technologies—A survey." Intelligent Transportation Systems, IEEE Transactions, vol. 10, no. 1, pp. 4–21, 2009.

[28] M. A. Quddus, W. Y. Ochieng, and R. B. Noland, "Current map-matching algorithms for transport applications: State-of-the art and future research directions." Transportation Research Part C: Emerging Technologies, vol. 15, no. 5, pp. 312–328, 2007.

[29] C. A. Quiroga and D. Bullock, "Travel time information using global positioning system and dynamic segmentation techniques." Transportation Research Record: J. Transportation Research Board, vol. 1660, no. 1, pp. 48–57, 1999.

[30] E. Murakami and D. P. Wagner, "Can using global positioning system (GPS) improve trip reporting?" Transportation Research Part C: Emerging Technologies, vol. 7, no. 2, pp. 149–165, 1999.

[31] D. Ashbrook and T. Starner, "Learning significant locations and predicting user movement with GPS," Wearable Computers, pp. 101–108, 2002 [Proceedings of the Sixth Int. Symposium on Wearable Computers, 2002].

[32] D. Ashbrook and T. Starner, "Using GPS to learn significant locations and predict movement across multiple users," Personal and Ubiquitous Computing, vol. 7, no. 5, pp. 275–286, 2003.

[33] T. Jia, K. Carling, and J. Håkansson, "Trips and their CO2 emissions to and from a shopping centre," J. Transport Geography, vol. 33, pp. 135–145, 2013.

[34] G. Leduc, "Road traffic data: Collection methods and applications," Working Papers on Energy, Transport and Climate Change, vol. 1, pp. 55, 2008.

[35] S. Van der Spek, J. Van Schaick, P. De Bois, and R. De Haan, "Sensing human activity: GPS tracking," Sensors, vol. 9, no. 4, pp. 3033–3055, 2009.

A Novel Rule-Based Root Extraction Algorithm for Arabic Language

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***Abstract*—Non-vocalized Arabic words are ambiguous words, because non-vocalized words may have different meanings. Therefore, these words may have more than one root. Many Arabic root extraction algorithms have been conducted to extract the roots of non-vocalized Arabic words. However, most of them return only one root and produce lower accuracy than reported when they are tested on different datasets. Arabic root extraction algorithm is an urgent need for applications like information retrieval systems, indexing, text mining, text classification, data compression, spell checking, text summarization, question answering systems and machine translation. In this work, a new rule-based Arabic root extraction algorithm is developed and focuses to overcome the limitation of previous works. The proposed algorithm is compared to the algorithm of Khoja, which is a well-known Arabic root extraction algorithm that produces high accuracy. The testing process was conducted on the corpus of Thalji, which is mainly built to test and compare Arabic roots extraction algorithms. It contains 720,000 word-root pairs from 12000 roots, 430 prefixes, 320 suffixes, and 4320 patterns. The experimental result shows that the algorithm of Khoja achieved 63%, meanwhile the proposed algorithm achieved 94% of accuracy.**

***Keywords*—Root; stem; rules; affix; pattern; corpus**

I. Introduction

Arabic texts are mainly categorized into two types. The first type is known as Classical Arabic e.g. the Qur'an text. The second type is called Modern Standard Arabic (MSA), which is the form that is used in all Arabic-speaking countries in publications, media and academic institutions [1]. The Modern Standard Arabic is then classified into three types, which are fully vocalized like elementary textbooks, partially vocalized like newspapers, and the non-vocalized text.

Vowels are used in Arabic to ensure the reading and the exact meaning of the words. If the word is non-vocalized, in many cases, it will represent an ambiguous word, and then we need to read the full sentence and sometimes the whole article or document to understand the exact meaning.

Root extraction is the process of extracting the root of the word. Root extraction correlates several terms into one common representation. Therefore, those words which are derived from the same root are grouped together. For example, root extraction algorithms reduce the word "fishing", "fished", and "fisher" to "fish". Root extraction is used in information retrieval systems, indexing, text mining, text classification, data compression, spell checking, text summarization, question answering systems and machine translation [2].

Arabic dialect contrasts from the Indo-European dialects morphologically, semantically, and grammatically. Building an Arabic root extraction is more complicated than building root extraction in any other European language such as English. English language root extraction is only concern with the removal of prefixes and suffixes [3].

Affixes in Arabic are prefixes, suffixes and infixes. Prefixes are attached at the beginning of the words, where suffixes are attached at the end, and infixes are found in the middle of the words [4]. For example, the word كبيوتكم which meaning is "like your houses" in English, ك is the prefix, which is a connected preposition, كم is the suffix, which is the subject here, and و is the infix. So, the root is بيت, where in English the preposition and subject are written separately. So, for the "houses" word no prefix, no infix, "s" is the suffix, and the root is "house".

In Arabic, words are made from roots and patterns. Patterns are non-consonant letters groupings which can be interceded on as templates [5]. Patterns can be added to the root of the word or can be found within the roots of the word following well-defined models [6]. Many words have the same pattern. The root of any words can be easily extracted if the word and the pattern are known. For example, if the words واستبدلته, واستجبرته, واستجهرته have the pattern of واستفعلته, therefore the roots will be بدل, جبر, جهر respectively.

As a result of a thorough investigation of existing algorithms, in this work, a new rule-based Arabic Root Extraction Algorithm (AREA) is proposed. Our algorithm is an extensive enhancement and improvement work which is done to overcome the limitations of the previous works that can be used in both IR and NLP applications in an effective way.

This paper is organized as follows. In Section II, the discussion regarding previous studies and their drawbacks is presented. Section III describes the proposed methodology, including details of each process. Section IV explains the experimental implementation of our algorithm and the evaluation process. Section V concludes the main points of the paper and gives some future directions.

II. Previous Studies

AREA can be categorized into a database search approach, statistical based approach, and a rule-based approach [7].

A. Database Approach

Database search approach is the simplest strategy; it simply looks for the root of the word in the lookup table. The database would also include a list of patterns that match different Arabic words and can be used to help identify different roots.

Most well-known works using this approach are Al-Fedaghi with Al-Anzi algorithm [8], and Al-Shalabi algorithm [9]. They proposed an algorithm to generate the root and pattern of a given Arabic word. The main problem of this type is when there is no pattern or root is matched from the database. The limitation of this method is the need to constantly update the database. Also, there is a possibility that the algorithm will detect more than one pattern for certain words.

B. A Weight-Based Approach

With this approach, the algorithm assigns different weights to letters in the word, and then, using mathematical calculations to find the root. Al-Serhan, Al Shalabi and Kannan algorithm [10] is an example of this approach. The main problem of this algorithm is it gives the same priority for the extra letters as the original letters. For example, it gives the same priority to (ف, ك, ب, ط, د) with (ث, ج,ح, خ, ذ, ر, ز , ش,ص ض,), although these letters sometimes are not the original root letters. For example, if a word contains the letters (ف, ب) as a prefix or the letter (ك) as a suffix, the algorithm fails to identify the root. This happens when it gives the letters' root less priority than other letters in the word. For example, if the letters' roots in (أ, م, ن ,إ) and the extra letters are in (ل,س ,ه).

C. A Rule-Based Approach

Most of the AREA in the literature today are rule-based. In the rule-based approach algorithms, a set of rules are built to find the Arabic root from the original word. In most cases, this approach will also use a database of patterns and affixes as well. These algorithms affected by the way the rules are arranged as well as the number of rules. Such algorithms would also involve a pre-processing to find a possible root.

Khoja and Garside algorithm [11] is the most popular rule-based Arabic root extraction algorithm. Khoja and Garside algorithm reported 96% accuracy of their algorithm using newspaper text.

Al-Shalabi [12] presents Arabic root extraction algorithm, which is a rule-based algorithm that is used to extract trilateral roots of Arabic words. This algorithm has been tested on a corpus of 72 abstracts, 10582 words from the Saudi Arabian National Computer Conference and they achieved 92% of accuracy.

Another work, Al-Kabi and AL-Mustafa algorithm [13] is based on affix removal. They tested their algorithm on small data sets containing 1,827 words. The system unable to analyse 55 words, since their patterns are unknown. This failure mostly due to foreign (Arabized) words. The system is able to analyse the rest (1,772 words), but it was stated that the accuracy of extracting the right roots is 91%.

Sonbol, Ghneim and Desouki algorithm [14] is another rule-based root-extraction algorithm where the principal idea is based on the encoding of Arabic letters with a new code that preserves morphologically useful information and simplifies it's capturing toward retrieving the root. They conducted their experiments using two different corpuses. The first corpus consists of lists of word-root pairs (167162 pairs). The second corpus is a collection of 585 Arabic articles from different categories (policy, economy, culture, science and technology, and sport). This corpus consists of 377793 words. Overall, the algorithm yields about 96%-98% of accuracy.

Ghwanmeh, Al-Shalabi, Kanaan, Khanfar and Rabab'ah algorithm [15] proposed a rule-based algorithm to find trilateral Arabic roots. According to Ghwanmeh et al, their algorithm only unable to analyse words that are normally foreign, irregular, or do not have trilateral roots. A corpus of 242 abstracts from the Proceedings of Saudi Arabian National Computer conferences in machine-readable form is used in the testing procedure. The set of abstracts was chosen randomly from the corpus for analysis. The results obtained showed that the algorithm extracts the correct roots with an accuracy rate up to 95%.

Up until now, various rule-based algorithms have been proposed such as the Kchaou and Kanoun algorithm [16], El-Defrawy, El-Sonbaty, and Belal algorithm [17], and Ayedh and Guanzheng algorithm [18] and many more works[19] [20] [21] [22] [23].

III. Method

This section describes the methodology for the new Arabic root extraction algorithm. The presented algorithm will find all possible roots for each word. The root is the base form of the word that gives the main meaning of the word.

A. Normalization

Normalization is the process that leads to the removal of unwanted letters, punctuations, and non-letters. The normalization steps consist of the followings:

- Remove kasheeda symbol ("ـ").
- Remove punctuations.
- Remove diacritics.
- Remove non-letters.
- Replace Hamza's forms ء, ,آ ,ؤ ,إ, ئ withأ .
- Duplicating any letter that has the Shaddah: "ّ" symbol.

B. Extracting the Constant Letters from the Word

The proposed algorithm finds all the possible roots of the word without removing prefixes and suffixes. It starts by extracting the constant letters in a word by applying the rules in the Table I. The starting process of the presented algorithm differs from most of the previous algorithms, because it does not start removing prefixes and suffixes from the words' derivations. Particularly, removing prefixes and suffixes from the words' derivations leads to omitting many letters from the root which leads also to wrong results. Most of the previous algorithms remove the prefixes and suffixes from the words' derivations which is depends on the expectation' processes. In other words, most of the previous algorithms do not sure exactly that prefixes and suffixes are affixes or not. For instance, consider the word " استماع". Most of the previous algorithms remove the prefix "است" from the word because they depend on the expectation' processes that the prefix "است" is founded in their prefix's lists. As a result, they remove it directly.

Next, we categorize the Arabic letters into groups as the work of Sonbol's Arabic root extraction algorithm. In Arabic, letters are categorized into two main groups; Constant and Nonconstant letters. Constant letters are: 'ث', 'ج', 'ح', 'خ', 'د', 'ذ', ' 'ر', 'ز', 'ش', 'ص', 'ض', 'ظ', 'ط', 'ع','ق', 'غ". If these letters appear in the derivation word, it also should appear in its root. For instance, the word "الجاحدون" has "جـ, حـ, د" constant letters. These constant letters must be part of the root. Therefore, constant letters are not being considered as affix letters.

The second Arabic letters' classification is the Non-constant letters which are divided into five categories; the prefix letters {ب, ف ،س ، ل}, the suffix letter {هـ}, the prefix-suffix letters {ك, م, ن}, the uncertain letters {ا, و, ي, ت} and an extra letter "ة". We face many urgent issues that need more understanding than constant letters' work because constant letters may appear in the derivation words, but not appear in their root.

TABLE I. RULES OF EXTRACTING THE CONSTANT LETTERS IN THE WORD

No	Rules	Example
1	Find out the constant letters in the word. If the number of constant letters is more than one letter, then they will be considered as one of the expected roots.	The input word "التقارير", the constant letters are {ق, ر, ر}, then {قرر} is one of the possible roots for the word "التقارير".
2	Check Ebdal rules to minimize the constant letters.	The input word "اصطحب", the constant letters are {ص, ط, ح, ب}, after applying Ebdal rules the constant letters become {ص, ح, ب}

C. Converting the Non-Constant Letters to the Constant Letters

The Non-constant letters in the derivation's word are the original root letters in some cases and considered as the additional letters to the root in other cases, depending on the position of the letters. In this section, a certain set of rules are applied to each letter in the non-constant letters' group in order to convert these letters into constant letters.

1) The prefix letters {ل, س, ف, ب}: The Prefix letters {ل, س, ف, ب} are one of the non-constants' letters. They are attached at beginning of the words. A certain set of rules has been implemented on each letter on the prefix letters' list to convert these letters from non-constant letters to a constant letter.

a) Prefix letter ل

Initially, the letter {ل} is a non-constant letter. It can be converted to a constant letter by applying the following rules:

Rule1: If the letter "ل " exists after the first constant letter, then the letter "ل" is treated as a constant letter. For example, with the word "اعتقل", the letters {ع, ق} have been identified constant letters. And the letter "ل" exists after the first constant letter. So, the letter "ل" is treated as a constant letter. Then the constants' letters list becomes {ع, ق, ل}.

Rule2: Check the position of the letter "ل" in the word. If the letter "ل" exists in the second half of the word, then it is treated as a constant letter. For example, consider the word "استلم". The letter "ل" is positioned in the second half of the word. Thus, in this case, it is considered a constant letter.

Rule3: If the letter "ل" is preceded by the letters "ال", it is treated as a constant letter. As it is in the word" الليل"

Rule4: The letter "ل" is treated as a constant letter if it has been preceded by one of these letters "ن, ت, ه, م, ي, س, ك". As it is in the following words" تلمس, نلمس, يلمس, كلمس, هلاك, ملاك, سلوك".

b) Prefix letter "س"

Initially, the letter "س" is a non-constant letter. It can be converted to a constant letter by applying the following rules: **Rule1:** If the letter "س" exists after the first constant letter, the letter "س" is treated as a constant letter. For example, with the word "أجناس", the letter "ج" has been identified a constant letter. Letter "س" exists after the first constant letter. So, "س" is treated as a constant letter. The constants letters list becomes "ج, س".

Rule2: If the letter "س" is preceded by the letters "ال", it is treated as a constant letter. As it is in the word" السباع".

Rule3: The letter "س" is treated as a constant letter if it has been preceded by one of the letters "ل, ب, س, ك, هـ". As it is in the words" لسماع, بسماع,"

Rule4: The letter "س" is treated as a constant letter if it hasn't been followed by one of the letters "أ, ا, ن, ي, ت". As it is in the words "سكان, سلالم".

Rule5: Check the position of the letter "س" in the word. If the letter "س" exists in the second half of the word, it is treated as a constant letter. For example, with the word "ميؤوس", the letter "س" is positioned in the second half of the word. Thus, in this case, it is considered a constant letter.

Rule6: When the letter "س" exists in the prefix part of the word, it is not possible to decide if the letter "س" is a constant letter or not. For instance, the word" استماع".

c) Prefix letter ف

Initially, the letter {ف} is a non-constant letter. It can be converted to a constant letter by applying the following rules:

Rule1: If the letter" ف" exists after the first constant letter, the letter "ف " is treated as a constant letter. For example, with the words "أجحف", the letters "ج, ح" have been identified constant letters. The letter "ف" exists after the first constant letter. Hence, the letter "ف" is treated as a constant letter. The constants' letters list becomes "ج, ح, ح".

Rule2: Check the position of the letter "ف" in the word. If the letter "ف" exists in the second half of the word, it is treated as a constant letter. For example, consider the word" استلف". The letter "ف" position in the second half of the word. Thus, in this case, it is considered a constant letter.

Rule3: If the letter "ف" is preceded by the letters "ال", it is treated as a constant letter. As it is in the word" الفنون".

Rule4: The letter "ف" is treated as a constant letter if it has been preceded by one of these letters "ت, ن, س, م, هـ, ي". As it is in the following words"تفلس, نفلس, هفوف, سفيه, مفلس, يفلس,"

d) Prefix letter ب

Initially, the letter {ب} is a non-constant letter. It can be converted to a constant letter by applying the following rules:

Rule1: -If the letter "ب" exists after the first constant letter, the letter "ب" is treated a constant letter. For example, with the word "صباح", the letters {ص, ح} have been identified constant letters. The letter "ب" exists after the first constant letter. So, the letter "ب" is treated as a constant letter. The constants letters' list becomes "ص, ب, ح".

Rule2: Check the position of the letter "ب" in the word. If the letter "ب" exists in the second half of the word, it is treated as a constant letter. For example, in the word "سالب", the letter "ب" positioned in the second half of the word. Thus, in this case, it is considered a constant letter.

Rule3: If the letter "ب" is preceded by the letters"ال", it is treated as a constant letter. As it is in the following word" الباسل".

Rule4: If the letter "ب" location is more than two in the word, it is treated as a constant letter. As it is in the word "الآبدين".

Rule5: The letter "ب" is treated as a constant letter if it has been preceded by one of these letters "ب, أ, ا, ت, ن, م, س, هـ, ي". As it is in the following words",أباركتم, ابان, ببعض, سباق, هبوب, يبتلع, نبدأ".

Rule6: When the letter "ب" exists in the prefix part of the word, It is not possible to decide if the letter "ب" is a constant letter or not. Such as the word" باسل".

2) Suffix letter " هـ:" Suffix letter is one of the non-constant letters and attached at the end of the words. A certain set of rules has been implemented to convert this letter from non-constant letter to a constant letter. In this algorithm "هـ" is the only suffix letter.

The letter "هـ" is treated as a non-constant letter if the letter "هـ" exists in the suffix part of the word. The letter "هـ" is treated as an original root letter if it exists in places rather than the suffix part of the word. Initially, the letter "هـ" is a non-constant letter. It can be converted into a constant letter by applying the following rules:

Rule 1: If the letter "هـ" exists before the last constant letter, the letter "هـ" is treated as a constant letter. For example, in the word "اجتهد", the letters "ج, د" have been identified as a constant letter. The letter "هـ" exists before the last constant letter. So, "هـ" is treated as a constant letter. The constants letters list becomes "ج, هـ, د".

Rule 2: Check the position of the letter "هـ" in the word. If the letter "هـ" exists in the first half of the word, it is treated as a constant letter. For example, consider the word" تهامة". The letter "هـ" position is in the first half of the word. So, in this case, it is considered a constant letter.

Rule 3: The letter "هـ" is considered as a constant letter if the letters "وا" exist at the end of the word and the letter "هـ" appears just before the letters "وا" , such as " انتبهوا, أماهوا, تلاهوا".

Rule 4: The letter "هـ" is treated as a constant letter if it has been preceded by one of the letters "ب, س, ف, ك, ل, هـ, ة", such as" الدهس, التلهف, أشبهك, فقاهة, اسهله, تأهل, أسهب,"

3) The prefix-suffix letters "م, ن ,ك": The Prefix-Suffix letters {م, ن ,ك} are non-constant letters; a certain set of rules has been implemented on each letter on the Prefix-Suffix letters' list in order to convert these letters from non-constant letters to constant letters. The Prefix-Suffix letters are treated as constant letters to the root if these letters exist in the Prefix part or the suffix part or of the word. In contrast, they are treated as original root letters if they exist in the places rather than the prefix part or the suffix part of the word.

a) The Prefix-Suffix letter " ك"

Initially, the letter "ك" is a non-constant letter; it can be converted to a constant letter by applying the following rules:

Rule1: The letter " ك" is treated as an original root letter if it exists between constant letters. In the word "الشكر", the letters "ش, ر" are identified as a root letter. Then the letter "ك" exists between the two constants letters, "ك" letter is treated as a constant letter also. Thus, the constant letters list is "ش, ك, ر".

Rule2: The letter "ك" is considered as a constant letter if it appears in the first half of the word and not following the " ف, و" letters, such as " أكلائها, الكلمات, مكاسر".

Rule3: The letter "ك" is considered as a constant letter if it appears in the second half of the word and before the last constant letter, such as "المنكر, النكاح".

Rule4: The letter "ك" is considered as a constant letter if it appears in the second half of the word and has been followed by "ين, ت, ات ," letters, such as "المؤتفكات, المساكين, تباكت".

Rule5: When the letter "ك" exists in the prefix or suffix part of the word, it is not possible to decide if "ك" is a constant letter or not. The word is ambiguous, such as "شراك, كثيب"

b) The Prefix-Suffix letter " م "

Initially, the letter "م" is a non-constant letter; it can be converted to a constant letter by applying the following rules:

Rule1: The letter "م" is treated as an original root letter if it exists between constant letters. For example, with the word "أعماق", the letters "ع ,ق" are identified as root letters, the letter "م" exists between the two constants letters, and "م" letter is treated as a constant letter. "م" letter is added to the constants letters list. In this case, one of the possible roots for the word "أعماق" is"عمق".

Rule2: The letter "م" is considered a constant letter if it appears in the second part of the word and before the last constant letter, such as "بالتمكث, والمكر".

Rule 3: The letter "م" is considered a constant letter if it appears in the first part of the word and is positioned after the first constant letter, such as "ثميلة "

Rule4: The letter "م" is treated as a constant letter if it appears in the first part of the word and has been preceded by one of the letters "ا, ت, ي, such as "تمدح ، امتنع, يمشي".

Rule5: The letter "م" is considered a constant letter if it has been preceded by one of the letters "ا, و, ي" only in case the letters "ا, و, ي" are appeared after the last constant letter in the word, such as "الرحيم, طعام, القوم".

Rule6: The letter "م" is considered a constant letter if it appears just after the last constant in the word, such as " الرحمن, العجم".

Rule7: The letter "م" is considered a constant letter if it appears in the second part of the word and followed by the letter "ات", such as "السالمات".

Rule8: The letter "م" is considered a non-constant letter if the word consists of three constant letters and the letter "م" appears just before the first constant letter, such as " للمطبوع, المفضل".

c) The Prefix-Suffix letter "ن"

Initially, the letter "ن" is a non-constant letter; it can be converted to a constant letter by applying the following rules:

Rule1: The letter "ن" is treated as an original root letter if it exists between constant letters. For example, in the word "أعناق", the letters "ع ,ق" have been identified as constant letters. Then the letter "ن" is treated as a constant letter. The letter "ن" is added to the constant letters list. In this case, one of the possible roots for the word "أعناق" is the root "عنق".

Rule2: The letter "ن" is considered as a constant letter if it appears in the first part of the word and it has been preceded by one of these letters "ال, ن" , such as "النواحي, ننشئهم".

Rule3: The letter "ن" is considered a constant letter if the word ended with the following letters "مين, ماء" , such as "الأيهمين, الأظماء".

Rule4: The letter "ن" is considered as a constant letter if it appears in the second part of the word and followed by the last constant letter, such as the words"المؤنث, بالاستنجاء ".

Rule5: The letter "ن" is considered a non-constant letter if the word consists of three constant letters and "ن" letter appears just before the first constant letter, such as " "وينزعج.

4) The uncertain letters "ء, و, أ, ا , ئ,ؤ": The uncertain letters "ء, و, أ, ا , ئ, ؤ" can appear in any part of the word. A certain set of rules has been implemented on each letter to convert these letters from non-constant letters to a constant letter by applying the following rules:

Rule1: The letter "ؤ" is considered as a constant letter if it not proceeded by one of these letters "ا, ي, و, أ", such as "المؤلف, البؤس".

Rule2: The letter "ئ" is considered as a constant letter if it appears in the word and has not been preceded by one of the letters "ا, ي, و" such as "الذئب, المئبر".

Rule3: The letter "ا" letter is considered as a constant letter if it appears in the word and followed by the letter "ة", such as "الصلاة, الرعاة".

Rule4: The letter "ء" is considered as a constant letter if it appears in the word and has not been preceded by one of the letters "ا, ي, و, أ", such as "المرء".

Rule5: The letter "و" is considered as a constant letter if it appears in the word and has been preceded by "ال" letter, such as "الولايات, الوليمه".

5) The extra letter "ة": The extra letter "ة" is not from the root's letter. Therefore, we remove this letter from the word.

D. Extracting All Possible Patterns for the Word

In the previous step, finding all constant letters will minimize the possible root's letters. The problem is when the algorithm does not find three constant letters or more, the algorithm tries to expert each letter in the word to complete the missing letter in the root.

1) Extracting all possible patterns when constant letters are three or more

Most of the Arabic words are derived from trilateral Arabic roots. However, there are very few quadric-literal Arabic roots relative to the number of trilateral Arabic roots. Most of the studies which related to Arabic Root extraction either are based on a dictionary of Arabic roots or use a set of rules to identify the verb patterns of the Arabic words. The rules are selected depending on the number of letters in the word to find the Arabic roots. In this section, we explain how to extract all possible patterns when constant letters are three or more. One possible verbal pattern exists if the word consists of three or more constant letters. The steps are summarized in Table II.

TABLE II. EXTRACTING PATTERNS WHEN CONSTANT LETTERS ARE THREE OR MORE

No.	Steps	Result
1	The input word	الحاشدون
2	Find constant letters	ح ش د
3	If constant letters are more than two letters, replace the first constant letter with "ف" letter; then replace the second constant letter with "ع" letter, after that replace the rest of constant letter with "ل" letter.	الفاعلون

According to Table II, with the word "الحاشدون," three constant letters are found in the word, which is forming one possible root for the word; it is "حشد." To find the pattern of the word "الحاشدون", replace "ح" letter with "ف" letter; then replace "ش" letter with "ع" letter, after that "د" letter with "ل" letter, in order to achieve the pattern"الفاعلون ". Another example that contains four constant letters with the word "المتدحرجات," . There are four constant letters forming the possible root "دحرج." Therefore, the pattern is "المتفعللات."

2) Extracting all possible patterns when constant letters are less than three

If the number of constant letters less than three letters, there will be more than one possible pattern. For instance, in the word"التقى," there is just only one constant letter "ق." In this case, we cannot build the pattern because we should have at least three constant letters to build the complete pattern. Therefore, the algorithm tries to find another two constant letters in the word in order to form the correct possible patterns. Note that all letters in the word are the candidate to be constant letters. Therefore, the suggested letters are "ال, ات, اى, لت, لى, تى". Referring to the suggested letters, the possible patterns are "الفعل, افتعل,افعلى,فلتعل, فلعلى,فعتلى" . Refer the process in Table III.

TABLE III. STEPS TO EXTRACT ALL POSSIBLE PATTERNS WITH JUST ONE CONSTANT LETTER

No.	Steps	Result
1	The input word	التقى
2	Find constant letters	ق
3	Find all possible other two letters	ال, ات, اى, لت, لى, تى
4	Extract all possible patterns	الفعل, افتعل,افعلى,فلتعل,فلعلى,فعتلى

3) Exclude the wrong patterns by applying the rules

In the previous section, some of the extracting of the possible patterns "الفعل, افتعل,افعلى,فلتعل,فلعلى,فعتلى ", patterns are wrong because the non-constant letters in the patterns are in the wrong places. So, the present algorithm applies the rules in section C in order to reject the wrong patterns.

TABLE IV. EXAMPLE OF EXCLUDING THE WRONG PATTERNS BY APPLYING THE RULES

No.	Steps	Result
1	All possible patterns	الفعل, افتعل,افعلى,فلتعل,فلعلى,فعتلى
2	Check the rules of non-constant letters	فلتعل,فلعلى are rejected
3	The accepted patterns	الفعل, افتعل,افعلى,فعتلى

With the word"التقى," the suggested patterns" فلتعل,فلعلى " are removed from the list after applying the rules. As indicated earlier for "ل" letter rule, if "ل" letter exists between two constant letters, it is considered as a constant letter. At the same time, it could not be extra letters. Therefore, the possible patterns are "الفعل , افعلى, افتعل,فعتلى" see the Table IV.

4) Minimizing the possible patterns by comparing them with patterns' list

A list of patterns in the corpus of Thalji [24] is automatically extracted and this list contains "4320" patterns. In order to ensure that the possible patterns are correct, they are compared with the patterns' list if they are not found they are rejected. For example, for the possible patterns in the word"التقى", the pattern "فعتلى" is not found in the list, so it is rejected, and the remaining possible patterns are"افتعل,افعلى, الفعل".

TABLE V. MINIMIZING PATTERNS BY COMPARING THEM WITH PATTERNS' LIST

Steps	Result
Possible patterns	الفعل, افتعل,افعلى
Compare the patterns with a pattern list	فعتلى is rejected
The accepted patterns	الفعل, افتعل,افعلى

E. Extract All Possible Roots for the Word

1) Finding all possible roots by matching the patterns

After finding all possible patterns, now all the possible roots that match the patterns are extracted. For example, in the word"التقى", the possible patterns are"افعلى, افتعل, الفعل" . Therefore, the possible roots are"لتق, لقى, تقى".

2) Finding all possible roots by applying Ebdal rules

After careful and considered review of the content of the Arabic dictionaries such as "Lessan AL-Arab" [25], it has been found that this dictionary has roots like",صطبل, صطفل, ضطر, زدر زدف". However, this the dictionary doesn't apply the Ebdal rule [26]. So, the Ebdal rules are always not applied. In our algorithm all the possible roots are returned with applying Ebdal rules and with don't apply it, to be in the safe side. Our proposed algorithm returns all the possible roots for each word by applying Ebdal rule and returning suggested roots without applying it.

F. Solve the Problem with Shaddah

This work is for the non-vocalized text. So, in many cases the writers don't write Shaddah above the letter, hence, the algorithm will try to check for missing Shaddah. It is started from the second letter in the word to check for missing Shaddah for all letters except the vowel letters. For example, the word "البر", the algorithm is generated by these possible missing Shaddah, "اللبر, الببر, البرر".

G. Solve the Problem with a Missing Vowel in Ealal Rules

In Arabic language, if the root has one or more long vowel, in derivation words these letters may be deleted. For example, for the root "قول", one of possible derivation word is "قل". During the derivation process, the long vowel "و" letter is deleted. So, in this case, the algorithm gives all possible cases of missing long vowel letter. The algorithm is generated these possible missing vowels "وقل, قول, قلو".

H. Solve the Problem by Changing the Vowel in Ealal Rules

In Arabic language, if the root has one or more long vowel, in derivation words these letters may be changed to deferent long vowel letter [27]. For example, with the root "قول", one of possible derivation word is "قال". During the derivation process, the long vowel "و" letter is changed to different long vowel letter, which is "ا". So, the algorithm gives all possible cases of changing long vowel letters. For example, with the word "قال", the algorithm is generated these possible different vowels ,قيل" "قول.

I. Minimizing Possible Roots by Comparing them with Roots' List

The algorithm generates a large number of possible roots, especially for words that found less than three constant letters and for vowel roots, because vowel roots have many more special cases. The presented algorithm uses the roots' list of Thalji [24] to minimize the possible roots. This list has 12000 roots. For example, the case of "درهم" word, the algorithm generates these root دير, درا, درو, دري, درر ادر, ودر, يدر, دار, دور, but the root "يدر " is excluded, because it is not founded in root's list.

J. Solve the Problem with Length One Words

In Arabic, there are some few words with only one letter length like "قِ، ع، ر", these words are derived from vowel root with length three letters, and these vowel letters are deleted during derivation process. The presented algorithm tries to find the root for such words by generating all possible vowels roots and all permutations. For example, with the word "قِ" all possible vowel letters are listed in Table VI, then these roots are compared with roots list of Thalji if these roots are founded the root is accepted otherwise the root is rejected.

TABLE VI. GENERATED ROOTS FOR WORD "قِ"

Generated root	Accepted or not
اقا	Accepted
اقو	Not accepted
اقي	Not accepted
ااق	Not accepted
اوق	Accepted
ايق	Accepted
وقا	Not accepted
وقو	Not accepted
وقي	Accepted
واق	Accepted
ووق	Accepted
ويق	Not accepted
يقا	Not accepted
يقو	Not accepted
يقي	Not accepted
ياق	Not accepted
يوق	Not accepted
ييق	Not accepted

K. Try to Find Other Roots

For words like the word "درهم", the algorithm result only includes these roots " درر, درأ، دري، دور، ودر ". In this word's case, the algorithm just finds two consonant letter and tries to find the third one, not the fourth one also. So, it misses the root "درهم" . In this case, the algorithm tries to check the word itself "درهم", since it's length is four. So, the result is درهم, درأ، درر ، دري، دور، ودر ".

IV. Experiment and Evaluation

In this section, the presented algorithm is compared with the Arabic root extraction algorithm of Khoja and Garside, which is the most popular Arabic root extraction algorithm, and the only Arabic root extraction algorithm that publicly available for download. Khoja and Garside tested their Arabic root extraction algorithm using newspaper text and achieved 95%. Specifically, we make a pure and completely comparison between the algorithm of Khoja and Garside and the presented algorithm on the corpus of Thalji. Thalji's corpus is an automatic corpus that is built from ten old Arabic dictionaries. This corpus is mainly built to test and fairly compare Arabic roots extraction algorithms. This corpus contains 720,000 words roots pair, which helps to avoid the interference of a human expert normally needed to verify the correct roots of each word used in the testing or comparison process. Moreover, this corpus has more than 4,320 types of words which derived from (12000) roots. So, it guarantees the comprehensiveness of words.

The experimental result shows that the accuracy of the algorithm of Khoja and Garside is 63%, and the accuracy of the presented algorithm achieves 94%. As shown in Figure I.

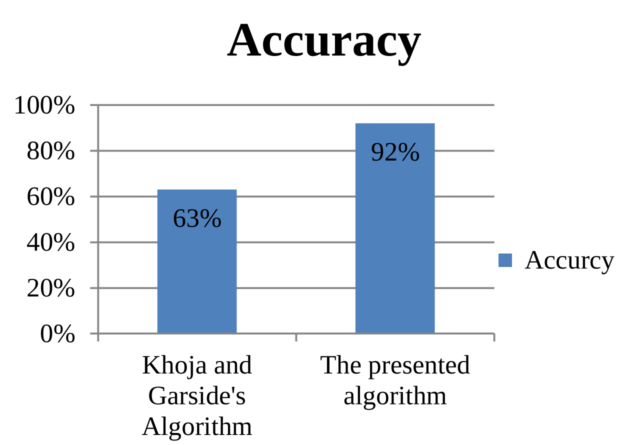

Fig. 1. Accuracy of Khoja Algorithm and the Presented Algorithm.

We observed that the following limitations caused the decrement of accuracy for the algorithm of Khoja and Garside:

1) The algorithm of Khoja and Garside is missing a large number of roots, prefixes, suffixes, and patterns. The dictionary of Khoja and Garside is restricting the result for just 4,748 roots, 3,822 trilateral roots, 926 quadrilateral roots. Because the algorithm of Khoja and Garside ignores 7252 roots, the result of ignoring these roots causes wrong results because if one uses any of ignoring roots, he/ she will not find the correct result or will not achieve the correct root. For example, the word *"مملوع"* is stemmed to the wrong root *"ولع"*, because it misses the root *"ملع"*, also the word *"لأصدقائك"* is not stemmed because it is missing the pattern *"لأفعلائك"*, the same thing will occur to the following words*: يحرمونهن ", اخلعوهن, تستبدل, حاسوب, ازدهر, اصطحب, اصطلح, لأصدقائك, نستخدمها, شركاؤنا"*.

2) The algorithm of Khoja and Garside suffers from affix ambiguity problems. For example, it returns *"ميع"* root for the word *"استماع"*, but it should also return the root *"سمع"*, this is because it starts by removing the longest suffix or prefix, but sometimes its neither prefix nor suffix, its root's letters.

3) The algorithm of Khoja and Garside, again, returns just one solution for non-vocalized words, ignoring other possible solutions. For example, the word *"قل"*, the possible roots are *"قول, قلل, قلو, وقل, قيل قلي"*, where the result is just *"قلل"*.

4) The algorithm of Khoja and Garside replaces a weak letter with the letter " *و*", which occasionally produces a root that is not related to the original word. For example, it returns *"صول"* root for the word *"أصيل"* which is the wrong root, the right root is *"أصل"*.

5) The algorithm of Khoja and Garside may generate invalid roots or fail to find roots for words that contain Ebdal rule "*ابدال*" like *اصطحب, اصطلح,"*and *"ازدهر*.

6) The algorithm of Khoja and Garside, also, doesn't deal with Shaddah. For example, with the word *"وأب"*, it returns the root *"أبي"*, where the possible root also is "*أبب*".

To be fair, the followings are the limitation points of the proposed algorithm:

7) The presented algorithm unable to find the root of words is in the word *"ذيعوعة"*, the algorithm result is just "*ذعع*" root. In this well-known word's case, if the algorithm finds three constant letters, it returns them as trilateral root which becomes the result. At the same time, the presented algorithm is not deal with exchanging the constant letter with the vowel letter because this case rarely happened.

8) The presented algorithm gives all possible roots of the word. However, this causes a misunderstanding result for the researcher to find which the exact root for the word is. This limitation coming up clearly because the presented algorithm deals with words rather than completed meaningful sentences in a paragraph.

V. Conclusion and Future Work

In this study, we investigate the rules which are based on the existing Arabic root extraction, analyse most previous Arabic root extraction algorithms, inspired by all their strong ideas, and overcome the weaknesses' points. This study continues what the others already started by performing extensive enhancement and improvements.

The presented Arabic root extraction algorithm is compared with the Arabic root extraction algorithm of Khoja and Garside, which is a well-known Arabic root extraction algorithm. The algorithm of Khoja and Garside yields 95% of accuracy when it was tested in the selective data set. However, the experimental result shows 63% accuracy when we tested their algorithm using Thalji's corpus. At the same time, we test the proposed algorithm on the same corpus and able to achieve 94%. The main reason of decreasing the percentage of the algorithm of Khoja and Garside from 95% to 63% is because of the different datasets that are used in the testing process. This proved that the algorithm of Khoja and Garside has insufficient rules to handle bigger test data with wider diversity and variation of words.

We plan to enhance the accuracy of the presented algorithm by solving its weakness points as stated in the above. The future works will include the enhancement of rules to obtain just the exact root instead of multiple roots, which requires the algorithm to analyse and understand the sentence or sometimes the paragraph.

References

[1] G. Kanaan, R. Al-shalabi and M. Sawalha, "Improving Arabic information retrieval systems using part of speech tagging," pp. 32-37, 2005.

[2] Z. Thalji, "A New Algorithm to Minimize Names in the Arabic Language," International Journal of Applied Engineering Research, vol. 13, no. 18, pp. 13950-13960, 2018.

[3] S. Al hakeem, G. Shakah, B. Abu Saleh and N. Thalji, "Developing an effective light stemmer for Arabic language information retrieval," International Journal of Computer and Information Technology, vol. 5, no. 1, pp. 55-59, 2016.

[4] T. M. T. Sembok and B. AbuAta, "Arabic word stemming algorithms and retrieval effectiveness," In Proceedings of the World Congress on Engineering , vol. 3, pp. 3-5, 2013.

[5] R. Kanaan and G. Kanaan, "An improved algorithm for the extraction of triliteral Arabic roots," European Scientific Journal, vol. 10, no. 3, pp. 346-355, 2014.

[6] B. Abuata and A. Al-Omari, "A rule-based stemmer for Arabic Gulf dialect," Journal of King Saud University-Computer and Information Sciences, vol. 27, no. 2, pp. 104-112., 2015.

[7] E. Al-shawakfa, A. Al-Badarneh, S. Shatnawi, K. Al-Rabab'ah and B. Bani-Ismail, "A Comparison study of some Arabic root finding," Journal Of The American Society For Information Science And Technology, vol. 61, no. 5, pp. 1015-1024, 2010.

[8] S. Al-Fedaghi and F. S. Al-Anzi, "A new algorithm to generate Arabic root-pattern forms," proceedings of the 11th national Computer Conference and Exhibition, 1989.

[9] R. Al-shalabi and M. Evens, "A Computational Morphology System for Arabic," In Proceedings of the Workshop on Computational Approaches to Semitic Languages. Association for Computational Linguistics., pp. 66-72, 1998.

[10] H. M. Al-Serhan, R. Al Shalabi and G. Kannan, "New approach for extracting Arabic roots," Proceedings of the 2003 Arab conference on Information Technology, pp. 42-59, 2003.

[11] S. Khoja and R. Garside, "Stemming Arabic text," Lancaster, UK, Computing Department, Lancaster University, 1999.

[12] R. Alshalabi, "Pattern-Based Stemmer for Finding Arabic Roots," Information Technology Journal, pp. 38-43., 2005.

[13] M. N. Al-kabi and R. AL-Mustafa, "Arabic Root Based Stemmer," Proceedings of the International Arab Conference on Information Technology, 2006.

[14] R. Sonbol, N. Ghneim and M. S. Desouki, "Arabic Morphological Analysis : a New Approach," In Information and Communication Technologies: From Theory to Applications, 3rd International Conference, IEEE, pp. 1-6, 2008.

[15] S. Ghwanmeh, S. Rabab'Ah, R. Al-Shalabi and G. Kanaan, "Enhanced Algorithm for Extracting the Root of Arabic Words," Sixth International Conference on Computer Graphics, Imaging and Visualization, pp. 388-391, 2009.

[16] Z. Kchaou and S. Kanoun, "Arabic stemming with two dictionaries," In Innovations in Information Technology, International Conference IEEE., pp. 688-691, 2008.

[17] M. El-Defrawy, Y. El-Sonbaty and N. Belal, "A Rule-Based Subject-Correlated Arabic Stemmer," Arabian Journal for Science and Engineering , vol. 41, no. 8, pp. 2883-2891, 2016.

[18] A. Ayedh and T. Guanzheng, "Building and Benchmarking Novel Arabic Stemmer for Document Classification," Journal of Computational and Theoretical Nanoscience, vol. 13, no. 3, pp. 1527-1535, 2016.

[19] K. Taghva, R. Elkhoury and J. Coombs, "Arabic Stemming without a root dictionary," In Information Technology: Coding and Computing, International Conference, IEEE, pp. 152-157, 2005.

[20] E. Al-Shammari and J. Lin, "A novel Arabic lemmatization algorithm," Al-Shammari, E., & Lin, J. (2008, JulyIn Proceedings of the second workshop on Analytics for noisy unstructured text data ACM., pp. 113-118, 2008.

[21] M. N. Al-Kabi, S. A. Kazakzeh, B. M. Abu Ata, S. A. Al-Rababah and I. M. Alsmadi, "A novel root based Arabic stemmer," Journal of King Saud University-Computer and Information Sciences, pp. 94-103, 2015.

[22] A.-K. N. Al-Kabi, "Towards Improving Khoja Rule-Based Arabic Stemmer," In Applied Electrical Engineering and Computing Technologies (AEECT), IEEE Jordan Conference, pp. 1-6, 2013.

[23] F. Abu Hawas and K. Emmert E, "Rule-based approach for Arabic root extraction: new rules to directly extract roots of Arabic words," Abu Hawas, F., & Emmert, K. E. (2014). Rule-based approach for Arabic rJournal of Computing and Information Technology, vol. 22, no. 1, pp. 57-68, 2014.

[24] N. Thalji, N. A. Hanin, Y. Yacob and S. Al-Hakeem, "Corpus for Test , Compare and Enhance Arabic Root Extraction Algorithms," International Journal of Advanced Computer Science and Applications, vol. 8, no. 5, pp. 229-236, 2017.

[25] M. Ibn Manzur, Lisan Al-Arab, no date.

[26] A. Abu altaeeb, Ebdal Book, Damascus: Arabic Language Group, 1961.

[27] E. Abdulaleem, Tayseer Ealal and Ebdal, Cairo: Dar Ghraib For Printing, Publishing and Distribution, 1993.

Runtime Reasoning of Requirements for Self-Adaptive Systems using AI Planning Techniques

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Abstract—Over the years, the domain of Self-Adaptive Systems (SAS) has gained significant importance in software engineering community. Such SAS must ensure high customizability and at the same time effective reasoning to meet their objectives by meeting end-user goals more effectively and efficiently. In this context, techniques related to *Automated Planning* have acquired substantial precedence owing to their adaptability to diverse scenarios based upon their enhanced knowledge extraction from available Knowledge Base. These AI planning techniques help in supporting self-adaptation mechanism of SAS. We have investigated these techniques to perform runtime reasoning of SAS requirements. This paper proposes an architecture for implementing the reasoning component of previously proposed Continuous Adaptive Requirement Engineering (CARE) framework. The proposed architecture has been experimentally verified by implementation of a prototype application using JSHOP2 (Java implementation of SHOP2, an HTN Planner).

Keywords—Self-Adaptive Systems (SAS); reasoning; requirement engineering; AI planning; CARE framework; runtime reasoning of requirements

I. Introduction

The software systems are increasingly expected to satisfy their functional and non-functional requirements, even under changing conditions in their environments, including fluctuations in user demands (requirements), resource availability (system parameters) and the presence of cyber adversaries. Self-Adaptive Systems (SAS) address this need, since they are required to modify themselves according to the changes in the end user requirements or the environment in which they operate or the system parameters, to remain operational [2] [24]. Such systems have the ability to continuously monitor their own state and the state of their environment, and to autonomously change their structure and behavior to operate as best as possible, with respect to a defined goal in the presence of run-time changing conditions.

The desired end states (goals), as defined by the user and dictated by the system itself for computational purposes, are translated in the form of explicit requirements. Requirements engineering approach provides the basic considerations for determining the performance of evolved system. However, pragmatically the existing requirements engineering (RE) techniques work well where requirements of system are well understood at design time and evolve very slowly with respect to time. These techniques fail to provide solutions in abruptly changing requirements, hence rendering them unable to support Self-Adaptive Systems (SAS) where changes in all domains are very dynamic [1].

Self-Adaptive Systems manifest themselves into uncertainty in both context and lack of knowledge thanks to the ever-changing variables [25]. It leads to a scenario where system is made to take critical decisions for adapting itself with respect to set goals (whether to adapt or not, when to adapt, which adaptation technique to use, etc) in a dynamic and partially observable environment. The authors in [27] argue that contextual uncertainty in the operating environment requires to be reduced in order to improve the performance of SAS.

In the literature, a few approaches attempt to handle uncertainty merely by including it in the description; whereas some approaches rely on monitoring of context but lack the ability to alter the system. Hence, the environment remains uncontrollable and true implementation of adaptation logic [26] cannot be affected thus leading to undesired adaptation results. This paper proposes a model that enables the SAS to continuously monitor the contextual variations and is equipped with the mechanism to alter itself at runtime according to the altering requirements.

The environment modelling approach that we have adopted bears a few resemblances with the model of artifacts proposed in [28] and [29]. Major dissimilarity between these two approaches is that in [29] an artifact denotes a physical or computational entity in the environment (e.g. a mouse, a sensor, a web-service etc) whereas in [28] an artifact connotes a conceptual or logical entity (e.g. a car, a house, a place etc). However, our approach is hybrid where an artifact can be physical or logical entity.

In order to effectively reason about the modelled artifacts stemming from dynamic environment, this paper expands the Continuously Adaptive Requirement Engineering (CARE) framework proposed in [3]. CARE is both goal and user oriented RE framework. This paper extends the *reasoning component* of CARE framework, which provides effective decision making to meet the end-user *preferences* based on hatched *goal models*, by effective use of *AI planning* techniques.

Rest of the paper is organized as follows. Section II presents a brief ***literature survey*** leading to the research work. It is followed by ***proposed architecture*** of reasoning component in section III. A ***case study*** is presented in section IV that demonstrates the proposed architecture along with its goal model, the planning domain description representation and its integration with Java based Self-adaptive application. A brief ***evaluation of proposed model*** through developed prototype application is presented in section V. Section VI ***concludes*** the paper.

II. Literature Survey

This section investigates various semi-plugged in voids involved in the realization of SASs with particular focus on their implementation at runtime and their ability to meet the requirements posed by system, context and user.

A. Requirement Engineering for SAS

In software development life cycle, requirement engineering is the ground activity upon which the working of whole system depends. Work of Fickas and Feather presented in [17] on requirements monitoring is a key contribution towards run-time requirements. Continuous requirements monitoring is necessary because of the deviation of system behavior at run-time from requirements model, which ultimately triggers the demand for system moderation. Such deviations need to be agreed with the changing conditions of environment so that the reasons can be identified and suitable adaptation is achieved. This is called monitoring and switching by Salifu in [32].

Berry, Cheng, and Zhang identified four-level model for engineering requirements posed by dynamic adaptive systems [9]. Level 1 includes traditional RE activities done by analyst. Level 2 includes run-time adaptive requirements. Level 3 includes requirements engineering done by analyst to determine the adaptation mechanism which actually enables the system to adapt. Level 4 includes adaptation requirements that are associated to specific adaptation solutions.

We also critically analyzed applicability of existing goal-oriented RE approaches related to our work.

TROPOS methodology for goal modeling is used by Penserini et al. [4] to model run-time changes in user needs and preferences. It involves BDI (Belief-Desire-Intention) agents, which may switch from one behavior to another depending upon environmental conditions and changes in user needs.

Liaskos et al. [31] uses requirements driven approach to address the problem of changing requirements by configuring software using goal-oriented approach. They model user's high level preferences as goal alternatives and then match them with the system's configurations. In this way, they support reasoning about goal models to achieve automatic system configurations. This approach i.e. goal based, seems very useful to depict the behavior of autonomic elements.

Zhu et al. [30] uses goal models to derive patterns of autonomic elements. To express different autonomic patterns, goal oriented RE approach and attribute based architectural style is used. In the field of goal oriented requirements engineering, Jureta [5] redefines the concepts of core requirements ontology. The core ontology is mainly based on goal oriented concepts and also on mentalistic notions which are called modalities.

KAOS [8] approach for requirements modeling focus on relating the functional and non-functional requirements to the enterprise goals because it assumes sufficient knowledge about the current organizational state. i* modeling approach [12] is used during early stages of RE when requirements are not clear enough and goals are not well defined. It focuses on understanding enterprise goals and how they affect the behaviors of actors.

The existing RE approaches discussed above anticipate run-time changes at design-time, so they are unable to accommodate new or changed requirements posed by the end-users at run-time. In this context [3, 6] proposes a novel framework that captures and analyzes user requirements at run-time. This framework is called Continuous Adaptive Requirement Engineering framework.

B. Uncertainty in SASs

The systems having the capability to adapt and alter the involved players or scenario inherently require continuous interaction with the environment either to sense or to change. The continuous altering nature of environment and system thus places additional burden on system, of dealing with the introduced uncertainty as argued in [23].

An elaborate description of SASs, and evaluation of various approaches and models leading to declaration of CARE as the most effective framework for reasoning of requirements at runtime in presence of uncertainty in [22] gives a venue for further capitalization on the concept.

C. Goal Modeling and HTNs

In the field of requirements engineering (RE), goal oriented modeling approaches have acquired substantial attention as they enable the system to traverse the unexplained gap between stakeholder requirements (goals) and the instruments (actions/tasks/plans) whose manipulation ensure attainment of these goals. The presently employed goal-oriented modeling frameworks [8, 12] consider goals as mandatory requirements that must be satisfied by any suitable solution. However, these frameworks are unable to satisfy the preference requirements presented by stakeholders. So a framework [10] is introduced allowing users to specify both the preference requirements and priorities, which are later utilized to select the specifications that meet the mandatory requirements while best satisfying the preference requirements as per accorded priorities.

In HTN (Hierarchical Task Network) [18] there is a provision to manage mandatory goals alongside preference goals based on evaluation of quantized criterion. This is achieved by the arrangement of tasks in a hierarchical order and their recursive mitigation into other sub tasks.

HTN domain is composed of operators and methods that outline feasible maneuvers to achieve goals whereas HTN problem specification comprises a list of predicates and higher level tasks that are required to be completed for the attainment of goal state. HTN based planner initially scans the domain and specification of problem and then recursively performs HTN tasks to attain high level goal state. Hence, the mandatory decomposition is translated into a set of HTN operators, methods, and tasks, while the set of priorities and preference goals are converted into PDDL 3.0 preference constraints and metrics, modelled into weighted evaluation function for reasoning [21].

D. AI Planners

Planning problems are represented in PDDL, STRIPS or HTNs which are processed by AI planners to generate solutions i.e. task sequences [10]. In our self-adaptive application we are using JSHOP2 planner [11] which is Java implementation of SHOP2 [16]. The core functionality of JSHOP2 is constructed on planning formalism called hierarchical task network planning [15, 11].

In most of the automated planning systems, planners have to strike out various possibilities prior to discovering a workable plan/solution; as they perform a trial-and error search of a large solution space. On the contrary, HTN planners conduct this same very search by firstly applying HTN methods to decompose tasks into subtasks thus creating a planning problem network [14] called hierarchical network of tasks, which in turn can be efficiently searched by planner to generate the requisite task sequence.

E. CARE Framework

CARE [7] is goal and user oriented requirement engineering framework that captures and analyzes user requirements at runtime. The main idea behind CARE is that the system itself plays the role of analyst i.e. it performs RE activities at runtime to satisfy end user preferences and adapt itself to meet changes in user goals and preferences. To achieve this adaptation, system automatically updates its knowledge about the operational environment and end user needs. The requirements captured by system at runtime are called service requests [5] in CARE which can be expressed in XML format. These service requests either consist of new requirements or refined set of requirements expressed as goals, quality constraints, preferences, priorities etc. These service requests are provided as an input to reasoning component. The *reasoner* performs three operations on incoming requirements data. First it evaluates the incoming data to determine which type of adaption is required [6], before activating a planner. After evaluating, the **Plan** activity activates the planner to generate task sequences and the selected plan is executed by Reasoner's **Adapt** activity [7].

III. Proposed Architecture

Fig.1 shows the revised architecture of CARE reasoning framework integrating goal modeling and automated planning techniques [12, 13]. The requirements are represented as goal model [10] that not only represents the functional requirements but also the user's preferences and non-functional requirements. In CARE, these goal trees are considered as a pool of adaptive requirements which are directly translated into planning action theory [7] by using HTN semantics. This action theory represents how user goals can be achieved in most suitable way under given conditions.

The architecture of CARE reasoning component is self-adaptive where different components/agents automatically interact with each other to support runtime reasoning of requirements. It consists of following four agents:

- User Agent
- Planning Agent
- Lookup Agent
- Update Agent

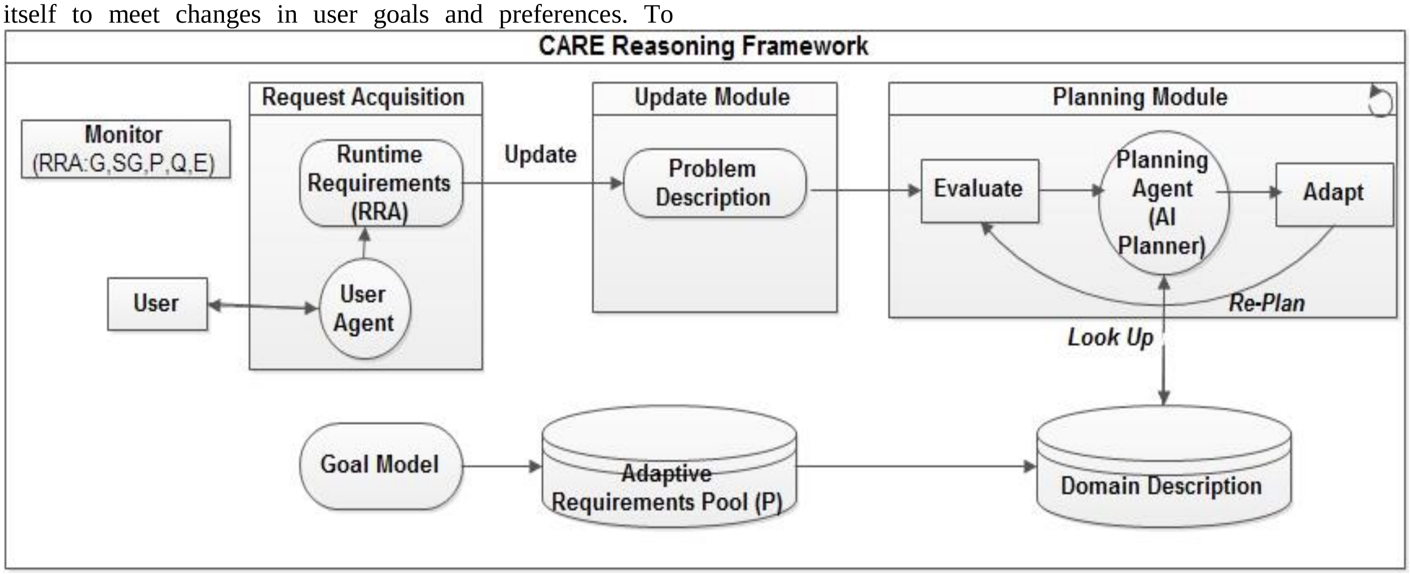

Fig. 1. Revised CARE Reasoning Framework.

The requirements which are called runtime requirements artifacts (RRA) are captured from the user through the ***user agent***. These RRAs consist of various requirement elements e.g. user hard and soft goals (G, SG), preferences (P), quality criteria (Q) and the data received from monitors which sense the changes in environmental conditions (E). These user RRAs are transformed into a complete problem description where the values of monitored variables formulate the initial conditions, user goals formulate the goal specification, and quantitative prioritization of preference goals covers the preferences specification [7]. The problem description is then input to the ***planning agent*** which first evaluates the information received from monitors and determines which type of adaptation is required. It then activates the AI Planner. As soon as the planner gets activated, the ***lookup agent*** starts searching (using A* Algorithm) for the best possible plan (sequence of tasks) in domain description that satisfies user goals defined in the given problem description. The resulting plan is displayed to the user again through the ***user agent***. Re-planning is required if some change is sensed in the environmental conditions or the prescribed plan is not executed as desired, thus warranting generation of a new plan having different initial conditions. The ***update agent*** is responsible for updating the problem description according to the new requirements.

IV. Case Study

We demonstrate the reasoning architecture presented in Fig.1 with the help of a prototype application aimed at acting as a Virtual Secretary to the user. The application covers basic daily life tasks of various professionals e.g. Lecturer, Surgeon and Businessman with the flexibility of incorporating his preferred selections and forced constraints met during plan execution. For instance, according to his preference of reaching his work place *cheaply* with no sense of *urgency* the application suggests him to move via train after evaluating the weighted preference against cost of executing the intermediate tasks in all possible cases as per defined *Goal Model* (see Fig.2). Figure demonstrates the identification of set of goals, set of AND/OR decomposed tasks along with their pre-requisite conditions to meet the goals, predefined methods encapsulating various tasks in order for meeting minor goals, system ground state conditions and in addition a pool of adaptive requirements.

The tasks are categorized as human and machine tasks, for example ***Pack Bag, Carry Wallet, Pack Laptop*** are the tasks performed by user but they are suggested as a reminder by application. Moreover, the application continuously senses the changes in its operational environment and re-plans according to these changes. For example, the system notifies ***Faulty ATM Machine*** and suggests user to ***Use Cheque*** to ***Draw Cash***. Preference goals are also supported for example ***reaching Urgent, Enjoying Route, Cost Effective*** etc. by assigning weighted metrics to each preference and evaluating the core heuristic function with the actions' accumulated costs.

A. HTN based Goal Model

The prototype application based on the above mentioned scenario in order to extend the desired features of adaptability and handling of runtime requirements entails a Goal Model that encompassed a few possible eventualities and recursive corrective actions. A segment of the Goal Model is presented in Fig.2. The given model is of transportation module which depicts the possibility of reaching the work place via three different modes i.e. ***By Walk, By Subway*** and ***By Car***. Selection of a mode is done upon weighing the resultant of selected user preference and environmental variables like ***IsRaining***, ***IsUrgent*** and ***HaveCash***. Each mode of transport is further disintegrated into sub tasks through AND/OR decomposition, rendering it an HTN Model.

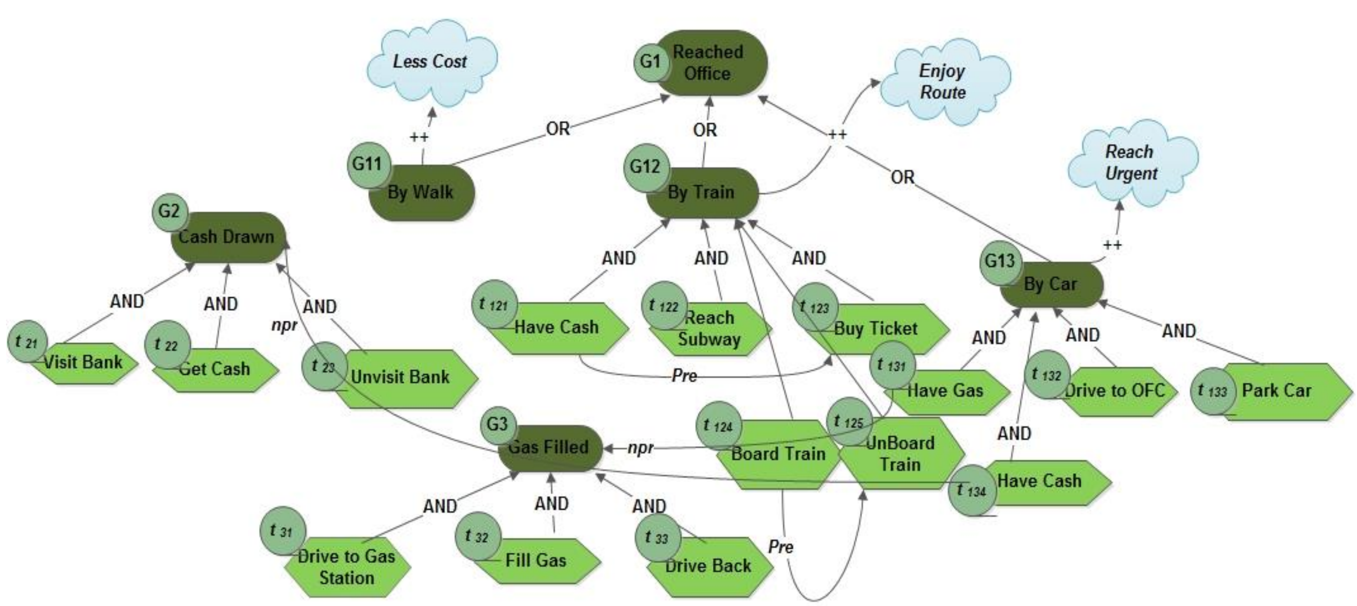

Fig. 2. Goal Model.

A plan [10] is devised for root goal satisfaction. Plan is a sequence of leaf level tasks that satisfy the root goal and is acquired by employing various sorts of tree searches e.g. A* Search, Depth First and Breadth First etc. For example following sequence is a plan when user wants to reach urgent and also does not have cash in wallet and gas in car : t_{21} ,t_{22} ,t_{23} ,t_{31} ,t_{32} ,t_{33} ,t_{132} ,t_{133}. Goal model in Fig.2 is a subset of i* Strategic Rationale Diagram [12, 19] but PRECEDENCE LINKS are additional to the core concept of i*. This concept of precedence links is used for goal modeling in [10, 20]

B. Mapping Goal Model to PDDL using HTN Semantics

This section explains how the above mentioned user goals, sub goals, preferences and tasks are translated to HTN and JSHOP2 compatible PDDL specifications to solve the planning problem and how action parameters and domain predicates help in richer representation of domain and its states.

1) Planning domain: Domain description is the knowledge base we prepare for the planner in order to enable it to solve the problems. The domain description, if done to the minutest details, catering for all the possible actions that might be involved in solving the possible problems enhances the planner's response in giving valid solutions. Domain is composed of various predicates, operators, axioms and methods.

JSHOP2 does not operate on standard PDDL, but a variant of it defined in LISP and dictated separately in its own grammar. A JSHOP2 compatible translation of prior mentioned scenario through its equivalent logical model is accomplished keeping in view the possible requirements that might be brought forth at runtime.

For the Transport Module of the application, the modes of transport are defined in a single category i.e. (***Via ?Mode)***, similarly all the locations as (***Present-At ?Loc)*** and so on. Reaching the work place via each selected mode is represented by means of methods, which are further subdivided into a set of ordered primitive tasks. Since the selection of mode of transportation is to be made upon evaluation of user based preferences, axiom of (**:- *Mode-Sel ?Mode***) is used to reason/evaluate and choose the preferred method of reaching the destination work place (Listing 1).

Listing 1: Planning Domain

Domain Axioms:

Is-Urgent(X) =>Mode-Sel(X)

Is-Enjoyable(X) => Mode-Sel(X)

Cost-eff(X) =>Mode-Sel(X)

Methods & Operators:

Operator: *Walk (Loc-from,Loc-to)*

Pre = *Is-At (Loc-from)*

Eff = *Is-At (Loc-to)*

Operator: *Drive (Mode-car,Loc-from,Loc-to)*

Pre = *Mode-Sel(Mode-car)∧ Car-At(Loc-from)∧ Have-Gas(Mode-Sel)*

Eff = *Car-At(Loc-to) ∧Is-At(Loc-to)*

Operator: *Ride (Mode-train, Loc-from, Loc-to)*

Pre **=** *Mode-Sel(Mode-train) ∧ Is-At(Loc-from) ∧ Have-ticket(Mode-train)*

Eff = *Is-At(Loc-to)*

Method: *Via-Car(Mode-Car, Loc-from, Loc-to)*

Pre **=** *Car-At(Loc-to) ∧ Is-At(Loc-from) ∧ Need-Gas(Mode-Car)*

Tasks **=** *{Unpark(Mode-Car), Drive(Mode-Car, Home, Gas-Station), Fill-Gas(Mode-Car, Cash), Pay(Cash, Gas-Station), Drive(Mode-Car, Gas-Station, Office), Park(Mode-Car)}*

2) Planning problem: Planning problem description is the precise description of planning problem at hand i.e. the initial or current state and the goal state or the tasks to be realized. Problem description also includes the identification of various object types i.e. actors in the planning problem along with problem specific knowledge.

Transport module of the application has identified three different modes for reaching work place, each attributed with certain preference depending upon the user specification. The corresponding problem for above mentioned domain includes the declaration of Objects i.e. *Transport (walk, car, and train), Locations (Home, Gas-Station, Bank, Work-Place, Subway-Station-A, Subway-Station-B)* and their user defined metric preferences for each. The system ground state is defined by manipulating the predicate variables already defined in corresponding Domain Description. The problem satisfier Goal i.e. *Reaching-Workplace* is expressed containing evaluating variables (Listing 2).

Listing 2: Planning Problem

Initial State:

{Is-Urgent(Car), Is-Enjoyable(Train), Is-Cost-eff(walk),

Need-Gas (Car), Have-Cash (Cash),….}

Goals:

{Reach-Work-Place(Pref-U, Pref-E,Pref-C)}

C. Development of CARE Reasoning Framework

Prototype application named INSTA PLANNER is developed to validate the proposed architecture of CARE reasoning framework. Application has been developed using Java Net Beans IDE, MySql and JSHOP2 AI-Planner which is Java version of SHOP2. INSTA PLANNER is AI-Planner based self-adaptive application that incorporates online Web Services and Virtual Sensors and generates plans to achieve daily goals of user based on data coming from virtual context sensors, web Services and user preferences.

In the Listing 3, implementation of transportation module of application is explained with the help of an algorithm.

Listing 3: Algorithm for Transportation Module

```
GeneratePlanForTransportation()
    PlanGenerationMode ← GetPlanGenerationModeFromUser();
    if  PlanGenerationMode = AUTO
        UserRRA ← RRAsFromConextSensors();
    else
        UserRRA ← UserPrefrencesForTransportation();
    ProblemSpecifications ←GenerateProblemSpecification(UserRRA);
    Invoke PlanningAgent (ProblemSpecification);
    Plan ← SearchPlan(DomainDescription);
    return Plan;
UserPreferncesForTransportation()
    ModeOfTransportation ← GetModeOfTransportation();
    AdditionalInfo ← GetAdditionalInfo(ModeOfTransportation);
    UserRRA ← GetUserRRA ( ModeOfTransportation, AdditonalInfo);
    return UserRRA;
RRAsFromConextSensors()
    WeatherCondition ← WeatherWebservice();
    FuelLevel ← FuelMointering(FuelContextSensor)
    CashStatus ← CashMointering(CashContextSensor)
    AtmWorkingStatus ← PullInfoFromBank(ATMService);
    UserRRA ← GetUserRRA(WeatherCondition, FuelLevel,
                          CashStatus, AtmWorkingStatus);
    return UserRRA;
```

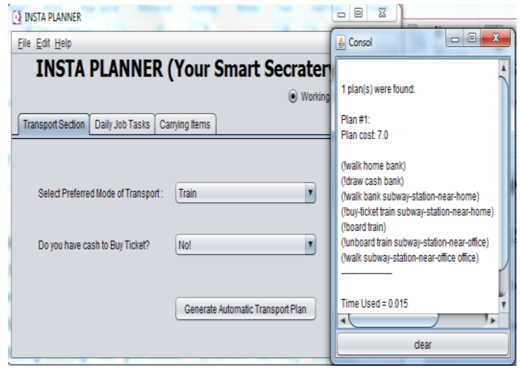

Fig. 3. INSTA Planner.

Fig. 4. INSTA Planner.

Application gets input from the user through UI and generates plans suggesting user the future course of action to be adopted based on his selected preferences. The screen shots presented in Fig.3 & Fig. 4 show the implementation of application with respect to above goal models.

V. Evaluation

The adopted technique incorporates Java front end UI integration of context sensors in order to impart ability to re-plan and adapt at runtime, seamless transition of domain and problem descriptions in PDDL to Java, and their parsing to Java based JSHOP2 for extraction of requisite plan. The complete cycle as depicted in Fig.1 when traversed should take considerably more time than existing non-adapting frameworks, but keeping in mind the performance aspect of proposed approach, the goal model is dis-integrated into sub-goal models; which are implemented with each having a considerably smaller domain, thus reducing the search space for each sub-problem and substantially enhancing its performance. Re-planning requires the multiple iterations of search space for reaching the most suitable plan. This is addressed by considering maximum possible scenarios (discussed below) that may pose user with unpredictable situations and incorporate them in goal model and generate search tree bifurcations. Fig.5 depicts the time consumption for tasks to achieve the final goal state shown in the goal model (Fig.2).

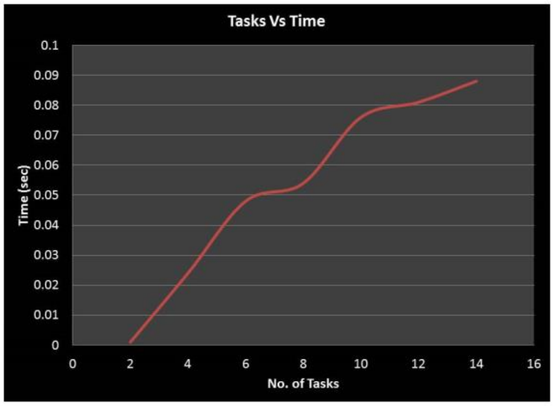

Fig. 5. Evaluation Trend.

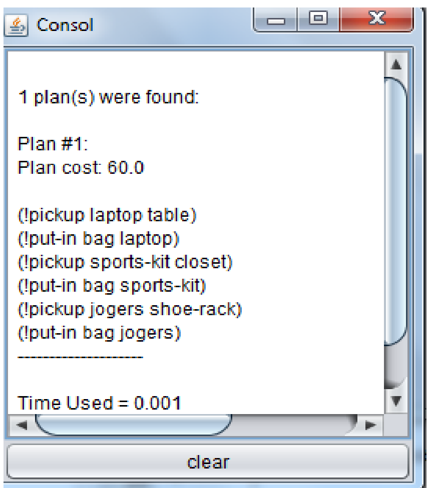

Fig. 6. Plan 1 generated by INSTA PLANNER without using CARE.

INSTA PLANNER is divided into two main modules. The first module covers the working day tasks of any professional. Second module is concerned with the weekend/holiday activities of individual. Following scenarios are developed to verify the proposed architecture.

Scenario 1: This scenario is taken from the working day module of application which does not involve CARE technology.

- In this simple case, planner application just reminds user to carry different things (based on some initial conditions) before leaving for job and also suggests some tasks that he has to perform before leaving home.
- This scenario does not involve input from the user and CARE context sensing mechanism.
- The generated plan is only dependent on the location of different things that he has to pack before leaving home.
- Fig. 6 shows the plan suggested by daily planner of application as a reminder of packing different things before leaving based on initial conditions and final goal state (without using CARE technology).

Scenario 2: This scenario is also taken from working day module but it involves CARE technology. In this case transportation is suggested to the user and by using the CARE methodology, system itself analyzes the user preferences (based on some initial conditions, environmental conditions and user/system context).

Case 1:

- John asks for application suggestion for his suitable mode of transportation to reach job place.
- The context sensing mechanism of application starts checking the weather forecast in his town through web service agent.
- If the weather is sensed as pleasant and no forecast of rain is found then train is suggested as the suitable mode of transportation for John.
- After suggesting train, application checks if John has cash. If no cash is found, then planner is again invoked for some new sequence of tasks (re-planning).
- Planner suggests John to walk to bank and draw cash, meanwhile application also checks whether the nearby ATM is functional or faulty.
- Plan generated for John is shown in Fig. 7.

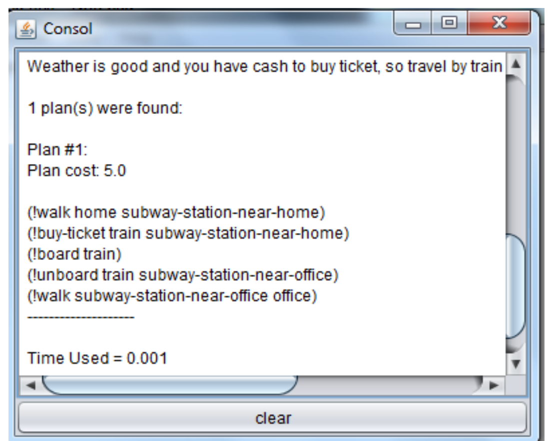

Fig.7. Plan 2 generated by INSTA PLANNER by using CARE.

Case 2:

- Any changes in weather conditions again activate the context sensing mechanism of application and it starts checking the weather conditions.
- If weather is sensed cloudy and forecast of rain is found then planner is again invoked and car is suggested as the suitable mode of transport for John.
- After suggesting car, application automatically checks if John has gas/petrol in car by fuel sensor. If no/less fuel is found, planner is again invoked which starts re-planning according to the changed situation.
- Finally, the plan shown in Fig. 8 is generated for John for his course of actions.

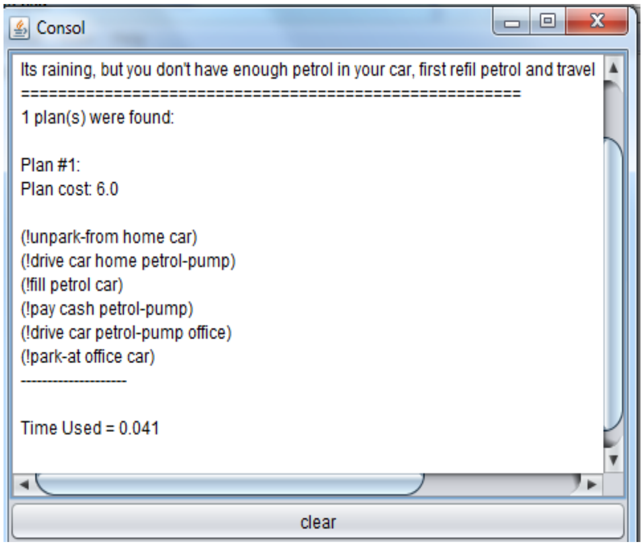

Fig.8. Plan 3 generated by INSTA PLANNER by using CARE.

Scenario 3: This scenario is taken from holiday module of INSTA PLANNER application in which system not only plans and re-plans for user but also performs some actions to facilitate him in achieving his goals (as suggested by planner).

- John wakes up early morning and starts INSTA PLANNER that plays the role of his smart secretary.
- INSTA PLANNER automatically checks the time of day. As it is early in the morning, it suggests different actions to John that he has to perform in morning like Prepare Breakfast, Clean snow, Clean house etc.
- In the afternoon, planner is invoked automatically and suggests to John that he has to perform some important tasks in afternoon like Do Laundry, Prepare Lunch etc. It also gives him some options for lunch, based on his preference that whether he wants some Healthy Food or Instant Food. Moreover, planner also suggests sequence of tasks to prepare selected lunch item.
- As soon as evening time is sensed INSTA PLANNER starts generating different excursion plans for John like Visit Relatives, Go for Movie or Go for Dinner.
- System also performs some actions to help John to achieve his final goal state, for example if he selects Go for Dinner, application starts searching for the nearby restaurants available in his city based on his preference of Chinese, Continental or Fast Food and also helps in reservation of table in his selected restaurant.
- If he selected Watch Movie as his goal then application gives him options of nearest cinema in his town and current movies in that cinema with their show timings. Application also gives him the option for online reservation of seats. Hundred percent goal state is achieved when application gives confirmation of seats reservation via email.

Table 1 presents a comparison of these three scenarios.

TABLE I. COMPARISON OF SCENARIOS

Sr. No	Planning	Context Sensing	Adaptation	Re-planning
Scenario 1	*Yes*	*No*	*No*	*No*
Scenario 2	*Yes*	*Yes*	*Yes*	*Yes*
Scenario 3	*Yes*	*Yes*	*Yes*	*Yes*

VI. CONCLUSION AND FUTURE WORK

This paper presents an adaptive reasoning mechanism for the run-time requirements in Self-Adaptive Systems (SAS). We have implemented a prototype application to validate our architecture by integrating AI planner with our application which addresses user preferences at runtime and generates plans according to these preferences. Moreover the said application also continuously senses changes in its operational environment and re-plans according to these changes. System also performs some actions to facilitate user to achieve his goals which is actually the execution of the selected plan.

Currently we are working on enabling the AI application to sense the changes in user intentions so that it can adapt and re-plan according to the changed mood and intentions of the user.

REFERENCES

[1] P. Sawyer, N. Bencomo, J. Whittle, E. Letier, and A. Finkelstein. *"Requirements-aware systems. A research agenda for RE for self-adaptive systems"*. In Proceedings of 18th International Requirements Engineering Conference, pages 95-103. IEEE, 2010.

[2] J. Anderson, R. de Lemos, S. Malek, D. Weyns. *"Modeling dimensions of self-adaptive software systems"*. In Betty H. C. Cheng et al., editors, LNCS Hot Topics on Software Engineering for Self-Adaptive Systems. Springer, 2009.

[3] N. A. Qureshi and A. Perini, *"Requirements engineering for adaptive service based applications"* in 18th IEEE Intl. Requirements Engineering Conf., pp. 108–111, sept. 2010.

[4] L. Penserini, A. Perini, A. Susi, and J. Mylopoulos. *"High variability design for software agents: Extending Tropos"*. TAAS, 2(4), 2007.

[5] I. Jureta, S. Faulkner, and P. Thiran, *"Dynamic requirements specification for adaptable and open service systems"* in 15th IEEE Intl. Requirements Engineering Conf. pp. 381– 382, 2007.

[6] N. A. Qureshi, A. Perini, N. A. Ernst, and J. Mylopoulos, *"Towards a continuous requirements engineering framework for self-adaptive systems"* in First Intl. Workshop on Requirements@ Run.Time, pp. 9 – 16, sept. 2010.

[7] N. A. Qureshi, S. Liaskos, and A. Perini. *"Reasoning about adaptive requirements for self-adaptive systems at runtime"*. In Proceedings of 2nd International Workshop on Requirements@run.time, page 16–22, August. 2011.

[8] Dardenne A, van Lamsweerde A, Fickas S *"Goal-directed requirements acquisition"*. Sci Comput Program 20(1–2):3–50. 1993.

[9] Berry, D., Cheng, B., and Zhang, J. *"The four levels of requirements engineering for and in dynamic adaptive systems"*, Proc. 11th International Workshop on Requirements Engineering Foundation for Software Quality (REFSQ'05), 2005.

[10] S. Liaskos, S. A. McIlraith, S. Sohrabi, and J. Mylopoulos. *"Representing and reasoning about preferences in requirements engineering"*. Requirements Engineering, 16:227–249, 2011. 10.1007/s00766-011-0129-9.

[11] Ilghami, O. *"Documentation for JSHOP2"*. Technical report CS-TR-4694, Department of Computer Science, University of Maryland. 2005.

[12] Yu ESK "*Towards modelling and reasoning support for early-phase requirements engineering"*. In: Proceedings of the 3rd IEEE international symposium on requirements engineering (RE'97). Washington, DC. 1997.

[13] Van Lamsweerde A *"Goal-oriented requirements engineering: a guided tour"*. In: Proceedings of the fifth IEEE international symposium on requirements engineering, RE '01. IEEE Computer Society, Washington, DC. 2001.

[14] Erol, K., Nau, D., & Hendler, J. *"HTN planning: Complexity and expressivity"*. In AAAI-94. 1994.

[15] Nau, D., T. C. Au, O. Ilghami, U. Kuter, D. Wu, F. Yaman, H. Munoz - Avila, and J. W. Murdock. *"Applications of SHOP and SHOP2"*. Intelligent Systems, 20(2):34–41. 2005.

[16] D. Nau, T.-C. Au, O. Ilghami, U. Kuter, W.Murdock, D. Wu, and F. Yaman *"SHOP2: An HTN Planning System"*. Journal of Artificial Intelligence Research. (2003).

[17] Fickas, S. and Feather, M. *"Requirements monitoring in dynamic environments"*, In Proc. of 2nd IEEE International Symposium on Requirements Engineering (RE'95), 1995.

[18] Nau D, Cao Y, Lotem A, noz Avila HM. *"SHOP: simple hierarchical ordered planner"*. In: Proceedings of the 16th International Joint Conference on Artificial Intelligence (IJCAI-99), pp 968–973. 1999.

[19] Wang X, Lesperance Y. *"Agent-oriented requirements engineering using ConGolog and i*"*. In: AOIS-2001 Bi-conference workshop at agents 2001 and CAiSE'01. 2001.

[20] Fuxman A, Liu L, Mylopoulos J, Pistore M, Roveri M, Traverso P *"Specifying and analyzing early requirements in Tropos"*. Requir Eng 9(2):132–150. 2004.

[21] Gerevini A, Long D *"Plan constraints and preferences in PDDL3. Technical report"*. Department of Electronics for Automation, University of Brescia. 2005.

[22] Krupitzer, Christian & Maximilian Roth, Felix & VanSyckel, Sebastian & Schiele, Gregor & Becker, Christian..*"A survey on engineering approaches for self-adaptive systems"*. Pervasive and Mobile Computing. 17. 10.1016/j.pmcj.2014.09.009. 2014.

[23] Zavala, Edith & Franch, Xavier & Marco, Jordi & Knauss, Alessia & Damian, Daniela. *"SACRE: Supporting contextual requirements' adaptation in modern self-adaptive systems in the presence of uncertainty at runtime"*. Expert Systems with Applications. 98. 10.1016/j.eswa.2018.01.009. 2018.

[24] Shang-Wen Cheng and David Garlan. *"Stitch: A language for architecture-based self-adaptation"*. Journal of Systems and Software 85, 12, 2860–2875. 2012.

[25] N. Esfahani and S. Malek. *"Uncertainty in self-adaptive software systems"*. In Software Engineering for Self-Adaptive Systems II, Rogério de Lemos, Holger Giese, Hausi A. Müller, and Mary Shaw (Eds.). Lecture Notes in Computer Science, Vol. 7475. Springer Berlin Heidelberg, 214–238. 2013.

[26] J. Andersson, L. Baresi, N. Bencomo, R. deLemos, A. Gorla, P. Inverardi, T. Vogel, *"Software engineering processes for self-adaptive systems"*, in: Software Engineering for Self- Adaptive Systems II , in : LNCS,vol.7475,pp.51–75, Springer,2013.

[27] Gabriel A. Moreno, Javier Cámara, David Garlan and Mark Klein.*"Uncertainty Reduction in Self Adaptive Systems"*. In Proc. of the 13th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS), Gothenburg, Sweden, 28-29 May 2018.

[28] M. A. Hashmi, A. E. Seghrouchni and M. U. Akram, *"A Planning Based Agent Programming Language Supporting Environment Modeling,"* 2015 IEEE / WIC / ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT), Singapore, pp. 76-83.doi:10.1109/WI-IAT.2015.22.

[29] A. Ricci, M. Piunti, and M. Viroli, *"Environment programming in multi-agent systems: an artifact-based perspective"* Autonomous Agents and Multi-Agent Systems, vol. 23, no. 2, pp. 158–192, 2011.

[30] Qin Zhu, Lin Lei, Holger M. Kienle, and Hausi A. Muller. *"Characterizing maintainability concerns in autonomic element design"*. IEEE International Conference on Software Maintenance (ICSM 2008), pages 197-206, 28-2008-Oct. 4 2008.

[31] S. Liaskos, A. Lapouchnian, Y. Wang, Y. Yu, and Steve M. Easterbrook. *"Configuring common personal software: a requirements driven approach"*. In 13th IEEE International Conference on Requirements Engineering, (RE05), Paris, France, pages 918, 2005.

[32] Salifu, M., Yu, Y., Nuseibeh, B. *"Specifying Monitoring and Switching Problems in Context"*. Proc. 15th IEEE International Conference of Requirements Engineering (RE07), pp. 211-220, 2007.

Design of Strategic Management System for Northern Border University using Unified Modeling Language

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***Abstract*—All organizations engage in the strategy management process either formally or informally. Strategy management is used to refer to the entire scope of strategic-decision making activity in an organization to ensure its continuous success. Hence, a strategic management system is viewed as an important tool for strategy management. Northern Border University started to initiate its first five-year strategy plan for the year 1435-1439H (2013-2018). However, the strategy plan is managed without having a strategic management system. Thus, the university has a fundamental disconnect between the formulation of the strategy and the execution of that strategy into useful action. There is no integration between the strategy formulation and implementation which are treated separately instead of as an integrated system. Therefore, it is difficult for the university to translate their strategies into operational objectives, processes and activities. This paper presents the design process of the strategic management system for the university, whose main purpose is to manage the university's strategy plan throughout its life cycle. The design of the strategic management system is based on object-oriented approach using Unified Modeling Language. The system will be used to formulate, implement, monitor and control appropriate university's strategy plan to support on strategic-decision making for the university. The solution will thus contribute to the improvement of the university's performance.**

Keywords—Strategy management; strategic management system; object-oriented analysis and design; unified modeling language

I. Introduction

Strategy management is used to refer to the entire scope of strategic-decision making activity in an organization. Basically, strategy management includes strategy planning and strategy implementation. Strategy planning consists of formulating strategies from which overall plans for implementing the strategy are developed. Strategy implementation consists of ensuring that the chosen strategy is being implemented properly and that it is producing the desired results. Strategies are the means by which long-term objectives will be achieved. The role of strategy is to identify the general approaches that the organization utilized to achieve its organizational objectives. Therefore, the choice of strategy is so central to the study and understanding of strategy management. The success of an organization is generally dependent upon the strategy management and organizational abilities of the management.

For the last two decades, strategy planning has been broadly regarded as the most important component of the strategic management process in the sense that it is more important than strategy implementation [15, 25]. The deficiency in strategy implementation creates a deadly spiral of two mutually enforcing factors poor planning and poor implementation [7]. Despite the perceived significance of strategy implementation, inadequate research has been carried out on the strategy management process component. In [22], Noble pointed out that the deep and cohesive bodies of strategy implementation research still do not exist. In fact, the strategy implementation is viewed as the most difficult component of the strategic management process [2, 10, 14, 26, 27], and the bulk of good strategy planning has failed in its implementation [1, 3, 4, 14, 17, 21]. Ramaseshan, Ishak, and Rabbanee [25] stated that there exist a small number of guidelines for successful strategy implementation. Research highlighted that the capability to implement strategy is viewed as very important in order to achieve superior business performance [11, 16, 21]. Parnell [24] also argues that strategy formulation only produces superior performance for an organization when it is successfully implemented. Today, strategy planning and implementation have become the key requirements for business performance [12, 20].

Strategy plan is one of the main factors that contribute to the success of any institution with different goals. It brings together the potentials of human, financial and moral resources to achieve objectives and aspirations with the support of a well-defined plan that can be accomplished according to a specific timeframe. Strategy plan is a means to achieve strategy aims and objectives, associated with the progress and development of the institution. It also represents a road map that serves as a guide to achieve the desired objective, in particular through proper planning, guidance and control in addition to considerations of long standing problems and issues.

Northern Border University (NBU) was established in 2007. The university started to initiate its first strategy plan for the year 1435-1439H (2013-2018). The strategy plan is created to be in line with the aims of the university, notably achieving a comprehensive development in both academic and institutional levels in order to improve its outcomes and services to meet both national and international quality assurance standards. The plan also aims to serve the university comprehensive development plans as well as meets the demands of the community and labor market. The strategy plan of the university has basic information about the Northern Borders province such as its characteristics and popular activities. It also provides information indicating the current status of the university and the Northern Borders region, notably general information about the university location and its branches in relation to other universities in the kingdom. The plan further involves an analysis of the indices of the field studies associated with the university, which in turn includes distinctive executive programs that are at the same time compatible with all tracks and programs of the university education future plan. All are considered to be within the framework of the five-year plan and the comprehensive development policies of the kingdom.

However, the strategy plan is managed without having a proper application system. Thus, the university has a fundamental disconnect between the formulation of the strategy and the execution of that strategy into useful action. There is no integration between the strategy formulation and implementation which are treated separately instead of as an integrated system. Therefore, it is difficult for the university to translate their strategies into operational objectives, processes and activities. An important reason for this is that the university is lacking an effective strategic management system with which they can realize their strategic and operational objectives. An effective strategic management system is absent that allows management to manage strategy planning and execution in an integrated way. Thus, a strategic management system is found vital to manage and support NBU's strategy management to formulate, implement, monitor and control appropriate university's strategy plan to support on strategic-decision making for the university.

The purpose of the paper is to present the analysis and design of a proposed strategic management application system for NBU based on object-oriented approach using Unified Modeling Language (UML). The paper is organized as follows. Section I provides the introduction of the paper. Section II discusses on the strategy management system. Section III describes the methodology used to analyze and design the strategic management application system. Section IV explains on the design of the strategic management application system for NBU, and finally Section V provides the conclusion of the paper.

II. Strategic Management System

Strategic management system (SMS) is a management system that aligns and integrates the strategy planning and strategy implementation to monitor and control the strategy plan and its execution for organizations to achieve its strategy plan and objectives. SMS consists of a planning, implementation and control cycle. Planning refers to strategic planning which is the formulation of the strategy, the translation of the strategy into strategic objectives. Implementation refers to the development of an implementation plan with operational objectives, processes, and activities. Control refers to strategy execution which is the monitoring of the progress of the execution and the adjustment of the strategy or its execution.

Various researches on strategic management system have been conducted for the last four decades [5, 6, 8, 9, 13, 18, 19, 23, 28]. Ghymn and Kings [13] presented a systems design methodology which implements five basic criteria for the design of a strategic planning Management Information System. The methodology uses discriminant analyses of the perceived importance to managers of various categories of strategic information to delineate the most significant information requirements of various managerial groups.

Cotterill [9] conducted a study to facilitate research on strategic management information systems (SMIS) by elaborating and using example from food system to illustrate the design and impact of SMIS.

Bungay and Goold [6] described the development and implementation of a strategic control process for the long-term planning by building long-term thinking into day-to-day operations where the strategic controls are considered as non-financial performance measures which are of particular value in a diversified company in controlling, monitoring and guiding the development of operating units.

Lanser [19] proposed a design of a strategic information system to assist executive and management staff make effective customer-focused program and service decisions, and implemented a customer driven organizational model called the "System of Education" to improve the effectiveness and competitiveness of communication and decision-making at Lakeshore Technical College.

Karim [18] explores the extent to which management information systems (MIS) implemented to make successful decisions at two selected financial organizations. He adapted the quantitative research design to examine whether the selected financial institutions vary as to the use of MIS on decision making for strategic and tactical planning purposes. The results showed that MIS was primarily used to enhance strategic planning in both financial institutions. The regression analysis revealed that Tactical planning is found to have no effect on Decision Making, while Strategic planning has a clear effect on the Decision Making Effectiveness in both organizations.

Wanjohi [28] conducted a study to identify and examine the relationship between the Strategic Control System (SCS) application and financial performance of Bamburi Cement Limited, Kenya using the Pearson's product moment correlation coefficient and regression analysis.

Bento and White [5] proposes and tests a model to explain the impact on business results of Strategic Performance Measurement Systems (SPMS). The SPMS information technology (IT) variables, which include both technical characteristics and technical outcomes, affect business results. IT and system variables are affected by organizational variables related to information processing capabilities and requirements. System effectiveness and Internet usage were the two IT variables found to have the most impact on business results. The system design had a significant role in determining all IT variables that had an impact on business results.

O'Sullivan [23] presented a case study on the implementing a Strategic Planning and Management System at a Private Higher Education Institution in the Middle East based on balanced score card. The balance score card is used as a means for measuring performance and driving strategy. The results of the study reveal that frequency change in strategy is a major factor leading to the difficulty to implement balance score card, which in turn suggests that local culture and local organization culture needs to be considered when implementing new planning and measurement system.

In term of strategic management application system, most of the organizations prefer to build their own strategic management application system in-house, to out-source the software development to companies or consultants, or to procure commercially available off-the-shelf strategy management software products such as StrategyBlocks, Cascade, ClearPoint, OnStrategy, Shibumi, FIBRES, CAMMsStrategy, i-nexus, Khorus, SAP Strategy Management, StrategyExecution or Envisio.

III. Unified Modeling Language

There are two approaches for the development of information system which are structured and object oriented approaches. The structured approach uses three techniques basically logical data modeling, data flow modeling and entity behavior modeling. Meanwhile, the object-oriented (OO) approach uses UML. In this research work, the latter approach using UML is used. UML is a language which provides a comprehensive notation for communicating the requirements, architecture, implementation, deployment, and states of a system. It is a modeling language that is used to provide a standard way to visualize the design of a system. The objective of UML is to provide a common vocabulary of object oriented terms and diagramming techniques that are rich enough to model any systems development project from analysis through implementation.

Although there are various diagramming techniques used in UML, but the most common diagrams used for software engineering are use case diagram, class diagram, and sequence diagram. Use Case diagram is used to gather the requirements of a system including internal and external influences by capture the dynamic behavior of a system. It gathers the functionalities as use case, identifying the actors, and set the relationships among the use cases and actors. Class diagram is a static structural diagram which represents the static view of a system. It is used to describe the attributes and operations of a class and also the constraints imposed on the system. The class diagram shows a collection of classes, interfaces, associations, collaborations, and constraints. Sequence diagram is used to model the interactions between objects in a single use case. It shows the interaction among a set of objects participated in a collaboration, and the messages that they send to each other in a chronological order.

OO system analysis and design focuses on three aspects which are object, analysis and design. Concepts in OO system include classes, objects, methods, encapsulation, inheritance, and dynamic binding. The concept of object contains both data and process which represents the real world. With the concept of encapsulation, an object hides its data and allows only the object's method to access its data which makes the system more flexible and easier to maintain if an object's data structure is changed. OO analysis (OOA) looks at the functional of the system resulted in conceptual model while the OO design (OOD) looks at how the system works covers both functional and non-functional. OOA resulted in functional model, structural model and behavioral models. At the analysis phase, functional model describes business processes and how the system interacts with its environment. The structural or conceptual modeling presents the logical organization of data independent from how the data are stored, created, or manipulated so that analysts can focus on the business without being distracted by technical details. The behavioral model describes what internal logic of the processes is without specifying how the processes are to be implemented. At the design phase, the structural model is updated with how the data will be stored in databases and files. In other words, OOA analysis and OOD uses the same diagramming techniques, the difference is that in design phase the system environment details are added and refined problem domain information to increase the likelihood of successfully delivering a system.

IV. Design of Strategic Management System

The proposed SMS comprises of three (3) modules which are Strategy Planning module, Strategy Implementation module, and Strategy Monitoring module. The functionalities of the proposed SMS is depicted in Fig. 1. The purpose of Strategy Planning module is to manage the strategy plan information which includes vision, mission, objectives and strategies. The functions of the Strategy Planning module are to manage strategy plan which includes maintaining strategy plan, objective, and strategy, and to generate reports. The purpose of Strategy Implementation module is to manage the strategy implementation plan, project plan, and project performance. The functions of Strategy Implementation Plan module are to manage strategy implementation plan which includes maintaining implementation plan, program, and project, to manage project plan which includes maintaining project plan, project information, and project performance, and to generate reports. The purpose of the Strategy Monitoring module is to monitor and evaluate the strategy planning and strategy implementation by providing learning and feed forward for strategy planning, and corrective actions and feedback for strategy implementation. The functions of Strategy Monitoring module are to monitor strategy planning and implementation which includes monitoring strategy plan, strategy implementation plan, project plan, and program and project performance, to evaluate performance of program and project, and to generate reports.

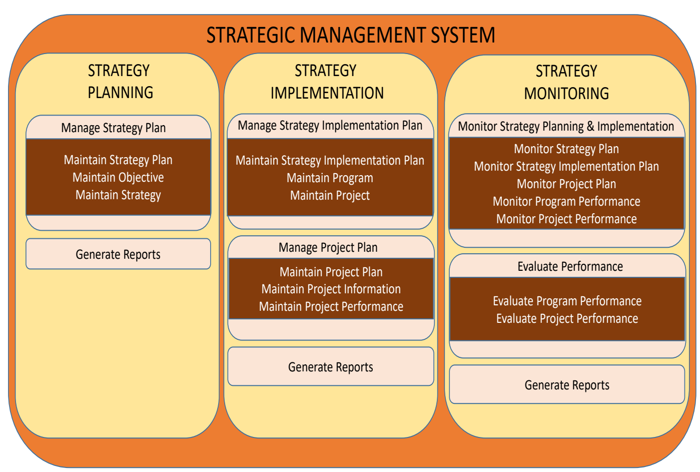

Fig. 1. Functionalities of Strategic Management System

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The design of the SMS is based on object-oriented approach using UML. Basically, three (3) main UML diagrams will be used to design the SMS which are: (i) Use Case diagram, (ii) Class diagram, and (iii) Sequence diagram. Use Case diagram is used to define the main actors and the functionalities of the SMS. Class diagram is used to define the objects or classes with their attributes, operations and relationships for SMS. Sequence diagram is used to define the processes for each of the functionalities of SMS.

A. Use Case Model

A Use Case model is developed using UML Use Case diagram to define the main actors that will interact with the system and the functionalities each actor would access in the SMS. Four main actors were identified which are the Strategy Planner, the Program Manager, the Project Manager, and the University's Council, where each one should be able to use a wide range of functionalities after authentication and validation. The Use case diagram with the system's main high level functionalities is depicted in Fig. 2.

The Strategy Planner is responsible for formulating the strategy plan. He will initiate the strategy plan, specifically to define the mission, values, and vision, and to formulate the objectives of the organization and the paths to take in order to reach the goals, and generate, evaluate and craft the strategy to achieve the objectives.

The Program Manager and Project Manager are responsible for the implementation of the strategy plan. The Program Manager will be responsible to formulate and manage the implementation plan. He will initiate the implementation plan, specifically to identify the programs and proper projects, and to appoint the Project Manager for the projects.

The Project Manager is responsible to execute and manage the project, after approval by the system, specifically to create the application system, to plan the activities, to identify the project team members, to allocate the necessary resources for each activity, and to update all financial aspects of a project.

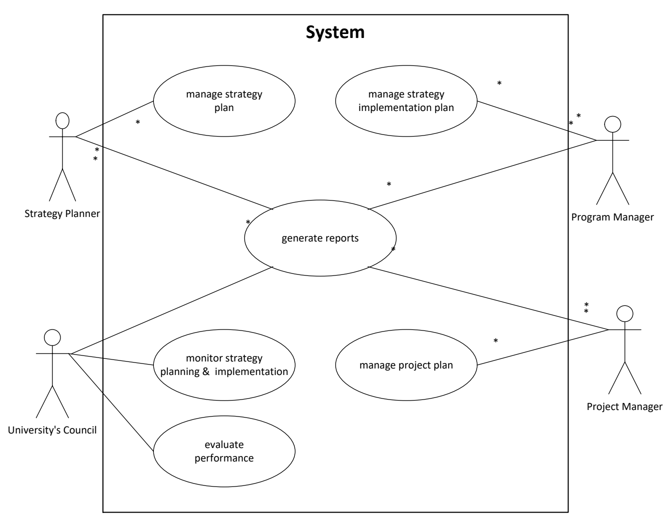

Fig. 2. Use Case Model for Strategic Management System

The University's Council is responsible for Strategy Monitoring and Control by measuring and evaluating performance, monitoring new developments, and initiating corrective adjustment for each project.

The SMS comprises of three (3) modules which are Strategy Planning module, Strategy Implementation module, and Strategy Monitoring module. The use cases for Strategy Planning Module are:

- Manage strategy plan:

a) To maintain strategy plan information: to create and update the vision, mission, value and strategy information.

b) To maintain objective: to create and update long and short term objectives

c) To maintain strategy: to create and update strategy

- Generate reports: to produce strategy progress reports

The use cases for Strategy Implementation Module are:

- Manage Strategy Implementation Plan:

a) To maintain strategy implementation plan: to create and update strategy implementation plan information

b) To maintain program: to create and update program

c) To maintain project: to create and update project

- Manage Project Plan:

a) To maintain project plan: to create and update by project plan information

b) To maintain project information: to create and update project information

c) To maintain project performance: to create and update project performance measures, project progress and project performance

- Generate reports: to produce strategy implementation progress reports and project progress reports

The use cases for Strategy Monitoring Module are:

- Monitor Strategy Planning and Implementation

a) To monitor strategy plan

b) To monitor strategy implementation plan

c) To monitor project plan

d) To monitor program performance

e) To monitor project performance

- Evaluate Performance: to evaluate program and project performance
- Generate reports: to produce program and project review reports

B. Class Model

A class model is developed using UML class diagram in order to address the identified requirements and to visually describe the problem domain in terms of types of objects (classes) related to each other in different ways for the SMS for NBU. The class diagram presents the abstract information model related to the life cycle of the strategy management. As shown in Figure 3, the class model for the SMS for NBU consists of fourteen (14) classes which are Plan class, Mission class, Objective class, Strategy class, Program class, Project class, Bodies class, Activity class, Resource class, Measure class, Outcome class, Progress class, Asset class, and Performance Indicator class.

The Plan class is used to represent the plan of a strategy plan. It has attributes: Plan ID, start date, end date and vision. The operations of Plan Class are to create Plan, update Plan, get Plan, and display Plan. The Plan class has composition relationship with Mission class and Objective class. The Mission class is used to represent the mission for a strategy plan. It has attributes: Mission ID, Plan ID, and mission. The operations of Mission Class are to create Mission, update Mission, and get Mission. The Objective class is used to represent the goals or objectives of a strategy plan. It has attributes: Objective ID, Plan ID and objective. The operations of Goal Class are to create Objective, update Objective, and get Objective. The Objective class has composition relationship with Strategy class. The Strategy class is used to represent the strategy of a strategy plan. It has attributes: Strategy ID, Objective ID and strategy. The operations of Strategy Class are to create Strategy, update Strategy, and get Strategy. The Strategy class has composition relationship with the Program class. The Program class is used to represent the programs of a strategy plan. It has attributes: Program ID, Strategy ID and program. The operations of Program Class are to create Program, update Program, get Program, and display Program. The Program class has composite relationship with Project class.

The Project class is used to represent the project of a strategy plan. It has attributes: Project ID, Program ID, start date, end date, budget, description, status, and remarks. The operations of Project Class are to create Project, update Project, get Project, and display Project. The Project class has composition relationship with Progress class, Bodies class, Measure class, Outcome class, Activity class, Resource class, Asset class, and Performance Indicator class. The Progress class is used to represent the progress of a particular project. It has attributes: Project Progress ID, Project ID, date, status and remarks. The operations of Progress Class are to create Progress, update Progress, get Progress, and display Progress. The Bodies class is used to represent the bodies of a particular project. It has attributes: Body ID, Program ID, body, type and description. The operations of Bodies Class are to create Bodies, update Bodies, and get Bodies. The Measure class is used to represent the performance measure of a particular project. It has attributes: Measure ID, Project ID, measure and type. The operations of Measure Class are to create Measure, update Measure, get Measure, and display Measure. The Outcome class is used to represent the outcome of a particular project. It has attributes: Outcome ID, Project ID and description. The operations of Outcome Class are to create Outcome, update Outcome, and get Outcome. The Activity class is used to represent the activities of a particular project. It has attributes: Activity ID, Project ID, start date, end date, description, status and comment. The operations of Activity Class are to create Activity, update Activity, and get Activity. The Resource class is used to represent the resources of a particular project. It has attributes: Resource ID, Project ID, name, type, role and responsibilities. The operations of Resource Class are to create Resource, update Resource, and get Resource. The Asset class is used to represent the assets of a particular project. It has attributes: Asset ID, Project ID, cost, purchase date, location, status, and remarks. The operations of Asset Class are to create Asset, update Asset, and get Asset. The Performance Indicator class is used to represent the performance indicators of a particular project. It has attributes: Performance Indicator ID, Project ID, description, date, status, and achievement. The operations of Performance Indicator Class are to create Performance Indicator, update Performance Indicator, get Performance Indicator, and display Performance Indicator.

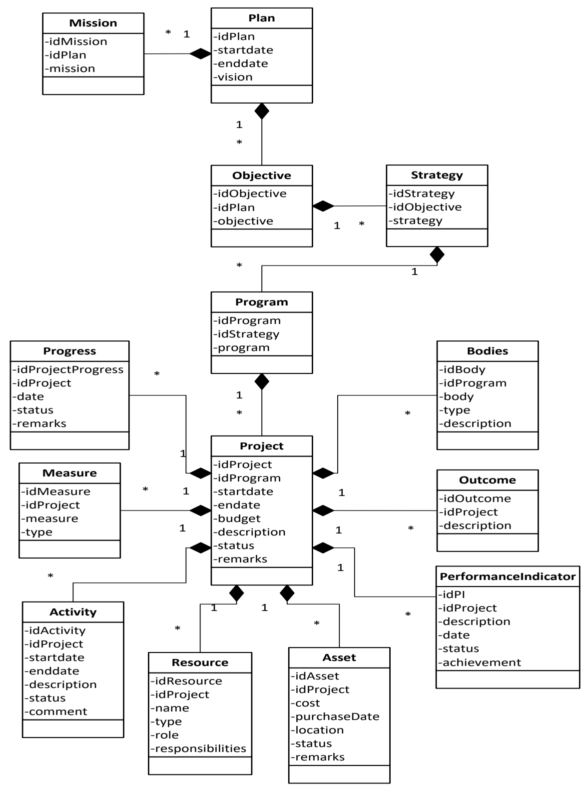

Fig. 3. Class Model for Strategic Management System

A relational database management system (RDBMS) will be used to store data of the SMS. The RDBMS supports referential integrity, providing input check of the uniqueness of primary key. The objects in our design will be converted so they can be stored in a table.

C. Sequence Diagram

The sequence diagrams for the SMS consists of manage strategy plan, manage strategy implementation plan, manage project plan, monitor strategy planning and implementation, evaluate performance, and generate reports.

- Manage Strategy Plan

The Strategy Planner is responsible to manage the strategy plan. The processes to manage strategy plan are to maintain (create or update) the strategy plan, to maintain (add or update) objective, and to maintain (add or update) strategy. As depicted in Fig. 4, the manage strategy plan sequence diagram consists of maintain strategy plan, maintain objective, and maintain strategy.

The steps to maintain (create or update) the strategy plan are as follows:

1) Select Create/Update Strategy Plan
2) Display data entry form to create/update strategy plan
3) Fill in the strategy plan information using the data entry form
4) Check and validate the information entered
5) If the data entry is incomplete, return a message “Incomplete data entry form” , else proceed to store the data into the database
6) Return data successful stored/updated into the database
7) Display data entry/Update successful
8) Retrieve updated Strategy plan information
9) Return strategy plan information
10) Display strategy plan information

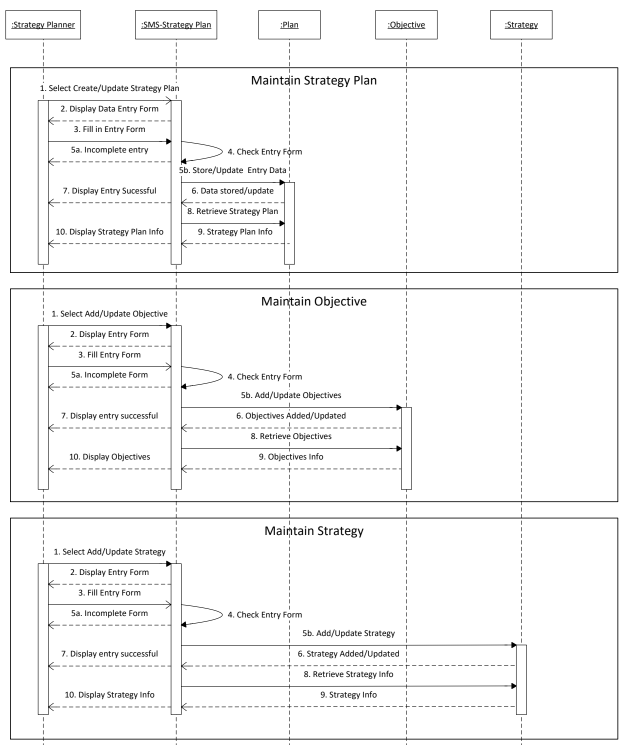

Fig. 4. Sequence diagram to manage strategy plan

The steps to maintain (add or update) the objective are as follows:

1) Select add/update objective of the Strategy Plan
2) Display data entry form to add/update objectives
3) Fill in the objectives of the strategy plan using the data entry form
4) Check and validate the information entered
5) If the data entry is incomplete, return a message “Incomplete data entry form”, else proceed to store/update the data into the database
6) Return data successful stored/update into the database
7) Display data entry/update successful
8) Retrieve updated objective’s information
9) Return objective’s information
10) Display objectives of the strategy plan

The steps to maintain (add or update) the strategy are as follows:

1) Select add/update strategy of the Strategy Plan
2) Display data entry form to add/update strategy
3) Fill in the strategy of the strategy plan using the data entry form
4) Check and validate the information entered
5) If the data entry is incomplete, return a message “Incomplete data entry form”, else proceed to store/update the data into the database
6) Return data successful stored/updated into the database
7) Display data entry/update successful
8) Retrieve updated strategy’s information
9) Return strategy’s information
10) Display strategies of the strategy plan

- Manage Strategy Implementation Plan

The program manager will be responsible to manage the strategy implementation plan to execute the strategy plan. The processes to manage the strategy implementation plan are: to maintain (create or update) strategy implementation plan, to maintain (add or update) program, and to maintain (add or update) project. As depicted in Fig. 5, the manage strategy implementation plan sequence diagram consists of maintain strategy implementation plan, maintain program and maintain project.

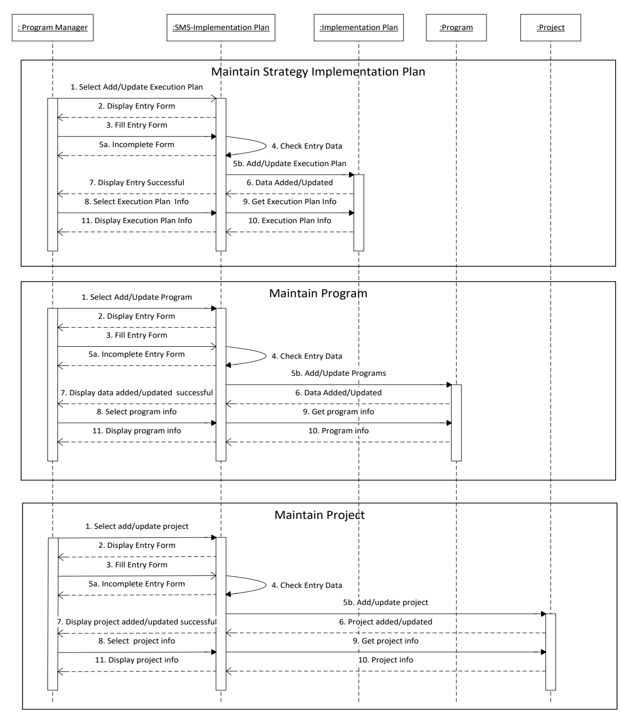

Fig. 5. Sequence diagram to manage strategy implementation plan

The steps to maintain (create or update) the strategy implementation plan are as follows:

1) Select create or update the strategy implementation plan

2) Display data entry form to create or update the strategy implementation plan

3) Fill in the strategy implementation plan information using the data entry form

4) Check and validate the information entered

5) If the data entry is incomplete, return a message “Incomplete data entry form” , else proceed to store the data into the database

6) Return data successful stored or update into the database

7) Display data entry or update successful

8) Retrieve strategy implementation plan information

9) Return strategy implementation plan information

10) Display strategy implementation plan information

The steps to maintain (add or update) program of the strategy implementation plan are as follows:

1) Select add or update program of the strategy implementation plan

2) Display data entry form to add/update programs

3) Fill in the program of the strategy implementation plan using the data entry form

4) Check and validate the information entered

5) If the data entry is incomplete, return a message “Incomplete data entry form” , else proceed to store or update the data into the database

6) Return data successful stored or updated into the database

7) Display data entry successful

8) Retrieve the program information

9) Return program information

10) Display programs of the strategy implementation plan

The steps to maintain (add or update) project of the strategy implementation plan are as follows:

1) Select add/update project of the strategy implementation plan

2) Display data entry form to add/update project

3) Fill in the project of the strategy implementation plan using the data entry form

4) Check and validate the information entered

5) If the data entry is incomplete, return a message “Incomplete data entry form” , else proceed to store the data into the database

6) Return data successful stored into the database

7) Display data entry successful

8) Retrieve the project information

9) Return project information

10) Display projects of the strategy implementation plan

- Manage Project Plan

The project manager is responsible to manage the project plan. The processes of manage project plan are to maintain (create or update) project plan, maintain (add or update) project information, and maintain (add and update) project performance. The sequence diagram to manage project plan is depicted in Fig. 6.

The steps to maintain (create or update) the project plan are as the follows:

1) Select create or update the project plan

2) Display data entry form to create or update the project plan

3) Fill in the project plan information using the data entry form. The project plan information includes the activities, resources, and timeline.

4) Check and validate the information entered

5) If the data entry is incomplete, return a message “Incomplete data entry form” , else proceed to store or update the data into the database

6) Return data successful stored or updated into the database

7) Display data entry successful

8) Select display project plan

9) Retrieve project plan information

10) Return project plan information

11) Display project plan information

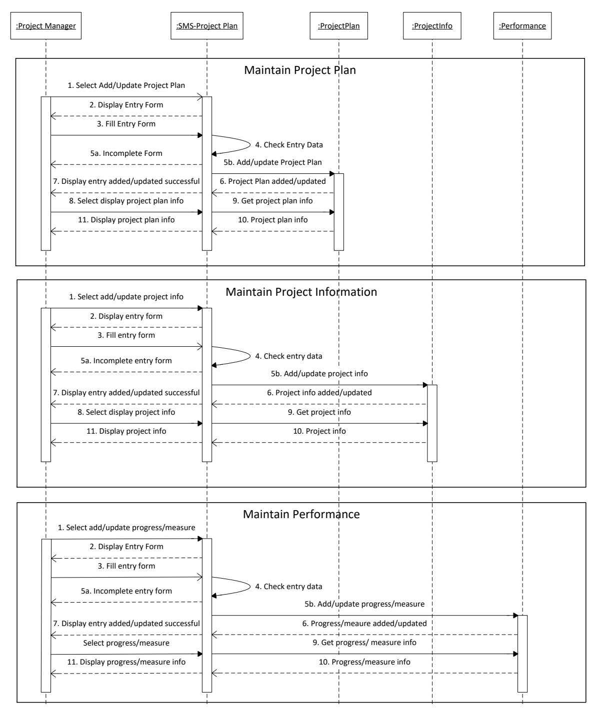

Fig. 6. Sequence diagram to manage project plan

The steps to maintain (add or update) project information are as follows:

1) Select add or update project information of the Project Plan

2) Display data entry form to add or update project information

3) Fill in the project information of the project plan using the data entry form

4) Check and validate the information entered

5) If the data entry is incomplete, return a message “Incomplete data entry form” , else proceed to store or update the data into the database

6) Return data successful stored or updated into the database

7) Display data entry successful

8) Retrieve the project information

9) Return project information

10) Display project information of the project plan

The steps to maintain (add or update) project performance:

1) Select add or update project progress or project performance measure of the project plan

2) Display data entry form to add or update project progress or project performance measure

3) Fill in the project progress or project performance measure of the project plan using the data entry form

4) Check and validate the information entered

5) If the data entry is incomplete, return a message “Incomplete data entry form” , else proceed to store or update the data into the database

6) Return data successful stored or updated into the database

7) Display data entry added or updated successful

8) Select display project progress or performance measure

9) Retrieve the project progress or performance measure information

10) Return project progress or performance measure information

11) Display project progress or project performance measure of the project plan

- Monitor Strategy Planning and Implementation

The University’s Council will be responsible to monitor and control the progress of the strategy planning and implementation. The processes of the monitor strategy planning and implementation are to monitor strategy plan, to monitor strategy implementation plan, to monitor project plan, and to monitor projects performance. The sequence diagram to monitor plan strategy planning and implementation is depicted in Fig. 7.

The steps to monitor strategy plan are as follows:

1) Display strategy plan’s list

2) Select strategy plan

3) Get strategy plan information

4) Return strategy plan information

5) Display strategy plan information for the selected strategy plan

The steps to monitor strategy implementation plan are as follows:

1) Display strategy implementation plan’s list

2) Select strategy implementation plan

3) Get strategy implementation plan information

4) Return strategy implementation plan information

5) Display selected strategy implementation plan information

The steps to monitor project plan are as the following:

1) Display project’s list

2) Select project

3) Get project plan information

4) Return project plan information

5) Display selected project plan information

The steps to monitor program performance are as follows:

1) Display program’s list

2) Select program

3) Get program’s projects

4) Return program’s project

5) Get program projects’ performance information

6) Return program projects’ performance information

7) Compute program’s performance

8) Display selected program performance information

The steps to monitor project performance are as follows:

1) Display project’s list

2) Select project

3) Get project performance information

4) Return project performance information

5) Compute project performance

6) Display selected project performance information

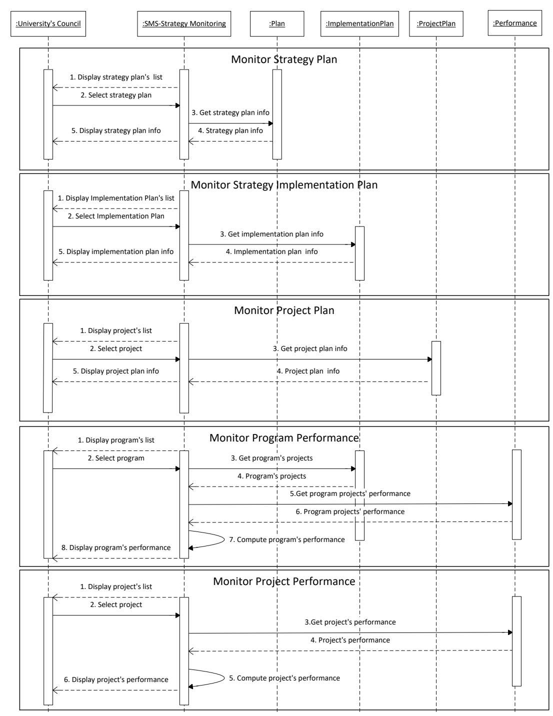

Fig. 7. Sequence diagram for monitoring strategy planning and implementation

- Evaluate Performance

The University’s Council will need to evaluate program and project performance. The sequence diagram to evaluate performance is depicted in Fig. 8. The steps to evaluate program performance are as follows:

1) Display program's list
2) Select program
3) Get program's projects
4) Return program's projects
5) Get the projects' performance measures for the selected program
6) Return projects' performance measures
7) Display projects' performance measures
8) Evaluate the program's performance
9) Store the program's performance evaluation
10) Return program's performance evaluation stored
11) Display selected program's performance evaluation stored successful

The steps to evaluate project performance are as follows:

1) Display project's list
2) Select project
3) Get the project's performance measures for the selected project
4) Return project's performance measure
5) Display project's performance measure
6) Evaluate the project's performance
7) Store the project's performance evaluation
8) Return project's performance evaluation added
9) Display selected project's performance evaluation added successful

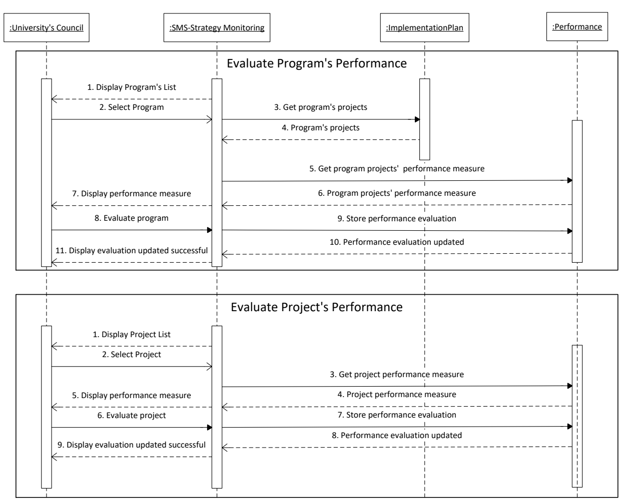

Fig. 8. Sequence diagram to evaluate performance

- Generate Reports

The Strategy Planner, Program Manager, Project Manager and University's Council will need to generate reports. The sequence diagram to generate reports is depicted in Fig. 9.

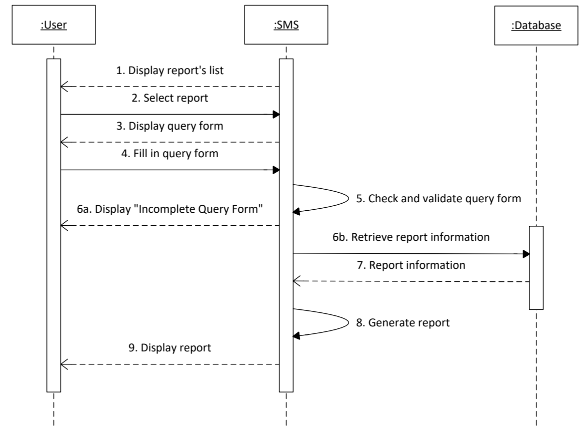

Fig. 9. Sequence diagram to generate reports

The steps to generate reports are as follows:

1) Display list of reports
2) Select report
3) Display query form to generate report
4) Fill in the required information using the query form
5) Check and validate the information entered
6) If the data entry is incomplete, return a message "Incomplete query form" , else proceed to retrieve the required information to generate the report from the database
7) Return the required information to generate report
8) Generate report
9) Display selected report information

V. Conclusions

The paper has presented an analysis and design for a proposed Strategic Management System for NBU. The design is based on UML which provides the Use Case diagram, Class diagram, and Sequence diagram of the proposed SMS. The Use Case diagram is used to define the main actors and the functionalities of the SMS. Class diagram is used to define the objects or classes with their attributes and operations for SMS. Sequence diagram is used to define the processes for each of the functionalities of SMS. The design of the SMS will be used as the basis to develop the SMS which will then be used to formulate, implement, monitor and control appropriate university's strategy plan to support on strategic-decision making for the university.

Acknowledgment

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References

[1] F. Alamsjah, "Key success factors in implementing strategy: middle-level management' perspective", Procedia Social and Behavioral Sciences, 24, 2011, pp.1444-1450

[2] M. K. Allio, "A short, practical guide to implementing strategy", Journal of Business Strategy, 26, 2005, pp.12-21

[3] S. M. Al-Ghamdi, “Obstacles to successful implementation of strategic decisions: The British experience”, European Business Review, 98(6), 1998, pp.322-327

[4] M. Beer and R. A. Eisenstat, “The six silent killers of strategy implementation”, Sloan Management Review, 29, 2000

[5] Al Bento, R. Bento, and L. F. White, , ”Strategic Performance Management Systems: Impact on Business Results“, The Journal of Computer Information Systems, Stillwater Vol. 54, Iss. 3, pp. 25-33, Spring 2014

[6] S. Bungay, and M. Goold,“Creating a strategic control system”, Long Range Planning, Vol. 24, Issue 3, pp. 32-39, , June 1991

[7] T. Cater and D. Pucko, “Factors of effective strategy implementation: empirical evidence from Slovenian business practice”, Journal for East European Management Studies, 3, 2010

[8] Don Collier, "Strategic Planning Systems Design and Operation", Journal of Business Strategy, Vol. 1 Issue: 2, 1980, pp.76-77

[9] R. W. Cotterill, “The Design and Impact of Strategic Management Information Systems”, American journal of agricultural economics, Vol. 70 Issue: 2, 1988, pp. 475

[10] F. R. David, “Strategic Management Concept and Cases (eight editions)”, Prentice Hall: New Jersey, 2010

[11] B. Faure and L. Rouleau, “The strategic competence of accountants and middle management in budget making”, Accounting, Organizations and Society, 36, 2011, pp.167-182

[12] P. C.Flood, T. Dromgole, S. J. Carroll, and L. Gorman (Eds), “Managing Strategy implementation: an Organizational Behavior Perspective”. Oxford: Blackwell, 2000

[13] Kyung II Ghymn and R. William, “Design of a strategic planning management information system“, Omega, Volume 4, Issue 5

[14] L.G.Hrebiniak, “Obstacles to effective strategy implementation”, Organizational Dynamics, 35(1), 2016, pp.12-31

[15] C. Jooste and B. Fourie, “The role of strategic leadership in effective strategy implementation: Perceptions of South African strategic leaders”, Southern African Business Review, 13(3), 2009.

[16] R. S. Kaplan and D.P. Norton “The strategy-focused organization: how balanced scorecard companies thrive in the new business environment”, MA: Harvard Business School Press, 2001

[17] R. S. Kaplan and D.P. Norton, “Strategy maps: turning tangible assets into tangible results”, MA: Harvard Business School Press, 2004

[18] Akram Jalal Karim, “The Significant of Management Information Systems for Enhancing Strategic and Tactical Planning”, Journal of Information Systems and Technology Management : JISTEM; Sao Paulo Vol. 8, Iss. 2, 2011, pp. 459-470.

[19] Michael Allan Lanser, “Design of a strategic information system to assist executive and management staff at Lakeshore Technical College make customer-focused program and service decisions”, Nova Southeastern University, ProQuest Dissertations Publishing, 1998. 9911543.

[20] Y. Li, S. Guohui, and M.J. Eppler, “Making strategy works: a literature review on the factors influencing strategy implementation”, ICA Working Paper 2, 2008

[21] M.C.Mankins and Steele, “Turning great strategy into great performance”, Harvard Business Review, 83(7/8), 2005, pp. 64-72

[22] C.H. Noble and M.P. Mokwa, “Implementing marketing strategies: Developing and testing a managemential theory”, Journal of Marketing, 63(October), 1999, pp.57-73.

[23] Kathy O'Sullivan, “Implementing a Strategic Planning and Management System at a Private Higher Education Institution in the Middle East: A Balanced Score Card or a Bewildering State of Confusion? “, Journal of Management education (Champaign, Ill.), Vol. 16 Issue 3, 2016, pp. 1-11

[24] J. A. Parnell, “Strategic capabilities, competitive strategy, and performance among retailer in Argentina,Peru and the United States”, Management Decision, 49(1), 2011, pp.130-155

[25] B. Ramaseshan, A. Ishak, and F.K. Rabbanee, “The Role of marketing management’ commitment and involvement in marketing strategy implementation”, Journal of Strategic Marketing, 2013.

[26] A.A.Thompson and A.J. Strickland, “Strategic Management: Concepts and Cases (thirteenth edition)”, New York: McGraw-Hill, 2003

[27] A. Thompson, M. Peteraf, J. Gamble, and Strickland III., “Crafting & Executing Strategy: The Quest for Competitive Advantage: Concept and Concepts and Cases”, Eighteenth (18th) Edition, 2011

[28] N. E.Wanjohi,“Strategic control systems in strategy implementation and financial performance of Bamburi Cement Limited, Kenya”, School of Business, University of Nairobi, Kenya, MBA Thesis, Sept 2013

The Design and Evaluation of a User-Centric Information Security Risk Assessment and Response Framework

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***Abstract*—The risk of sensitive information disclosure and modification through the use of online services has increased considerably and may result in significant damage. As the management and assessment of such risks is a well-known discipline for organizations, it is a challenge for users from the general public. Users have difficulties in using, understanding and reacting to security-related threats. Moreover, users only try to protect themselves from risks salient to them. Motivated by the lack of risk assessment solutions and limited impact of awareness programs tailored for users of the general public, this paper aims to develop a structured approach to help in protecting users from threats and vulnerabilities and, thus, reducing the overall information security risks. By focusing on the user and that different users react differently to the same stimuli, the authors developed a user-centric risk assessment and response framework that assesses and communicates risk on both user and system level in an individualized, timely and continuous way. Three risk assessment models were proposed that depend on user-centric and behavior-related factors when calculating risk. This framework was evaluated using a scenario-based simulation of a number of users and results analyzed. The analysis demonstrated the effectiveness and feasibility of the proposed approach. Encouragingly, this analysis provided an indication that risk can be assessed differently for the same behavior based upon a number of user-centric and behavioral-related factors resulting in an individualized granular risk score/level. This granular risk assessment, provided a more insightful evaluation of both risk and response. The analysis of results was also useful in demonstrating how risk is not the same for all users and how the proposed model is effective in adapting to differences between users offering a novel approach to assessing information security risks.**

Keywords—Risk; analysis; security behavior; BFI; correlation

I. Introduction

Given the rapid growth of technology and the wide range of 24/7 e-services provided by different devices such as laptops, mobile phones and wearable technology, the number of users is growing every day. With more than 3.8 billion Internet users in 2017 compared to 2.9 billion in 2014 [1] and one or more Internet-connected devices used in most homes [2], users massively use Information Technology (IT) systems to carry out their everyday activities. With this increased popularity of the Internet and its services, comes an increase in information security threats such as malware, social engineering and hacking that some users are arguably not aware of [3]. Despite the common use of various security methods such as intrusion detection systems and antivirus software to protect IT systems from different attacks, the security threat landscape is rapidly evolving and attackers are increasing their efforts in developing sophisticated and advanced malware and hacking methods. This is evident as the number of created malware grew from 274 million in 2014 to almost 670 million with a rate of 1.8 million threats introduced everyday in 2017 [4] and an email malware rate of 1 in 131in 2016 compared to 1 in 244 and 1 in 220 in 2014 and 2015 respectively [5]. Attackers have a higher chance of infecting a user's computing device with malware if it has at least one popular installed application that is vulnerable and out-of-date [6].

Managing and assessing information security risks in organizations is a well understood and accepted approach used widely by enterprise organizations to provide a safe environment to carry out their business using the most cost-efficient and effective means [7][8]. Many Information Security Risk Management (ISRM) methodologies were issued by National and International organizations such as The National Institute of Standards and Technologies (NIST) Special Publication 800-series [9] and The International Standards Organization ISO/IEC 27000 [10] or as research projects [11]. Unfortunately, these traditional risk assessment methodologies and tools are designed for organizations and not members of the public. Considering the increased number of Internet users, the variety of used devices where each device has its own security requirements and the continuously evolving threat landscape, the need for assessing information security risks is not limited to organizations only. Actually, this need is expanded to a wider population to include users from the general public or simply, users.

Unfortunately, little evidence is found demonstrating that users are knowledgeable of information security threats and protection, and actually practicing it [12][13][14]. Indeed, it has been found that they are less willing to perform money-related and sensitive data tasks on some of these devices such as smartphones due to issues related to security, privacy, trust and usability [15][16]. Furthermore, users have difficulties in using, understanding and reacting to security-related threats [16][17][18]. Although educating users about information security threats is a well-established and accepted approach in organizations where resources are, arguably, allocated to achieve the organizations' goals, it is a challenge in the case of users [19]. Almost 90% of reported security incidents resulted from exploits against software vulnerabilities whereas human-error was considered as one of the top threats to information security and almost 1.8 million pieces of malware introduced every day [4][14][20][21]. Hence, the need for a usable security tool that calculates and assesses risk on both system and user level in a timely manner is essential. Additionally, the limited impact of awareness programs suggests the need for a structured approach tailored for users to help in protecting them from threats and vulnerabilities and, thus, reducing the overall information security risks [22]. By focusing on the user, increased security awareness through understanding risk is expected to improve security behavior and lead to reduced security risks [23]. Therefore, the aim of this paper is to develop a comprehensive and continuous framework that assesses and communicates information security risks for users of the public in both an individualized and timely manner.

The remainder of this paper is structured as follows: Section 2 reviews related work on assessing and communicating risks to users. Section 3 presents a user-centric framework to information security risk assessment and response. This proposed framework is evaluated in Section 4 followed by a discussion in Section 5. Finally, conclusions and future work are highlighted in Section 6.

II. Related Work

There are a large number of proposed ISRM methodologies and guidelines around the world that differ in their approach, level of detail, usage complexity and applicability to different-sized organizations [24][25]. There are various Information security standards by organizations such as ISO/IEC 27005:2011[10] and NIST SP 800-30 [9]. Additionally, various Risk Assessment (RA) methodologies were developed by professional organizations to meet specific requirements and therefore incorporate different steps, objectives, level of application and structure. Examples of such methodologies are CRAMM [26], CORAS [27], OCTAVE [28], Magerit [29] and Mehari [30] that have been fully or partially adopted by organizations to identify, analyze and treat their information security risks. Furthermore, these methodologies have different analysis approaches towards risk whether threat-oriented, Asset/Impact oriented or Vulnerability-oriented. They are quantitative, qualitative or semi-quantitative in nature where there is no exact risk value because of the uncertainty and subjectivity in defining likelihood and severity of consequences [31]. To reveal major risks and to get a general indication of the risk level, a quantitative estimation could be used first followed by a qualitative analysis. Among those techniques used to calculate information system's risks is Vulnerability Management that is represented by The Security Content Automation Protocol SCAP [32][33]. To communicate security information, SCAP provides several standard specifications, including Open Vulnerability and Assessment Language (OVAL) [34] ,Common Vulnerabilities and Exposure (CVE) [35] and Common Platform Enumeration (CPE) [36]. The Common Vulnerability Scoring System (CVSS) is a scoring system that provides a standard specification that measures the severity of software vulnerabilities [37] and a widely used cybersecurity model [21][32][33][38][39][40]. The National Vulnerability Database (NVD) is a valuable source of security knowledge and publically available online [41]. Each NVD record contains CVE-id, vulnerable software list, vulnerability published date and time, CVSS base metrics and scores and so on. NVD uses CVSS to measure vulnerabilities severity which provides evidence of the wide and accepted adoption of CVSS by the security community [42]. Moreover, it is often used as a metric for risk [38].

There are many proposed RA methodologies in the literature that are built on those methodologies where each method has its own objectives, steps, structure and level of application. Based on the OCTAVE methodology and in the context of educational organizations for example , authors of [43] proposed risk assessment framework for a university computing environment and [44] performed an ISRM study in order to educate management and users of a computer information system in secondary schools on how to protect their information assets and reduce risks to their information systems through risk management. In the former, the risk assessment proposed needed skilled individuals that understand statistics, probabilities and information technology. Whereas in the latter, given the conservative environment of schools, the observed behavior of the selected sample members maybe inaccurate with the presence of the researcher and may not reflect their actual normal behavior. Authors of [45] proposed a RA methodology for smartphones that has an ISO/IEC 27005:2011 compatible theoretical basis. The proposed risk assessment method provides "fined-grained" valuation. User input for (sub) asset impact is based on two-dimensional data taxonomy. This user involvement, leads to a 'personalized' risk assessment, where other smartphone oriented methods use mainly expert opinion. However, user input details vary according to user skill which may affect the quality of results. Also, users assessing the asset impact of application is complex where the number of applications maybe numerous and the user is assumed to know the applications significance. A risk management methodology was proposed in [46] based on NIST SP 800-30 risk management guide. However, the proposed methodology does not determine the exact interaction between controls and resource dependency nor evaluate the way in which threats spread through the system. Authors of [47] used a qualitative approach, structured interviews, to identify potential threats then a quantitative approach, survival analysis, to analyze the risks. A particular strength of this framework is that it considers the time dimension in identifying threats that vary over time. However, there could be difficulties with applying this framework in practice since it has not been tested yet, so no indications of its effectiveness and reliability.

To the author's knowledge, despite the increased attention on Information Security Risk Assessment (ISRA) in enterprise organizations, there is a lack of tools and methods in the literature that are tailored for the general public. Nevertheless, some websites do provide information and advice on how to protect yourself in the cyber world such as Getsafeonline.org and staysafeonline.org. However, they could be used as awareness tools that provide advice and guidance to users to make informed decisions regarding their security behavior. These tools do not provide the expected level of RA that users are exposed to. Many of these users are not aware of these risks and/or do not have the necessary knowledge to use the available websites to analyze these risks and overcome security risks problem. A web-based risk analysis tool for home users based on the ISO 17799 standard was proposed by [48]. The performance of the tool was evaluated with means of the interface design described as user-friendly, easy to use and accessible. No evaluation regarding the way the tool assessed the different security levels and the provided support, maybe because it has not been tested by users with a certain level of security background. Authors of [49] proposed a Mobile Device Risk Assessment (MDRA) risk assessment method based on a 6-step risk calculation scheme. Although the proposed approach is clear and easy to use by different stakeholders, the whole risk calculation process was challenging for novice users. The framework proposed by [23] was a continuous and automated risk assessment framework for Android mobile applications called RiskMon. The main idea of RiskMon is to use machine-learned ranking to assess risks. Although, users specifying security requirements for security tools is a challenging task, the framework design allows for user's expected behavior rather than developers practices. However, it is subjective since it relies on user's input of relevancy levels for permission groups (user's expectations) and their understanding of these permission groups for each trusted application. This may result in biased choices. Although this risk model provides a continuous and automated RA, it is considered as low (machine)-level and limited to Android Mobile Apps. Moreover, users rely on a diversity of platforms and operating systems which makes it challenging as it increases the knowledge burden on users in maintain security in these different devices [50].

Not limited to assessing information security risks, many studies in the literature advice that, aside from the "one-size-fits-all" approach, a targeted risk communication approach should be adopted where messages contain the required technical and non-technical context, engaging and above all examined to ensure if they have an impact on users or not [3][33][51][52][53][54]. Actually, when these messages are not understood by the user, this may result in negative consequences that experts blame users for. The authors of [54] suggest that to effectively communicate security risks, users should be categorized according to their IT knowledge. Whereas a user education approach in risk communication that improves user's self-confidence and stresses on his responsibility of his own protection is recommended by authors of [19][55][56]. However, [51] argue that due to the timing and used terminology, information security threats warnings are easily and often ignored. Hence, human security behavior is critical to ensure an efficient information security environment that does not depend on technology only. It is suggested that risk communication should go one step further to changing user's security behavior [57][58][59]. However, several studies have confirmed that users do not react in the same manner to the same security threat nor the same user make the same decision in all situations. Moreover, they stressed that due to different factors filtered through user's personality, intended behavior may differ from actual behavior [52][60][61][62]. Many studies have highlighted the influence of user's characteristics such as personality traits [63][64], demographics and mother tongue [65][66][67] and IT proficiency [68][69] on user's security behaviors. In addition to these characteristics, [70] identified other factors related to the used security software such as risk communication, usefulness and delivery methods. Further to that, [70] demonstrated the impact of user's characteristics from a holistic point of view on user's risk-taking behavior and why some users are at risk more than others. Their findings suggest that given a certain user behavior and different users, risk is not the same for all of them. This work will be based on their findings. These studies demonstrate the importance of a targeted user-focused and not fact-focused risk communication that transforms the user from being ill-informed to a security minded user.

III. User-Centric Information Security and Response (UCRAR) Framework

Many types of data are stored on user's devices such as photos, contacts, documents and messages that are accessed by different applications. The terms software and application will be used interchangeably to refer to any piece of software installed on user's device. However, the unauthorized modification or disclosure of this data may result in a number of undesirable consequences on the CIA and privacy of such data. As each application has different impacts on data, which suggests that the risk level is changing within the application. Actually, different processes within an application have different impacts, thus, generating different risk levels for the same application. As a result, no single risk level could be assigned to an application. Not limited to that, but the way in which the user uses these processes may escalate or de-escalate these risk levels. For example, in a financial-based mobile application there are a range of functionalities and services that have different levels of risk associated to them. Services where there is no sharing of user's data as in reading products, services and offers have no impact on data, thus, from an application based behavioral perspective, risk is kept to a minimum. However, this risk level could escalate when combined with other non-app related behaviors such as connecting to a public Wi-Fi network or using a non-updated version of the application. Another example is the process of adding a photo in the Facebook application. On the one hand, adding a photo of The London Eye, for example, has a *low* risk level whether the user's account is public or private. Whereas adding the same photo with location data may have an impact on user's privacy, thus, escalating the risk level to *medium* in a private account and possibly *high* in a public account. On the other hand, for the same process of adding a photo but of the user's child, for example, in a private account has a *medium* risk level that escalates to *high* when the account is public. These examples serve to demonstrate that the risk level of user's behaviors within an application process could change when combined with other behaviors within the same application. Thus, arguably, assessing the risk level based on user's behavior may result in a more realistic and accurate assessment. To the best of the researcher's knowledge, assessing and calculating risk for each user behavior of each process within an application and combining it with other behaviors simultaneously, and using user-centric factors, i.e. user's characteristics, such as demographics, online activity, personality traits and IT expertise as additional risk factors to create a user-centric risk profile has not been investigated yet. Moreover, combining this user-centric risk assessment with system-level risk assessment and smoothing it with community-based risk data to create an individualized risk profile is a novel approach to security risk assessment. Therefore, the necessity for a timely user-centric risk assessment and communication approach that adapts to user's characteristics and can be used across services and technologies becomes more apparent.

The proposed User-centric Risk Assessment and Response (UCRAR) framework is composed of two main components as in Fig.1. Namely, the Risk Assessment component and the Risk Communication component. As part of the novelty of this proposed framework, user-centric factors are utilized, among other factors, in both components. To accomplish this, the following processes are established:

A. Risk Assessment Component

In this component, user's behaviors are monitored, security risks are assessed on both system and user level and an individualized risk profile is created accordingly. The functionality of this component is accomplished by the following processes:

1) Good (expected) behavior: Among the requirements to assess each behavior independently is a clear description of a good user behavior. Thus, this knowledge base will include a set of descriptors that suggest what a good behavior should be in a certain aspect and used as a reference for user security compliance. In password hygiene, for instance, a list of good behaviors related to password's behaviors will be provided such as the same password is not used for multiple accounts, frequency of changing passwords and not allowing web browsers/software/apps to store passwords.

2) Software detector: There are millions of software products in the world. For example, the number of applications in Google Play store increased from 400,000 in 2011 to 3.5 million in 2017 with an average of almost 6000 applications released on a daily basis [2]. However this fails to consider the existence of organizational applications. Many applications could be installed on the user's device. To individually risk assess each installed application would be a time consuming task. Thus, the aim of this process is to detect all installed software on user's device and assign a quantitative score to each detected software/app. This score could be determined in many ways such as level of application/service usage, how important the software is to the user or in terms of its CIA impact. To support the user and reduce the burden on him in individually scoring each installed application, especially if the number of installed applications is numerous, that may result in him dumping/rejecting the Risk Assessment tool, the categorization approach proposed by [49] is adopted. In this approach, applications are classified into groups according to their type/usage. Then, each group is assigned a certain score. This score assignment will be part of system startup/configuration where each group will be assigned a quantitative value by the user according to its importance from his perspective. A scale of 0-**very low** to 4-**very high** will be used. Then, each detected installed application will be mapped into its corresponding group and assigned a score accordingly resulting in an *app-score*. For example, applications are classified but not limited to as in Table 1. As a vulnerable/out-of-date application and those originating from an illegitimate source are possible sources of risk, application version, *app-ver*, and the name of the source/market from which the application was installed from, *install-name*, are detected.

Thus, the output of this process is the following tuple:

Sw-info = (*sw-id*, *app-score*, *install-name*)

where: *sw-id* is the software/app ID in Common Product Enumeration CPE.

3) User behavior monitor: With this continuously evolving threat landscape and the wide range of computing platforms and services accessed, the need to continuously monitor and assess user's behaviors in a timely manner becomes more apparent. Certain users' characteristics, i.e user-centric factors, were related to changing/influencing his risk level, as discussed in Section 2, suggesting that user's-centric factors need to be gathered. Hence, the functionality of this process is a two-fold:

- To continuously monitor user's behavior independently of the used software and compare it against good/expected behavior. This is done in near real-time and is event triggered. For example, if a user is to close a browser/app, he will be reminded to sign off from online service before closing.
- To collect user info in terms of the specified user's characteristics, i.e. user-centric factors. This data collection is done in three ways, namely, explicitly, implicitly and by taking a specialized test as in Table 2. For IT proficiency and service usage level user-centric factors, the worst-case scenario is adopted. Thus, the categories whom found to be in highest risk as of [70] are assumed as default values, i.e. non-IT professional and high service usage. As the user is using the system, his behavior is monitored and these categories will be adjusted according to a predefined set of metrics.

Thus, the output of this process is the following tuple:

B-info = (B-expected, B-actual, U-info),

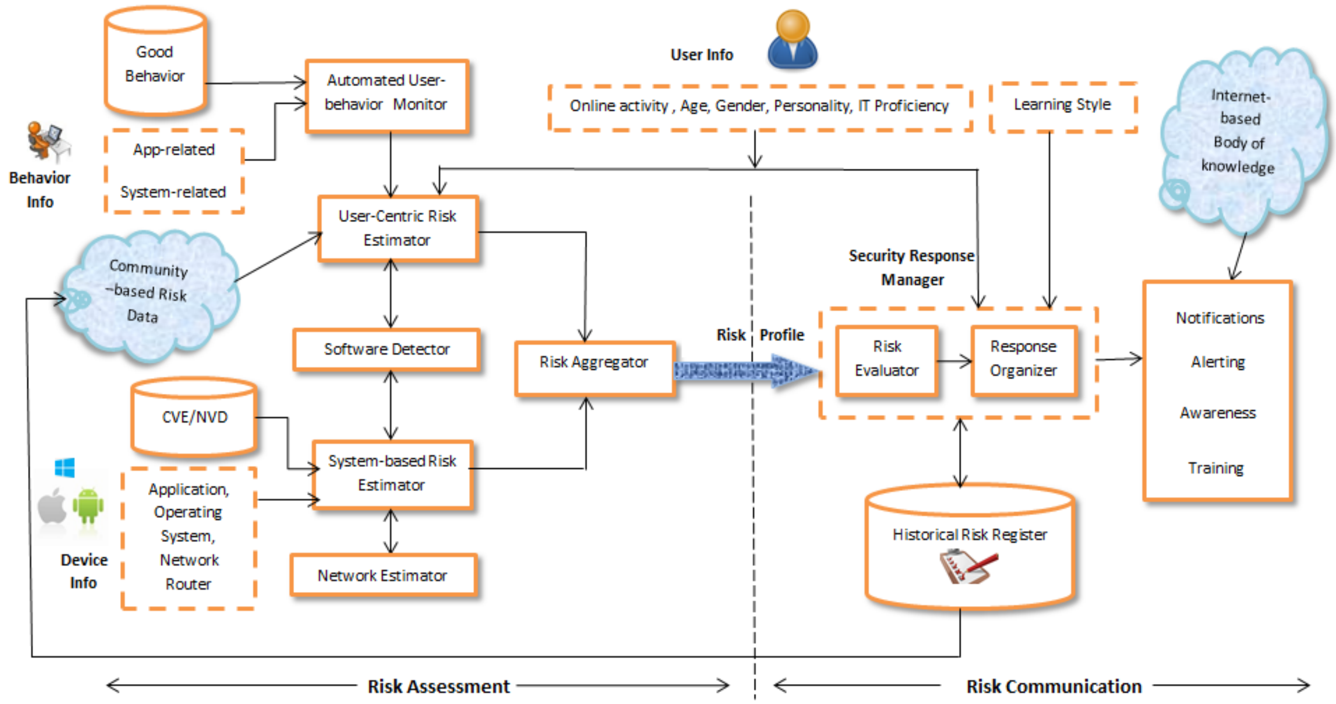

Fig. 1. The User-centric Risk Assessment and Response, UCRAR, Framework.

TABLE I. AN EXAMPLE OF SOFTWARE GROUPS

Social networking	e-banking
Messaging	Maps and navigation
News	Shopping
e-mail	Web access
Entertainment (games, music …etc)	Photography
Office applications (Ms Word, Ms Excel …etc)	Security
Operating system	

where B-expected is the expected good behavior derived from the Good Behavior knowledge base, B-actual is user's current behavior and U-info is user-centric factors expressed as the tuple (Age, Gender, Personality, Learning-style, IT-level, Use-level)

Nevertheless, due to this continuous monitoring, a very important aspect is that users need to trust this system and that it will not violate their privacy. They need to be aware that this monitoring is done for their own protection and any collected data will not be used for purposes other than those intended for risk assessment and will not be shared with any other application. This could be done by having the user, when installed the application, accept an agreement terms.

4) Community-based risk data: The proposed UCRAR is based upon user's behaviors in a certain point of time. Once the proposed system is running with many people using it, there is the chance to look at their user-centric factors, behaviors and responses in real time on a continuous basis. Information about users, behaviors and responses are fed into this Community-Based Risk Data in an anonymized form on a continuous basis. Hence, those found statistically significant correlations according to [70] could be re-evaluated and the user-centric risk estimation will be modified accordingly. For example, if the user-centric factor of age no longer has a statistically significant correlation with a certain behavior or a new user-centric factor becomes significant for a behavior then the system will adapt accordingly. The system has all required information to do this so called re-evaluation by mapping user's actual responses to a more meaningful risky/non-risky decision. This will allow it to move beyond the static point in time to a continuous understanding of these factors and correlations. Therefore, by knowing the actual behavior and response, those found significant correlations will be truly significant. Further to that, new threats might be introduced and impact a behavior quite differently depending on user-centric factors. As such, those relations are periodically revised such as every six months. Not limited to that, user's responses will be periodically used to intelligently re-measure user-centric factors. For example, user's IT-level could be changed from a non-IT professional to an IT-professional based on his behavior. These examples serve to demonstrate that UCRAR can dynamically adapt to changes in user-centric factors. Hopefully, this process will be used as feedback mechanism to keep the system up-to-date and gradually move away from behavioral intent to actual behavior.

TABLE II. SETTINGS OF USER-CENTRIC FACTORS

User-centric factor	Description	Determined
Age	Users will be classified into three age groups: 18-30 years, 31-50 years and 51+ years	Offline. By explicitly answering a direct question, as part of system setup/configurations
Gender	Users will be classified as either male or female	
Personality	According to their BFI score users will be classified as either high or low in one of the personality traits of Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism.	Offline. By using a BFI tool, as part of system setup/configurations
Learning style	According to their preferred learning style, users will be classified according to their VARK learning style as either Visual, Aural, Read/write or Kinesthetic	Offline. By using a LS tool, as part of system setup/configurations
IT level	According to predefined metrics to measure their IT expertise such as settings and modification of web browser configurations, frequent use of shortcut keys and the use of advanced features in software/apps such as section breaks and cross sections in MS Word and macros in MS Excel, the user will be assigned an IT proficiency level of either professional or not	Online. Determined implicitly by the User Behavior Monitor
Service usage	According to predefined metrics to measure their service usage and online activity such as number of unique IP addresses accessed, number of hours spent online on a predefined basis and volume of transferred data, the user will be assigned a service usage level of high usage, medium usage or low usage.	

5) User-centric risk estimator: This process performs a mapping of user behavior to applications. Hence, what is the user doing against what application given that a threat against an application maybe increased by a user's *insecure* behavior. User-centric factors will be considered as a risk factor when assessing risk on the user level. As the threat against a certain application maybe increased due to user's insecure behavior, behaviors are assessed, resulting in a risk score/level, *behavior-score*, and used as a risk factor. Additionally, other risk factors that are behavior-related are considered such as the application importance, *app-score*, as detected by the Software Detector process and the used communication channel. Consequently, assessing these user-centric and behavior-related risk factors will result in an individualized risk score/level, *behavior-risk* which is the output of this process.

6) Network estimator: Given that a vulnerable router is more likely to be exposed and used as a threat source [32], this process will monitor the status of the network in which the user is connected to and is kept to a minimum level. Hence, information about the used network devices, i.e. routers, are collected and passed to the System-Based Risk Estimator. Router information will be expressed in terms of router's software name and version and passed to System-Based Risk Estimator to check it for vulnerabilities. Thus, the output of this process is the parameter *r-id* which is the ID of the software executed on the router in CPE.

7) System-based risk estimator: As perfect security is considered to be unachievable for information systems, then the goal is to achieve a security level that is deemed appropriate to user's needs and requirements. A vulnerable software could be exploited by attackers compromising the system where this software is running [6] such that the more vulnerabilities in a software the less secure it is and, eventually, the lower its trustworthiness level. This process analyses and calculates security risks on system level. This is accomplished by checking all installed applications, router software and also platform information in terms of the used Operating System for vulnerabilities. For each of the previously mentioned, the System-Based Risk Estimator will check vulnerabilities knowledge bases such as NVD and CVE for known vulnerabilities and calculate a software risk score accordingly. Then, a final system risk score, *system-risk*, will be calculated which is the output of this process.

8) Risk aggregator: The purpose of this process is to evaluate/assess security risks based on information obtained from User-Centric Risk Estimator and System-Based Risk Estimator and generate a risk profile that adapts to users accordingly. Hence, this risk profile is composed of a set of parameters that are required by the Security Response Manager to do its job. This Aggregator will assess and analyze the security risk and determine the final risk score, *overall-risk*. However, the quality of the risk assessment depends on the accuracy and granularity of data provided by the previously mentioned processes. Thus, the output of this process is the generated risk profile as follows:

Risk-Profile=(*B-actual*, *U-info* ,*overall-risk* ,*risk-level*, *date*)

where *overall-risk* is the quantitatively expressed and calculated overall risk score, *risk-level* is the qualitatively expressed overall risk level and *date* is the date and time stamp this behavior was performed.

The operational flow in this Risk Assessment Component is as demonstrated in Fig 2.

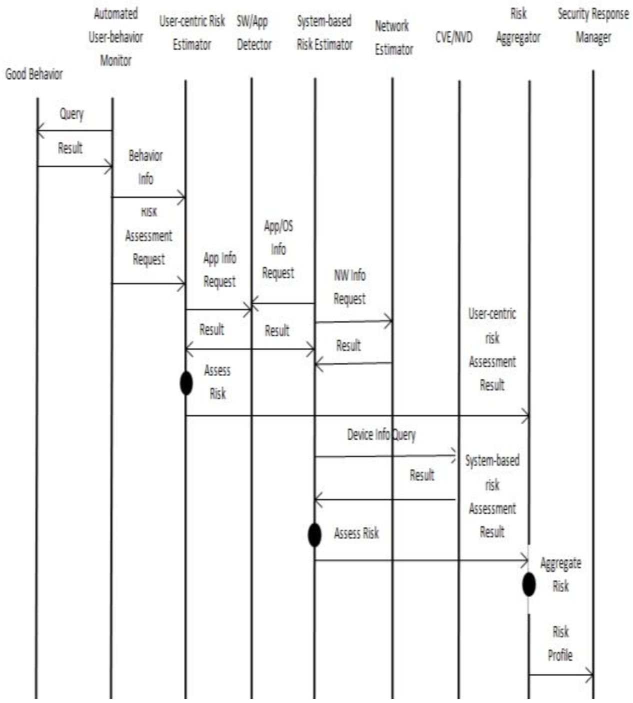

Fig. 2. Operational Flow in the Risk Assessment Component of UCRAR

B. Risk Estimation Models

As UCRAR provided a mechanism for understanding both system and user/behavior based risk and how to respond to them, a mechanism for estimating such risks is required. For the purposes of this Paper, three risk estimation models are proposed. These are a System-based, User-centric and Aggregated Risk Estimation Models to be used by the System-based Risk Estimator, User-centric Risk Estimator and the Risk Aggregator processes of UCRAR's Risk Assessment Component.

1) System-based risk estimation model: For the system-based risk estimation, a vulnerability-oriented approach will be used to assess and analyze security risks on the system level through the use of CVSS scoring algorithm [37]. Accordingly, any estimated risk score/level in UCRAR will be in accordance with the used CVSS scoring system, i.e. 0..3.9 low risk, 4..6.9 medium risk and 7..10 high risk. The nature of the proposed model allows the use of any software risk scoring methodology utilizing a CVSS scoring algorithm. Thus, the methodology proposed by [21] will be used to calculate the risk score of installed applications, *app-risk*, the used Operating System, *os-risk*, and router's software, *nw-risk*. Additionally, the source name of the installed application, *install-name*, is used as a risk factor. Since this risk factor is application-specific, it will be added to the calculated *app-risk*. If the application was installed from an illegitimate source, then the final security score of the application, *app-risk*, is calculated as follows:

IF *install-name* = illegitimate THEN (1)

{increase app risk level from low to medium}

IF 0<= *app-risk* <= 3.9 THEN *app-risk* = 4

{increase app risk level from medium to high}

ELSE IF 4<= app-risk <=6.9 THEN app-risk = 7

Therefore, the final system risk score, *system-risk*, is calculated as follows:

$$System\text{-}risk = app\_risk * w_{app} + os\_risk * w_{os} + nw\_risk * w_{nw} / (w_{app}+w_{os}+w_{nw}) \quad (2)$$

where w_{app}, w_{os} and w_{nw} are subjective weights.

Unfortunately, there is no evidence yet on how to weight *app-risk*, *os-risk* and *nw-risk* or suggest the proportion of impact each of them has on the system risk score/level, *system-risk*. Thus, these weights are suggested as 0.5, 0.3 and 0.2 respectively. However, the proposed model allows for a variety of ways such that whenever future research is available regarding this proportion, the proposed model could easily adopt to it.

2) User-Centric risk estimation model: Assessing user-centric and behavior-related risk factors will result in an individualized risk score/level, *behavior-risk*. In order to understand what needs to be measured and quantified , a list of possible user's behaviors is necessary. Nevertheless, it is unrealistic to assume all possible user's behaviors especially with the existence of multiple platforms and the increasing number of applications on a yearly basis [2]. Therefore, structuring it will provide a more meaningful risk assessment. Accordingly, a categorization of user's behaviors is suggested as in Fig. 3. Namely, these behaviors could usefully be categorized as System/Device-related behaviors and application-related behaviors that are further categorized according to the nature of the behavior and type of data accessed. Data is categorized according to the risk and impact on user's CIA and privacy when this data is modified or disclosed.

a) Application-Related Behaviors

The impact of consequences (CIA and P) of various user behaviors generate different risk levels within an application as discussed in section 3. Not limited to assessing user's behaviors, but behavior-related risk factors are assessed such as the used password, the used communication medium and account type if any. Among the several risk methodologies discussed in section II is CRAMM [26]. Seven impact consequences adopted from CRAMM are identified. Namely, impacts of disruption (D), personal privacy (P), data corruption (DC), embarrassment (E), financial lost (F), legal liability (LL), personal safety (S). As it is hard to assess this from one user to another due to different user-centric factors and to provide a fine-grained valuation that reduces the burden on the user in terms of user input, the potential consequences will be assessed and assigned for each behavior category. Then, each behavior will be mapped into its corresponding category. An example of potential consequences is as in Table 3 where they are rated as 0-Low, 1-Medium and 2-High.

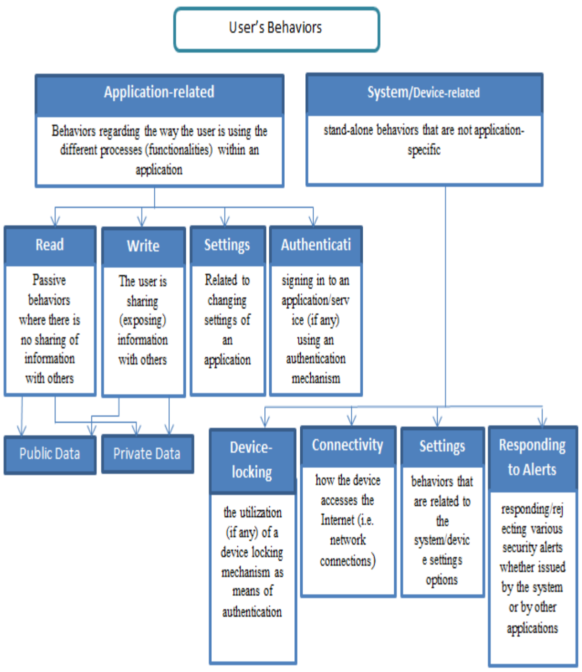

Fig. 3. A Suggested Categorization of User's Behaviors.

TABLE III. AN EXAMPLE OF SUGGESTED BEHAVIOR CONSEQUENCES

	Suggested Consequences						
Behavior Category	E	F	P	DC	LL	S	D
Read-private-data	2 (H)	0 (L)	2 (H)	2 (H)	0 (L)	0 (L)	1 (M)
Write-private-data	1 (M)	2 (H)	2 (H)	2 (H)	1 (M)	0 (L)	0 (L)
Write-public-data	1 (M)	0 (L)	1 (M)	1 (M)	0 (L)	0 (L)	1 (M)

To estimates risk, a matrix-based approach will be used and a risk matrix is generated for each consequence as in Matrix 1.The first step in assessing the behavioral risk score, *behavior-score*, is by mapping the behavior's potential consequences and the application's importance level *app-score* as detected by the Software Detector process in Matrix 1. This will result in seven quantitative scores (one for each consequence). Second, based on the "worst case scenario" principle [45], the maximum value resulting from the Matrix 1 is used. Hence, a behavioral risk score, *behavior-score*, will be generated as:

behavior-score = MAX(consequences) (3)

		Consequence/ Attribute / Connectivity		
		Low	Medium	High
app-score	0	0	1	2
	1	1	2	3
	2	2	3	4
	3	3	4	5
	4	4	5	6

Matrix 1: UCRAR Risk Matrix

The same approach is used for estimating behavioral-related factors such as the used password *auth-score* and the used communication channel *connect-score* if any. For calculating auth-*score*, password's hygiene is checked for several attributes such as its length and password reuse. An authentication risk matrix is generated for each attribute as in Matrix 1. Each password attribute is assessed as 0-Low, 1-Medium or 2-High. After mapping the application's importance level *app-score* and password's attributes in Matrix 1, the maximum value resulting from the above risk matrix is used. Whereas for estimating *connect-score*, a risk level is pre-assigned for each type of communication channel such as Low for 3G/4G, Medium for Bluetooth, NFC and private WiFi and High for Public WiFi. These risk levels are based on the security measures utilized for data transmission by the communication channel. The used communication channel's pre-assigned risk level is mapped with the related *app-score* in Matrix 1 to generate a *connect-score*. Hence, the resulting *behavior-score/auth-score/connect-score* is a quantitative value from 0 to 6. However, based on findings of [70], two situations are identified. If the assessed behavior is significantly correlated with a user-centric factor, then the resulting *behavior-score* is recalculated first based on the significance correlation risk factor as explained in the next section. then *behavior-risk* is calculated as in (4). Otherwise, *behavior-risk* is calculated as in (4). In both cases, the resulting *behavior-risk* will be normalized because all scores used in the risks calculations are from 0 to 10.

Given that the disclosure or modification of private data in a private Facebook account, for example, has a lower risk level than in a public account, a pre-set score of 1 and 2 is assigned for private and public accounts respectively as the *account-type-score* (if any).

Finally, to estimate *behavior-risk*,

behavior-risk=AVG(*behavior-score*,*auth-score*,*connect-score*)+*account-type-score* (4)

b) System/Device-Related Behaviors

A risk estimation model is proposed for each system/device-related behavior category. Connectivity behaviors are assessed in the same approach as in estimating *connect-score*. In responding to alerts or settings behaviors, risk is estimated for these behaviors as stand-alone behaviors regardless of application importance, *app-score*. If an alert is ignored/no action taken by the user or a setting is disabled, then risk is high and an averaging approach is used to calculate *behavior-score* by adding the values at both ends of the level's scale (high risk level has a risk score between 7 and 10) and dividing it by 2 as in (5). For Device locking behaviors, risk is not only estimated if such control is utilized or not, but also the degree it complies to good authentication behavior such as password hygiene. Hence, risk is estimated such that If no lock is used, then risk is high and *behavior-score* is estimated as in (5). If device lock (PIN) is used, then it is assessed for its hygiene using Matrix 1 in an approach similar to that of estimating *auth-score*.

behavior-score= (7 + 10)/2 = 8.5 (5)

The resulting *behavior-score* is recalculated based on the significance correlation risk factor (if any) resulting in *behavior-risk*.

3) The significance correlation risk factor: The novelty of this risk assessment scheme is that a different risk profile is created for the same behavior given a number of users. Based on our work [70], it was found that the risk score/level of a behavior may be positively or negatively affected by certain user-centric factor such as personality trait, age and IT expertise. Thus, the significance of the correlation between a user's behavior and user's-centric factors (if any) is used as a risk factor to reassess the behavioral risk score, *behavior-score*. However, when considering the significance correlated risk factor, two situations are identified, namely, the significance correlation risk factor for application-related behaviors and the significance correlation risk factor for system/device-related behaviors. In the former, the significance of a correlation implies that due to certain user-centric factors values (Low, Medium, High), the likelihood of a security threat is either decreased or increased. Asset value is equivalent to the application's importance level from the user's perspective whereas how easy a security breach may occur depends on the type of user's behavior. Hence, the significance correlation matrix, matrix 2, is adopted from [10] where user-centric factor value, *behavior-score* and *app-score* are used instead of threat likelihood, ease of exploitation and asset value respectively in the original matrix.

User-centric factor Value		**Low**			**Medium**			**High**		
behavior-score		**L**	**M**	**H**	**L**	**M**	**H**	**L**	**M**	**H**
App-score	0	0	1	2	1	2	3	2	3	4
	1	1	2	3	2	3	4	3	4	5
	2	2	3	4	3	4	5	4	5	6
	3	3	4	5	4	5	6	5	6	7
	4	4	5	6	5	6	7	6	7	8

Matrix 2: Significance Correlation Matrix

The proposed methodology for the significance correlation risk factor for system/device-related behaviors and application-related behaviors is as described in Figs. 4 and 5.

4) Aggregated risk estimation model: The proposed model for aggregating the user-centric risk score, *behavior-risk*, and the system-based risk score, *system-risk*, for application-related behaviors is as follows:

$$\textit{Overall-risk} = (\textit{behavior-risk} * w_{br}) + (\textit{system-risk} * w_{sr}) \quad (10)$$

```
GET user-centric factor value, app-score, behavior-score.
IF behavior-score Є {0,1,2} THEN low risk
ELSE IF behavior-score = 3 THEN medium risk
 ELSE IF behavior-score Є {4,5,6} THEN high risk
IF –ve correlation THEN                                          (6)
 IF user-centric factor = high THEN   {decrease the risk }
   user-centric factor = low level
   MAP user-centric factor value, behavior-score and app-score in Matrix 2
   GET new behavior-score
 ELSE IF user-centric factor = low THEN      {increase the risk }
   user-centric factor = high level
   MAP user-centric factor value, behavior-score and app-score in Matrix 2
   GET new behavior-score
   ELSE IF user-centric factor = medium THEN
    user-centric factor = medium level
    MAP user-centric factor value, behavior-score and app-score in Matrix 2
   GET new behavior-score
IF +ve correlation THEN                                          (7)
 IF user-centric factor = high THEN   {increase the risk}
   user-centric factor = high
   MAP user-centric value, behavior-score and app-score in Matrix 2
   GET new behavior-score.
 ELSE IF user-centric factor = low THEN      {decrease the risk }
   user-centric factor = low
   MAP user-centric factor, behavior-score and app-score in Matrix 2
   GET new behavior-score.
 ELSE IF user-centric factor = medium THEN
   user-centric factor = medium
   MAP user-centric factor, behavior-score and app-score in Matrix 2
   GET new behavior-score.
```

Fig. 4. Application-Related Behavior's Methodology for Significance Correlation Factor.

```
GET user-centric factor value, behavior-score.
IF –ve correlation THEN                                          (8)
  IF user-centric factor = high THEN   {decrease the risk }
    behavior-score = behavior-score - 1
  ELSE IF user-centric factor = low THEN      {increase the risk }
    behavior-score = behavior-score + 1
   ELSE IF user-centric factor = medium THEN
     Neither increase nor decrease the risk score.
IF +ve correlation THEN                                          (9)
  IF user-centric factor = high THEN   {increase the risk }
    behavior-score = behavior-score +1
  ELSE IF user-centric factor = low THEN      {decrease the risk score}
    behavior-score = behavior-score - 1
  ELSE IF user-centric factor = medium THEN
    Neither increase nor decrease the risk score
```

Fig. 5. System/Device-Related Behavior's Methodology for Significance Correlation Factor.

Where w_{br} and w_{sr} are subjective weights and suggested as 0.5. Unfortunately, there is no evidence yet on how to weight *behavior-risk* and *system-risk* or suggest the proportion of impact each of them have on the final risk score/level, *overall-risk*. However, the proposed model allows for a variety of ways such that whenever future research is available regarding this proportion, the proposed model could easily adopt to it.

As a vulnerable application is not considered, arguably, as a threat source when assessing risks of system/device-related behaviors such as in not utilizing a device lock or in connecting to a public WiFi network. Moreover, the threat is in the behavior itself as a stand-alone behavior regardless of compound risks. Thus, *overall-risk* for system/device related behaviors is the same as the user-centric risk score as

Overall-risk = *behavior-risk* (11)

C. Risk Communication Component

The second component of the framework, Risk Communication, starts by receiving the individualized risk profile form the Risk Aggregator, analyzing it and deciding on the most suitable form of communicating/educating the risk to the user. Different from the related work described in Section II, the proposed model is intended to assess and communicate risks in near real time and alert the user before taking further action. Evidence suggests that static risk communication may result in users becoming inattentive to messages delivered [51][71][72]. Hence, the robustness of risk communication should be suited to the encountered risk by providing the user with real time needed security education about his risk taking behavior. This is done in an individualized persuasive manner to transform him from being ill-informed to a security minded user. To accomplish this risk communication, the following processes are established:

1) The security response manager: Based on the user's behavior risk level, the Security Response Manager will make a decision on what the next step is. However, when communicating risk to the user, the response manager will decide upon the best form of persuasive technology that best suits the user based upon *U-info* that is part of the risk profile. Thus, to educate user's about security risks and promote good behavior, user-tailored messages that take into account the individual user-centric factors are used. Two sub-processes carry on the functionality of The Security Response Manager as follows:

- **Risk Evaluator**: Once the risk profile is received, the risk level is checked first. If the behavior is secure, i.e. low risk, then behavior-response-information is sent immediately to the Historical Risk Register. If the behavior is insecure, i.e. risk level is medium or high, then the risk profile is forwarded to The Response Organizer.

- **Response Organizer**: Prior to issuing a message, it will check the Historical Risk Register of previous incidents of the same behavior and the issued security messages related to it. Hence, the response mechanism of this process depends on two concepts, namely, informing the user of his behavior's risk score/ level and deciding on the best way to communicate/educate the user about his risk-taking behavior. Hence, based on the information received in the risk profile and historical data about the same behavior (if any) from the Historical Risk Register process, a gradual, individualized and persuasive response mechanism of varying gradual response levels is suggested.

2) Historical risk register: All user's behaviors, whether secure or insecure, and information related to it are continuously stored in this register/database for a limited time period then discarded. This time period will be reasonable enough to capture the latest changes in user's behavior without exhausting resources in storing too much data. Whenever a risk profile is received, it is compared with relevant historical risk data. The result of this comparison is used to determine the type/level of response. This will be stored as the following tuple:

res-behavior = (*b-actual, date, response, module, u- action, risk-score, risk level*) (12)

Where: *response* is the response level. However, 0 is used to indicate no response issued, i.e. secure behavior. *Module* is to indicate the type of recommended security education module (if any) of either security **aw**areness, **tr**aining or **no**ne, *Module* Є {aw, tr, no}. *u-action* is user's behavior towards a given module if any, i.e. **i**gnored, **p**ostponed or **o**beyed *U-action* Є {i,p,o} Additionally, this information will be used by the Security Response Manager when issuing a motivation alert, user's behavior report and to identify areas in which the user has mostly behaved insecurely and in need of further education.

3) Alerts, reminders/notifications, awareness and training: Security is "rarely the user's primary goal" and users only try to protect themselves from risks salient to them [71]. This targeted risk communication goes beyond passively notifying/warning users of security risks to act as a tool to educating and training the user on good behavior to make security informed decisions whilst displaying the security message. This is accomplished through additional teaching/education in the user's preferred learning style such as gamification, video or podcast.

4) Internet-based Body of Knowledge: To educate the user about security, a form of targeted security education will be provided based on user's behavior focusing, mainly, on educating him of his risk taking behavior. This will be decided upon by searching an Internet based body of knowledge that is developed by a third party, or simply the Internet as a huge knowledge base for security information such that the required security information will be searched for, identified and located on the Internet. As the accuracy and effectiveness of such provided info should be evaluated, the creation of such knowledge base and evaluation of retrieved security information are outside the scope of work of this research and could be part of future work. Hence, operational flow in this component is as demonstrated in Fig. 6.

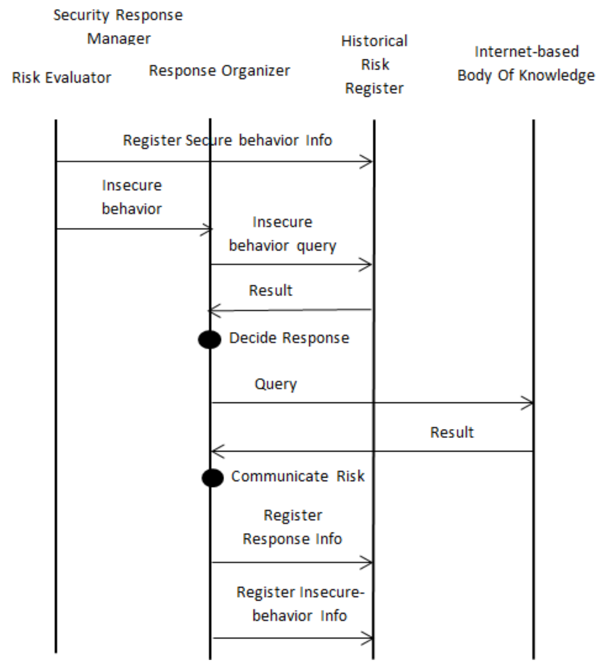

Fig. 6. Operational Flow in the Risk Communication Component of UCRAR.

IV. Evaluation of UCRAR

The resulting risk scores/levels from the Risk Assessment component will enable other processes of the proposed UCRAR, the Security Response Manager for example, to take that information and act accordingly. Given the aim and objectives of this paper to develop a user-centric approach towards risk assessment, a decision was made by the authors to focus on the Risk Assessment component of UCRAR and to have further work in the Risk Communication component as future work.

As UCRAR is dependent upon a variety of factors, whether user-centric such as IT proficiency and personality traits, or behavioral-related such as the used communication medium and authentication hygiene, the aim is to evaluate its effectiveness, feasibility and nature, i.e. how it works given a number of different users with different characteristics and behaviors. Furthermore, to empirically investigate whether the dynamics of the proposed UCRAR operate in the envisaged manner and the factors identified to impact risk do have an impact upon the resulting risk scores/levels. However, to evaluate the model, there exists a number of challenges in implementing the proposed model on real users and within a real environment. The need to develop the required controls to do the process of user monitoring and the development of several knowledge bases such as the community-based risk data are examples of such challenges. Although different approaches could be taken to evaluate the model, the most complete and comprehensive approach that will enable a comprehensive analysis of the model appeared to be a simulation-based approach. In this approach, a number of users with different risk profiles across the spectrum will be replicated. Hence, risk will be estimated/calculated independently for each user.

In order to do a walkthrough of the proposed model and understand, in a categorized fashion, how different users are impacted by risk, a scenario-based simulation based upon a variety of users' profiles from one end to the other is designed considering the following:

1) All possible user-centric factors permutations for different users.

2) To understand the nature of how user's behaviors impact the risk scores/levels, behaviors included in the scenario reflects examples of each behavior type from the proposed Categorization of Behaviors as in Fig. 3 .

3) Behaviors selected demonstrate the difference between the resulting risk scores/levels of behaviors that were found to be most significantly correlated with a certain user-centric factor and those that were not (Behavior 6).

4) Varying *app-scores* with low, medium, high and very high importance are assumed.

The simulation is done as follows:

- The scenario is assumed to model the nature of the risk process. However, it is worth highlighting that the scenario selected is an example and has no specific basis only that it introduces a number of different risks a typical user might encounter.
- A variety of users with different user-centric factors are assumed.
- The model is applied and risk is calculated.
- Results are analyzed to understand how different users are impacted by risk

Hence, assuming the scenario of a user is sitting in Starbucks coffee shop and connected to their WiFi. While browsing his email's inbox, he opened an email from an unknown sender asking for his credentials and bank account number to claim a won lottery prize, but ignored it. Then, he opened another email from a friend and downloaded a greeting card that was attached to it. Meanwhile, he was alerted that a new update for his AntiVirus application is available, but cancelled it. At that time, a friend came to sit with him where they chatted for an hour. When his friend left, he unlocked his device and started browsing job websites. When a job request was found and wanted to apply for it, he was asked to register with a username and password first. After registration, he was prompted by the browser to remember this password and accepted. Subsequent to signing in, he was redirected to another website unknown to him to download and fill an application form. Ignoring an alert not to open this document, he opened the document, filled it up and clicked on "SEND". As he was typing the BBC News website's URL, he was alerted that a preinstalled application (AntiVirus application) is slowing down his device so he immediately disabled it and continued browsing. Starbucks's Router is using CISCO AIRONET access point software version 8.1 (112.3). The user is using a Samsung Galaxy Note 3 running Android version 4.4.4, Google Chrome application version 39.0.2171.45 and Email application version 4.2.2.0200. The user is using Symantec Mobile Security as an

AntiVirus application. All installed applications were downloaded from GooglePlay. Both the email's password and the job website's password comply to all password hygiene attributes except that the former does not contain uppercase letters and the same password is used for his Twitter account while the latter is 5 characters long. The used device pin lock is 1111. The user rated the importance of Twitter application as low (*app-score* = 1), Chrome as medium (*app-score* = 2), Email as High (*app-score* = 3) and Symantec Mobile Security as very high (*app-score* = 4). However, all applications were installed from Google Play which is a legitimate market.

The types of users assumed along with their user-centric factors are as in Table 4. Given the above scenario, a list of insecure security behaviors, i.e risks, along with their behavior type and the user-centric factor that was found to have the most significant correlation with that behavior according to findings of [70] are as in Table 5.

To assess risk of the behaviors mentioned in Table 5, risk is estimated on the system level first then on the user level.

To estimate risks on the system level, *system risk* :

Using the methodology proposed by [21], the security scores of each of the mentioned applications , *app-risk*, the used Operating System, *os-risk*, and router's software, *nw-risk*, are calculated. Then, *System-risk* is estimated for the applications of Chrome, Email and Mobile security as 5.8, 5.8 and 5.5 respectively.

To estimate risks on the user level, *behavior- risk* and *overall-risk*:

For each behavior in Table 5, risk of the behavior, *behavior-risk*, is estimated first followed by estimation of aggregated/final risk, *overall-risk* resulting in scores as in Table 6. This is done according to user's rating of used applications, Twitter's *app-score* = 1, Chrome's *app-score* = 2, Email's *app-score* = 3 and Symantec Mobile Security's *app-score* = 4. For space limitations detailed calculations are not included. These are available upon request.

TABLE IV. USER"R-CENTRIC FACTORS --- * USER WITH HIGHEST RISK PROFILE, ** USER WITH LOWEST RISK PROFILE

User	Personality Traits					Age	Gender	IT Proficiency	Service Usage
	Extra.	Agree.	Con.	Neuro.	Open.				
A	High	Low	Low	High	Low	40 Years	Male	IT Pro.	Low
B	High	High	High	Low	Low	55 Years	Female	Non IT Pro.	Medium
C	Low	Low	High	Low	High	27 Years	Male	IT Pro.	High
D*	High	Low	Low	High	Low	19 Years	Female	Non IT Pro.	High
E**	Low	High	High	Low	High	52 Years	Male	IT Pro.	Low

TABLE V. A LIST OF USER'S INSECURE BEHAVIORS

B#	Behavior	Behavior Type	Most Significant Characteristic	Correlation
B1	Connecting to a public WiFi	System-Device/ Connectivity	Service Usage	Positive
B2	Same password for multiple Accounts	Application/Authentication	IT proficiency	Negative
B3	Did not delete a suspicious email	Application/ Write - Private data	Age	Negative
B4	Opened an attachment in an email from a friend without checking	Application/ Read -Private data	IT proficiency	Negative
B5	AntiVirus software not updated	System-Device / Settings	IT proficiency	Negative
B6	Cancelled a security related update	System-Device / Responding to alerts	None	None
B7	Did not disable WiFi when not using it	System-Device / Connectivity	Gender	Negative
B8	Device Lock of "1111"	System-Device / Device locking	Con. Personality trait	Negative
B9	Allowed browser to remember his password	Application/ Write - Private data	Service usage	Positive
B10	Opened a document despite security warning	System-Device / Responding to alerts	Age	Negative
B11	Disabled AntiVirus software	Application/ Settings	Con. Personality trait	Negative
B12	Downloaded a file from an unknown website	Application/ Write - Public data	Con. Personality trait	Negative

TABLE VI. THE RESULTING USERS' RISK PROFILES

		Users				
B#	**Calculated risk**	**A**	**B**	**C**	**D***	**E****
B1	•*behavior-risk*	7.5	8.5	9.5	9.5	7.5
	overall-risk	7.5	8.5	9.5	9.5	7.5
B2	▲*behavior-risk*	6.3	8.8	6.3	8.8	6.3
	overall-risk	5.9	7.2	5.9	7.2	5.9
B3	▲*behavior-risk*	6.3	6	6.7	6.7	6
	overall-risk	6.1	5.9	6.3	6.3	5.9
B4	▲*behavior-risk*	6	6.7	6	6.7	6
	overall-risk	5.9	6.3	5.9	6.3	5.9
B5	•*behavior-risk*	7.5	9.5	7.5	9.5	7.5
	overall-risk	7.5	9.5	7.5	9.5	7.5
B6	•*behavior-risk*	8.5	8.5	8.5	8.5	8.5
	overall-risk	8.5	8.5	8.5	8.5	8.5
B7	•*behavior-risk*	7.5	9.5	7.5	9.5	7.5
	overall-risk	7.5	9.5	7.5	9.5	7.5
B8	•*behavior-risk*	8	6	6	8	6
	overall-risk	8	6	6	8	6
B9	▲*behavior-risk*	5	5.3	5.7	5.7	5
	overall-risk	5.4	5.6	5.8	5.8	5.4
B10	•*behavior-risk*	8.5	7.5	9.5	9.5	7.5
	overall-risk	8.5	7.5	9.5	9.5	7.5
B11	▲*behavior-risk*	10	7.5	7.5	10	7.5
	overall-risk	7.8	6.5	6.5	7.8	6.5
B12	▲*behavior-risk*	5.3	4.7	4.7	5.3	4.7
	overall-risk	5.6	5.3	5.3	5.6	5.3

*user with highest risk profile , **user with lowest risk profile, ▲application-related behavior, ● system/device-related behavior

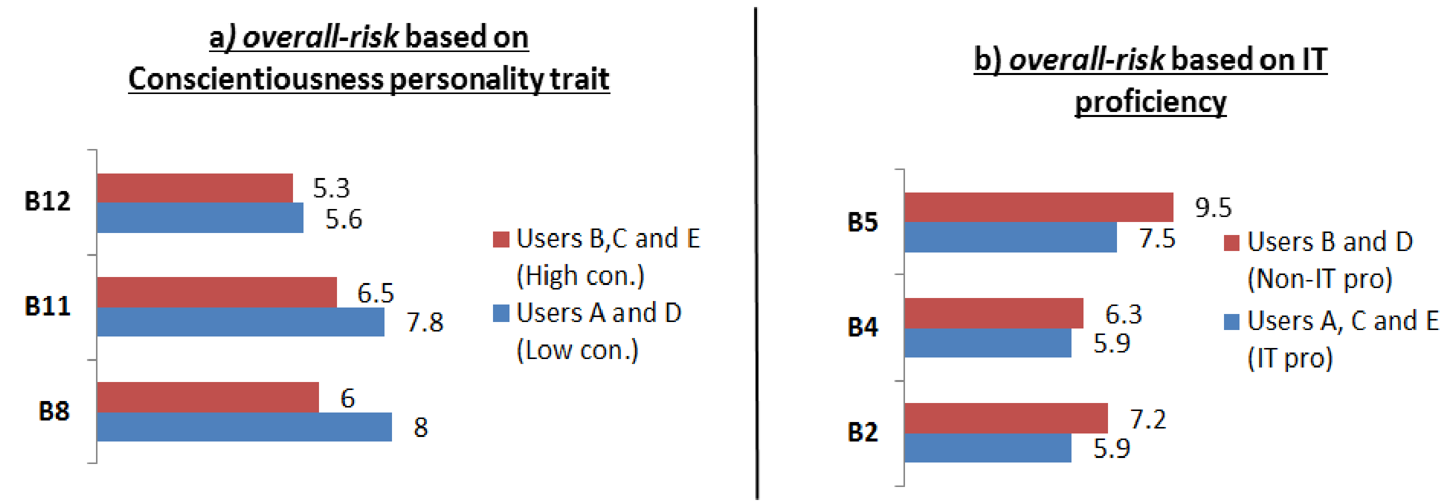

Fig. 7. Overall-Risk based on Personality, IT Proficiency.

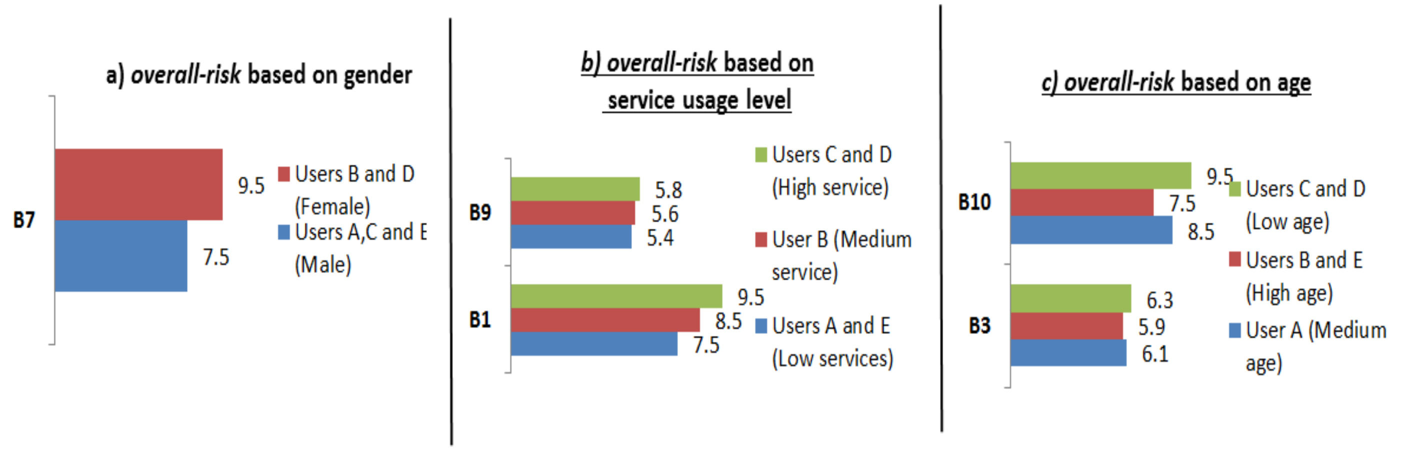

Fig. 8. Overall-Risk based on Gender, Service-usage Level and Age.

A comparison of these results based upon the impact of user-centric factors on the resulting risk scores/levels, highlights a number of trends. As IT proficiency and conscientiousness personality trait user-centric factors were found to be most significantly negatively correlated with behaviors B2, B4 and B5 for the former and behaviors B8, B10 and B12 for the latter, this impact is explicit. IT professionals and those with a high level of conscientiousness personality trait were in lower risk than non-IT professionals and users with lower levels of conscientiousness as in Fig. 7 a and b. A similar impact was apparent for males over females as gender user-centric factor is most significantly negatively correlated with behavior B7 as in Fig. 8 a. The user-centric factors of age and service usage levels are categorized in three levels of low, medium and high with an opposing significant correlation with behaviors B1 and B9 for the former and B3 and B10 for the latter. As illustrated in Fig. 8 b and c, the variations in these user-centric factors resulted in varying risk profiles for users as the higher the service usage level of the user the higher the risk and conversely, the older the user the lower his risk level. These results are in line with findings of [70].

Opposing to the above mentioned behaviors resulting risk scores/levels, behavior B6 that was found not to be significantly correlated with any of the studied user-centric factors resulted in a unified risk score/level, i.e. 8.5 High risk, for all users as in Fig. 9. The comparison between resulting risk scores/levels of other behaviors and those of behavior B6 serve to show how the proposed risk models take into account the variations in the most significant correlated user-centric factors when calculating risk. Moreover, it shows the difference between an individualized and a none-individualized resulting risk scores/levels. To this end, different risk profiles were obtained for the same behavior as a result of variations in users-centric factors. This suggests that the proposed model can adapt to these variations resulting in a more realistic and individualized risk score/level.

This simulation is based on a time line scenario of activities. To reflect the evolving nature of risk over time, Fig.10 illustrates how the risk score changes for each user as the time goes through the scenario based upon the behaviors being exhibited. As *system-risk* is almost constant of 5.8, the resulting deviation of risk scores from 5 to 10 is based upon a single scenario. However, in other scenarios with other systems, different varying system risks will be included which will result in varying risk scores across the spectrum, i.e from 0 to 10.

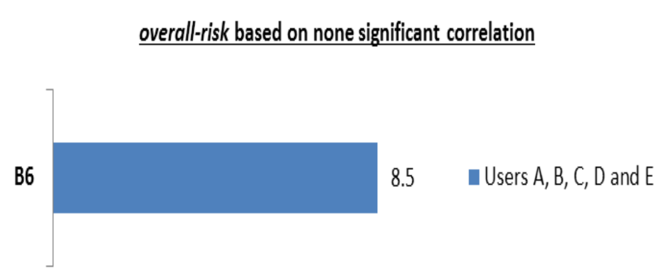

Fig. 9. Overall-Risk based on None Significant Correlation.

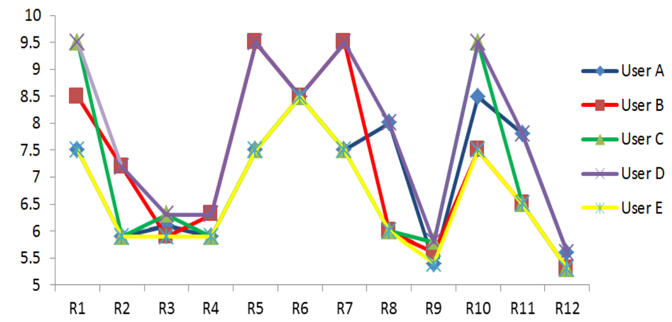

Fig. 10. Resulting Users' Risk Profiles Over Time.

To this end, the analysis of the simulation results provided an indication that risk could be assessed differently for the same behavior based upon a number of user-centric and behavioral-related factors resulting in an individualized granular risk score/level. This granular risk assessment, away from high, medium and low, provided a more insightful evaluation of both risk and response. The analysis of results was also useful in demonstrating how risk is not the same for all users and how the proposed model is effective in adapting to differences between users offering a novel approach to assessing information security risks.

V. Discussion

A user-centric risk assessment and response framework that takes into account, when estimating risk, variations in user's characteristics is proposed. In addition, other behavioral-related factors were considered in estimating risk resulting in a risk score/level not of a single behavior but of compound risk. Using a scenario-based simulation of a variety of users with different risk profiles, the proposed risk estimation models were applied and results analyzed. Actually, this was an opportunity to show that risk has to be based on the user and there are factors whether user-centric or behavioral-related that influences his behavior and risk score/level accordingly. This is evident as different risk profiles were obtained for the same behavior as a result of variations in users'-centric factors such as his age, personality trait and service level usage showing that the proposed model can adapt to change in these factors to produce an individualized risk score/level. However, when comparing the resulting risk scores/levels of a certain behavior for different users, as in B4 for instance, we are able to see no difference in the risk level, i.e. medium. From the user's perspective, this increase or decrease in the risk score but within the same risk level may not be relevant. Consequently, the nature of the proposed models do not allow for a decrease or an increase of 3, for instance, in one hit. Thus, this level of granularity is picked up and understood by the security response manager that this 0.5 increase or decrease, for example, does mean something and acts accordingly. This is similar in concept to the concept of "Fever" in the human body. As the normal temperature is 37.5°c, an increase of temperature of 0.30°c to 37.8° implies that the person has high fever and a medical procedure has to be applied. Similarly, the temperature of 39°c is still considered high fever but the difference is in how it is treated.

To this end, user-centric factors do contribute to the resulting risk scores/levels either by escalating or deescalating it. There is clear evidence to suggest that, in comparison to prior work, the proposed risk assessment methodology is a novel approach that incorporates user-centric and behavioral-related factors when calculating risk.

VI. Conclusion

A user-centric framework that assesses and calculates risk on both user and system level was proposed. This framework is composed of two components, risk assessment and risk communication. Three risk estimation models were proposed to calculate both *behavior-risk* and *overall-risk*. These models used a number of risk factors when estimating risk. The risk assessment component of the proposed framework was evaluated using a scenario-based simulation of different users and results analyzed. The proposed risk calculation models worked in the way they were expected to. The analysis of results revealed a number of trends and relations. Further to that, the analysis provided evidence that the level of impact and contribution of risk factors is not fixed for all users and behaviors. There are other sources of risk to the user other than his actual behavior. These sources range from user-centric to behavioral-related. Aside from the traditional "*one size fits all*" solution in prior literature, encouragingly, the results of this simulation provided an indication that risk could be assessed differently for the same behavior based on a number of user-centric and behavioral-related factors resulting in an individualized and timely risk score/level. Future work will focus on evaluating the risk communication component of UCRAR first, then have a running/implemented version of UCRAR to conduct a series of experiments with real users to evaluate its effectiveness as a whole.

References

[1] Number of Internet Users *(2017) - Internet Live Stats* (2017) [Online]. 2017. Available at: http://internetlivestats.com/internet-users

[2] Statista - *The Statistics Portal* (2017) [Online]. 2017. Available at: http://statista.com.

[3] Bawazir, M., Mahmud, M., Abdul Molok, N., Ibrahim, J. (2016) Persuasive Technology for Improving Information Security Awarenessand Behavior: Literature Review. In: (ICT4M) 6th International Conference on Information and Communication Technology for The Muslim World. 2016, IEEE, pp. 228-233

[4] Symantec, (2018) *Symantec Internet Security Threat Report*. Symantec Corporation.

[5] Symantec, (2017) *Symantec Internet Security Threat Report*. Symantec Corporation.

[6] Kaspersky, (2016) *Kaspersky security bulletin 2014*. Kaspersky Labs

[7] European Agency For Network and Information Security (ENISA), (nvd.) *Inventory of Risk Management- Risk Assessment Methods and Tools*. [Online]. Available at: http://rm-inv.enisa.europa.eu/methods.

[8] Tiganoaia, B. (2012) Comparative Study Regarding The Tools Used for Security Risk Management. *Revista Academiei Fortelor Terestre*, 17(3), pp. 319-325.

[9] National Institute of Standards and Technology NIST Special Publication 800-30, Revision 1, (2012) *Guide for Conducting Risk Assessment*.

[10] The International Organization for Standardization, The International Electrotechnical Commission (ISO/IEC), (2011) *ISO/IEC 27005:2011, Information Technology- Security Techniques- Information Security Risk Management*. Switzerland.

[11] Karabacak, B. and Sogukpinar, I. (2005) ISRAM: information security risk analysis method. *Computers & Security*, 24(2), pp. 147-159.

[12] Talib, S., Clarke, N., and Furnell, S. (2010) An Analysis of information security awareness within home and work environments. In: *International Conference on Availability, Reliability and Security*. 2010, IEEE, pp. 196 - 203.

[13] Kritzinger, E. and Von Solms, S. (2013) Home user security from thick security-oriented home users to thin security-oriented home users. In: *Science and Information Conference*. 2013, pp. 340 - 345.

[14] Rao, U. and Pati, B. (2012) Study of Internet security threats among home users. In: *Fourth International Conference on Computational Aspects of Social Networks*. 2012, IEEE, pp. 217 - 221.

[15] Mylonas, A., Kastania, A., and Gritzalis, D. (2013) Delegate the smartphone user? Security awareness in smartphone platforms. *Computers & Security*, 34, pp. 47-66

[16] Zabaa, Z., Furnell, S., and Dowland, P. (2011) End- user Perception and Usability of Information Security. In: *5th International Symposium on Human Aspects of Information Security and Assurance (HAISA)*. 2011, pp. 97-107.

[17] Komatsu, A., Takagi, D., and Takemura, T. (2013) Human aspects of information security. *Information Management & Computer Security*, 21(1), pp. 5-15

[18] Mensch, S. and Wilkie, L. (2011) Information Security Activities of College Students: An Exploratory Study. *Academy of Information and Management Sciences*, 14(2), pp. 91-116

[19] Furnell, S. and Clarke, N. (2012) Power to the people? The evolving recognition of human aspects of security. *Computers & Security*, 31(8), pp. 983-988.

[20] Hansch, N. and Benenson, Z. (2014) Specifying IT security awareness. In: *25th International Workshop on Database and Expert Systems Applications*. 2014, IEEE, pp. 326 – 330

[21] Wu, B. and Wang, A. (2011) EVMAT: An OVAL and NVD Based Enterprise Vulnerability Modeling and Assessment Tool. In: *Proceedings of the 49th Annual Southeast Regional Conference*. 2011, ACM, pp. 115-120.

[22] Van Cleef, A. (2010) A Risk Management Process for Consumers: The Next Step in Information Security. In: *2010 Workshop on New security Paradigms (NSPW)*. 2010, pp. 107-114.

[23] Jing, Y., Ahn, G., Zhao, Z., and Hu, H. (2014) RiskMon: Continuous and Automated Risk Assessment of Mobile Applications. In: *Proceedings of The 4th Conference on Data and Application Security and Privacy*. 2014, ACM, pp. 99-110.

[24] Paul, S. and Vignon-Davillier, R. (2014) Unifying traditional risk assessment approaches with attack trees. *Journal of Information Security and Applications*, 19(3), pp. 165-181

[25] Wangen, G. (2017) Information Security Risk Assessment: A Method Comparison. Computer, IEEE, 50 (4), pp. 52-61

[26] Yazar, Z. (2011) A Qualitative Risk Analysis and Management Tool-CRAMM. *SANS Institue Information security Reading Room*,

[27] CORAS, The CORAS Method (n.d.) [Online]. Available at: http://coras.sourceforge.net. (Accessed: 15 December 2014).

[28] OCTAVE Available at: octave

[29] Magerit, (2006) *Methodology for Information Systems Risk Analysis and Management: Book 1- The Method*. Madrid: Ministerio de Administracones Publicas.

[30] Mehari, (2007) Overview. *Club de la Securite de I'Information Francis (CLUSIF)*,

[31] Bhattacharjee, J., Sengputa, A., Mazumdar, C., and Barik, M. (2012) A two-phase Quantitative Methodology for Enterprise Information Security Risk Analysis. In: *CUBE*. 2012, ACM, pp. 809-815.

[32] Alsaleh, M. and Alshaer, E. (2014) Enterprise Risk Assessment Based on Compliance Reports and Vulnerability Scoring Systems. In: *Proceedings of the 2014 Workshop on Cyber Security Analytics, Intelligence and Automation (SafeConfig)*. 2014, pp. 25-28

[33] Takahashi, T., Emura, K., Kanaoka, A., Matsuo, S., and Minowa, T. (2013) Risk visualization and alerting system: Architecture and proof-of-concept implementation. In: *SESP'13*. 2013, ACM, pp. 3 -10.

[34] OVAL [Online]. Available at: http://oval.mitre.org.

[35] CVE [Online]. Available at: http://cve.mitre.org. (Accessed: 30 March

2018).

[36] CPE [Online]. Available at: http://nvd.nist.gov/cpe.cfm. (Accessed: 4 February 2018)

[37] Mell, P., Scarfone, K., and Romanosky, S. (2007) *CVSS: a complete guide to the common vulnerability scoring system version 2.0*. [Online]. 2007. Available at: http://first.org/cvss/cvss-guide.html. (Accessed: 18 December 2017).

[38] Allodi, L. and Massacci, F. (2014) Comparing Vulnerability Severity and Exploits Using Case-Control Studies. *ACM Transactions on Information and System Security*, 17(1), pp. 1-20

[39] Holm, H., Ekstedt, M., and Andersson, D. (2012) Empirical Analysis of System-Level Vulnerability Metrics through Actual Attacks. *IEEE Transactions on Dependable and Secure Computing*, 9(6), pp. 825-837

[40] Wright, J., McQueen, M., and Wellman, L. (2013) Analyses of two end-user software vulnerability exposure metrics (extended version). *Information Security Technical Report*, 17(4), pp. 173-184.

[41] National Vulnerability Database NVD [Online]. Available at: http://nvd.nist.gov/cpe.cfm

[42] Spanos, G., Sioziou, A., and Angelis, L. (2013) WIVSS: A New Methodology for Scoring Information Systems Vulnerabilities. In: *Proceedings of the 17th Panhellenic Conference on Informatics (PCI)*. 2013, ACM, pp. 83-90.

[43] Joshi, C.,and Singh, U. (2016) Quantitative Information Security Risk Assessment Model for University Computing Environment. In: (ICIT 2016) International Conference on Information Technology. 2016, IEEE, pp. 69-74

[44] Moyo, M., Abdullah, H., and Nienaber, R. (2013) Information Security Risk Management in Small-scale Organizations: A Case Study of Secondary Schools Computerized Information Systems. In: *Conference of Information Security for South Africa*. 2013, pp. 1-6.

[45] Theoharidou, M., Mylonas, A., and Gritzalis, D. (2012) A Risk Assessment Method for Smartphones. *IFIP Advances in Information and Communication Technology*, 376, pp. 443-456.

[46] Gros, S. (2011) Complex Systems and Risk Management. In: *MIPRO*. 2011, pp. 1522-1527.

[47] Samy, G., Ahmad, R., and Ismail, Z. (2010) A Framework for Integrated Risk Management Process Using Survival Analysis Approach in Information security. In: *6th International Conference on Information assurance and Security*. 2010, pp. 185-190.

[48] Jain, M. and Clarke, N. (2010) Web-Based Risk Analysis for Home Users. *Advances in Communications, Computing, Networks and Security*, 7, pp. 151-158.

[49] Ledermuller, T. and Clarke, N. (2011) Risk Assessment for Mobile Devices. *Lecture Notes in Computer Science*, 6863, pp. 210-221.

[50] Alohali, M., Clarke, N., Furnell, S. and AlBakri, S. (2017) Information Security Behavior: Recognizing the Influencers. In: (*SAI 2017) Computing Conference*. 2017, IEEE, pp. 844-853.

[51] Blythe, J., Camp, J., and Garg, (2011) Targeted risk communication for computer security. In: *IUI' 11*. 2011, ACM, pp. 295 - 298.

[52] Martin, N. and Rice, J. (2011) Cybercrime: Understanding and addressing the concerns of stakeholders. *Computers & Security*, 30(8), pp. 803-814.

[53] Maurer, M., De Luca, A., and Kempe, S. (2011) Using data type based security alert dialogs to raise online security awareness. In: *SOUPS' 2011*. 2011, pp. 1 – 13

[54] Shillair, R., Cotten, S., Tsai, H., Alhabash, S., LaRose, R., and Rifon, N. (2015) Online safety begins with you and me: Convincing Internet users to protect themselves. *Computers in Human Behavior*, 48, pp. 199-207

[55] Furnell, S. and Moore, L. (2014) Security literacy: the missing link in today's online society?. *Computer Fraud & Security*, 2014(5), pp. 12-18.

[56] Metalidou, E., Marinagi, C., Trivellas, P., Eberhagen, N., Skourlas, C., and Giannakopoulos, G. (2014) The Human Factor of Information Security: Unintentional Damage Perspective. *Procedia - Social and Behavioral Sciences*, 147, pp. 424-428

[57] Al-Hadadi, M. and Al Shihani, A. (2013) Smartphone security awareness: Time to act. In: *(CTIT) International Conference for Current Trends in Information Technology*. 2013, IEEE, pp. 166 - 171.

[58] Alarifi, A., Tootell, H., and Hyland, P. (2012) A Study of information security awareness and practices in Saudi Arabia. In: *(ICCIT 2012) The 2nd International Conference on Communication and Information Technology*. 2012, IEEE, pp. 6 – 12

[59] Abawajy, J. (2012) User preference of cyber security awareness delivery methods. *Behaviour & Information Technology*, 33(3), pp. 237-248.

[60] Webb, J., Ahmad, A., Maynard, S., and Shanks, G. (2014) A situation awareness model for information security risk management. *Computers & Security*, 44, pp. 1-15.

[61] Stewart, G. and Lacey, D. (2012) Death by a thousand facts: Criticizing the technocratic approach to information security awareness. *Information Management and Computer Security*, 20(1), pp. 29-38

[62] Shropshire, J., Warkentin, M., and Sharma, S. (2015) Personality, attitudes, and intentions: Predicting initial adoption of information security behavior. *Computers & Security*, 49, pp. 177-191

[63] Gabriel, T. and Furnell, S. (2011) Selecting security champions, Computer Fraud & Security 2011 (8), pp. 8-12

[64] Halevi, T., Lewis, J., and Memon, N. (2013) A Pilot Study of Cyber Security and Privacy Related Behavior and Personality Traits. In: *International World Wide Web Conference (IW3C2)*. 2013, Rio de Janero, Brazil: ACM, pp. 737-744.

[65] Workman, M. (2007) Wisecrackers: a theory grounded investigation of phishing and pretext social engineering threats to information security. Journal of the American Society of Information Science and Technology, (59) , pp. 662–674

[66] Sheng, S., Holbrook, M., Kumaraguru, P., Cranor, L., and Downs, J. (2010) Who falls for phish? A demographic analysis of phishing susceptibility and effectiveness of intervensions. In: *CHI 2010: Privacy Behaviors*. 2010, ACM, pp. 373 – 382

[67] Kruger, H., Flowerday, S., Drevin, L., and Steyn, T. (2011) An assessment of the role of cultural factors in information security awareness. In: *(ISSA) Information Security South Africa*. 2011, IEEE, pp. 1 – 7

[68] Jeske, D., Coventry, L., Briggs, P., and Moorsel, A. (2014) Nudging whom how: IT proficiency, impulse control and secure behavior. *Networks*, 49(18).

[69] Johnston, A., Warkentin, M., McBride, M. and Carter, L. (2016) Dispositional and situational factors: influences on information security policy violations, European Journal of Information Systems, 25(3), pp. 231–251.

[70] Alohali, M., Clarke, N., Li, F. and Furnell, S. (2018) Identifying and Predicting End-user's Risk-taking Behavior. *Information and Computer Security*, Vol. 26, Issue 3, pp. 306-326

[71] Blythe, J. and Camp, L. (2012) Implementing mental models. In: *Security and Privacy Workshops*. 2012, IEEE, pp. 86 - 90.

[72] Wash, R. and Rader, E. (2011) Influencing mental models of security: A research agenda. In: *NSPW' 11*. 2011, ACM, pp. 57 - 66.

ABJAD Arabic-Based Encryption

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***Abstract*—The researcher introduced an enhanced classical Arabic-based encryption technique that is essentially designed for Arab nations. The new algorithm uses the shared key technique where the Keyword system Modulus is employed to add randomness and confusion to the table of alphabets being used. The results proved that the technique is resistant to brute force and cryptanalysis attacks. The time needed to break the algorithm is huge and the possibilities of decrypting the cipher text using the language frequency and language characteristics are hard and unfeasible. The technique assumes the existence of a secure channel for the keyword exchange.**

Keywords—Arabic-based cryptography; classical encryption; Arabic language encryption; shared key; keyword

I. Introduction

Cryptography is an Arab-born science unlike other sciences like mathematics and physics which were translated from their original language founders, developed and then enriched by western scientists [1]. *David Khan*, who is one of the greatest historians in cryptology, stated that cryptology was born in Arabic world [2]. This fact was confirmed in some Arabic cryptologic treatises in 1980 which were found in Istanbul's *Suleymanye* library [3] in addition to the work of other scholars who wrote about cryptography and cryptanalysis in the Arab world [4], [5], [6].

Data protection mechanisms currently use two main algorithmic approaches, symmetric and asymmetric algorithms. Some examples are the AES and RSA algorithms that have proven their strength and practical use over many years. The development in the field of quantum computing has brought a serious threat to the current state-of-the-art cryptology systems [7]. However, some cryptographic asymmetric systems such as RSA with a four-thousand-bit key are believed not to resist attacks by large quantum computers whereas cryptographic symmetric systems, such as AES-256 bits, can resist attacks by large quantum computers. For instance, to break a single AES encryption, an exhaustive search would take $2^{256} > 10^{75}$ steps requiring billions of years with state-of-the-art ultra-massive computing resources [8] [9]. Therefore, researchers have started to explore new encryption methods that are safe in classical computers as well as quantum computers. Some algorithms said to be post-quantum cryptography that remain secure with the assumption that the attacker has a large quantum computing power [10].

A. Research Problem

Recently, Arab communities encounter a real need for Arabic-Based cryptographic algorithm to be used as a second alternative technique in addition to the available encryption standards in the market. Thus, this research comes to bridge the gap that the Arab communities need. It is worth mentioning that such encryption algorithm will be used solely in Arab language encryption intercommunication.

B. Research Objectives and Limitations

Arabic language is spoken by more than 350 million native speakers in 23 countries of the Arab world and is used by more than 57 countries of the Islamic world. It is also one of the six official languages of the United Nations [11] [12]. This research grant supports the design of Arabic-Based encryption technique that can be used by governments, institutions, public and private sectors or individuals.

The research work aims to achieve the following objectives:

1) developing an Arabic-based encryption technique that is fast, cheap, secure and suitable for Arab communities

2) encouraging Arab researchers to employ modern technology in the service of Arabic language sciences

3) building cryptographic algorithms that use pure Arabic letters

The project is restricted to the following criteria:

1) It assumes the existence of secure Quantum Key Distribution (QKD) protocol like (BB84, SARG04, E91 or any other secure Key Distribution (KD) protocol) [9].

2) It is designed for Arabic alphanumeric data format. which is derived from the Arabic coding character set standard (ISO-8859-6).

3) It does not use the Unicode, ASCII, EBCDIC or any other data format or representation.

4) It is targeted for the Arab language users.

5) The non-Arabic character sets are excluded in this phase of the project.

6) It is limited to text message formats only.

II. Related Work

In his paper, *Ibrahim A. Al-Kadit* proves that Arabs are the origins of cryptography. The researcher discussed the factors behind the Arab advancement in cryptology like translation, linguistic studies, administrative studies, public literacy and the advanced mathematics. The researcher briefly listed some of the famous Arab scientists who have contributed to cryptology as *AL-Khalil*, *Jabir ibn Hayyan (Geber)*, *Thoban al-Masry*, *Al-Kindi*, *Ibn Wahshiyya*, *Mohammad ibn Ahmad ibn Tabataba*, *As'sa ibn Muhadhdhab ibn Mammati, Ibn*

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Adlan, Ibn Dunainair, Ibn ad-Durihimi, Ali ibn Mohammad ibn Aidamur al-Jaldki and Al-Qalqashandi. The researcher proved that the word encryption have developed from Arab literacy; the word “cipher” means concealment of clear meaning of messages or simply encryption. The Arabic word “*sifr*” stands for the digit “zero” (0). Then it was transformed into European technical terms that mean encryption and which was later converted from “sifr” in Arabic to “cipher” in Latin cipher [13].

Yahya Alqahtani, Prakash Kuppuswamy, Sikandhar Shah have proposed a modified version of the *Vigenère* cipher based on Arabic alphabets. The original *Vigenère* cipher is a method of encrypting alphabetic text by using a series of different *Caesar* ciphers based on the letters of a keyword [14]. The modified version of the *Vigenère* cipher works by adding a keyword repeatedly into the plaintext. The alphabets consist of 28 characters of Arabic letters, 1 blank character and 10 characters for the numbers. So the total number of the alphabets is 39 characters. The addition is carried out using the system modulo 39. That is to say, if the result is greater than 39, we subtract as many multiples of 39 as needed to bring us into the range (0 . . . 38). The above mentioned researchers claimed that they have a better secure algorithm than the original one using the Arabic alphabets and that their work is a milestone in Arabic language secure communication [15].

Haifaa Abdul-Zahra Atee has proposed a new cryptographic algorithm based on Arabic letters. The researcher demonstrated an encryption/ decryption example but she did not provide it with afterwards investigation regardding the strength of the algorithm and did not compare the results with any known classical algorithm [5].

In their work “Hybrid combination of Message Encryption Techniques on Arabic Text”, *Mohammed Abdullah Aysan* and *Prakash Kuppuswamy* have adopted the *Caesar* cipher approach to Arabic letters after adding the 28 Arabic alphabet characters in addition to the 10 decimal numerals. Then they proposed generating two keys; the first key is based on a synthetic specific value for each Arabic letter from (0, 1… 38), whereas the second key is the logarithmic value of the generated key (X), ($\log_3$(X)). The researchers have argued that their algorithm is simple, fast and has the advantage of using standard methods. Besides, it consumes less processing time and capacity [16].

On the other hand, *Prakash Kuppuswamy, Yahya Alqahtani* have proposed another symmetric encryption technique that is based on Arabic alphabets. Likewise, the initial key is randomly selected and its inverse is calculated. Then another negative number is selected and its inverse is calculated again before generating the cipher text. The decryption is carried out using the reverse order process. The researchers have argued that their work presents more secure algorithms than being used by similar classical encryptions [4].

None of the related works can be adopted by Arab communities because they are either weak or not well designed. The proposed algorithm in this work might be the outset after adding further enhancements and testing to the algorithm to be strong enough and attack resistance.

III. The Proposed Solution

In this work, we proposed an enhanced classical symmetric encryption algorithm that is based on an old encryption technique invented by al-Kindī who was known as "the Philosopher of the Arab world" [3]. The technique is similar to the Porta Cipher but with a modern renovation [17]. The proposed encryption technique is an enhanced version inspired by some techniques as Playfair, al-Kindy, Caeser and Porta ciphers [18].

Arabic encoding is similar to any other language alphabetic scripts. For instance, the Unicode standard is used for encoding a raw text not as a glyph list. The Unicode Standard specifies an algorithm for the presentation of the text with a bidirectional behavior i.e. Arabic and English [19]. In our project, we do not use the known standards as Unicode, ASCII or EBCDIC data representations but rather we use the Arabic alphanumeric data representation [20].

Arabic letters have many characteristics. For example, it has 28 characters, it has no upper or lower case characters, it views some of the two-character pairs as a single character and it is read and written from right to left. Moreover, some shapes of Arabic Letters change depending on the context; some Arabic letters may have up to four shapes depending on the position of the letter in the word, its predecessor and its successor. Arabic Letters also have an isolated shape, a connected shape, a left-connected shape and a right connected shape.

TABLE I. Forms of Order

0	Weight	ABJAD	Normal
1	0	أ	أ
2	1	ب	ب
3	2	ج	ت
4	3	د	ث
5	4	ه	ج
6	5	و	ح
7	6	ز	خ
8	7	ح	د
9	8	ط	ذ
10	9	ي	ر
11	10	ك	ز
12	11	ل	س
13	12	م	ش
14	13	ن	ص
15	14	س	ض
16	15	ع	ط
17	16	ف	ظ
18	17	ص	ع
19	18	ق	غ
20	19	ر	ف
21	20	ش	ق
22	21	ت	ك
23	22	ث	ل
24	23	خ	م
25	24	ذ	ن
26	25	ض	ه
27	26	ط	و
28	27	غ	ي

Furthermore, Arabic has several diacritics (small vowels) that can be written above or beneath each letter. The use of diacritics is determined by the grammatical state of the word and eventually the meaning of the statement changes accordingly [19] [21]. However, in our research, we will not consider diacritics or language grammar.

In addition to the normal order of Arabic alphabet (as used in dictionaries), Arabic has another order known as “ABJAD” pronounced /ˈæbdʒɑːd/ [22] [23]. The two alphabetical orders are shown Table 1 Forms of order.

The table 1 (forms of order) is read from right to left. The first row (serial) shows the alphabets order, the second row (weight), represents a given numeric equivalent to each letter, the third row (ABJAD) represent the ABJAD order of the Arabic letters and the last row (normal) represents the normal alphabets order.

A. The Solution Description

The Arabic coding of character set (ISO-8859-6) [24] is used to create a modified synthetic table composed of 75 characters that represent the standard alphabets, numbers and special characters. Table 2"Modified Arabic (ISO-8859-6)", represents a matrix *M* of (5x15) rows and columns. The matrix *M(mi,j)* contains 75 characters where *mi,j* represents the ith and jth character of the matrix (M). So ((1<= i <=5) and (1<=j< 15)), as defined in Equation (1).

$$\mathrm{M} = [i-j]_{5X15} = \begin{bmatrix} m1{,}1 & \cdots & m1{,}15 \\ \vdots & \ddots & \vdots \\ m5{,}1 & \cdots & m5{,}15 \end{bmatrix} \qquad (1)$$

The matrix M(mi,j) is the initial matrix and is reconstructed by distributing its content (characters) according to the keyword characters modulus value. The keyword is randomly chosen by the user. Besides, there are no restrictions on the length of the keyword yet it is recommended to be more than 10 characters. The Keyword is used as a shared key between the communicating parties. For the algorithm calculation purposes, a copy of the keyword with non-redundant characters is used. Then the copied Keyword Length (KL) is calculated as defined in Equation 2. The Keyword Position (KP) in Equation 3 determines the insertion position in the table of alphabets. Nevertheless, the insertion includes the Keyword with non-redundant characters followed by the rest of the non-contributing characters in the keyword from Table 2. Using the system modulus 75 adds randomness and confusion to the algorithm and hence will make it hard to brute-force attacks. The keyword insertion process is performed by filling the unique characters of the keyword followed by the rest of Table 2 starting from position *(m1,15),(m1,14)… (m1,1), (m2,15), (m1,14)… (m2,1)…. (m5,15), (m5,14)…. (m5,1)*. Finally, at the end of the table reconstruction process, a new generated matrix (table) that is called the modified *MM(mi,j)* is created for the encryption purposes.

$$KL = \sum(Keyword\ \text{Characters Weights}) \qquad (2)$$

$$KP = KL\ Mod\ 75 \qquad (3)$$

To access the matrix (table), we need two indexes *(r,c)*, the right index *(r)* and the top index *(c)*. The right index *(Row)* has the values *(r1,r2,r3,r4,r5)* and the top index (Column) has the values *(c1,c2,c3,…….c14,c15)*. While the ABJAD alphabets are used to fill in the *(r,c)* pairs, the two indexes *(r,c)* are used to point to the matrix MM elements where *MM(mi,j)* elements are respectively determined by the value of *(r,c)* (i.e. *i=r* and *j=c*).

To determine which character of the ABJAD alphabets is the starting character to fill the *(r,c)* contents, the sum of the (keyword Weights system modulus 28) is used as defined in Equation 4. The resulting value points to the starting character to be inserted in r5. So the next character will be in *r4,r3,r2,r1 ,c15,c14,c13,…….c2,c1*.

$$KP = KL\ Mod\ 28 \qquad (4)$$

Using the keyword system modulus as in Equation (4) assures the randomness in choosing the starting character of the ABJAD alphabets. For each new plaintext character that is going to be encrypted, the ABJAD alphabets will be down-shifted for one character in a circular-round fashion (down-circular-shift). Using the down-circular-shift makes the algorithm more attack-resistant by adding randomness and confusion to the algorithm.

The encryption process is performed in two steps. In the first step, the plain text is divided into distinct characters where each individual character is substituted with the corresponding pairs of characters from the row *(ri)* that is concatenated with column *(cj)* and which are both from *MM(mi,j)* table. The resulting text is a two-character text (S) as defined in Equation (5).

$$\mathrm{S} = MM(mi,j) = (\mathrm{ri}||\mathrm{cj})) \qquad (5)$$

TABLE II. MODIFIED ARABIC (ISO-8859-6)

<table>
<tr><td>ض</td><td>ص</td><td>ش</td><td>س</td><td>ز</td><td>ر</td><td>ذ</td><td>د</td><td>خ</td><td>ح</td><td>ج</td><td>ث</td><td>ت</td><td>ب</td><td>أ</td></tr>
<tr><td>1</td><td>0</td><td>ي</td><td>و</td><td>ه</td><td>ن</td><td>م</td><td>ل</td><td>ك</td><td>ق</td><td>ف</td><td>غ</td><td>ع</td><td>ظ</td><td>ط</td></tr>
<tr><td>&</td><td>%</td><td>$</td><td>#</td><td>"</td><td>!</td><td></td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td></tr>
<tr><td>?</td><td>></td><td>=</td><td><</td><td>;</td><td>:</td><td>/</td><td>.</td><td>-</td><td>,</td><td>+</td><td>*</td><td>)</td><td>(</td><td>'</td></tr>
<tr><td>-</td><td>؟</td><td>؛</td><td>،</td><td>~</td><td>}</td><td>|</td><td>{</td><td>`</td><td>_</td><td>^</td><td>]</td><td>\</td><td>[</td><td>@</td></tr>
</table>

In the second step, the resulting two-character pairs (S) are converted back to one character by substituting the corresponding letter from the original Table 2. The intersection of right index *(r)* and top index *(c)* determines the letter being substituted as defined in Equation 6. Likewise, the whole encryption process is repeated for each plain text character in the same way until the end of the plain text message.

$$(mi,j) = \mathrm{S} = (\mathrm{ri}||\mathrm{cj})) \qquad (6)$$

The decryption process works the same as the aforementioned encryption process but in reverse order.

B. The Algorithm Steps

The whole algorithm is clarified by steps, pseudo code and examples. A detailed explanation is shown with examples in the following section:

The encryption algorithm consists of the following phases:

1) The initialization phase that consists of the following steps:

a) The keyword selection: The keyword selection is the choice of the user and it is recommended to meet the following properties.

i. The Keyword characters should be selected from Table 2.

ii. The *Keyword* length is recommended to be not less than ten-character long and to contain a mixture of characters.

iii. After algorithm calculations, the *Keyword* characters should be unique (i.e. each character appears only once, sans duplicates).

Example: the Keyword "@؟12 بسم الله" becomes "بسم اله@؟12".

b) The Keyword calculations: The calculations are performed as in Equations 3 and 4:

i. The *keyword* characters' weights

Example:

Σ	@	؟	1	2	هـ	ل	أ	sp	م	س	ب
298	60	59	29	30	25	22	0	38	23	11	1

ii. The *keyword* summation modulus 75 is computed as in Equation 3.

Example:

KP= 298 mod 75=73,
where the *keyword* starts

iii. The *keyword* summation modulus 28 is computed as in Equation 4.

Example:

KP= 298 mod 28=23, where the ABJAD alphabets start from "ص"

c) The table reconstruction: The table reconstruction is built as follows:

i. The *keyword* inside the table starts from the position determined by computing the system modulus 75.

298 mod 75=73, where the *keyword* starts

ii. Filling the tables from the rest of the non-contributing characters in the *keyword* is continued.

d) The indexes reconstruction: In this step, the right (r) and top indexes (j) of the table are reconstructed as follows:

i. The starting letter of the ABJAD alphabets is determined to build the right and top indexes.

298 mod 28=23, where the ABJAD alphabets start

ii. The ABJAD alphabets are written starting from the last r5 then backward until c1.

2) The encryption phase in which the encryption is performed in two rounds:

a) Round-1, one to two characters substitution: Each single character from the plaintext is substituted with two-cipher characters from the first reconstructed table.

b) Round-2, two to one character substitution: The resulted two-cipher characters are substituted with one cipher text character from the second reconstructed table.

In the abovementioned example, the encryption of the plain text "جامعة" is encrypted in two rounds.

i. In the first round, each plaintext character is substituted with two characters and the resulted text is "توثضخذخوضج".

ii. In the second round, the resulted text is substituted (encrypted) with one ciphertext and the resulted ciphertext is "ستأمج".

3) The decryption phase in which the decryption is performed in two rounds:

a) Round-1, one to two characters substitution back: Each single character from the cipher text is converted back to two characters from the first reconstructed table.

b) Round-2, two to one character substitution back: The resulted two-cipher characters are converted back to the original plain text characters from the second reconstructed table.

In the decryption process, the ciphertext "ستأمج" is converted back to its original plaintext characters in two rounds:

i. Round-1, in the ciphertext "ستأمج", each character is converted back to its two-characters equivalent from the second reconstructed table and the result is "توثضخذخوضج".

ii. Round-2, in the ciphertext "توثضخذخوضج", each two-character pairs was decrypted back to its original plaintext and the result is "جامعة".

IV. Discussion and Analysis

The research encryption algorithm is neither classical nor modern; it is better classified as a hybrid approach for it employs mathematics and is inspired by modern encryptions.

The number of the alphabets in Arabic language is more than in English. Thus, the use of 75 characters that are randomly distributed in the modified table MM(mi,j) makes the algorithm better in terms of the attack-resistance than many of the other known modern encryptions.

The algorithm analysis complies with the most common types of attacks like the cryptanalysis and the brute-force attacks. In the brute-force attack, the attacker tries every possible key until an intelligible translation of the ciphertext into plaintext is obtained [18]. The brute-force attack requires that three items should be known by the attacker: the encryption algorithms, the language of the plaintext and the number of the possible keys that could be generated [25].

In our work, to break the key, all the resulted alphabet diagraphs need to be obtained which means that you neeed to choose among the 75 characters minus the keyword length multiplied by the 28 possible characters from the ABJAD alphabets. The mathematical combinational formula (*n choose r*; *C(n,r)*) is the best formula to describe our results. To make it clear, this formula is used when the chosen characters do not need to be repeated and the order does not matter [26]. The formula is also called the Binomial Coefficient as defined in equation (7).

Example: If we choose a keyword of n-character length, the number of possible generated diagraphs (combinations) to break a single letter is calculated according to the following formula:

$$\boldsymbol{Diagraph\ D} = \frac{\boldsymbol{n}!}{\boldsymbol{r}!(\boldsymbol{n}-\boldsymbol{r})!} \qquad ..\ (7)$$

Where D is the result, n is the set of characters to choose from, and r is the chosen character.

Example: Suppose the keyword length n=15.

$\text{Diagraphs} = \frac{75!}{15!(75-15)!} * 28 = 6.38\ \text{X}\ (10)^{16}$ = 63840355228050240 which is more than 63 quadrillion diagraphs.

If we assume a supercomputer that is developed by China's National University of Defense Technology [27] and is with 33.86 Peta-flops (33.86 quadrillion operations/second) that has been used to crack the fifteen-character keyword, then this process will take approximately about $5.9\ \text{X}\ (10)^{37}$ years to break the keyword.

$$\text{Time in Years} = \frac{6.38\ \text{X}\ (10)^{16}}{33.86\ \text{X}\ (10)^{15} * 365 * 24 * 60 * 60} = 5.9\ \text{X}\ (10)^{37}\ \text{Years}$$

In the cryptanalysis attack, using the language characteristics to attack the ciphertext is unfeasible since the encryption algorithm passes through two rounds of encryptions that are previously explained. Hence the attacker will not get benefits of language frequency and language characteristics since the relationship between letters will disappear. For example, the two and three letters that appear together like "ال" or "نيه" will be scrambled and converted to different alphabets in each sub-process. This is also valid for the letters frequency analysis since it is hard for the crypto analysts to get benefits of letters frequency because each letter will not be encrypted to the same cipher-text. That is to say, it will be encrypted to a different cipher-text in each sub-process of the algorithm.

The encryption process guarantees randomness of the table distribution since the same character will be encrypted differently each time. Thus, hackers are not able to get benefit of having two or three combination letters that usually come together since each letter is encrypted separately and independently. By nature, the encryption algorithm disseminates and hides the language characteristics and letters frequency.

We performed some experiment measures to compare our algorithm speed with the well-known algorithms (AES and DES). We used the open source library Crypto++ for C++ programming language on a laptop core i5, 2.5 GHz CPU with operating Windows 7 operating system and we used six different plaintext data size. The collected performance metrics are the encryption and the decryption time.

The encryption speed chart in Table 3 shows that our algorithm speed outperforms the other two-encryption DES and AES algorithms. In the comparison chart (the encryption chart), our algorithm is faster than the DES and the AES in the encryption process especially when the data size gets larger in size.

TABLE III. THE ENCRYPTION TIME

Plaintext Size/KB	DES	AES	Ours
15	3.8	5.07	2.08
30	7.5	17.09	4.2
45	8.5	19.96	5.7
60	8.8	22.91	6.1
75	9.33	29.99	7.4
90	10.7	38.15	8.3

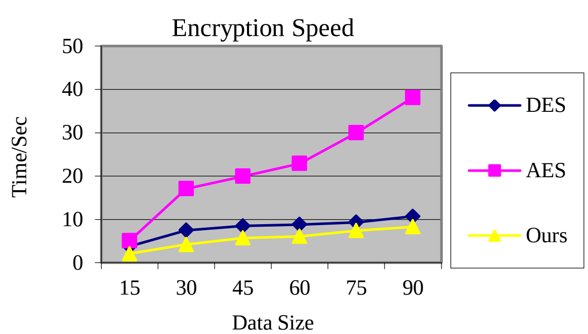

Fig. 1. Encryption Speed.

The Encryption and Decryption speed are shown on Table 3, Table 4, Figure 1 and Figure 2. All the tables and figures show that our algorithm is faster than the DES and AES decryptions especially when the data size grows in size.

TABLE IV. THE DECRYPTION TIME

Plaintext Size/KB	DES	AES	Ours
15	3.6	4.09	2.2
30	4.4	17.04	4.6
45	8.3	19.85	5.9
60	8.9	22.8	6.5
75	9.4	30.3	7.9
90	10.6	38.4	8.6

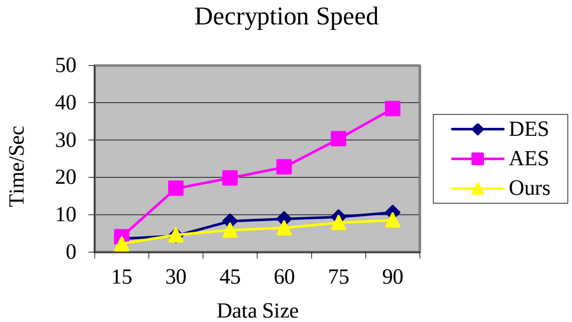

Fig. 2. Decryption Speed.

The proof of concept used in this work aims to confirm that Arabic language can accommodate new technologies especially the encryption which is essentially an Arab-born science. The algorithm uses a shared-key classical encryption technique and gets benefits of mathematics and the spirit of modern encryptions, the fact that assures the flexibility and adaptability of Arabic language and encourages researchers from the Arab world to pay more attention to Arabic-based encryption techniques. The main contribution in this work is designing a new encryption algorithm that is based on the ABJAD-order Arabic alphabets and employing the Modified Arabic (ISO-8859-6) to perform the encryption/decryption processes. The new algorithm is resistant to the brute-force attacks and can relatively perform fast and secure encryption/decryption processes.

V. Conclusion and Future Work

Arabic language has special features that could be positively employed for the benefit of developing cryptographic algorithms specially designed to Arab nations. The research shows that Arabic language can be reactivated to generate more Arabic-based cryptographic techniques that could be used to serve the Arab community.

The results of the research project prove that the presented algorithm is hard to break using brute-force attack; it needs a very long time to obtain the key or to decrypt the message. The Cryptanalysis attack is also very hard to be used since the letter frequency and language characteristics disappear.

In the future, the cryptographic algorithm could be generalized to be used in any other language and will not be limited to Arabic language. The algorithm can also be expanded to include more characters, symbols from other languages, data types and file formats that could be flexibly included. Moreover, other enhancements could be added to the algorithm like rounds of substitutions and permutations in addition to a keyword dynamic change in the encryption process.

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References

[1] Yahya Meer Alam, M. Hassan at-Tayyan Mohammed Mrayati, al-Kindi's Treatise on Cryptanalysis.: KFCRIS & KACST, 2003.

[2] Monica Borda, Fundamentals in Information Theory and Coding.: Springer, 2011.

[3] Yaḥyá Mīr ʻAlam, M. Hassan At-Tayyan. (et al) Muḥammad Marāyātī, Al-Kindi's treatise on cryptanalysis. Riyadh: KFCRIS & KACST, c2003.

[4] Yahya Alqahtani Prakash Kuppuswamy, "NEW INNOVATION OF ARABIC LANGUAGE ENCRYPTION TECHNIQUE USING NEW SYMMETRIC KEY ALGORITHM," vol. 7, no. 1, 2014.

[5] Haifaa Abdul-Zahra Atee, "DEVELOPMENT OF A NEW WAY TO ENCRYPT THE ARABIC LANGUAGE LETTERS USING THE SYMMETRIC ENCRYPTION SYSTEM," no. 1818653X , 2011.

[6] Ibn Tabataba Treatise Cryptanalysis of Arabic Poetry, "Bushra Mohamed Elamin Elnaim, Hayder Abood S. Wsmi Al-Lam," vol. 5, no. 2, 2017.

[7] Lidong Chen, Dr Özgür Dagdelen (et al) Matthew Campagna, "Quantum Safe Cryptography and Security, An introduction, benefits, enablers and challenges," 979-10-92620-03-0, 2015.

[8] Peter W. Shor, "Polynomial-time algorithms for prime factorization and discrete logarithms on a quantum computer," SIAM, vol. 41, no. 2, pp. 303-332, 1999.

[9] Nitin, et al. Jain, "Attacks on practical quantum key distribution systems (and how to prevent them)," Contemporary Physics, vol. 57, no. 3, pp. 366-387, Feb. 2016.

[10] Erik Dahmen Daniel J. Bernstein •Johannes Buchmann, "Post-Quantum Cryptography," 2009.

[11] British Council, "ARABIC LANGUAGE AND CULTURE CONFERENCE, PROMOTING THE TEACHING AND LEARNING OF ARABIC IN THE UK," Qatar Foundation, Doha, Qatar, Conference Precedding 2013.

[12] Yusuf Perwej, "Recurrent Neural Network Method in Arabic Words Recognition System," International Journal of Computer Science and Telecommunications, vol. 3, no. 11, pp. 43-48, 2012.

[13] Ibrahim A. Al-Kadit, "ORIGINS OF CRYPTOLOGY: THE ARAB CONTRIBUTIONS," vol. 16, no. 2, 2010.

[14] Aiden A. & Forcinito, Mario A Bruen, Cryptography, Information Theory, and Error-Correction: A Handbook for the 21st Century.: John Wiley & Sons., 978-1-118-03138-4.

[15] Prakash Kuppuswamy, Sikandhar Shah Yahya Alqahtani, "NEW APPROACH OF ARABIC ENCRYPTION/DECRYPTION TECHNIQUE USING VIGENERE CIPHER ON MOD 39," International Journal of Advanced Research in IT and Engineering, 2013.

[16] Mohammed Abdullah Aysan and Prakash Kuppuswamy, "HYBRID COMBINATION OF MESSAGE ENCRYPTION TECHNIQUES ON ARABIC TEXT: USING NEW SYMMETRIC KEY AND SIMPLE LOGARITHM FUNCTION," International Journal of Scientific Knowledge, vol. 5, no. 5, pp. 37-41, Aug 2014.

[17] Friedrich L. Bauer, Decreypted Secrets Methods and Maxims of Cryptology, 1st ed. Munchen, Germany: Springer, 1997.

[18] William Stallings, Cryptography and Network Security: Principles and Practice, 7th ed.: Pearson, 2017.

[19] Khalil Shihab, "Arabic and Multilingual Scripts Sorting and Analysis ," in 6th WSEAS International Conference on Applied Informatics and Communications, Elounda, Greece, 2006, pp. 157-162.

[20] Irv Englander, The Architecture of Computer Hardware, Systems Software, and Networking: An Information Technology Approach, 5th ed.: Wiley, 2014.

[21] Husni, and Chris Mellish Al-Muhtaseb, "Some Differences Between Arabic and English: A Step Towards an Arabic Upper Model," in 6th International Conference on Multilingual Computing, 1998.

[22] M. V. McDonald, "The Order and Phoetic Value of Arabic Siblants in the "ABJAD"," Semitic Studies, vol. XIX, no. 1, pp. 36-46, March 1974.

[23] Alain George, "Calligraphy, Colour and Light in the Blue Qur'an," Journal of Qur'anic Studies, vol. 11, no. 1, pp. 75-125, 2009.

[24] ISO/IEC JTC 1/SC 2. (1999, Dec.) International Organization for Standardization. [Online]. https://www.iso.org/standard/28250.html

[25] Seymour Bosworth et al., Computer Security Handbook, 6th ed., M. E. Kabay (Editor), Eric Whyne (Editor) Seymour Bosworth (Editor), Ed.: Wiley, 2014.

[26] Waits, Foley, Kennedy Demana, Precalculus: Graphical, Numerical, Algebraic, Teacher's Edition, 7th ed.: PEARSON, 2007.

[27] Shawon S. M. Rahman, Tanvir Ahmed Shaon Abdullah Al- Mamun, "Security Analysis of AES and Enhancing its Security by Modifying S-Box With an Additional Byte ," International Journal of Computer Networks & Communications (IJCNC), vol. 9, no. 2, pp. 69-88, 2017.

Negotiation as a Collaborative Tool for Determining Permissions and Detection of Malicious Applications

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***Abstract*—In Android OS users find it very difficult to understand and comprehend its permission mechanism. Frequently, users tend to ignore permission negotiations dialogs during installation of an application. Users, who pay attention to the permission negotiation dialogs, find it tough to comprehend the description and evaluation of permission procedure. They do not know the impact of granting these permissions on their data. One major issue is that user is unaware about how application uses their data. He has no insight after granting permission to the application and effect of these permissions on his data's privacy and security. This research reveals that discrete permission settings are helpful for user to secure his device resources and data. This study uses a distinct technique to detect danger of unnecessary permissions. It helps end users of Android OSs to understand the problems and provides them batter way to deal with the problems and grounds to explore alternatives.**

Keywords*—*Collaborative learning; intrusion detection; mobile applications; information security; web based learning

I. Introduction

Smart phone is becoming most widespread device in the world used for different purposes. The cloud storage is easily accessible, proficient for performance and data storage makes mobile as a primary computer for numerous end users. Many mobile operating systems (OSs) and platforms have become popular during past few decades. The integration of mobile phone, internet, and peculiar computation has resulted in the appearance of the smart phone. Symbian's, iOS, and Android are very popular OSs. The demand of smart phone is increasing every year. Universal growth in the consignment of the smart phone is approximately 17% each year.

Android is most widely used OS in mobile phones because of its open source frame work. Its open source makes its customization easy for smart phone companies to accomplish their features and pricing requirements for their targeted group of users. It is a feature rich platform for application developers for building applications. It is the OS for large number of smart phone devices in more than 192 countries all around the world. Its growth is increasing day by day. Well renowned brands have started using Android in their smart phones. In this study, we focus on Android due to its abundant use all over the world. Main reason for increasing use of Android OS is that it is very easy to use, even common less educated users can use and comprehend its functionalities easily. Users can easily install applications for Android from different market places. It is very easy to install any third party application without any major modification in the Android frame work to fulfill ones need and requirements while other platforms do not provide such freedom. Android is open source which has more fairness to software developers and end users mainly focusing on three key philosophies: durability, clearness and ownership. For software level, they aim to enhance durability by supporting their product for as long as possible. Android's goal for transparency includes making software as open as possible, making users more aware of the data they are sharing, and giving them more control over their applications. It is believed that the phone is yours, and your data belongs to you.

The security features of Android applications are components protection, type safety, permissions and memory management unit [1].

Centralized approach for end users allows them to search applications quickly to satisfy their needs however, this is useful for distributors also. It is devastating for the operators of this open market to accurately scrutinize their genuine intent of applications uploaded onto the marketplace. Applications of third parties run on Android and can increase the risk of security [2]. Therefore, centralized market has made an environment easy for malware developers to exploit many potential victims. Several smart phone applications like Google Play Store, which is most popular of them, provides end users a choice of either programmed or manual updates for the applications that are present in market.

Operating systems have more aggressive permissions than desktop apps and can increase complications in user's decision taking procedure about smart phone applications updates [3]. People can use your GPS to estimation for example what time you are not at home; this fact can put you in danger. By default some applications gain read and write access to the address book, which permits hackers addition of a reprobate email address to existing email addresses and receive email correspondence. At present, there are several Android applications in market that uses the Android smart phone as a security surveillance camera, e.g. Android Eye, these malicious camera applications can periodically check the screen state and run the stealthy video recording only when the screen is off,

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which means that the user is not using the phone and the camera device is idle [4].

In this paper, the proposed technique will check additional permissions at application installing time. Some techniques have already been proposed during recent researches that work at installation time of an application [5-6]. Customized installer Apex allows to selectively giving permissions at installation stage [7]. However, it gives right of decision to the end users which is very complex for end users because of lack of comprehension of the permission systems. In the same way, Kirin and Saint both proposed a security policy for making automatic decision at the time of installation [6] [7]. Security policy on the bases of Prolog is used by Kirin and Saint using security rules stored in database. Both these techniques do not give permissions for advanced end users. These tools by no means collect end users views about expected service from the applications.

Current permission systems are ineffective due to two main reasons; firstly most of the users of Android OSs are inexperience and secondly the description of permission is very technical for novice users. They do not understand the whole process of granting permissions. This research provides user flexibility for sharing their date. Users can manually allow or deny permissions for an application. To understand the complexity of the permissions descriptions, risk factors are calculated using risky permission combinations. Proposed frame work increases the understanding of the users regarding to the permission mechanisms used in Android OS. This framework also helps to find malicious applications in Android market which uses excessive permissions.

Rest of the paper is organized into different sections. Section II presents literature review. Section III highlights the methodology. Proposed algorithm is presented in Section IV and proposed application is discussed in detail in Section V. Section VI presents the design of survey questions and Section VII consists of results and discussion along with comparison of our proposed scheme with different applications vulnerable of different attacks. Section VIII and Section IX consist of findings of user survey and analysis, respectively. Conclusion and future directions are highlighted in Section X.

II. Literature Review

Permissions of Android are used basically for two purposes. Primarily OS used them to access certain functions of an application and secondly is to convey that information to the user. A researchers group at Berkeley formed a software package to map the permissions an application is requesting for to the permissions that are in fact presented to users [8]. The objective was to determine if apps are using characteristics that they are not revealing to the users in the permission rules. The research found that about one-third of the 940 applications the researchers considered were using permissions that were not making known in the permissions offered to users. The researchers found that in most cases the applications were only missing a few permissions in their disclosures and as a result came to the conclusion that in most cases these are probably simply errors of documentations. Their results show that applications generally are over privileged by only a few permissions, and much extra permissions can be attributed to developer's confusion. This indicates that developers attempt to obtain least privileges for their applications but fall short due to application programming interface (API) documentation errors and lack of developers understanding. The researchers concluded that application developers most likely misunderstood the connection between the functioning of the application and disclosing those functions to the users [9]. A further question is that even if the permission policies were constructed correctly, do users actually read or understand them?

Since 2008 updates for Android OSs are apparently regular, compared to their PC matching part as there have been twenty five firm issues. Over the air (OTA) fresh version brings up to date meaningfully variations in the standing version by adding and amending large quantity of files through Android platform certifying uprightness of current user data and applications [10]. New variety update is assisted from end to end a service called package management system. Previous research completed a broad revision of pileup susceptibilities that can be misused by malware applications in case of new version improvements. For example, older version can declare dangerous permissions in AndroidManifest.xml that has been introduced in next version. All through in update process, Android does not ask users to verify newly active permissions in that current application and awards them automatically. Thus, it affects the security of the Android device.

A programmer implements permissions inside the API package and for the duration of application installation all of these permissions are presented to end users. On the bases of those presented permissions, end users have to make decision either the application is malevolent or benign. It seems big policy fault to ask the users decide the nature of applications by purely looking permissions used by the application.

The fundamental point is that the users are not the only stack holders but they are simply a part of the entire process. End users just scan application permissions where the critical goal is to filter the application at a number of layers. It looks good decision but the most important demand is whether the layer is operative in its job. Basically adding a number of safety layers could not do anything without those layers are carrying out their tasks. Previous studies mostly estimate user's responsiveness and understanding of concerning permissions [9]. From study they tested if end user gives any consideration to Android permissions in advance to installing an application, they also tested that the user can comprehend how these permissions link to an application license. They viewed very low proportion of consideration. Many of the end users are totally heedless of permissions. Those who has knowledge of permissions to some extant also does not pay any consideration and saw a very small fraction of comprehension. Those end users who noted permissions while installation achieved superior in comprehension than rest of the others. They determined that the mainstream of Android handlers do not give consideration to or know permissions cautions.

Two most interesting facts observed are that those users who have more understanding of permissions installed applications from Google play store, while others used unofficial application stores. Secondly they are not aware of security consequence [9]. Assuming these two situations, we have enthusiasm in that the end users will show extra consideration to permissions if they are conscious of security consequences.

The results of previous studies do not show complete failure or success of the current securities policies. Some of the participants of the studies understand the permissions, but they are very small in numbers, and are likely to proliferate with time, awareness and education [11-14].

In this research, our main focus is to increase the comprehension of permission mechanism of Android applications. Users do not understand the permissions usefulness by their observations only. This research calculates risk factor involved in permissions of an application during installation, where many permissions are not risky when they are used in a package alone. But they become risky when they are used in combination with other permissions. This research investigates combination permissions.

III. Methodology

The proposed research technique consists of two main steps. In first step, we compare common take it or leave it approach with the collaborative permissions approach. In this step, we also detect the malevolent Android applications using permissions change procedure during updates.

Second step of this research calculates risk factor of Android third party applications by using combination of permissions to enhance the knowledge of end users. Mostly permissions are not risky when these are used alone by any application. For example access contact list permission is not risky when any application uses this permission without using any network group permission (e.g. internet permission). It will become risky when both internet and access contact list permission uses at the same time as a combination in an application.

The objective of the risk factor function is to provide assistance to end users of third party Android applications to decide if they want to use specific applications on their devices. It can help them for selecting any application having fewer security implications and assist them in selecting any application with other parameters such as total number of downloads, assessments and mouth references etc.

Package manager of Android permits end users to retrieve all those permissions which are requested by Android applications during installation procedure. To estimate risk factor using these permissions needs an algorithm. If risk factor of every permission is considered same than any application which has less number of permissions are more secure than others but all permissions are not risky and do not breach the security of smart phone.

Classic take it or leave technique provides less flexibility for the end users of the Android applications. It has more chances to attack by the malware using permissions oscillations and application update attacks by changing the manifest file during updating applications. To avoid such situation, hashing functions are used. For calculating hash of permissions and compare values with the previous stored values in the database, SHA512 hash function is used. For any case of mismatching in hash values, it is declared that application has a malicious intent and prompt users to take appropriate action. Users have choice to revoke permissions or continue.

This research is conducts on Android, most popular OS for handheld devices. That is a fast growing OS. Aim of this study is to make end users aware about what the excessive permissions in an application do without the users concerns. Users are not focusing on the security implications of third party application distributers. Those are taking the advantage of the user's ignorance and steal their information and share that with third parties and generate revenue for distributors and developers.

This research falls under clearness and ownership. It starts with the intention to make users clear about the risk factors that are hanging over the Android users while using third party Android distributor's applications. It then makes them able to understand security implications of Android applications. The end users can revoke Android permissions of any installed application as per their needs and desires. In current version Android permissions are categorized in to different set of permissions, user of the device has only option to allow or deny that specific set of permissions that is under the normal security tag.

Core research objective is to enhance the usability of the Android permission systems in order to increase user awareness and comprehension with respect to security and privacy. Such as:

1) How can Android permissions be translated into something that is easy to understand?

2) How to use them for raising responsiveness on security of the Android users?

3) Do these modifications raise attentiveness and comprehension in users?

IV. Proposed Algorithm for Finding Malicious Combination

In this paper, we propose an algorithm that focuses on malware detection by using excessive permissions only. We believe those combinations are risky which has any dangerous permission in it, see Algo. 1. Here p is permission used by Android application. $dPcomb$ represent all combination in which dangerous permissions are present. To calculate risk factor we use Eq. 1 for all dangerous permission combinations.

$$Risk\_factor = [\{dPcomb / (dPcomb + N)\} * 100] \quad (1)$$

Here N is the number of other permissions which are less dangerous. As an alternative of minor permissions, total numbers of combinations affect the risk factor. This research looks at combinations of permissions that can be possibly dangerous.

ALGORITHM 1. *MyPrivacy*

```
Input:   All application permissions
Output:  List of dangerous permission combinations
dPcomb=0
P_Comb_List←All applications having p>2
For each comb P_Comb_List do
        if comb has dP then
                dPcomb (comb) = dPcomb (comb) + 1
        else
                dPcomb = dPcomb
        end if
end for
```

V. Proposed Application Detail

We propose an application called MyPrivacy, it contains two main modules. First calculates hash value and compares the hash value stored in the database for detection of malicious application. Hash value is calculated using SHA512 hash algorithm.

Secondly, user might discover that an application uses a particular permission excessively using risk factor calculation. For example, an application that has access to your contacts keeps reading them out every day at noon. By using our proposed application the user might know that this behavior is unnecessary and indicates suspicious activity.

A. *Interface Structure*

This research is used to build an expressive consensus tool for Android OSs. It is an investigational tool which is used to detect malwares and also enhance the knowledge and understanding about the user's security of smart phone. During installing or execution of application user asked which data he wants to share.

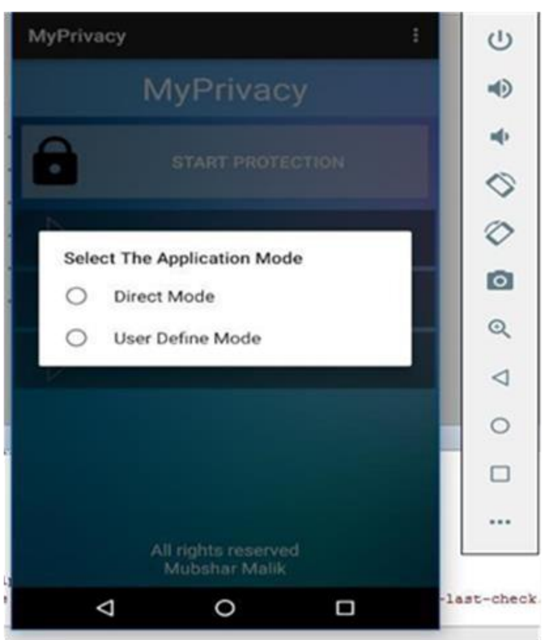

Fig. 1. Main Screen of Myprivacy Application.

The volume of data and fact is being shared affects the privacy of the user. The more volume user chooses to share the more chances of security breaches. This research chooses a permissions set that are mostly requested by applications in two events, settings and assessment of initial user study, see Fig. 1.

1) Settings: In this section privacy settings are displayed to the end user. These settings define permissions and the type of data end users are agreeing to share. The implementation of these settings is of two different modes; direct and user define.

a) Direct mode

Before Android 6.0 individuals must agree to all permissions for installation of an Android application. Users have only option to accept or deny permissions. If user denies then application does not installed. Accepting permissions is mandatory for installation of application. Installation of application is aborted without accepting permissions. User cannot change permissions, only option is to uninstall application to revoke permissions.

b) User define mode

Main objective of designing the customize mode is to allow end user to collaborate with OS for application permissions to access their personal data. User has option to give or revoke permissions at any time when he wants to change.

Based on the given permissions, risk factor of the application is calculated, which shows user how much his security and privacy is affected by the application which he wants to install. It makes very easy for user to decide which permission or combination of permissions is risk for his security. This mode is dual purpose. Firstly, it provides end users complete awareness of the penalties and consequences of the selected permissions. Permission settings make it solid and important to the user. Secondly, it permits to measure level without a doubt and equates different collaborative designs. Permissions selection is shown in Fig. 2.

c) Understanding and comprehension of study process

We test permissions set of common Android applications. Study procedure was comprehensible to participants and they were alert of the selections that have been asked to do. In precise, our investigational design needs that participants should consider their selections have honest privacy significances and impacts.

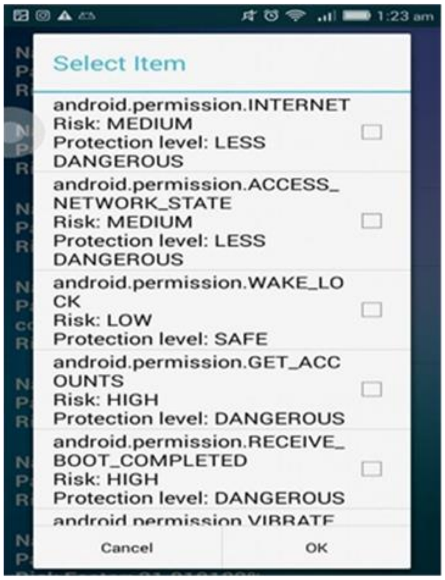

Fig. 2. Permission while using User Define Mode.

d) Suitability of selected statistics

We test if the application is trustworthy and the data random sampling is a part of the application, in fact gathering possibly sensitive material that would provide participants cause to ponder twice about the probable significances of publication of data.

2) Initial user study: This research performed initial test with the core purpose to inspect three key factors:

a) Insight to participant reaction

We desire to increase primary insight into the choice building procedure of our participants. Specifically, we are interested in features of gathering data or probable concerns are taken by members as they assess. However, whether or not they desire to share certain categories of individual fragments of facts with others.

In this research, we conduct a study to investigate key factors affect the security of Android OS and end user. The gap between user understanding and permissions policy is the major risk for Android application.

VI. Design of Survey Questions

In survey, we asked ten questions to the participants about method they are using while installation of new application or during application update. Ten questions were asked in survey about method they use and prefer as well as the effectiveness of Google Play's current application installation method.

Users were inquired how frequently they install applications and method they choose for installation. Participants were provided with options such as, "I feel safe using this method," "My phone's OS does support other methods," and "For each case I use different method". These interrogations give us comprehensions about users' behaviors and how they are involved with application installation.

Participants were also inquired about their experiences with application installations principally in situations they select method or they regret on any installation.

From these user know-hows, we can judge whether existing methods of installation of applications are useful and helpful for positive decision making.

Participants inquired which elements influence the decision making procedure for application installation. In this research users are asked about the factors like author, application store, number of download, application trust etc.

These outcomes help us to gain insight in planning application updates and installation and factors we should focus on. Other information we collected are age, gender, Android experience and education.

A. Deployment of Survey

To deploy this survey, those participants were selected who fulfilled the following conditions. Age should be more than eighteen years, he or she should understand and read English language and at least 3 months of experience of Android usage with other application stores and Google play store.

B. Analysis of Survey Data

In our survey both multiple choices as well as open questions are asked by the participants, and both types of questions are analyzed contrarily. At first we analyzed answers of the multiple choice questions. Percentage of each selection is computed for getting insight about user's application installation behaviors and approaches toward application update.

For the evaluation of our application think-aloud study is used with independent participants who were requested to install application and use it. After gathering basic demographic information, we requested each participant to install 12 applications. Six applications using direct mode and rest using customized mode that has collaborative interface.

In order to provoke diverse responses we offered the participants with changing pricing setups, in which the combination or grouping of permissions was appreciated contrarily in terms of risk factor.

Participants observed similar pricing factor in both strategies and design. In each case, they interrelate interchangeably with the review settings activity.

We asked users how they install application. They were provided choice to install application using take it or leave mechanism or negotiation permission granting policy. Responses of these questions provide us insight the behavior of users that how they are involved in security mechanism of application and the factors they think are affecting user security [15-17].

Participants asked to share their experience during installation of third party applications and if they have any difficulty for installation of an Android application. Respondent were questioned about factors they think affect their decision making.

VII. Results and Discussions

For experimental purpose we built a database of downloaded Android applications from Google play store. These are 1000 prominent applications from 30 categories shown in Table I. From un-trusted sources we have downloaded cracked version of those applications to examine the accuracy of proposed technique using sample of malicious applications. Cracked versions of top paid Android applications are also downloaded. Table II shows the most frequently requested permissions.

TABLE I. Application Categories and Average Number of Permissions

Category	Average Permissions	Total number of Application
Communication	23	56
Games	4	89
Finance	2	12
Media & Video	10	43
Entertainment	9	32
Family	4	17
Photography	16	34
News & Magazines	18	76
Social	30	43
Tools	12	59
Lifestyle	12	53
Comic	9	10
Medical	15	21
Music & Audio	14	82
Education	9	78
Personalization	19	4
Productivity	18	17
Health & Fitness	17	28
Sports	10	16
Transport	13	15
Travel & Local	24	31
Shopping	15	10
Weather	11	14
Others	9	160

This research has two parts, first is detection of malicious applications, and second is to increase the knowledge of users by computing risk factors of applications and providing run time permissions for Android applications. As discussed in literature many malware families can steal data of user of mobile phones.

For detection of malicious applications, this research developed direct mode in our prototype which is designed for analysis. We installed different applications from Android play store and their cracked versions form third party application stores in direct mode. We found that detection rate of our technique is encouraging. Results of this comparison are shown the Table III. We can see that our scheme detected malicious and cracked applications in utilities with at least 91% accuracy rate. It gives maximum accuracy 98.5% in social media category.

TABLE II. Most Requested App Permission and Percentage in Play Store

Permission	What application does after installation?	Percentage of permission	Access resource
Full network access	It established a network outlet using protocols of routine network. It provides applications and browser resources to send data over the internet.	83%	Hardware
View network	information about network connections such as which networks exist and are connected	69%	hardware
Modify contents of your USB storage	It writes to the USB and allows writing on the SD card.	54%	User info
Read phone status and identity	This permission allows the application to determine the phone number and device IDs, whether a call is active, and the remote number connected by a call.	35%	User info
Precise location	Apps may use this to determine where you are, and may consume additional battery power	24%	User info

TABLE III. Application Categories and Detection Rate

Application categories	Cracked Apps	Detection rate
Social media	20	97.5%
Games	20	94%
Media and videos	10	97%
Entertainment	10	96%
Utilities	10	91%

C. Attacks

1) Update via internet: Update via internet should be through authenticated web address that is written in Manifest.xml. If web address is not correct while updating an application, this behavior shows that the specific application have piece of malicious code in it and user of the smart phone should not update it. When any change of address is appeared in Manifest.xml of package our application detects it accurately.

2) Side installation: Our technique does not detect side installation first time but when once application is installed than it detects malicious and cracked applications with 100% accuracy.

Comparison of our technique with other techniques is given in Table IV.

Second part of our research is related to user understanding of application's permissions and to increase user knowledge and comprehension.

As in the point of contact, Android OS is a three-party association among the Google, user and developers of third party applications. The role of Google in this relationship is as a moderator between the third party developer and user of the application using permissions set for every application downloaded by user. Permissions are way of demanding designers to reveal how the application will be co-operating with the handlers of device and what resources the application will access.

In ecosystem of Android, the whole liability is on the designer of the application to select the accurate permissions that define to the end user what function application is undertaking. It does not mean to say Google is completely out in this process, but the initial phase starts with the developer of the application.

After completion of application built process, select the right permissions; generate the list by which users will ultimately agree, scanning of the application for malicious code, and malware is done by Google.

Our research is mainly related to the user's role in Android ecosystem. Mostly the users who are using Android systems are unaware of the risks that are compromising the security of user devices.

TABLE IV. COMPARISON WITH OTHER SIMILAR TECHNIQUE

Name of application	**Internet update**	**Side installation**	**Pre-crack Application**
Anti-malware	No	No	No
Anomaly malware Detector	No	Yes	No
Malbee Malware Scanner	No	No	Yes
Droid Dream Malware Cleaner	No	No	No
MyPrivacy	Yes	Yes	Yes

VIII. RESULTS OF THE USER SURVEY

Suitability of specific information and participants reactions enthusiastically tied up in the collaborative procedure. Every application is asking approximately 3 to 10 permissions for their installation on smart phone device. For experimental evaluation we conducted a survey and collected the data about the users' behavior and their understanding about the security of Android permission mechanism.

We collected approximately 120 filled questionnaires from the participants of this research study. Participants showed lot of interest for decision making in the permission granting procedure during installation of an application. They were also interested in reviewing their data and permission settings. Amongst the 120 participants about 65% of them are male, 35% are female, see Table V. About 14% of them are security experts, graduates are about 46% and 40% are undergraduates and the 25.5 years are average age of the participants, see Table VI. Fig. 3 shows how the education background and experience affects the decision making process.

We found that participants are very much interested in the application installation process and want to know how have permissions effect their data and how?

Analyzing their responses, 70% of survey participant's use take it and leave it policy because of the lake of understanding of permission systems, about 15% use their applications manually, 8% use certain applications manually and certain applications automatically, 7% of them have not known the whole process but they are also interested in reviewing their data and permission settings, see Fig. 4.

TABLE V. NUMBER OF RESPONDENTS WITH RESPECT GENDER

Gander	**Number of respondents**	
	Frequency	***Percent***
Male	78	65%
Female	42	35%
Total	120	100%

TABLE VI. NUMBER OF RESPONDENTS WITH RESPECT EDUCATION

	Number of respondents	
	Frequency	***Percent***
Security experts	17	14%
Graduates	55	46%
Undergraduates	48	40%
Total	120	100%

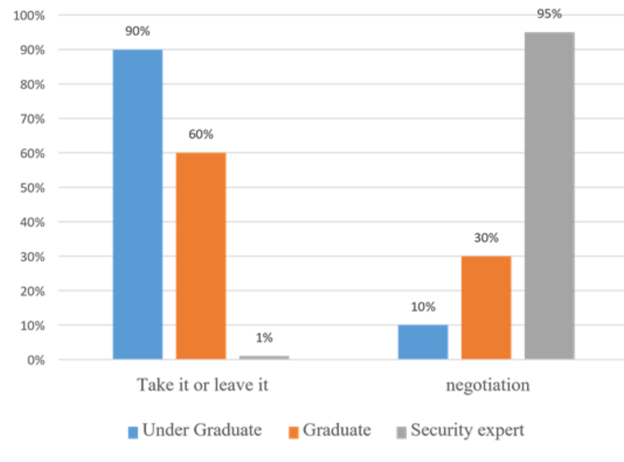

Fig. 3. Different Permission Mechanism used Percentage.

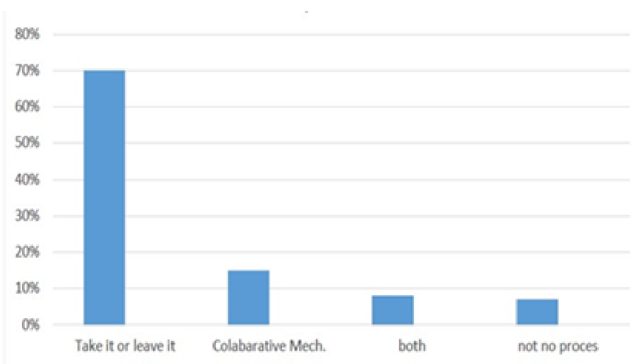

Fig. 4. Application Installation Mechanism used by the End Users.

A. Call Logs

Mostly the participants are very keen about the permissions related to their calls. They show lot of concerns about this permission and are not willing to share at any cost level. Some participants think that their calls are meaningless to others. But majority of the participants does not allow this permission.

B. SMS and MMS Messages

Maximum numbers of participants are anxious about sharing SMS and MMS messages. However, some participants do not show interest in SMS and MMS related permissions.

C. Read and Write in Memory

Reading and updating contents in the memory are most important permissions and participants of our study show huge interest in these. Any application permission that wants to access the storage area of the device is not granted by majority of the participants.

D. Location

Majority of the users are using applications that are using location information for providing them services like weather forecasting. They are comfortable to share location with server for getting services and they revoke this permission when they want.

E. Photographs and Contacts

Approximately all of the participants are reluctant toward photographs and contacts sharing. They show lot of reservations for sharing the photographs. They think no one have right of decision about the contact details of other people.

F. Cookies

No or minor concerns are raised about sharing of browsing history. Participants are comfortable to share browsing history to get the better recommendations. Although they know it is used for advertising purpose also.

IX. Users Analysis

This research observed five main observations into participant thinking throughout the study, which is although preliminary because the small user sample and period of study. Customized mode provides review of permission, which is easy for participants and allows them to instantly restrict sharing of their information and data.

A. Minute Knowledge of Permission

Participants have very little knowledge about permission demanded by the applications and effects of those permissions on security and privacy of the end users. Although well educated and experienced users who had knowledge of causes and effects are concerned about the security of their devices.

B. Collaboration of Permission is Favored

When the question is asked to the user which mechanism they prefer to use for installation and usage of applications mostly they want to use collaborative mechanism for permissions because of flexibility provided in use this mechanism. While using this mechanism they feel they have more control than ever before and feel more secure using customized mode rather than direct which is based on take it or live it policy.

C. Increase User Knowledge

Using combination of permissions, we calculated risk factor of applications. Application ranked malicious when risk factor crossed threshold which provides users insight of the application usage and help them in deciding process. Users become able to decide which application is malicious.

D. Education and Experience

Education and experience of Android affect the user security decision making procedure. Those who are highly educated make effective decisions related to their privacy and security.

Main drawback of this approach is that it shows those applications malicious which actually does not cause any malfunctioning. Quantitative results analysis of this research shows that social networking and game applications show high risk factors see Table VII. These applications share end users contact information to the server. These servers may use the information for advertising purpose.

TABLE VII. RISK-FACTOR OF INSTALLED APPLICATION

Package name	Risk-factor
Internet Browser	92.30%
Download Application	33.33%
Imo	77%
Candi Crash	89%
Face Book	85%
Contact Manager	91%

TABLE VIII. COMPARISONS WITH OTHER TECHNIQUE

System	Method of detection	Object detection	Layers	Side of working	Usage
Kirin [5]	Based on rules	Permission	1	Mobile	Lower
CrowDroid [18]	Based on behaviour	CallsofLinuxKernel	2	Server	Medium
DroidRanger [19]	Based on permission	Permission	2	Server	Higher
MyPrivacy	Based on permission	Permission and Hash value	3	Mobile	lower

Application contact manager may send your contact list to the server that affects the security of the end users. Users are very concerned about their personal information. We analyzed the applications which are freely available asks for more permissions than paid applications, free applications get about 20% more permission then paid ones. True caller is an application which gains information and stores it on its server.

The detection of risky intending is a procedure to screen applications that behave malevolently established on the exiting intention. Dependent on the desires of real situation this detection method can be reiterate over and over. Particularly, we compared and analyzed the performance of our proposed technique with other three classic malware detection systems including detection layer, detection method, resources usage and other five aspects. Here, the detection layer means the number of layers of malicious detection techniques to analyze the characteristics and usage specifies the detection techniques require using the total amount of the resources during working. As revealed in Table VIII the outcome of this comparison show that the proposed framework has obvious advantages in detecting efficiency, workload, number of layers, method of deployment and performance.

Android applications need user to approve permissions as a necessary condition for using an application. Such as hardware permissions that allow an application to fine tune the volume for user's phone. Sometime these are crucial for the primary functioning of an application. These set of permissions have inclusive effects for personal data. Some of the important outcomes of our analysis of the Android permissions include:

1) *Internet connectivity the most common permissions to get access in the smartphone*: Commonly these permissions help the applications to get access to the internet. The full network access permission used by 81% of application and permission view network connections are used by about 70% of application. The third is to get to memory access on the smart phone and fourth allows saving data to the device.

2) *The application of business and communication require more permissions*: Google divide applications into 41 diverse classes. Among them all categories business and communication classes request the maximum permissions to function.

3) *Large number of permissions are about hardware related information*: Permissions are placed into two comprehensive categories: 1) permissions for hardware functions 2) permissions for user information access. About 70 permissions could access user information whereas 165 allowed control some hardware function such as volume and vibration function or controlling flash of the camera.

X. CONCLUSION AND FUTURE WORK

Our novel technique seems better way out for finding of over privileged applications based on permissions model. It joins suitable fragments. Our technique enhances a computable appearance of the probable risk factor of an Android application.

Furthermore, the risk factor is established on intuitive division of permissions according to the risk category based on existing research and application category as well as proposed method. For working properly our technique does not require any permission or root access. Results we attained in this work considerably rest on formed rules in the suggested analysis methodology. Whole procedure was founded on independent view, which is revealed in these results. The attained results can be changed, if other constraints are used in this risk factor counting methodology with approved conditions, not the same lists of permissions, or dissimilar estimation functions. The current constraints notify the user of probable over privileged, and need his energetic contribution in identifying probable malware. Advance study in this field is necessary to improve the several parameters for a further automated over privileged and potential detection of malevolent applications in Android market places.

In future, data mining techniques can be applied for permission recommendations at the running time of an application on Android devices. This can automatically suggest permissions to the user, which can preserve user's security and privacy.

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CONFLICT OF INTERESTS

The authors declare no conflict of interests.

REFERENCES

[1] F. Al-Qershi, M. Al-Qurishi, S.M.M. Rahman and A. Al-Amri, "Android vs. iOS: The security battle," *in Proc. IEEE World Congress on Computer Applications and Information Systems (WCCAIS)*, 2014, pp.1-8.

[2] V. Rastogi, Y. Chen and W. Enck, "AppsPlayground: automatic security analysis of smartphone applications," *in Proc. ACM conference on Data and application security and privacy*, 2013, pp. 209-220.

[3] K.E. Vaniea, E. Rader and R. Wash, "Betrayed by updates: how negative experiences affect future security," *in Proc. SIGCHI Conference on Human Factors in Computing Systems*, 2014, pp. 2671-2674.

[4] L. Wu, X. Du and X. Fu, "Security threats to mobile multimedia applications: Camera-based attacks on mobile phone," *IEEE Communications Magazine*, vol. 52,no. 3, pp. 80-87, 2014.

[5] W. Enck, M. Ongtang and P. McDaniel, "On lightweight mobile phone application certification," *in Proc. ACM conference on Computer and communications security*, 2009, pp. 235-245.

[6] M. Nauman, S. Khan, A.T. Othman and S. Musa, "Realization of a user-centric, privacy preserving permission framework for Android," *Security Comm. Networks*, vol. 8, pp. 368–382, 2015.

[7] M. Ongtang, S. McLaughlin, W. Enck and P. McDaniel, "Semantically rich application-centric security in Android," *Security and Communication Networks*, vol. 5, no. 6, pp. 658-673, 2012.

[8] A.P. Felt, E. Chin, S. Hanna, D. Song, and D. Wagner, "Android permissions demystified," *in Proc. ACM conference on Computer and communications security*, 2011, pp. 627-638.

[9] A.P. Felt, E.S. Ha, A. Egelman, E. Haney, E. Chin and D. Wagner, "Android permissions: User attention, comprehension, and behaviour," *in Proc. Symposium on Usable Privacy and Security*, 2012.

[10] L. Xing, X. Pan, R. Wang, K. Yuan and X. Wang, "Upgrading your android, elevating my malware: Privilege escalation through mobile OS updating," *in Proc. IEEE Symposium on Security and Privacy*, 2014, pp. 393-408.

[11] R. Neissea, G. Steria, D. Geneiatakisb, I.N. Fovinoa, "A privacy enforcing framework for Android applications," *Computers & Security*, vol. 62, pp. 257-277, 2016.

[12] W. Wang, Z. Gao, M. Zhao, Y. Li, J. Liu, X. Zhang, "DroidEnsemble: Detecting Android Malicious Applications With Ensemble of String and Structural Static Features," *IEEE Access*, vol. 6, pp. 31798-31807, 2018.

[13] S. Arshad, M.A. Shah, A. Wahid, A. Mehmood, H. Song, H. Yu, "SAMADroid: A Novel 3-Level Hybrid Malware Detection Model for Android Operating System," *IEEE Access*, vol. 6, pp. 4321-4339, 2018.

[14] L. Wei, W. Luo, J. Weng, Y. Zhong, X. Zhang, Z. Yan, "Machine Learning-Based Malicious Application Detection of Android," *IEEE Access*, vol. 5, pp. 25591-25601, 2017.

[15] R. Riaz, S.S. Rizvi, E. Mushtaq, S. Shokat, "OSAP: Online Smartphone's User Authentication Protocol," International Journal of Computer Science and Network Security, vol. 17, no. 3, pp. 7-12, 2017.

[16] R. Riaz, T.S. Chung, S.S. Rizvi, N. Yaqub, "BAS: The Bi-phase Authentication Scheme for Wireless Sensor Networks," International Journal of Security and Communication Networks, 2017.

[17] R. Riaz, S.S. Rizvi, F. Riaz, N. Hameed, S. Shokat, "Analysis of Web based Structural Security Patterns by Employing Ten Security Principles," International Journal of Computer Science and Network Security, vol. 17, no. 10, pp. 45-56, 2017.

[18] I. Burguera, U. Zurutuza, and S.N. Tehrani, "Crowdroid: behavior-based malware detection system for Android," *in Proc. ACM workshop on Security and privacy in smartphones and mobile devices*, 2011, pp. 15-26.

[19] Y. Zhou, Z. Wang, W. Zhou, X. Jiang, "Hey you get off of my market: Detecting malicious apps in official and alternative Android markets," *in Proc. 19th Annu. Netw. Distrib. Syst. Secur. Symp.*, 2012, pp. 5-8.

Assessment of Groundwater Vulnerability to Pollution using DRASTIC Model and Fuzzy Logic in Herat City, Afghanistan

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***Abstract*—Groundwater (GW) vulnerability maps have become a standard tool for protecting groundwater resources from pollution because, from one hand groundwater represents the main source of drinking water, and on the other hand high concentrations of human activities such as industrial, agricultural, and household represent real or potential sources of groundwater contamination. The main objective of this study is to assess the groundwater vulnerable zones in Herat city, which is the second fastest growing big city in Afghanistan, using the DRASTIC model and fuzzy logic. DRASTIC is based on the seven data layers i.e. Depth of water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone and hydraulic Conductivity that provide the input to the modeling. The study shows that 51% of the city's groundwater is under highly vulnerable to water pollution. Validation of model showed that vulnerability map which integrated by kriging interpolated layers has better accuracy than inverse distance weighing (IDW) method. The study suggests, that the proposed model can be an effective tool for local authorities who are responsible for managing groundwater resources especially in Afghanistan and assigning rating value of DRASTIC parameters using inference system of fuzzy logic.**

***Keywords*—Afghanistan; DRASTIC; de-fuzzification; groundwater; modeling; vulnerability; herat**

I. Introduction

Most of GW related problems generally focus on the water contamination and quality reduction which depend to factors such as urbanization, industrialization, irregular use of fertilizers and pesticides in agriculture, nonstandard disposal of wastewater and increment of population. Groundwater quality protection is a vital and important theme specially, in high growing urban areas. because GW is the only major source of water for drinking and industrial activities. GW quality concerns can cause big problems for communities, if there is not be a specific and precise plan for protection and monitoring of it. Because from one hand the cost of reducing groundwater contaminants is not cheap and from other hand it may take long time. Therefore, it is necessity to define which systems and hydrogeological models are most suitable to use for groundwater quality protection. GW vulnerability assessment can be noted as a preventive function for protection of GW quality prior to start monitoring of groundwater resource in the area. This approach has been widely used for GW vulnerability to pollution.

Afghanistan's climate is arid to semi-arid where the weather is cold in winter and hot and dry in summer with temperature that ranges from −20°C in winter to 50°C in summer. The drinking water quality in Afghanistan's big cities has been deteriorating in recent years mainly due to the high growth of population, agricultural activities, septic tanks system and municipal wastes [1]. Most of the cities and towns do not have central sewer line systems, there are just individual septic tanks installed for each house. These tanks are not constructed in a sanitary condition and standard distance from drinking water well to prevent infiltration of wastewater into the groundwater.

II. Research Proposed

Better cognition of groundwater importance caused that groundwater manager and policy maker in the world attempting to prevent and reduce groundwater contamination by analyzing effective factors. Unfortunately, there is few researches regarding groundwater vulnerability in Afghanistan yet, and since lack of GW vulnerability assessment may increase groundwater pollution in big cities like Herat, so the main goal of this study is to assess GW vulnerability to pollution using the DRASTIC model [2] and fuzzy logic [3] in Herat city Afghanistan.

III. Relational Studies

There are various concepts to assess GW vulnerability. Generally, they consist process-based methods, statistical methods, and overlay and index methods [4]. The process-based methods use simulation models to estimate the contaminant transmission. Disadvantages of these methods are data shortage and computational difficulties [5]. Statistical methods use statistics such as clustering, frequency ratio and scoring equations to establish a relationship between spatial variables and actual occurrence of contaminant in the aquifer. Careful choosing of spatial variables, data accuracy and insufficient observation points can be noted as limitations of these methods. The main advantage of Overlay and index methods which integrate parameters controlling the movement of contaminants from the ground surface into the saturated zone resulting in vulnerability indices at different locations is that, all the parameters such as net recharge and hydraulic conductivity and water level can be available for wide areas, that is why these methods are more suitable for vulnerability assessments than two others methods [6].

In the overlay and index methods there are different methods like DRASTIC, GOD [7], SINTACS [8] and SI [9] methods but among them DRASTIC has been used more for GW vulnerability assessment. This model dose not predict the occurrence of GW pollution. The merit of the overlay and index method such as that used by DRASTIC is that changes can be easily made [10]. Combination of Fuzzy rules and DRASTIC model provide comparable results with less input data and has been caused for improvement of vulnerability prediction [11]. A GW vulnerability assessment methodology that needs less field data, is robust and useful screening tool when less data is available. Khemiri et al, [12] compared DRASTIC, GOD, SINTACS and SI method for assessment of GW vulnerability to pollution in scenarios of semi-arid climate in Foussan in the central of Tunisia. The output of his comparison showed that DRASTIC model is more suitable in semi-arid climate. Xiaoyu et al, [13] applied modified DRASTIC model for assessment of groundwater vulnerability in Beihai City, China. This study modified the rating of DRASTIC parameters based on the local environmental conditions and weight of parameters assigned by analytic hierarchy process (AHP) to reduce the subjectivity of humans to vulnerability assessment; Maryam Hosseini, [14] used Modified DRASTIC and GOD models for assessment and estimating GW vulnerability to pollution in Malayer Plain of Iran. In This study ranking and weighing of nitrate pollutant inserted in DRASTIC equation and zoning map of DRASTIC has been calibrated by nitrate concentration also, this method showed that DRASTIC model has more accuracy than GOD model in arid and semi-arid climate.

IV. Research Area

Herat city which has been chosen as research area in this study located in the center of Herat province, Afghanistan between (34.248° and 34.474°) latitudes, and (61.942° and 62.442°) longitudes with an area of 730 km^2. The altitude in the research area ranges from 858 to 1636 above sea level. The average annual precipitation is 210*mm*. GW resources in the study area include qanat, springs, and deep and semi-deep wells. The general trend of GW flow is from the east to west.

V. Materials and Method of DRASTIC Model

Assessment of GW vulnerability in this study consist of 3 steps. At the first step thematic layers for each DRASTIC parameter were prepared using point data and IDW and Kriging interpolation methods. At the next step as a modification in DRASTIC model fuzzy inference system were used to determine rating value for each class of thematic layers. At the last step conventual DRASTIC algorithm were used to calculate vulnerability index. Validation of the model were done using splitting the research area and comparing with existing nitrate contamination in the research area.

A. DRASTIC Model

DRASTIC model as a standard system for assessing GW vulnerability to pollution was used here in this study. Availability of input required information from various government departments can be noted as advantage of this model. DRASTIC model is based on seven parameters which to be used as input parameters for modeling. For each DRASTIC parameters a thematic layer to be prepared. Then each thematic layer should be classified into ranges based on its media types, which have an influence on vulnerability. Membership degree of thematic layers determined here by fuzzy inference system. The assigned Weight of DRASTIC model are then used for each factor to balance and increase its importance. The final vulnerability map is based on the DRASTIC index (Di) which is computed as the weighted sum overlay of the seven layers using (1):

$$D_i = D_r \times D_w + R_r \times R_w + A_r \times A_w + S_r \times S_w + T_r \times T_w + I_r \times I_r + C_r \times C_w \qquad (1)$$

Where, D, R, A, S, T, I and C are the seven parameters, r is the rating value, and w the weight assigned to each parameter. Each parameter in the model has a fixed weight indicating the relative influence of the parameter in transporting contaminants to GW. Weights vary from 1 to 5 [15], with higher values describing greater vulnerability. Also, ratings vary from 0 to 1, with higher value describing grater vulnerability. In this study, de-fuzzification method of fuzzy logic used instead of empirical method to scientifically determine rating values for different classes of thematic layers [16]. Fig. 1 shows the flowchart of the DRASTIC model which indicates the following process:

- Using seven types of raw data at the first step
- Converting raw data to thematic layers map using interpolation, Clipping and DEM classification methods.
- Integrating reclassified thematic layers using conventional DRASTCI algorithm.

B. Mapping

To prepare thematic layers of DRASTIC parameters based on the point data, IDW [17] and Kriging [18] interpolation methods were picked up. The main objective behind using two interpolation methods is, to know which one of them has better accuracy in DRASTIC model of GW vulnerability assessment.

To predict a value for an unknown point, IDW uses the known values surrounding the prediction point. The known values closest to the prediction location have more impact on the predicted value than those farther away. IDW assumes that each known point has a local impact that diminishes with distance. The prediction values are calculated by (2):

$$V_p = \sum_{i=1}^{n} \left(v_i / d_i \right) \Big/ \sum_{i=1}^{n} \left(1 / d_i \right) \qquad (2)$$

Where, V_p is prediction value, v_i is measured value and d_i is distance between prediction location and location of measured values .

Kriging is a statistical method that uses of a variograms to calculate the spatial autocorrelation between points at graduated distances to determine the weights that should be applied at various distances. As with IDW interpolation, the known values closest to the unknown locations have the most impact. But differs in that weights are helped determined by the semi variogram as (3):

$$\gamma(h)=\sum_{i=1}^{N}\left[Z(x_i+h)-Z(x_i)\right]^2 \Big/ 2N \quad (3)$$

Where, N is the number of pairs of sample points of observations, z is the attribute separated against distance h and x_i is known value.

C. Thematic Layers

Thematic layers of all parameters expect soil media and slope percent were prepared using point data and IDW and Kriging interpolation methods. To prepare soil media and topography layers, soil shape data of Afghanistan and Digital Elevation Model (DEM) were used, respectively.

Depth to GW can be counted as one of the most important factors which has effect on GW vulnerability because it directly depends to the thickness of material which located above aquifer. The water must travel through this material before reaching to the aquifer saturated zone. In general, GW vulnerability increases with depth to GW. Depth to GW maps prepared and classified in 6 classes.

Recharge water is a significant vehicle for percolating and transporting contaminants within the vadose zone to the saturated zone. It carries the solid and liquid contaminants to the water table and increases the water tables. The net recharge layer prepared using rise method of water-table fluctuations [19]. This method provides a point value of recharge calculated from the water-level rise in a well multiplied by the specific yield (*SY*) of the aquifer equation as shown in (4).

$$R = SY \times \Delta H \quad (4)$$

Where, R is point value of recharge, SY is the ratio of the volume of water obtained by draining a sample of saturated rock or soil V_w to the gross volume of the sample V_m.

$$SY = V_w \big/ V_m \quad (5)$$

ΔH is annual water level change. Based on the SY of each monitoring well [20] and ΔH from Dec 2016 to Dec 2017. Net recharge maps of research area were prepared and classified in 7 classes.

The presence of fine grain size materials, such as clay, peat, or silt, and the percentage of organic matter within the soil cover can decrease intrinsic permeability, and retard or prevent contaminant migration via physical-chemical processes. The soil map was prepared from the Afghanistan soil shape data [21].

The contaminant attenuation of the aquifer depends on the amount and sorting of fine grains. The aquifer media map was prepared from the well log and classified in 9 classes.

Aquifer hydraulic conductivity is the ability of the aquifer formation to transmit water. Grain size method was used to estimate the hydraulic conductivity of aquifer by the Hazen approximation [22]:

$$K = C \times D_{10}^2 \quad (6)$$

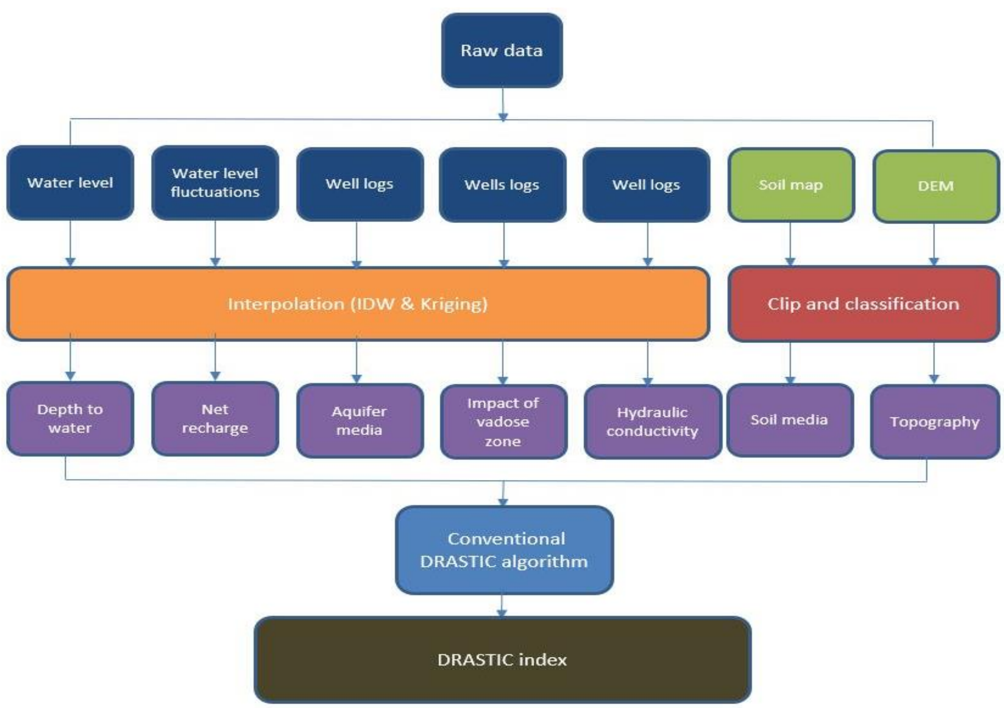

Fig. 1. Flow Chart of DRASTIC Model.

Where K is hydraulic conductivity in cm/sec, C is Hazen coefficient, (0.8-1.2) typically 1[23] and D is the diameter of the 10-percentile grain size of the material. Hydraulic conductivity in research area is classified in 9 classes.

The vadose zone has a high impact on water movement if it is composed of a permeable material. Impact of vadose zone was prepared from well-log which classified in 9 classes.

TABLE I. WEIGHT AND RATING VALUE OF THEMATIC LAYERS

Layer	w	Class	r
Depth to water(m)	5	(0-4)	0.77
		(4.1-15)	0.59
		(15-25)	0.31
		(25-35)	0.11
		(35-45)	0.04
		(45-63)	0.03
Net Recharge (mm/year)	4	(-17-12)	0.3
		(12-27)	0.37
		(27-34)	0.4
		(34-48)	0.45
		(48-79)	0.57
		(79-144)	0.7
		(144-283)	0.8
Aquifer media	3	compacted clay, Very hard gravel	0.14
		Cobble Gravel & sand	0.22
		compact sand, silty clay	0.32
		Sandy gravel, clay	0.44
		Sandy gravel, silty Clay	0.56
		Sandy gravel	0.69
		Sandy gravel, gravel	0.78
		gravel	0.8
		large gravel	0.84
Soil media	2	fine grained & coarse-grained soils: clay & silty sand (shallow), silt & clay (moderately deep to deep)	0.64
		fine grained & coarse-grained soils: gravel overlain by clay	0.35
		coarse grained: gravel overlain by silty sand and clayey sand	0.85
		fine grained soils: clay underlain by gravel and silty sand	0.16
Topography (slope%)	1	<5	0.72
		(5-10)	0.63
		(10-18)	0.47
		(18-30)	0.29
		>30	0.15
Impact of Vadose zone media	5	clay	0.09
		Sandy & Silty Clay	0.2
		Sandy gravel, clay	0.26
		Silty sand	0.39
		clay, gravel	0.4
		Silty Clay & gravel, sandy gravel	0.43
		Silty clay & gravel	0.55
		gravel	0.77
		Large gravel	0.91
Hydraulic Conductivity (cm/sec)	3	(4-131)	0.14
		(131-258)	0.2
		(258-385)	0.27
		(385-512)	0.37
		(512-639)	0.45
		(639-766)	0.54
		(766-893)	0.62
		(893-1020)	0.77
		(1020-1147)	0.92

Topography demonstrates slope of an area. The precipitation water stays in the area with low slop for a long time. This allows a greater infiltration which causes pollution migration. Unlike, Areas with higher slopes have large amounts of runoff, smaller amounts of infiltration and are less vulnerable to GW pollution. The topographic map was prepared from the DEM and it was divided into five classes.

Table. 1 shows rating values for different classes of thematic layers which prepared by centroid method of de-fuzzification in fuzzy inference system

Then all seven layers reclassified by rating values and integrated by (1). Once the DRASTIC index has been computed, then divided into 3 classes as shown in Fig .2.

VI. Validation

To validate the model, a comparison between prepared vulnerability maps and existing level of nitrate in research area which recorded by local government in Herat province at the end of 2017 has been done. For this propose, 51 water sample from bore wells interpolated by both IDW and Kriging methods as shown in Fig .3.

Overlaying vulnerability maps by nitrate maps shows that, percentage of contaminated area which exceed permissible limit (10mg/lit) and located in high vulnerable zone with Kriging is greater than IDW. Fig.4 and Table 2 show numerical and graphical values of this relationship, respectively. Since high vulnerable zone should be contaminated first, so it seems that Kriging interpolation has better accuracy than IDW.

In addition, to verify this validation, the research area was splinted into west and east parts and the process started from the beginning in west part as 2nd research area. Finally, when vulnerability maps of 2nd research area overlaid by nitrate maps of 2nd research area, it shows same results. Fig. 5 and Table 3 show this relationship, respectively.

Hence, GW vulnerability map of Fig. 2b which interpolated by Kriging interpolation method and developed by applying DRASTIC model and fuzzy logic to the thematic layers is final goal of this study. The results indicate that GW in Herat city in most parts is in the vulnerable to high vulnerable zones. The vulnerable zones have been classified into low vulnerable, vulnerable, and high vulnerable zones. The study showed that 51.09 % of the total research area in final vulnerability map, i.e. Fig. 2b is under the high vulnerable zone. About 46% of the area is under vulnerable zone and just 2.9% of research area has low vulnerability.

VII. Conclusion

Determination of rating value in DRASTIC model using centroid de-fuzzification method of fuzzy logic which is more scientific than conventional empirical method and preparation of DRASTIC parameter using kriging interpolation which showed better accuracy that IDW can be noted as highlight point of this study. This study can assist groundwater manager and local authorities because it gives a very clear classification of groundwater vulnerability to pollution. In the high vulnerable class, it necessary for local authorities manage GW resources, monitor this problem deeply and to act seriously. the risk of GW contaminant can only be reduced by planning, construction, and operation of a standard infiltration systems in the urban area. It can help the urban engineers and decision-makers while choosing the areas for waste disposal and industrial sites. This study suggests assigning rating value of DRASTIC parameters using fuzzy inference system of fuzzy logic. Furthermore, using the DRASTIC model can also manage monitoring schedule, there should be high and very high vulnerable zones in prioritization in order to check fluctuations of pollutants level and act for reducing of them. The future work includes applying the current study to web application to be easily accessible by local authorities, groundwater researchers and even public users.

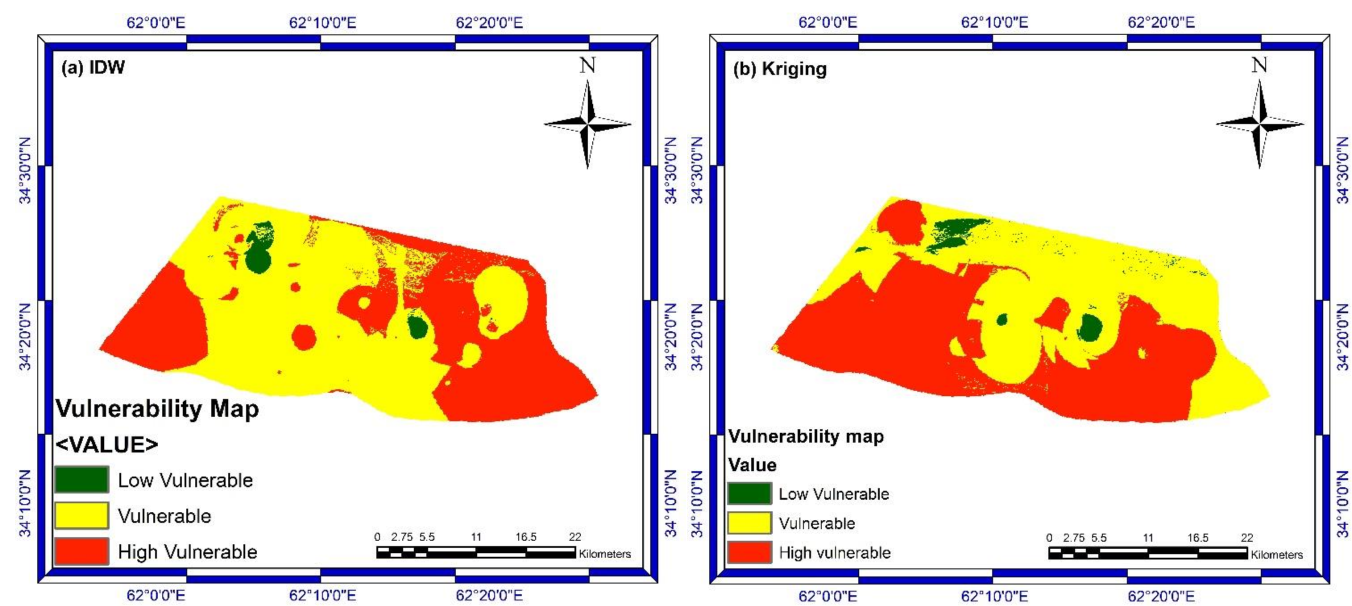

Fig. 2. Vulnerability Maps with IDW and Kriging.

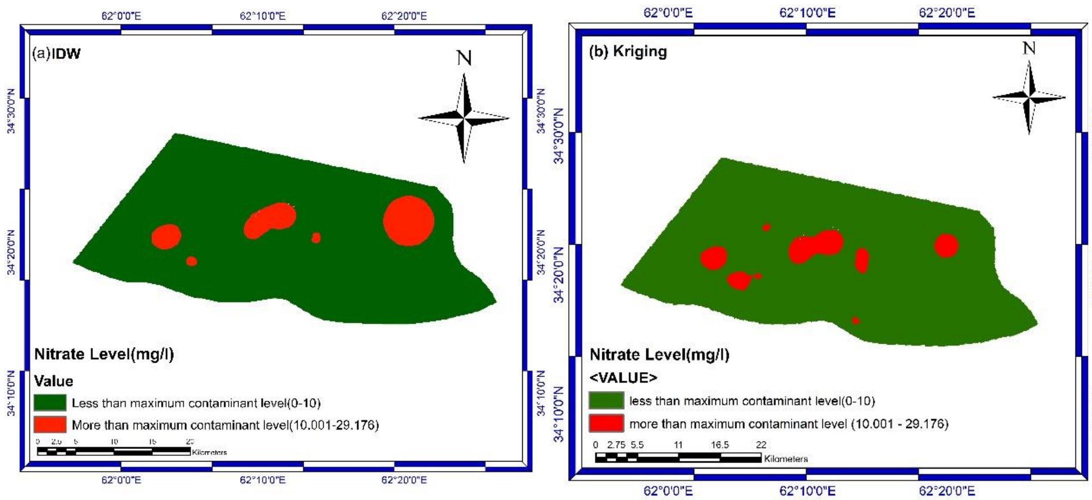

Fig. 3. Nitrate Level Maps with IDW and Kriging.

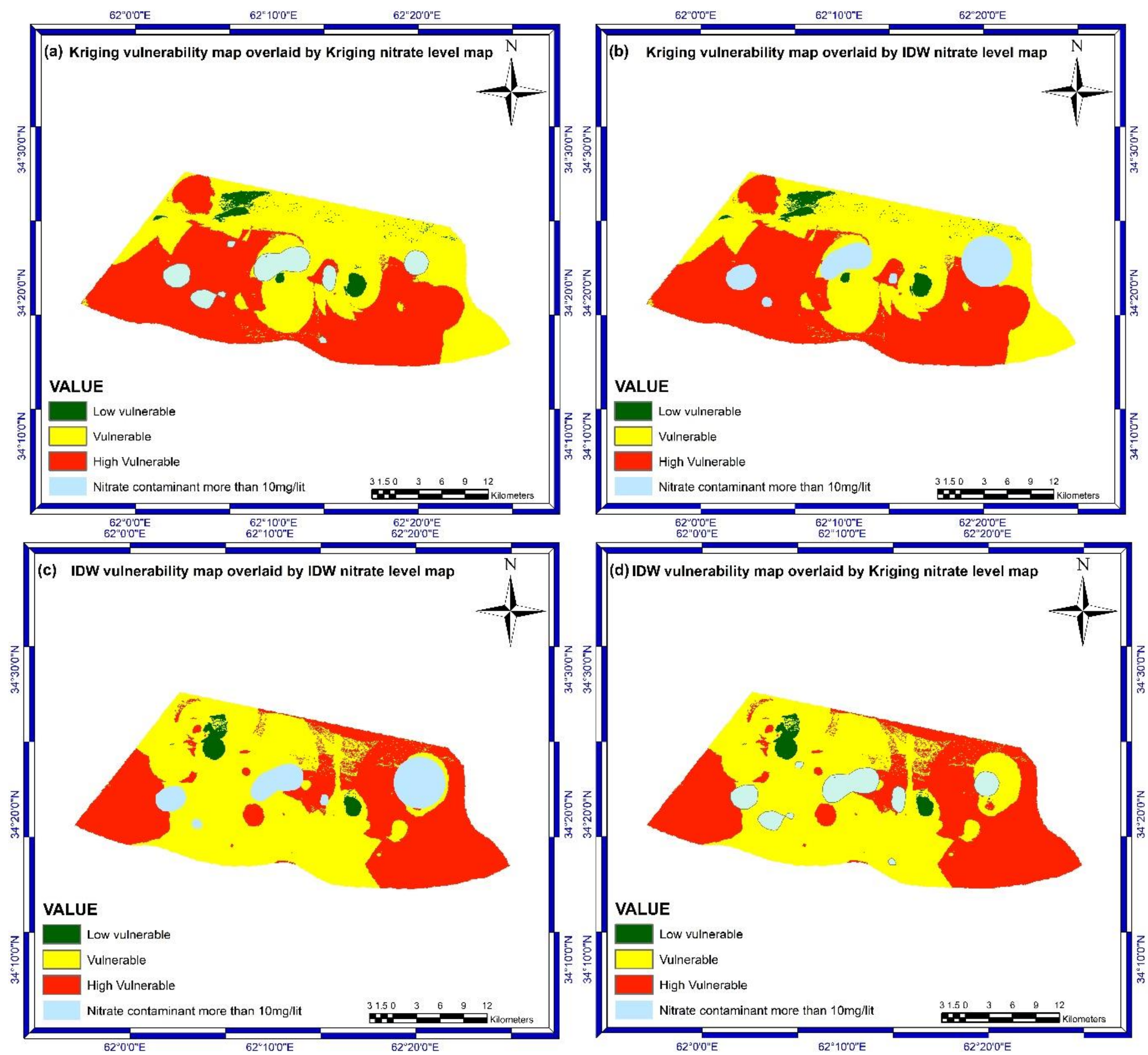

Fig. 4. Validation maps (a) Kriging vulnerability map Overlaid by Kriging nitrate level map(b) K vulnerability map overlaid by IDW nitrate level map(c) IDW vulnerability map overlaid by IDW nitrate level map (d) IDW vulnerability map by Kriging nitrate level map.

TABLE III. NUMERICAL RELATIONSHIP OF OVERLAP AREAS

Vulnerability Maps (Kriging& IDW) overlaid by Kriging nitrate map (Fig.4a &Fig. 4b)		
Class	**Percentage of contaminated area which exceed permissible limit (10*mg/lit*)**	
	Kriging	IDW
Low Vulnerable	0.01	0.02
Vulnerable	55.61	72.92
High Vulnerable	44.38	27.06
Vulnerability Maps (Kriging& IDW) overlaid by IDW nitrate map (Fig.4c &Fig.4d)		
Class	**Percentage of contaminated area which exceed permissible limit (10*mg/lit*)**	
	Kriging	IDW
Low Vulnerable	0.12	0.04
Vulnerable	71.1	75.78
High Vulnerable	28.78	24.18

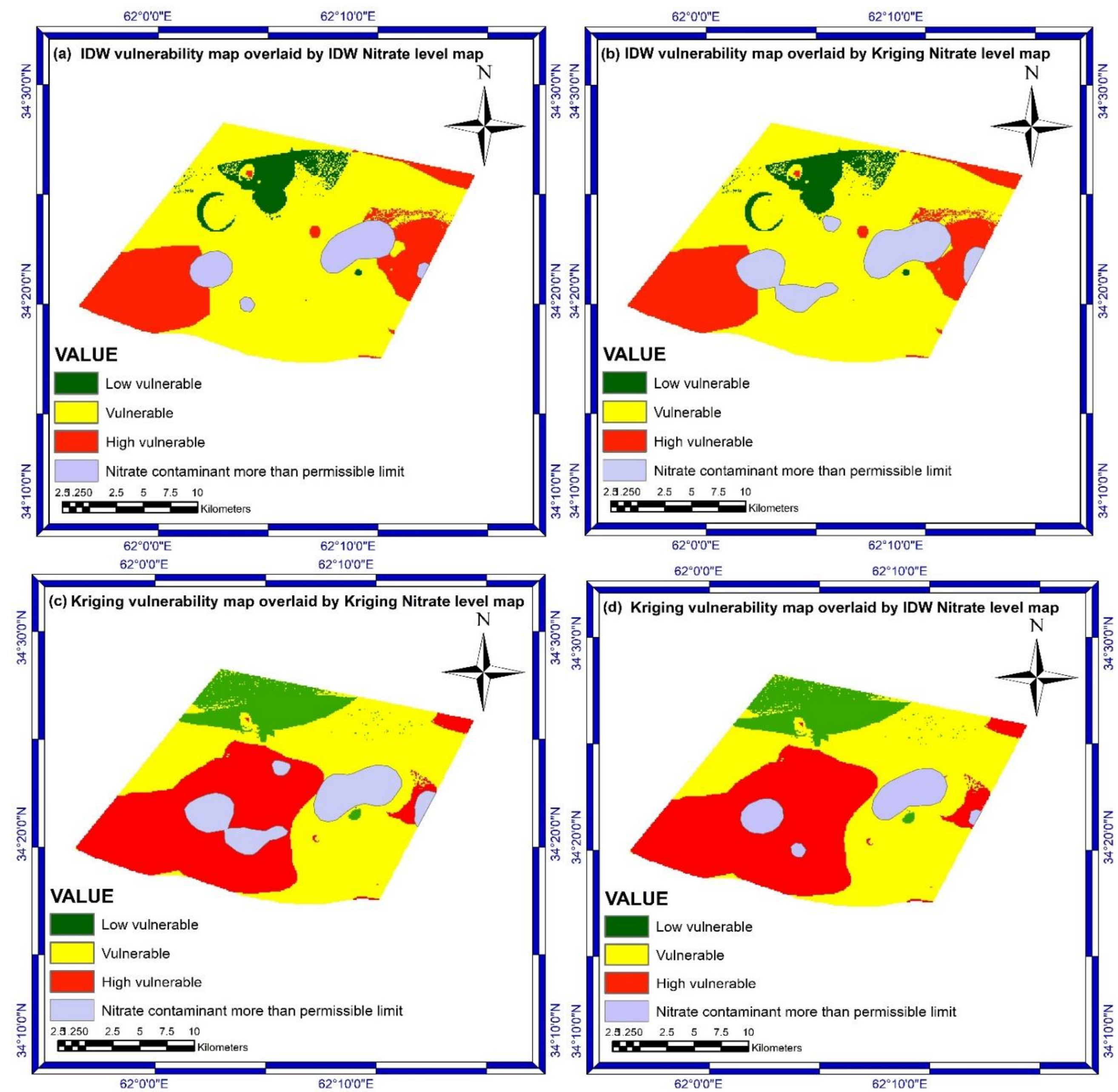

Fig. 5. Validation maps of 2nd research area (a) IDW vulnerability map by IDW nitrate level map(b) IDW vulnerability map by Kriging nitrate level map(c) Kriging vulnerability map by IDW nitrate level map (d) Kriging vulnerability map by IDW nitrate level map.

TABLE IV. NUMERICAL RELATIONSHIP OF OVERLAP AREAS FOR 2ND RESEARCH AREA

Vulnerability Maps (IDW& kriging) overlaid by Kriging nitrate map (Fig. 5b & Fig. 5c)		
Class	**Percentage of contaminated area which exceed permissible limit (10mg/lit)**	
	IDW	Kriging
Low Vulnerable	0.16	0.15
Vulnerable	70.48	48.5
High Vulnerable	29.35	55.35
Vulnerability Maps (IDW& kriging) overlaid by IDW nitrate map (Fig. 5a & Fig. 5d)		
Class	**Percentage of contaminated area which exceed permissible limit (10mg/lit)**	
	IDW	Kriging
Low Vulnerable	0.13	0.12
Vulnerable	64.83	61.71
High Vulnerable	35.04	38.71

REFERENCES

[1] Ehsanullah Hayat & Alper Baba, Quality of groundwater resources in Afghanistan *Environ Monit Assess*, 189: 318, 2017.

[2] US EPA (Environmental Protection Agency). DRASTIC: *a standard system for evaluating groundwater potential using hydrogeological settings*, WA/EPA Series, p. 163, Ada, Oklahoma, 1985.

[3] Zadeh, L.A,"Fuzzy sets". Information and Control,vol. 8 (3) , pp. 338–353, 1965.

[4] Tesoriero AJ, Inkpen E.L, Voss FD, "Assessing ground-water vulnerability using logistic regression". source Water Assessment and Protection 98, Technical Conference Proceedings, pp. 157-165 ,April 1998

[5] Barbash JE, Resek EA. "Pesticides in ground water: distribution, trends, and governing factors"(Chelsea, MI: Ann Arbor Press;1996).

[6] Thapinta A, Hudak PF. Use of geographic information systems for assessing groundwater pollution potential by pesticides in Central Thailand. Environ Int,vol. 29(1), pp. 87–93,2003

[7] Foster, S.S.D. and R. Hirata., "Groundwater Pollution Risk Assessment: A Methodology using Available Data", WHO – PAHO / HPE – CEPIS Technical Manual. *WHO: Lima, Peru*. 78,1998.

[8] Civita, M, Le Carte délia Vulnerabilitâdegli Acquiferiall'Inqulnamento. TeoriaiPratica (Aquifer vulnerability maps to pollution). *Pitagora Ed. (publisher)*, Bologna, 1994.

[9] Luís Ribeiro, Juan Carlos Pindo, Luis Dominguez-Granda, Assessment of groundwater vulnerability in the Daule aquifer, Ecuador using the susceptibility index method, *Science of the Total Environment*, vol. 574, 1, pp. 1674-1683, January 2017.

[10] EPA. (2003),Contaminated sediment transport and fate modeling Athens, GA, p. 30605, http://www.epa.gov/nerl/research/2003/ g5-4.html.

[11] Dixon, B, "Groundwater vulnerability mapping: A GIS and fuzzy rule based integrated tool". *Applied Geography*, vol. 25(4), pp. 327–347,2005.

[12] Sami Khemiri, Afef Khnissi, Mohsen Ben Alaya1, Salwa Saidi and Fouad Zargouni1, "Using GIS for the Comparison of Intrinsic Parametric Methods Assessment of Groundwater Vulnerability to Pollution in Scenarios of Semi-Arid Climate. The Case of Foussana Groundwater in the Central of Tunisia", Journal of Water Resource and Protection, vol. 5, pp. 835-845,2013.

[13] Xiaoyu WUBin LIChuanming MA, "Assessment of groundwater vulnerability by applying the modified DRASTIC model in Beihai City, China", Environmental Science and Pollution Research, vol. 25(13), ,pp. 12713–12727, May 2018.

[14] Maryam Hosseini, Ali Saremi, "Assessment and Estimating Groundwater Vulnerability to Pollution Using a Modified DRASTIC and GODS Models (Case Study: Malayer Plain of Iran)", Civil Engineering Journal, vol. 4(2),pp. 433-442, 2018.

[15] Aller, L, Bennett, T, Lehr, J. H, Petty, R.J, and Hackett G, "*DRASTIC*: A standardized system for evaluating groundwater pollution potential using hydrogeologic settings", (NWWA/EPA Series, EPA-600/2-87-035,1987, 622 p).

[16] Nasir Ahmad Gesim, Takeo Okazaki, Identification of groundwater artificial recharge sites in Herat city, Afghanistan, using Fuzzy logic, International Journal of Engineering and Technical Research, vol. 8(2), pp. 40-45, 2018.

[17] Paul V. Bolstad, *GIS fundamentals 3rd ed*, (Eider Press, White Bear Lake, Minnesota, United states ,2007)

[18] Burrough, P. A, "Principles of Geographical Information Systems for Land Resources Assessment",New York: Oxford University Press, 1986.

[19] John R. Nimmo, Charles Horowitz, and Lara Mitchell, "Discrete-Storm Water-Table Fluctuation Method to Estimate Episodic Recharge" Groundwater,vol. 53(2),pp. 282–292,March-April 2015.

[20] A. I. Johnson, "Specific Yield - Compilation of Specific Yields for Various Materials" (U S government printing office, Washington, 1967).

[21] USDA (United States Department of Agriculture), Natural Resources Conservation Service Soils, "Soil Regions Map of Afghanistan", https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/use/?cid=nrcs142p2_054000.

[22] Hazen, A, Discussion of Dams on sand formations, by A.C. Koenig. Transactions of the American Society of Civil Engineers, vol. 73, ,pp. 199–203, 1911.

[23] Fetter, C.W,Applied Hydrogeology. 4th Edition (Pearson, Higher Education, New Jersey, 2001).

CryptoROS: A Secure Communication Architecture for ROS-Based Applications

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***Abstract*—Cyber-attacks are a growing threat to future robots. The shift towards automatization has increased relevance and reliance on robots. Securing robots has been secondary or ternary priority and thus robots are vulnerable to cyber-attacks. Securing robots must become an essential (built-in) part of the design rather than being considered as a subsequent (later) add-on. ROS is a widely used and popular open source framework and robots using ROS are increasing in popularity. However, ROS is vulnerable to cyber-attacks. ROS needs to be secured before robots using ROS reach mass market. This study aims at proposing an architecture to secure ROS, using cryptography mechanism, which addresses the most common ROS safety issues. The advantages of our proposed secure architecture, CryptoROS, is that no changes to ROS software libraries and tools is required, it works with all ROS client libraries (e.g. rospy, roscpp) and rebuilding nodes is not necessary.**

Keywords*—Robotics; ROS; cyber security; cryptography; access control

I. Introduction

Autonomous robots are expanding not only in science-fiction movies, but in our regular, everyday tangible world. For example, applications of robots are used in education [1], [2], accounting [3], target searching and detection [4], [5], and many more. With robots becoming further ubiquitous in society, cyber-attacks are rapidly growing into a cogent issue. Home service robots, autonomous vehicles, industrial automation, along with many other robotics domains offer a route for the spread of cyber threats into real-world risks. Personal robots with the potential to integrate with the Internet of Things (IoT) may very well be targeted, in the same fashion as PCs and smartphones, and lead to violations of privacy and breaches of confidentiality. For robot software development, ROS, a group of open source software libraries and tools, is used. Programmable robots are becoming increasingly popular, and as robots appear more within the society, the safety of ROS is becoming an important concern and should be considered vital because it may become a target for breaches of confidentiality and / or violation of integrity [6]-[8].

In ROS, every node running has a XML-RPC URI. XML-RPC is a remote procedure call, encoding complex data structures using XML and transmitting / transporting them using HTTP [9]. As depicted in figure 1, the publisher advertises, via the master's XML-RPC, its intent to publish to topic chatter. Then the subscriber subscribes to topic chatter via the master's XML-RPC. In response the master returns the publisher's XML-RPC URI to the subscriber. The subscriber then requests and negotiates a topic connection via the publisher's XML-RPC. In response the publisher returns the proper setting for the selected topic transport to the subscriber. Using the provided setting, the subscriber then establishes a new connection to the publisher [10].

The remainder of this paper has been structured as follows: next section explores the related work. Section three introduces the proposed architecture used to secure ROS. Finally, section four discusses the ROS issues fixed.

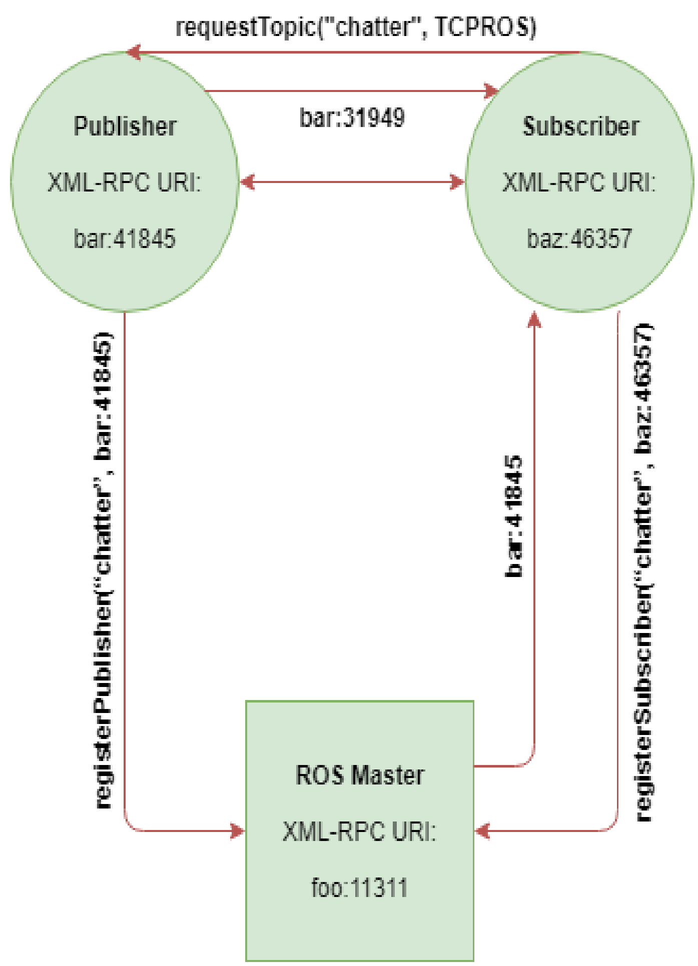


Fig. 1. ROS Architecture.

* 1st corresponding author, ** 2nd corresponding author.

II. Background Study

The development of ROS is influenced by features and properties most valued by robotics researchers and therefore fails to provide any protection against cyber-attacks. For example, a newly created node replaces an existing node with the same name, because nodes need to be named uniquely. Therefore, an attacker can shut down / kill a node and replace it, simply by running a node with the same name as the target node [6], [11]. A node can freely publish messages to a random / chosen topic without prior authorization. An unauthorized node publishing malicious messages to a topic can cause an unforeseen motion by a robot that damages its surroundings and / or harms nearby humans. A node can freely and without prior authorization subscribe to a random / chosen topic and receive all messages published to this topic. These messages might contain confidential information. A node can freely publish large number of messages to a random / chosen topic, preventing the subscriber of this topic from carrying out meaningful information processing and causing a denial of service. The topic transport channel is not secure. It reveals messages to unauthorized persons (breach of confidentiality), cannot detect unauthorized intentional or unintentional alteration of messages (violation of integrity), cannot prove that the involved parties (e.g. publishers, subscribers) are who they say they are [7], [12].

An attacker with expertise in ROS can execute a man-in-the-middle attack by acting as a publisher to a subscriber and as a subscriber to a publisher. An attacker with adequate knowledge and background in cyber security can find the XML-RPC URI of the master and armed with this information [12]:

1) The attacker calls the remote procedure "getSystemState" at the master and retrieves a list representing the names of current publishers, subscribers and service providers.

2) The attacker calls the remote procedure "lookupNode" at the master, provides the name associated with the targeted publisher / subscriber as parameter and retrieves the XML-RPC URI of that publisher / subscriber.

3) The attacker calls the remote procedure "publisherUpdate" at the subscriber and provides, among other parameters, the XML-RPC URI of the publisher under his / her control.

4) The attacker executes a man-in-the-middle attack and intercepts, monitors (passive attack), if desired alters / changes (active attack) and reroutes the conversation as shown in figure 2.

During DEF CON 20 conference [13], a car-like robot equipped with two cameras, a compass and a single board computer running Linux and ROS was deployed to emulate and experience the cyber-physical issues related to mobile robots built using ROS. Attendees interacted (e.g. drive the robot) with the physical robot via a webpage and were asked to exploit the vulnerable mobile robot. During the conference, an attendee with knowledge and background in ROS injected / published malicious messages and operated the robot without interacting with the webpage.

There are many researches that have been done to address ROS safety issues. ROSRV was introduced in [11], which has been designed in such a way that no changes to ROS software libraries and tools is required. ROSRV intercepts all requests to master and monitors and if required alters the messages, thus enforcing access control policies and monitoring safety properties. However, ROSRV transmits unencrypted traffic, disclosing private data and failing to prevent unauthorized alteration of data. ROSRV also relies and enforces access control policies based on the source IP address of the request. This exposes the architecture to IP spoofing. ROSRV could encounter scaling problems because all the monitors reside in the same multithreaded process.

Transport Layer Security (TLS) was used in SROS [6]. SROS encrypts all network traffic using TLS by changing the ROS client library, or more specifically rospy client library. Each node is supplied a X.509 certificate, with the access control policies embedded within the X.509 certificate extensions. One drawback is that at the time of writing this paper SROS only supported rospy client library with TCPROS. Another drawback is that because the access control policies are embedded within the X.509 certificate extensions, 1) mutating a node's permissions requires revocation of the current X.509 certificate and issuance of a new one, 2) the access control policies are made public.

In [7] the authors described a concept similar to SROS but implemented by changing the roscpp client library. However, it fails to secure the master and the request / response sent / received via XML-RPC.

A scheme was introduced by [8] where by a node publishes messages in clear to a topic (/sensor/messages). An encrypting node subscribes to this topic (/sensor/messages), performs message encryption and publishes it to another topic (/sensor/encrypt/messages). A decrypting node subscribes to this topic (/sensor/encrypt/messages) and performs message decryption. The symmetric key is stored within the master and is only known by authorized entities. However, this testbed fails to prevent nodes from subscribing to /sensor/messages topic, which results in exposure of messages to unauthorized entities, a clear breach of confidentiality. It also fails to detect intentional or accidental alteration of messages, a clear violation of integrity. The testbed does not also check that the involved entities are who they say they are (no authenticity) [12].

In [14] the authors introduced an architecture in which prior to publishing and / or subscribing to a topic, nodes send their login credentials to an authorization node with the help of a set of overloaded / overridden functions. The authorization node generates a special key and returns it to the node to be included in all future conversations. however, the authors have mentioned that ROS uses SSH to secure all conversations. This is not true and will allow attackers to easily break / bypass their scheme. They also require changes to be made to ROS client libraries.

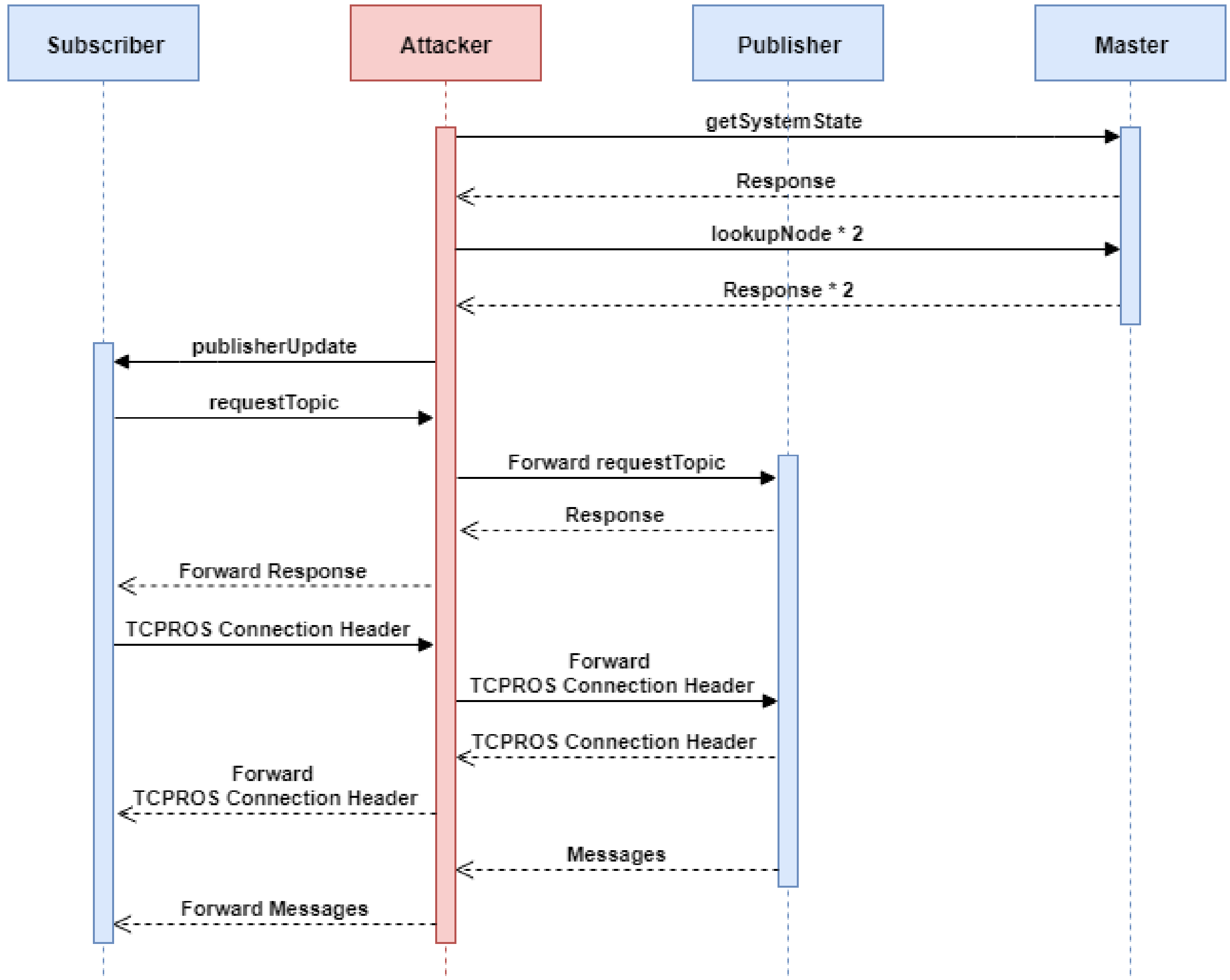


Fig. 2. Man-in-the-Middle Attack.

III. Proposed Architecture

A. Security Requirements

In our proposed architecture, we focus on the peer-to-peer conversations between nodes, which have to be confidential and checked for integrity violation. The Computation Graph [15] must be available and functional at all times. This involves decreasing the attack surface for denial of service attacks. The involved entities must also be scrutinized to ensure they are who they say they are. Nodes should not be allowed to publish / subscribe to a topic or advertise / call a service without prior authorization.

B. Proposed Secure ROS Architecture: CryptoROS

CryptoROS has been designed to fix some of the safety issues related to ROS. Manager as the name implies manages all nodes running on a computer. The Authorization Server checks the Manager's credentials and creates an Access Token representing the predefined set of actions the Manager has been authorized to perform as shown in figure 3. The Manager and the Authorization Server, each has been issued a X.509 certificate by a CA and supplied / configured with all the intermediate CA certificates to chain to the root CA certificate.

The entire conversation is secured using TLS 1.2, therefore the Access Token is never made public. The Access Token is made up of three parts: header, payload, and signature. The payload contains, among other claims, an expiry date claim. Involved parties perform a signature check to ensure the information contained in the Access Token has not been altered / changed (integrity check) and the Access Token has been created by a trusted entity (authenticity check). Therefore, the Authorization Server has been configured to use the private key associated with one of the intermediate CA certificates to create the signature.

As shown in figure 4, unbeknown to the Publisher / Subscriber, Publisher / Subscriber calls a remote procedure at the Manager and announces its intention to publish / subscribe to topic chatter (step 1 and 4). The Manager generates an Interceptor (step 2 and 5). The Interceptor announces, via the ROS Master's XML-RPC, its intent to publish / subscribe to topic chatter (step 3 and 6). In response to step 6, the ROS Master returns the Interceptor_P's XML-RPC URI to the Interceptor_S (step 7). Henceforth, the Interceptor acts as a publisher to a subscriber (step 8) or as a subscriber to a publisher, transparently intercepting, monitoring and if required altering / changing the conversations between Publisher and Subscriber.

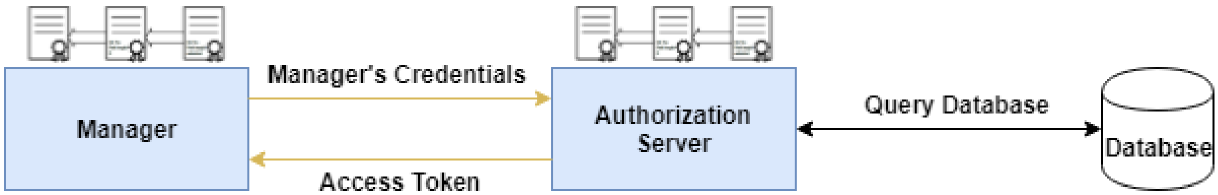


Fig. 3. Requesting an Access Token.

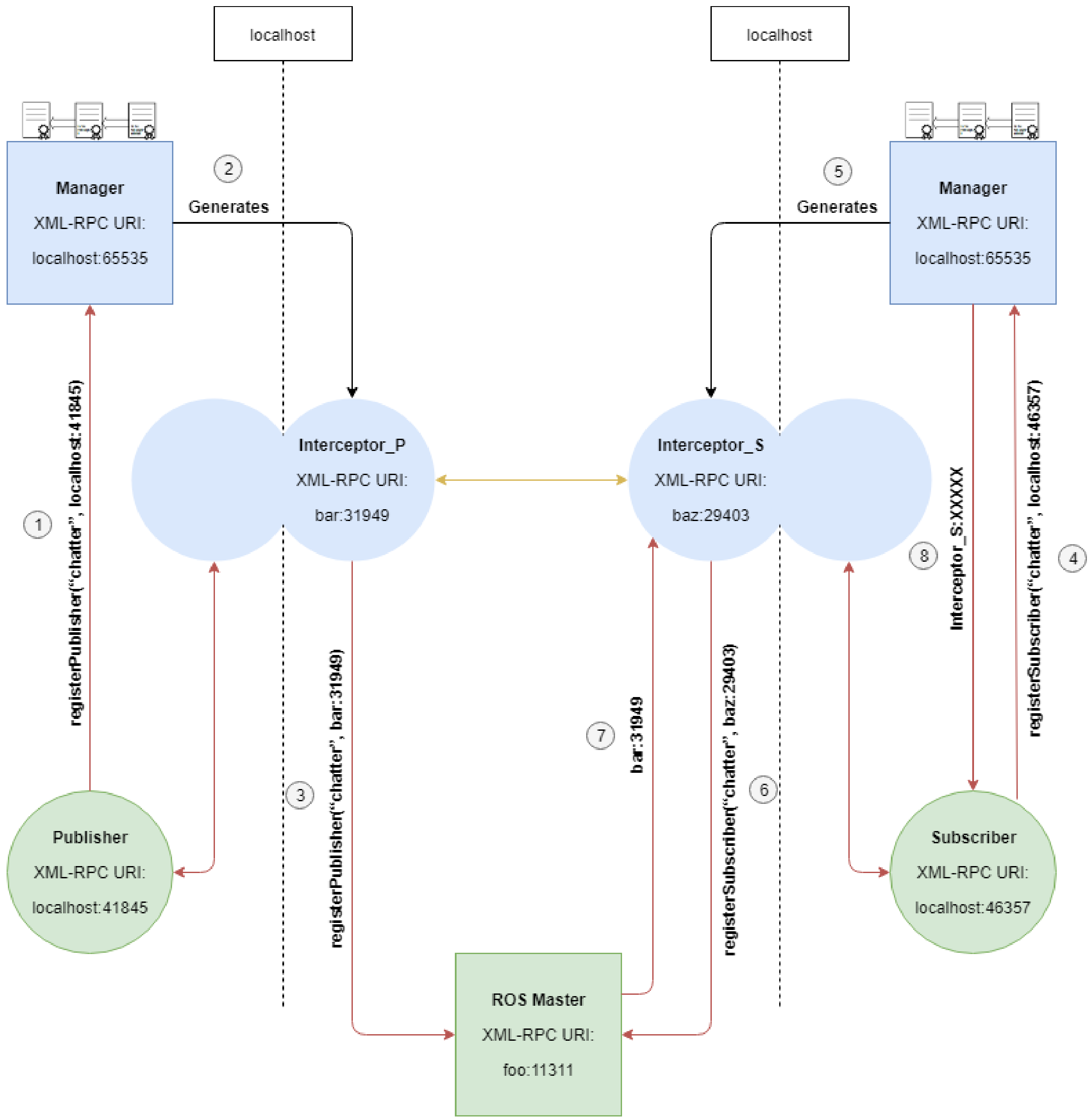


Fig. 4. CryptoROS Architecture. Orange Arrow Means the Conversation has been Secured using TLS 1.2.

In summary, the Publisher and the Subscriber have been configured to contact the Manager instead of the ROS Master by setting the ROS_MASTER_URI environment variable to the IP address and port number of the Manager. The Manager generates an Interceptor for each node. An Interceptor intercepts, monitors and if required alters all network traffic to / from the node and decrypts / encrypts them accordingly. The Interceptors act as publishers to subscribers and as subscribers to publishers. All conversations (network traffic) between the Interceptors are secured using TLS 1.2 except the XML-RPC request / response sent / received.

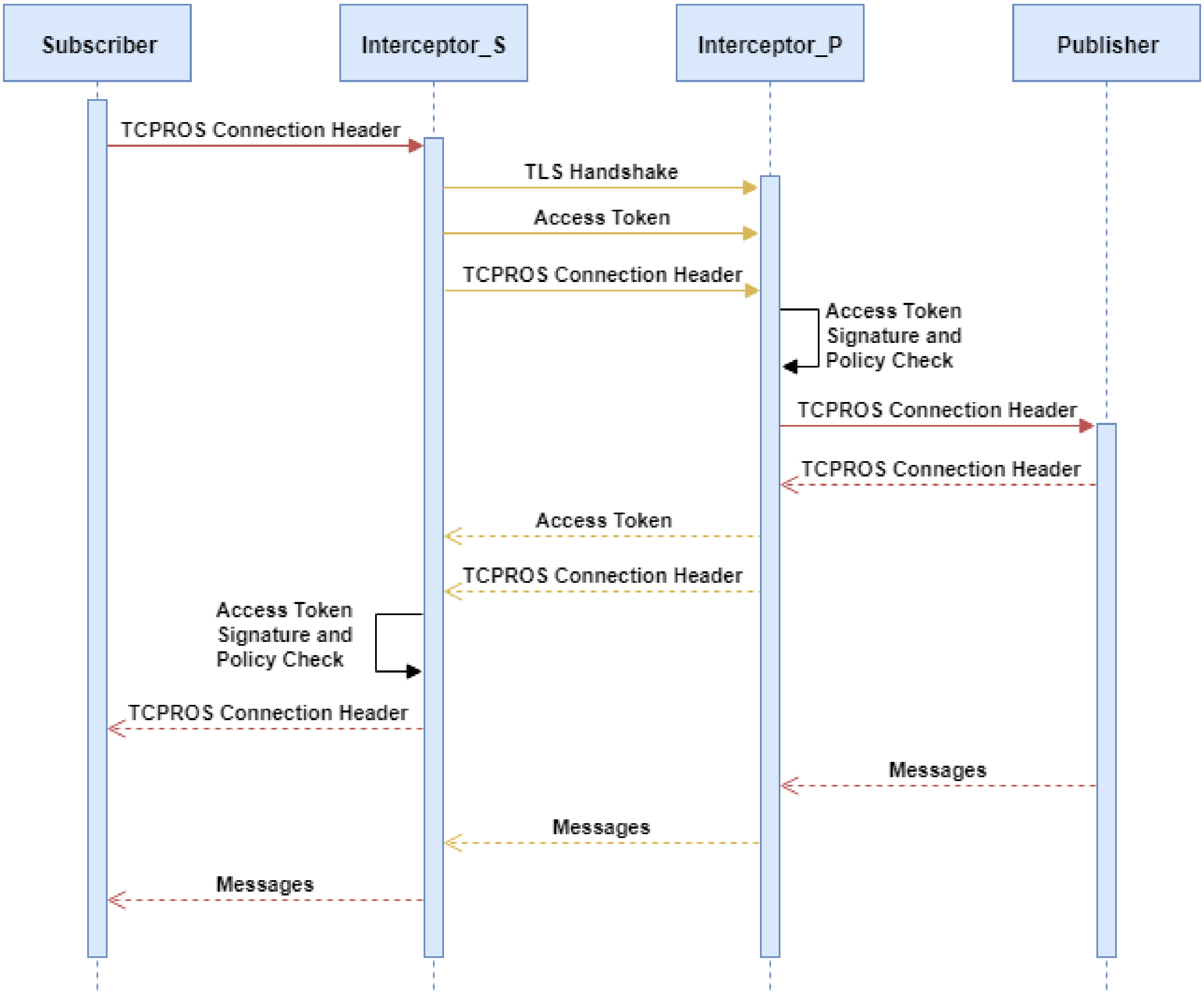


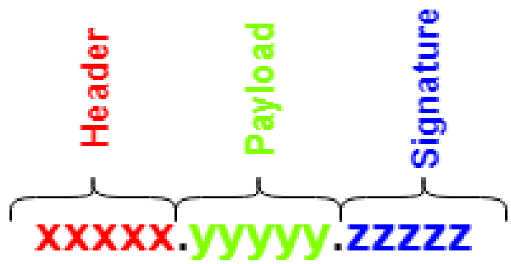
Fig. 5. Sequence Diagram. During the TLS Handshake, an Interceptor uses the X.509 Certificate Belonging to the Manager that Generated it. Orange Arrow Means the Conversation has been Secured using TLS 1.2.

As depicted in figure 5, upon receiving an Access Token, the Interceptor performs a signature check and then inspects the access control policies embedded within the Access Token to ensure the node is allowed to publish / subscribe to a topic or advertise / call a service. The expiry date of the Access Token is also checked. The same process applies to services and service clients.

The manager and the nodes (e.g. Publisher, Subscriber) have been bound to 127.0.0.1. This is done to prevent remote machine connections.

C. Access Token

As mentioned above the Access Token is made up of three parts: header, payload, and signature. The header contains the algorithm claim which denotes the cryptographic / signing algorithm used (e.g. RSASSA PKCS1 v1.5 using SHA-256). The payload contains, along with the access control policies, an issuer, a subject, and an expiry date claim. The issuer holds the unique / distinguished name of the entity that issued the Access Token. The subject contains the unique / distinguished name of the party that this Access Token bears claims about. The expiry date holds the date and time after which this Access Token is no longer considered usable. Figure 6 shows the Access Token structure.



6. Access Token.

TABLE I. COMPARISON BETWEEN ARCHITECTURES

Scheme	Advantage	Disadvantage
CryptoROS	- secures / encrypts peer-to-peer conversations between nodes. - stops unauthorized publishers, subscribers, services and service clients. - reduces the attack surface for DoS attacks. - no changes to ROS software libraries and tools. - supports all ROS client libraries.	- unsecured / unencrypted XML-RPC requests / responses sent / received. - does not protect ROS Master.
ROSRV	- no changes to ROS software libraries and tools.	- unsecured / unencrypted network traffic and reliance on IP addresses when enforcing access control policies exposes the architecture to a wide variety of attacks.
SROS	- secures / encrypts all network traffic. - stops unauthorized publishers, subscribers, services and service clients. - notably reduces the attack surface for DoS attacks.	- changes ROS software libraries and tools. - supports rospy only.

Table I compares CryptoROS with some of the solutions discussed previously and list some of their advantages and disadvantages.

IV. CONCLUSIONS AND FUTURE WORK

CryptoROS has been designed in such a way that no changes to ROS software libraries and tools is required. Additionally, rebuilding nodes is not required in order to benefit from the secure conversation channel. CryptoROS also works with all ROS client libraries regardless of the programming language they have been implemented / written in.

With our approach we managed to prevent unauthorized publishing and subscribing because the TLS handshake for the inbound and the outbound peer-to-peer connection will fail, prohibiting / preventing malicious nodes which are not supposed to be part of a specific conversation from injecting and / or eavesdropping data. The attack surface for denial of service in ROS has also been decreased. The Interceptors could be configured to drop XML-RPC shutdown requests, preventing attackers from shutting down / killing nodes.

With this approach we also made sure the messages and the service requests / responses will not be disclosed to unauthorized persons (confidentiality), any unauthorized intentional or accidental alteration of them will be detected (integrity) and we also made sure the involved entities are who they say they are (authenticity).

Some deployed robots might have inadequate computational power. Therefore, as a future work we will implement the proposed secure architecture and measure the performance impact on both the CPU and network traffic. In addition, we will attempt to secure master and XML-RPC requests / responses sent / received.

ACKNOWLEDGMENT

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REFERENCES

[1] N. F. A. Zainal, R. Din, M. F. Nasrudin, S. Abdullah, A. H. A. Rahman, S. N. H. S. Abdullah, K. A. Z. Ariffin, S. M. Jaafar, and N. A. A. Majid, “Robotic prototype and module specification for increasing the interest of Malaysian students in STEM education,” International Journal of Engineering and Technology, vol. 7, no. 3.25, pp. 286-290, Jan, 2018.

[2] L. P. E. Toh, A. Causo, P. W. Tzuo, I. M. Chen, and S. H. Yeo, “A Review on the Use of Robots in Education and Young Children,” Educational Technology and Society, vol. 19, no. 2, pp. 148-163, 2016.

[3] D. Fernandez and A. Aman, “Impacts of Robotic Process Automation on Global Accounting Services,” Asian Journal of Accounting and Governance, vol. 9, pp. 141-150, 2018.

[4] B. Nakisa, M. N. Rastgoo, M. Z. A. Nazri, and M. J. Nordin, “Target searching in unknown environment of multi-robot system using a hybrid particle swarm optimization,” Journal of Theoretical and Applied Information Technology, vol. 96, no.13, pp. 4055-4065, July, 2018.

[5] A. H. A. Rahman, K. A. Z. Ariffin, N. S. Sani, and H. Zamzuri, “Pedestrian Detection using Triple Laser Range Finders,” International Journal of Electrical and Computer Engineering (IJECE), vol. 7, no. 6, pp. 3037-3045, Dec, 2017.

[6] R. White, H. I. Christensen, and M. Quigley, “SROS: Securing ROS over the wire, in the graph, and through the kernel,” IEEE-RAS International Conference on Humanoid Robots (HUMANOIDS), 2016.

[7] B. Breiling, B. Dieber and P. Schartner, "Secure communication for the robot operating system," 2017 Annual IEEE International Systems Conference (SysCon), Montreal, QC, 2017, pp. 1-6.

[8] F. J. R. Lera, J. Balsa, F. Casado, C. Fernandez, F. M. Rico, and V. Matellan, “Cybersecurity in Autonomous Systems: Evaluating the performance of hardening ROS,” Proc. XVII Workshop of Physical Agents, Spain, Málaga, 2016, pp. 47-53.

[9] XML-RPC.Com. (1999, June 14). Retrieved September 9, 2018, from http://xmlrpc.scripting.com/

[10] Vilches, V. M. (Ed.). (2014, June 15). ROS Technical Overview. Retrieved September 9, 2018, from http://wiki.ros.org/ROS/Technical Overview

[11] J. Huang, C. Erdogan, Y. Zhang, B. Moore, Q. Luo, A. Sundaresan, and G. Rosu, “ROSRV: Runtime Verification for Robots,” International Conference on Runtime Verification, 2014, pp. 247-254.

[12] B. Dieber, B. Breiling, S. Taurer, S. Kacianka, S. Rass, and P. Schartner, “Security for the Robot Operating System,” Robotics and Autonomous Systems, vol. 98, no. C, pp. 192-203, Dec, 2017. doi: https://doi.org/10.1016/j.robot.2017.09.017

[13] J. McClean, C. Stull, C. Farrar, and D. Mascarenas, “A preliminary cyber-physical security assessment of the Robot Operating System (ROS),” SPIE Defense Security and Sensing, Baltimore, Maryland, United States, 2013.

[14] R. Dóczi et al., "Increasing ROS 1.x communication security for medical surgery robot," 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Budapest, 2016, pp. 004444-004449.

[15] Romero, A. M. (Ed.). (2014, June 21). ROS Concepts. Retrieved September 9, 2018, from http://wiki.ros.org/ROS/Concepts

Evaluating the Effectiveness of Decision Support System: Findings and Comparison

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***Abstract*—Nowadays, regardless of the popularity and credibility of Decision Support Systems (DSS), measuring the efficacy of the decisions taken by the DSS is yet to be proven. As previous works identifies the complexities involved in measuring the efficiency of DSS, most of the time DSS efficiency is case dependent. The list of methods for collecting and analyzing data, building models, deployment models, data and model integration, and finally taking decisions are some of the major issues related to measuring DSS effectiveness. This paper focuses on measuring the effectiveness of DSS. The paper highlights the issues that still need to be addressed with efficient frameworks. Based on the literature review and discussion presented in Section I and II, this study proposed a framework and its implementation. Presents how the proposed model can improve the previous work. The major findings of this study reflect that every decision made by DSS is based on the collected data, analyzed by DSS tools, as well as depends on the developed models. Therefore, this study illustrated that each component of DSS plays vital role in measuring the effectiveness of DSS whatever the case and problem for which the DSS has been built and implemented for. In addition, the supporting methods and measuring factors for each component are other findings of this study. Any decision taken by DSS will be evaluated separately in order to measure the effectiveness of the system. The proposed framework resembles a new framework for the decision makers working in any industry.**

Keywords—DSS; effectiveness of decisions; framework; measurement phase

I. Introduction

A decision support system (DSS) is a kind of information system that is developed to help organizations in storing, managing, analyzing and ultimately supporting managers in decision making process [1]. DSS is an old term, and researchers have been describing its major components from different perspectives, such as problem solver, system function, and development process [2]. In the late 1960s, an updated version of information system proposed based on model-oriented was known as decision support system in order to support organizational decision making process [1]. Since then the evolution of DSS has started at where different research articles were published in different information systems related journal. Furthermore, as described by [3], a famous business journal in 1979 took an advanced initiative to offer the researchers to publish articled related to decision making process, business decision systems, strategic management and decision management systems.

Thereafter, researches have been elaborating on DSS characteristics, components, and deployment in different industries. Vast literature works discovered that DSS implementation and usage has been tested and verified in different kinds of business and their applications. Examples covers areas such as logistic [4], customer relationship management [5], enterprise resource planning [6], supply chain management [7], clinical information system [8]. A system architecture of DSS based on GIS is proposed in [9], which can provide help in alarming disastrous situations such as floods in order to reduce disaster effects on living communities. Predicting and assessing the employee's behavior in an organization is a work presented by [10], using analytic network process. Another proposal has been presented to evaluate the customer reviews impact decision making while purchasing online [11]. The study highlighted that new customers are very much influenced by previous consumer reviews that ultimately help them to make purchasing decisions. DSS application employed in hospital industry as in [12]. The research proposed a diabetes decision support application using fuzzy based expert system. The idea is to provide assistance to medical staff and doctors in diagnosing the diabetes with potential patients.

Making a proper decision demands adequate data analysis, analytical and statistical study, evaluating alternatives, and evaluating optimization criteria for decisions, etc., which might result in exhaustive and extensive analysis. Given that DSS consists of four major components; namely, user interface, data, model, and knowledge base [15], this research proposes a framework that is component dependent for measuring the effectiveness of DSS by considering the importance of each DSS component to measure their impacts on decisions, and hence overcoming the associated complexities of decision optimization.

To conclude this section, the DSS is responsible to perform several tasks such as storing, managing, and analyzing vast amount of data to improve the efficiency of decision-making process. In this research, we focus on how an organization can assess the impact of decisions made previously. As such, the study elaborates on answering the following research questions:

- Is each component of DSS required same attention while evaluating the effectiveness of the decisions made by DSS?

- What are the supporting methods and measuring metrics can be used for measuring the effectiveness of DSS?

The structure of remaining paper is organized as follows. The subsequent section elaborates the previous literatures discussing the frameworks or methods to evaluate the impact of DSS. The later sections describes the proposed framework and its implementation. Finally, the paper highlighting the future work and summary of the paper in the conclusion section.

II. Measuring the Effectiveness of DSS

DSS is a kind of information system, which is for an organization to fulfill single or multiple decision demands [1]. Storing and managing data, predicting solutions, or list solutions can be provided depending on the type of problem and its degree of structure; namely structured, semi-structured, and unstructured in [13]. Since, categorizing DSS is based on context degree of structure and set of alternative, the effectiveness of decisions is still a complex issue for the researchers. The explanation regarding the list of alternatives and decision-making criteria given by [13], suggests that DSS effectiveness can be measured based on different types of decision. Mainly, they purposed that building DSS is based on data analysis and reports generated by a DSS with the help of model based and knowledge base. In [14], to measure the effectiveness of DSS, all components including the user interface need to be assessed thoroughly, whereas the list of input and output variables represents major components during evaluation phase as shown in Fig. 1. In [14], many factors such as; business process, participants, information, technology, infrastructure and strategy shapes the adequate DSS.

Many other articles discuss the quality and effectiveness of DSS decision making process [8], [15]–[18]. Since DSS is an information system, it requires a designated measurement model. System's user, organization's environment and success criteria are the major parts of measuring the effectiveness of DSS in [19]. Multiple strategies and models to evaluate different kinds of information system are presented in [6], [20]–[27].

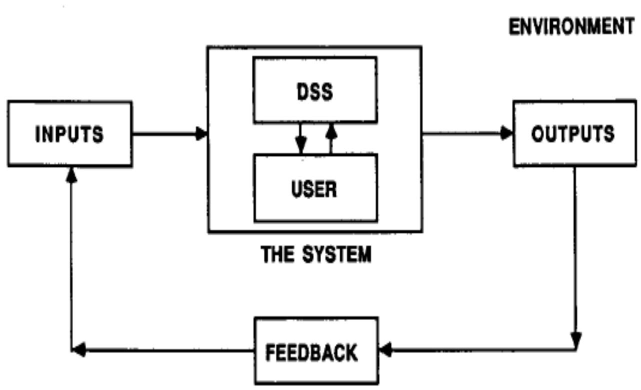

Fig. 1. The Working of DSS and Environment [15].

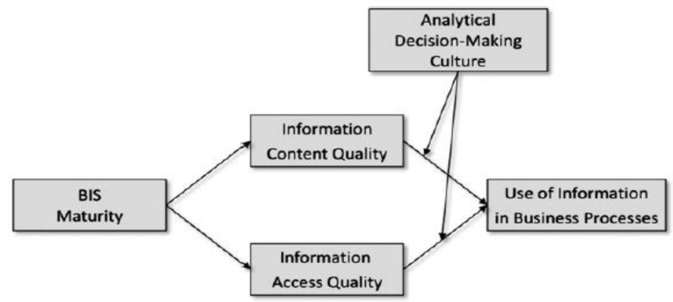

Fig. 2. Importance of Data Quality in IS Success Model [29].

In [13], data management is shown to be a compulsory element of any DSS. In this research a standalone database for specific DSS provides fast and intelligent decision making process. Since querying data and data quality are the basic characteristics of DSS, measuring the data efficacy is a part of evaluation process as described in [28]. Measuring the business intelligence is considered one of the major output of DSS [13], [29]. Data quality represents major part of successful DSS model as shown in Fig. 2 [28].

The above literatures highlight the major components of DSS (i.e. data, model, knowledge, user interface) can be considered as a part of a framework for measuring the effectiveness of decision support system. The discussion also leads to the conclusion that the boundaries of evaluating the decision making process is not limited with data and environment only, but there are other elements which need to be considered equally during evaluation process. This includes feedback from users, user interface, input process, output procedures, reports, analysis and strategy. However, as the development of DSS can either be based on structured, semi-structured, or unstructured problem, the complexity of the evaluation process can considerably be high.

The major elements that affect measuring the effectiveness of DSS can be summarized as follows:

- Data, user interface, and knowledge building
- Model building using quantitative and qualitative analysis.
- Deployment of analytical and statistical methods such as; what-if scenario, data tables, and optimization tool.
- An interactive user interface including with customize query facility, user authentication, and separated dashboard for different kinds of users.
- An efficient and automated building of knowledge base, where different kinds of techniques can apply such as; data mining, classification of data, rules building, and prediction tools.

III. Proposed Framework for DSS with Extended Measurement Phase

The framework presented in this research is the extension of traditional DSS model in a more structured way. The proposed model helps as supportive method for each component and measurement criteria for assessing the effectiveness of decisions. As described by [30], that DSS consists of multidisciplinary contexts where it connects combination resources such as database, knowledge base, human computer interaction, machine learning, data analysis and statistical methods. Therefore, the proposed extension of DSS model is relatively exploring the sub-components of DSS need to be deployed to support the decision making process. Figure 3 highlights the composition of DSS of different layers. The description and working of each components is discussed subsequent sections.

A. Data

Data is the fundamental element for any DSS. The data management component provides several functionalities such as storing, process, and organize data, as well as generating reports and templates to enable adequate decision making process.

The data management component provides basic information that is very helpful to many cases such as; finances, funding, and most importantly customer's related strategies. The data management subsystem can be incorporated with large data sources such as; data mart and data warehouse, whereas data analytics and visualization tools can represents the data in more attractive way to the decision makers. Data extraction, retrieval, querying, tracking of data, log files, and flexibility are kind of functionalities that data management subsystem provides to the DSS. All of these functionalities are part of measuring the effectiveness of proposed DSS.

B. Model

The model component in DSS is a complete package including with basic building blocks' capabilities. For example, financial, statistical, graphical, quantitative and qualitative elements are all considered. Model management subsystem contains library of models with model catalog, and query facilities. The model management subsystem's capabilities are similar to data management subsystem. Both subsystems provide the management and tracking facilities. Model management typically depends on the pre-processed data coming from data management subsystem, which ultimately helps in developing appropriate model based on provided data. During measuring phase, model building facility, model manipulation efficiency, model tracking, and model availability are considered factors to assess the effectiveness of DSS.

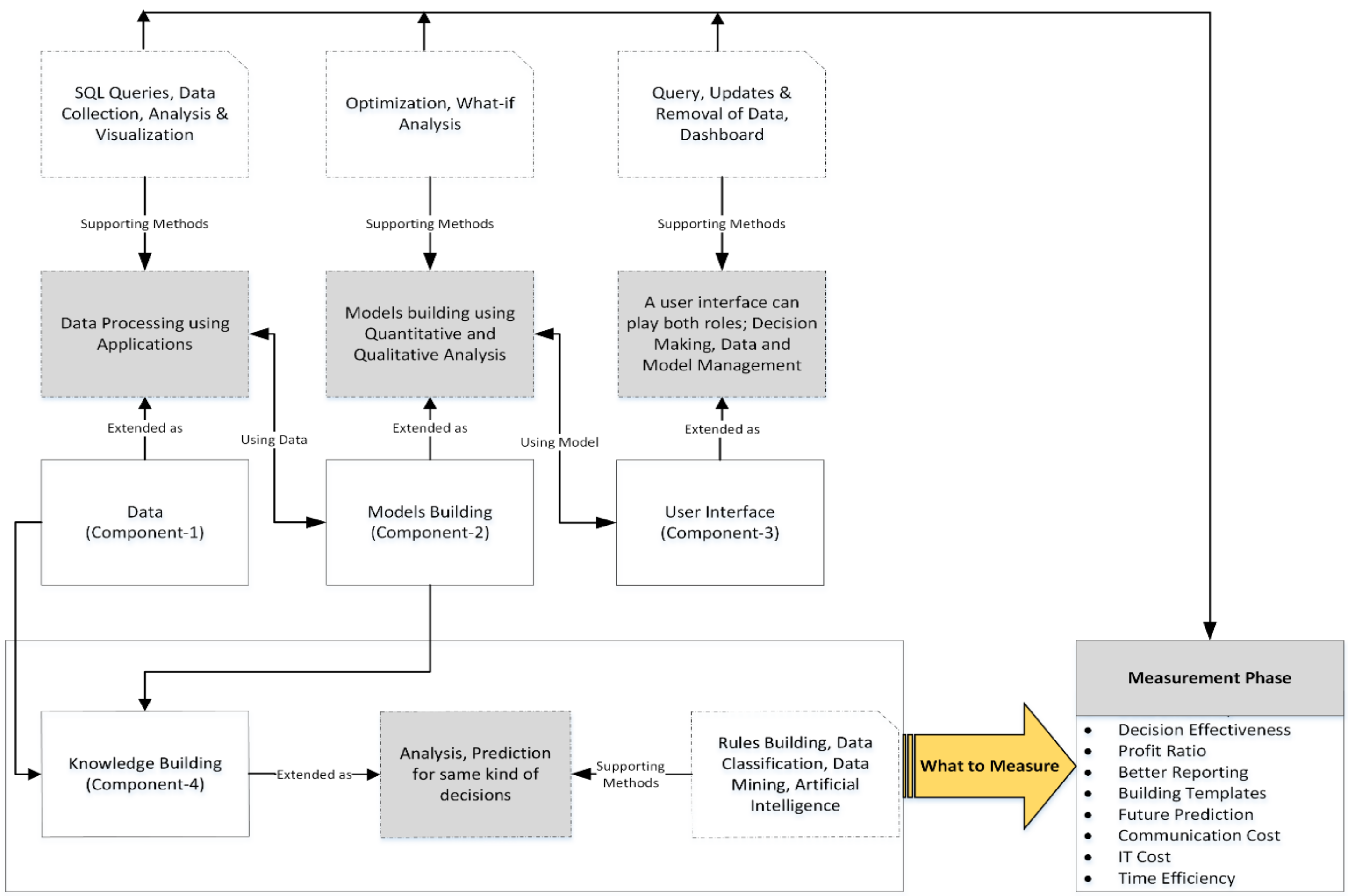

Fig. 3. Proposed Framework for Measuring the Effectiveness of DSS.

C. User Interface

User interface is a component directly connected with data management subsystem and model management subsystem. This component is used for direct communication with DSS users with variety of user interface derivatives. In a DSS environment, users represent a major element of the system. They are communicated with through web browser, dashboard, ready-made programmable and customized gateway, and excel worksheet. User interface provide the facility to users to establish a data query from database, forwarded to model management and get the best solution from selected alternatives. The major functionalities of user interface may provide are customized query facility, flexible user environment, integration between multiple data sources using option boxes, capturing and data storage choice, and list of alternatives. Theses functionalities are enabled by the incorporation of user interface with data management subsystem and model management subsystem. Ultimately, the user interface friendly environment eases the work for DSS utilization and provides basic functions available all the time with simple steps. Additionally, the user interface plays significant role in measuring the effectiveness of decision proposed by DSS. Historical data would be available to calculate measuring factors reciprocally. The purpose of measuring phase is to evaluate the effectiveness of decision support system using different factors; i.e. number of queries asked, successful completion of queries, using data management, model management, and user interface.

D. Knowledge Building

Apart from the three essential components of DSS; namely, data management, model management, user interface, knowledge management system is another but optional component of DSS. The knowledge base is supposed to work individually and may provide collective support to other subsystems in DSS environment. The main purpose of knowledge base is to provide intelligence to the decision making process. A knowledge building can be accomplished by connecting knowledge management through organizational database, or it can take utilize external resources such as data warehouse or web servers.

Knowledge building follows a systematic approach to develop an efficient knowledge base management for future purposes. It performs symbolic reasoning and develops artificial neural networks for creating an environment where decision makers can get fast and accurate decisions. The data mining techniques like classification, clustering, and association mining are some famous techniques which may be integrated with DSS. It is very important to enhance the knowledge base within proper timing in order to improve the decision making process. Most of the time, the knowledge building tool is not directly connected to the decision making process except if required and approved by decision makers. On the other side, the main task of knowledge base is to keep updating the kind of problems occurs and the list of alternatives suggested by DSS. In this regard, knowledge base is helpful for predicting the solutions for same kind of problems in future.

E. How the Framework can Implement

Based on the previous discussion, the proposed framework of DSS is an extension of the ordinary DSS with a measurement phase. The model presented in this research is providing the approach for measuring the effectiveness of decisions made by any DSS. Table I presents the details of each element demonstrated in the framework. Overall, this table is showing three columns; DSS components, supporting methods, and measuring factors. For example, the “data” is one of the major elements in DSS environment, which is responsible for storing, managing and analyzing data extracted from different sources. This component supports the DSS as it represents data retrieval for analyzing alternatives of a given problem. Furthermore, the “data” component helps customizing queries according to the required context and problem statement. The whole process of “data” component involves data extraction, data analysis, alternatives development, criteria analysis, and querying facility. Accordingly, “data” component resemble the major DSS. The related challenging issue is how to measure the task accomplished by this component of DSS. The column “measuring factors” mentioned in Table I, represents efficacy evaluator of “data” component. It consists of variables that are extracted from the performed tasks. It reflects how the data being analyzed, communication cost, time taken during data extraction and analysis are some of measuring variables.

Table II presents a comparison between previous related works and the enhanced framework presented in this study. It shows the contrast between the models presented in the main related works [15, 29] and the proposed model of this study. As such, the major contribution of this research is considering all components of DSS for evaluating their impact on decisions, as each of these components resembles a major value to the decision.

TABLE I. MAJOR FRAMEWORK ELEMENTS

Components of DSS	**Supporting Methods**	**Measuring Factors**
Data	Data extraction Data retrieval Data querying Tracking of data Log files Flexibility Different data forms Template building	Reporting efficiency Profit/loss ratio Communication cost What-if scenario DSS environment Decision quality Intelligent decision Time management New templates Effectiveness
Model	Library of models Model catalog Model query facility Financial & statistical model Quantitative & qualitative model	Model building facility Model manipulation Efficiency Tracking of the model Model availability Number of request and completion time Profit/loss ratio Time efficiency
User Interface	Customized query facility Flexible user environment Integration multiple data sources Capture and data storage options	Number of alternative generated Search results credibility Number of queries solved Completion of requests Communication cost IT cost effectiveness Architecture of IT Client-Server response
Knowledge Building	Intelligent search engine performance Intelligent agents for alerts when problem occurs Classification of data Rules generation Prediction techniques Machine learning	Number of problems solved through intelligent agent Prediction accuracy Frequent rules patterns The performance of search engine Decisions efficiency IT cost effectiveness

TABLE II. THE COMPARISON BETWEEN PREVIOUS AND ENHANCED FRAMEWORKS

Model	**Model Description**	**Limitations**	**Enhancement in Proposed Framework**
Schematic View of DSS [16]	A DSS model which highlights the components of DSS including with type of database for each component. The model is good to understand the data integration process while measuring the impact to DSS.	• The framework is supposed to understand the architecture of DSS and its components with respect to data. • The model is not suitable for understanding the comprehensive list of measuring factors which can assess the effectiveness of DSS.	• The proposed framework highlights the list of all components including the knowledge base (an optional component) • The model represents all components with its supporting methods with is helpful to measure the impact of DSS.
The Evaluation Realms [15]	An evaluation framework which is based on assessing the set of alternatives.	• The framework does not consider all components during evaluation phase. It is only based on decision criteria, where the knowledge base is only the part of evaluation.	• The framework elaborates on the several measuring factors based on the integration of all components of DSS. • The framework consider each factors with its supporting methods.
The BIS success model [29]	BIS success model is based on IS success model to assess the business intelligence.	• Mainly depend on measuring the business intelligence. • Information access quality and information content quality are part of framework, but model management subsystem is not the part of this framework.	• All four components in measuring the effectiveness are considered including model base, and knowledge base.

IV. Conclusion and Future Work

This study discusses DSS components, implementation, evaluation, and domains of utilization. The paper presented the importance of each DSS components and their roles to DSS in decision-making process. It proposed a framework for evaluating these components' effectiveness on decisions by considering the "measuring factors" of each component and its relevance for evaluation phase. A potential future work can be validated the framework using a real DSS scenarios implemented in organizations.

References

[1] D. J. Power, "A Brief History of Decision Support Systems," *DSSResources.COM,* 2003. [Online]. Available: http://dssresources.com/history/dsshistory.html. [Accessed: 10-Sep-2018].

[2] M. Ginzberg and E. Stohr, "Decision support systems: Issues and Perspectives," *Cent. Digit. Econ. Res.*, vol. 27, no. 82–12, 1982.

[3] J. Sprague, R. H. and H. J. Watson, "Bit by Bit: Toward Decision Support Systems," *Calif. Manage. Rev.*, vol. XXII, no. 1, pp. 60–68, 1979.

[4] O. Fadiya, P. Georgakis, E. Chinyio, and C. Nwagboso, "Decision-making framework for selecting ICT-based construction logistics systems," *J. Eng. Des. Technol.*, vol. 13, no. 2, pp. 260–281, 2015.

[5] F. Saleem and A. S. Al-Malaise, "Implementation of Data Mining Approach for Building Automated Decision Support Systems," in *Information Society (i-Society), International Conference on (pp. 127-130). IEEE.*, 2012, pp. 127–130.

[6] K. Bokovec, T. Damij, and T. Rajkovič, "Evaluating ERP Projects with multi-attribute decision support systems," *Comput. Ind.*, vol. 73, pp. 93–104, 2015.

[7] J. C. M. Siluk *et al.*, "A performance measurement decision support system method applied for technology-based firms' suppliers," *J. Decis. Syst.*, vol. 26, no. 1, pp. 93–109, 2017.

[8] P. Amnarayan *et al.*, "Measuring the Impact of Diagnostic Decision Support on the Quality of Clinical Decision Making: Development of a Reliable and Valid Composite Score," *J. Am. Med. Informatics Assoc.*, vol. 10, no. 6, pp. 563–572, 2003.

[9] Y. Huang, W. Lin, and H. Zheng, "A decision support system based on GIS for flood prevention of Quanzhou City," in *Proceedings - 2013 5th International Conference on Intelligent Human-Machine Systems and Cybernetics, IHMSC 2013*, 2013, vol. 1, pp. 50–53.

[10] O. A. Arda, D. Delen, E. Tatoglu, and S. Zaim, "An analytic approach to assessing organizational citizenship behavior," *Decis. Support Syst.*, vol. 103, pp. 9–23, 2017.

[11] B. von Helversen, K. Abramczuk, W. Kopeć, and R. Nielek, "Influence of consumer reviews on online purchasing decisions in older and younger adults," *Decis. Support Syst.*, vol. 113, no. June, pp. 1–10, 2018.

[12] C.-S. Lee and M.-H. Wang, "A fuzzy expert system for diabetes decision support application.," *IEEE Trans. Syst. MAN, Cybern. B Cybern.*, vol. 41, no. 1, pp. 139–153, 2011.

[13] S. Alter, "A work system view of DSS in its fourth decade," *Decis. Support Syst.*, vol. 38, no. 3, pp. 319–327, 2004.

[14] G. Marin, "Decision Support Systems," *Fac. Comput. Sci. Bus. Manag. , Rom. Am. Univ. , Bucharest , Rom.*, 2011.

[15] D. Khazanchi, "Evaluating Decision Support System : A Dialectical Perspective," *J. Inf. Syst.*, pp. 90–97, 1991.

[16] E. Turban, R. Sharda, and D. Delen, *Decision Support and Business Intelligence Systems*, 10th ed. Pearson, 2010.

[17] F. D. . Van Schaik, *Effectiveness of Decision Support Systems*. 1988.

[18] R. Sharda, S. H. Barr, and J. C. McDonnell, "Decision Support System Effectiveness : A Review and an Empirical Test Author (s): Ramesh Sharda , Steve H . Barr and James C . McDonnell Published by : INFORMS Stable URL : http://www.jstor.org/stable/2632057 Accessed : 10-05-2016 17 : 37 UTC Your use," *INFORMS*, vol. 34, no. 2, pp. 139–159, 2016.

[19] F. Saleem and A. AL-Malaise AL-Ghamdi, "Implementation of data mining approach for building automated decision support systems," in *International Conference on Information Society, i-Society 2012*, 2012, pp. 127–130.

[20] S. Petter, W. H. DeLone, and E. R. McLean, "Measuring information systems success: models, dimensions, measures, and interrelationships," *Eur. J. Inf. Syst.*, vol. 17, no. 3, pp. 236–263, 2008.

[21] W. H. Tsai, Y. S. Shen, P. L. Lee, and L. Kuo, "An empirical investigation of the impacts of ERP consultant selections and project management on ERP IS success assessment," *IEEM 2009 - IEEE Int. Conf. Ind. Eng. Eng. Manag.*, pp. 568–572, 2009.

[22] A. A. Rabaa, "Assessing Information Systems Success Models : Empirical Comparison (Research in Progress)," 2009.

[23] A. S. Al-Mudimigh, F. Saleem, and Z. Ullah, "The effects of Data Mining in ERP-CRM model - A case study of MADAR," *WSEAS Trans. Comput.*, vol. 8, no. 5, 2009.

[24] J.-S. Chou and J.-H. Hong, "Assessing the impact of quality determinants and user characteristics on successful enterprise resource planning project implementation," *J. Manuf. Syst.*, vol. 32, no. 4, pp. 792–800, 2013.

[25] Z. Ullah, A. S. Al-Mudimigh, A. A. L.-M. Al-Ghamdi, and F. Saleem, "Critical success factors of ERP implementation at higher education institutes: A brief case study," *Inf.*, vol. 16, no. 10, 2013.

[26] F. Al-Mudimigh, A. S., Ullah, Z., & Saleem, "A framework of an automated data mining systems using ERP model.," *Int. J. Comput. Electr. Eng.*, vol. 1, no. 5, 2009.

[27] F. Saleem, N. Salim, A. G. Fayoumi, and A. Alghamdi, *A General Framework for Measuring Information and Communication Technology Investment: Case Study of Kingdom of Saudi Arabia*, vol. 322. 2012.

[28] A. A.-M. AL-Ghamdi and F. Saleem, "Enterprise application integration as a middleware: Modification in data & process layer," in *Proceedings of 2014 Science and Information Conference, SAI 2014*, 2014, pp. 698–701.

[29] A. Popovič, R. Hackney, P. S. Coelho, and J. Jaklič, "Towards business intelligence systems success: Effects of maturity and culture on analytical decision making," *Decis. Support Syst.*, vol. 54, no. 1, pp. 729–739, 2012.

[30] V. Vallurupalli and I. Bose, "Business intelligence for performance measurement: A case based analysis," *Decis. Support Syst.*, vol. 111, no. May, pp. 72–85, 2018.

A Study of Mobile Forensic Tools Evaluation on Android-Based LINE Messenger

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***Abstract*—The limitation of forensic tool and the mobile device's operating system are two problems for researchers in mobile forensics field. Nevertheless, some kinds of forensic tools testing in several devices might be helpful in an investigation. Therefore, the evaluation of forensic tool is one gate to reach the goal of a digital forensics study. Mobile forensics as one of the digital forensics branch that focusing on data recovery process on mobile devices has some problems in the analytical ability because of the different features of forensic tools. In this research, the researchers present studies and techniques on tools ability and evaluated them based on digital evidence of LINE analysis. The experiment was combined VV methods and NIST standard forensic methods to produce a model of forensic tool evaluation steps. As the result of the experiment, Oxygen Forensic has 61.90% of index number and MOBILedit Forensic has the highest index number at 76.19% in messenger application analysis. This research has successfully assessed the performance of forensic tools.**

***Keywords*—Forensic; investigation; mobile; evaluation; performance**

I. Introduction

Cybercrime is escalating and the race against cybercriminals is never ending since the internet established. The huge number of mobile phone users nowadays add the new problem of this issue. As a result of this many users, in addition to the traditional usage of mobile phones including making phone calls and texting in SMS, now mobile phones are also used for making video calls and chatting in the instant messenger.

The development of Android smartphone technology has an impact on the fast-growing number of applications developed for Android. Even though, cybercrime can happen in Android smartphone. The investigator has to be able to solve the crime case with a mobile forensic method to find a digital evidence. Digital evidence is fragile, volatile and vulnerable if it is not handled properly [1], especially in the mobile device. Mobile forensic is a science field that studies the process of digital evidence recovery using the appropriate way from a mobile device [2] which usually doing in a digital forensic investigation by the police. Digital forensic investigation is the phenomenon that solves the digitally committed crime and explores the culprit legally [3]. It is important for examiners and investigators to have the knowledge about mobile forensic methods and the tools.

National Institute of Standard Technology (NIST) considers that forensic tools might have ~~a~~ degree of error and need to be evaluated by the test against different mobile devices [4]. Experiments conducted with mobile device forensic tools can indicate the capability of the tools. The forensic tools should produce valid results based on the fact in terms of data objects that are acceptable in the court.

II. Literature Review

A. Related Work

In [5] the researchers conducted a comparative evaluation of forensic tools for WhatsApp analysis on Android-based smartphones. The author choose WhatsApp because of its easiness for expanding the user base. When installing it, one can virtually reach all contacts in his/her address book on the phone who have installed the same apps [6]. The researcher evaluating performance and ability of some forensic tools, i.e. WhatsApp DB/Key Extractor, Belkasoft Evidence, and Oxygen Forensic. The evaluation using the NIST forensic tool parameter and additional parameters from the researcher. The author did at least four steps to conduct this evaluation, i.e simulation, forensic analysis, analysis result, and conclusion.

In [7] the authors want to emphasize on the forensic investigation process and to compare mobile forensic tools used in this research by using a framework developed by National Institute of Standard and Technology (NIST). The authors used four forensic tools to examine one Android device. The performance of forensic tools was rated quantitatively. There is no strong reason in this work and the previous reference why the forensic process has to use NIST method or the specific tools.

According to [8] the researchers suggest the decision method theories trough performance and relevance parameter while doing a hypothesis testing on forensic method and tools selection. This paper is inspired by the freedom of choice necessitates theory. The freedom choice theory is a sense of responsibility that asks for separation between true and false. Sometimes the selecting process for choosing the right forensics tool is complex with major consequences. The author suggest the project to evaluate the performance of more tools against a broader set of mobile devices will help in the selection of the most appropriate forensics tool. In the previous work, the National Institute for Standards and

Technology (NIST) conducted an evaluation of the forensics tools as an independent third party.

In reference [9] the researcher doing "Validation approach" since the tools were of propitiatory nature and there was no access to their documentation and source code. This paper presents the findings with respect to the reliability of the tools only. The authors evaluate XRY and UFED forensic tool in the light of NIST Smartphone Tool Specification which consists of a number of specifications with their associated Test Assertions and Conformance Indicators.

Performance can be measured from historical data or from the results of carefully designed experiments. Historical data included performance evaluation results by both the vendors and a trusted third party. The problems, however, were that: (i) vendor evaluation lacked trust and (ii) trusted third party's evaluation used different mobile devices to evaluate the forensic tools. The tools were not evaluated on equal grounds and thus the results cannot be generalized for comparing their performance.

Every digital forensic method has different stages in each handling of the digital evidence found, so in the handling of various evidence, it requires different digital forensic models [10]. In many references, digital forensics process at least can be divided into four steps as in Fig. 1**,** collection, preservation, analysis, and presentation [11]. The naming four stage of digital forensic model is very flexible to be changed as needed for investigation. Sometimes at the end of the process called "reporting" instead of presentation and at the beginning begins with the identification process before collection/preservation.

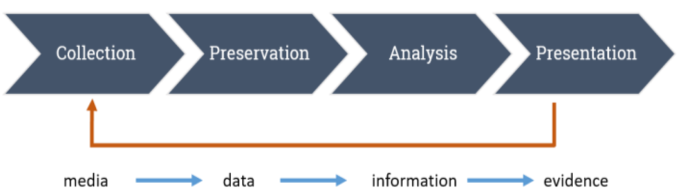

Fig. 1. Digital Forensic Process.

Having knowledge of the digital forensic process is important, same as forensic tools that have a vital role in the whole forensic process. Examiners must understand the capabilities of a forensic tool with insights from good references of tool testing. But, most of the mobile forensic tool testing and evaluations are done by the vendors. Mobile forensic tools developed in the forensic world are rarely validated independently and scientifically. Moreover, forensic tools are used almost in all the stage of mobile forensics process.

B. Digital Forensics Problem

There are many proprietary forensic tools have been developed. As a result, a wide variety of tools exist to extract evidence from mobile devices, no one tool or method can acquire all the evidence from all devices [12]. The software applications for mobile forensics available today are not 100% forensically sound [13]. The complexity formally representing all the science need to start with a literature and discussions with industry leaders from diverse backgrounds [14]. Experiment in the past concentrated on the trustworthiness of digital evidence that is the product of the process and not the validity of the tools. Recently, there is an attempt to formalize the theory of digital forensics and dissertation about definitive research that focuses on the model the process has already started to appear. There is also research on validation of the investigation results forensic (that is the reliability of the evidence), only a few on the reliability of tools that produces the evidence. The researcher have to consider that when the examiner/investigator want to conduct an analysis, they need to use a method along with forensically tested tools [15]. Each tools can be validated and verified on its merits and the examiner can focus on the results required rather than the domain of all possible functions and all possible specifications.

C. Mobile Device Forensic Tools Evaluation

Mobile device forensic tools evaluation is consist of the validation and verification process. Validation is the confirmation by examination and the provision of objective evidence that a tool, technique or procedure functions correctly and as intended, while verification is the confirmation of a validation with laboratories tools, techniques, and procedures [14]. It is important for a forensic examiner to know how reliable and accurate a tool is before being used. The researcher have used the evaluation to gauge and verify the reliability and accuracy of two most prominent mobile forensic tools such as MOBILedit Forensic and Oxygen Forensics based on the Smart Phone Tools Specifications by NIST [16]. The parameters for tool evaluation are depend on the needs of researchers, but they are not far from the issue background.

III. Research Methodology

A. Evaluation Method

This article is inspired by many previous works of forensic tool evaluation, one of them is validation verification (VV) methodology that was proposed by Guo, Slay, and Beckett [17]. The first step in evaluation is listing the forensic tools function. From the documentation of both tools; Oxygen Forensic and MOBILedit Forensic, their function as seen as in Table 1.

TABLE I. Forensic Tools Functions

Oxygen Forensic	**MOBILedit Forensic**
Device Identification	Device identification
Data Extraction	Application data extraction for Android and iOS
Messenger Application Analysis	Application Analysis
Data Report	Data Report
Case Management	-
-	Deleted data retrieval

- Device Identification : The ability of a forensic tool in device recognition
- Data Extraction : The ability in data extraction from the device
- Messenger Application Analysis : The Ability to show the content of messenger application
- Data Report: The ability of tools evidence documentation in form of report file (.xml, .pdf, .xsl, etc.)
- Case Management : Management of cases during the analysis process
- Deleted data retrieval : The capability of a forensic tool to retrieve any deleted data from the device

Six aspects above need for validation and verification for evaluating the tools. Validation technique used quantitative calculation so that assessment more objective, but to verify, the researcher simply apply quantitative assessment. Among the aspects that can be considered qualitatively are device identification, data extraction, case management and deleted data retrieval. While to messenger application analysis and data report can be assessed quantitatively in the term of the performance in producing the evidence.

Fig. 2. A Brief Process of Forensic Tools Evaluation.

This experiment was conducted using simulations on a smartphone and two forensic tools. The brief process of this experiment is described in Fig. 2. The explanation of the tool verification and validation will be described in the next section.

B. *Tool Verification*

In the verification process, the researcher compare the function of the forensic tools with the experiment they did. Some functions that need to be verified are device identification, data extraction, case management in Oxygen Forensics, and deleted data retrieval in MOBILedit forensic. Verification is done manually by comparing one by one function then assessed by its performance.

C. *Tool Validation*

Forensic tools validation can be done accurately by judging the performance index number as shown in equation (1). Performance is measured in terms of probability of successful (Ps) extraction of a particular type of digital evidence by a specific forensics tool using the equations below:

$$P_s = \frac{x}{n} \qquad (1)$$

The number of objects extracted by two forensic tools, Oxygen Forensic and MOBILedit Forensic. Objects that populated in this experiment is from LINE messenger by manual acquisition. Equation (1) used to calculate the index number of the messenger application analysis and the data report from each forensic tool. This equation also can be used in validating the data report for each forensic tools. The equipment that used in this research can be seen in Table 2 as follows:

The whole research processes can be drawn as in Fig. 3. This research model is an adoption of NIST method with alteration with VV methodology as needed for the research purposes.

TABLE II. EVALUTION RESULT FROM OXYGEN FORENSIC AND MOBILEDIT FORENSIC

No.	Equipment	Description
1	SONY Xperia Z	Android Smartphone
2	ASUS A455L	Workstation, OS Win.10
3	Oxygen Forensics	Suite 2014
4	MOBILedit Forensic Express	Ver. 4.0
5	USB Cable	Ver. 2.0

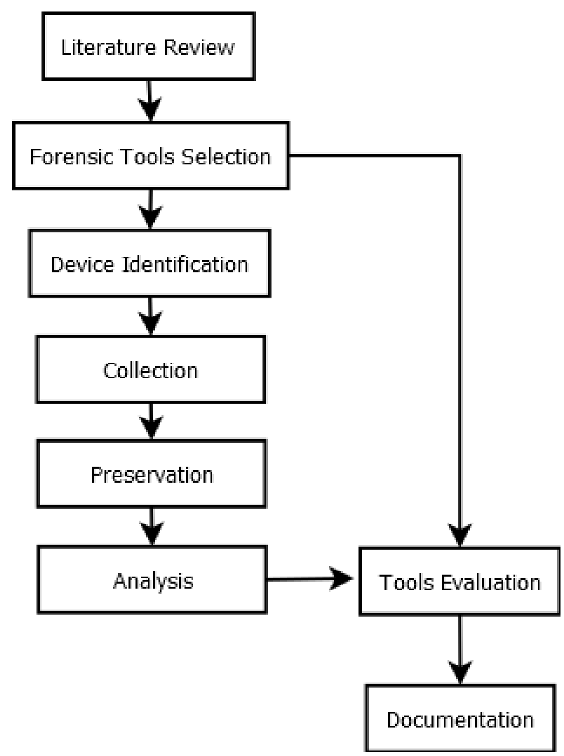

Fig. 3. Tools Evaluation Methodology.

The evaluation methodology can be modified according to the needs and the expected results. The method above is one method that can be applied in evaluation tool research.

IV. Result and Analysis

The evaluation is ended with the documentation process. This documentation can be either a report or a presentation file to show to the examiner and investigator. The results of the evaluation process that is conducted by applying VV methods are as follows:

A. Device Identification

The device identification is the first step that must be done by any forensic tool. The collection of information about the device is very useful in the report on the final process. Oxygen forensic is able to identify the device that the researcher use, Sony C6602 or known as Sony Xperia Z, as can be seen in Fig. 4. But, Oxygen forensics is not able to recognize the IMEI number or the serial number of this device.

While in MOBILedit forensic the device identification result is as expected. Metadata from the device like serial number, IMEI, IMSI, ICCID, Root status. All of the important metadata can be revealed and documented as in Fig. 5. MOBILedit forensic is quite successful in identification mobiledit mobile device.

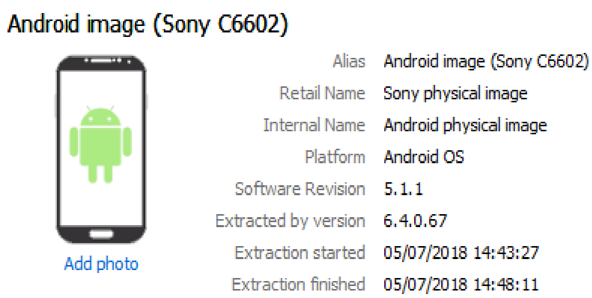

Fig. 4. Device Identification by Oxygen Forensic.

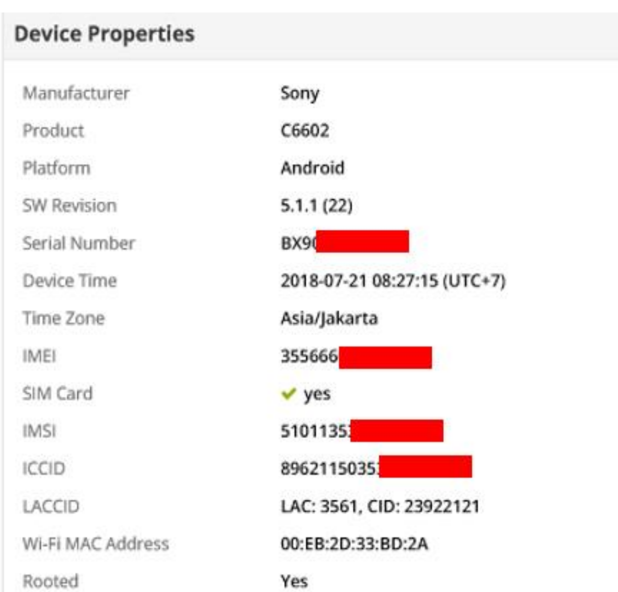

Fig. 5. Device Identification by MOBILedit.

Both devices are quite good in the device identification function. Although Oxygen forensics has its lack, at least it can recognize the device's manufacturer name. These results may be different on the other devices.

B. Data Extraction

Data extraction on both devices is desirable, as this is much needed in a long-period investigation. Data extraction on Oxygen Forensics is quite successful because it is able to create backup files from data acquisition devices, as shown in Fig. 6.

While in MOBILedit, as seen in Fig. 7, data extraction to generate backup data is not as good as expected, because the data extraction data that we get was corupted and error.

Both forensic tools have different ways of extracting data. MOBILedit is not success in performing its functions. However, Oxygen can be used in investigations over a long period of time, so the examiner can analyze the digital evidence more deeply. The difference of the forensic tools result can be aspect that can be considered by the examiner.

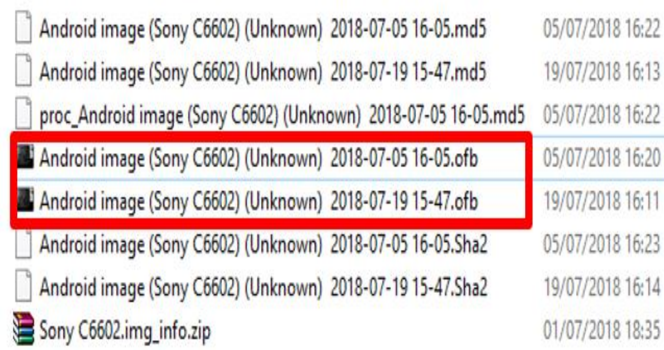

Fig. 6. Data Extraction by Oxygen Forensic.

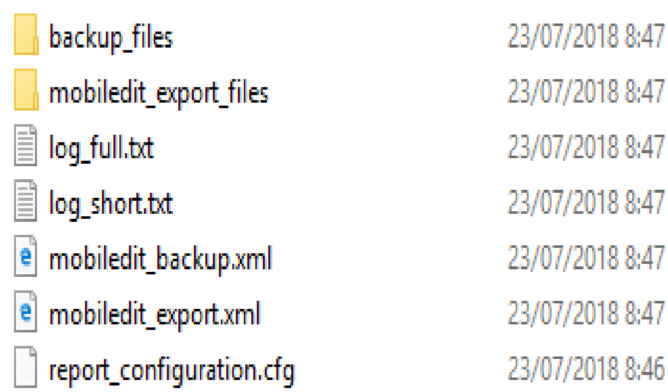

Fig. 7. Data Extraction by MOBILedit Forensic.

C. Messenger Application Analysis

Analysis of messenger apps in this experiment will see the ability of forensic tools on LINE messenger analysis. LINE messenger that was tested is the latest version, with simulated conversations that have been done in it. In Oxygen forensic, messenger analysis result is presented in table form by displaying ID, the direction of the message, remote party, text, and the timestamp. In the Fig. 8 there are no any images nor videos that can be displayed.

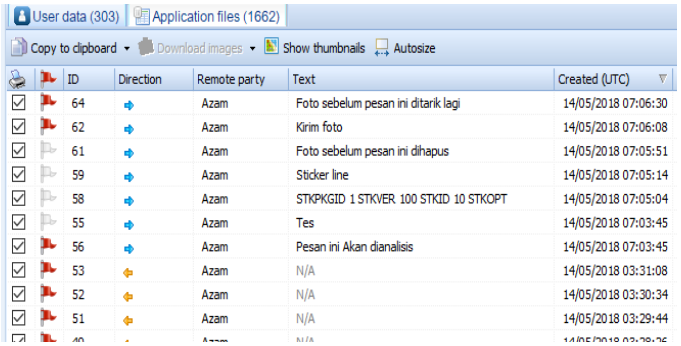

Fig. 8. LINE Messenger Analysis in Oxygen Forensic.

While in MOBILedit forensic, analysis of messenger is presented in the report file with a colored block display like a message application look, as shown in Fig. 9.

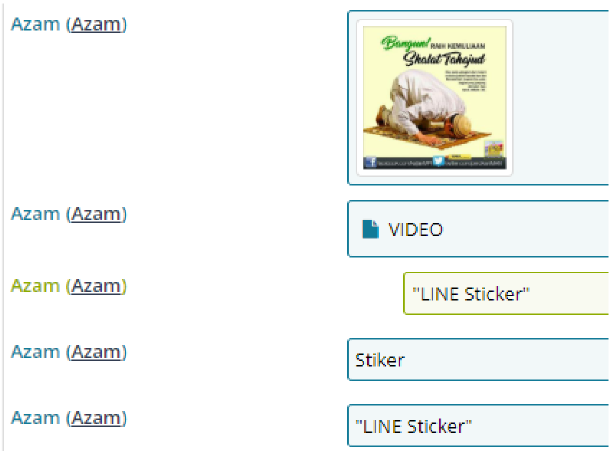

Fig. 9. LINE Messenger Analysis in MOBILedit Forensic.

Both of forensic tools have the ability to analyze the data, but in different way. In this experiment, MOBILedit is perform better than Oxygen Forensics.

D. Data Report

Oxygen forensic has the ability to create reports in the form of pdf, rtf, xls, xml, csv, tsv, and html. While MOBILedit has the ability to create reports in html, pdf, and excel formats. In oxygen forensic, only pdf files that unable work properly while others are pretty good. In MOBILedit report is very complete and works entirely.

E. Case Management

Case management in Oxygen Forensics is reliable for deeper analysis. While on MOBILedit, there is no case management like in Oxygen forensic. For this feature, MOBILedit has to consider for completed their tools.

F. Deleted Data Retrieval

The function for deleted data recovery was found on the MOBILedit forensic express. While on Oxygen this function the researcher did not find it. This function is helpful in criminal cases where the perpetrator removes some data from digital devices.

TABLE III. EVALUATION RESULT FROM OXYGEN FORENSIC AND MOBILEDIT FORENSIC

Function	**Oxygen Forensic**	**MOBILedit Forensic Express**
Device Identification	As expected	As expected
Data Extraction	As expected	Not As expected
Case Management	As expected	N/A
Deleted Data Retrieval	N/A	As expected
Messenger Application Analysis	61,90%	76,19%
Data Report	90%	100%

Table 3 shows a summary of the results from tools evaluation that we have been done. It can be seen that MOBILedit looks better than Oxygen. However, for some functions, such as data extraction and case management, MOBILedit needs to consider installing it on the tool.

V. CONCLUSION

Analytical ability of MOBILedit Forensic has the highest index number as much as 76.19% while Oxygen Forensic has 61.90% of index number. In this case LINE messenger analysis. Oxygen Forensic can be better in data report than MOBILedit forensic. MOBILedit has a limit in extracting video in LINE messenger. However, MOBILedit Forensic is don’t have case management function to as in Oxygen Forensic, but MOBILedit is very efficient in term of data report and data extraction.

VI. FUTURE WORK

Considering the growing number of smartphones and forensic methods emerging, research on forensic evaluation has to be done. In Future work, the researchers suggest the evaluation of forensic methods and forensic tools more detailed, so that the reference to this issue more complete. Some suggestions about the evaluation parameter can be discuss in the further research as well as additional variations of forensic tools that can be evaluated.

REFERENCES

[1] I. Riadi, R. Umar, and A. Firdonsyah, “Identification Of Digital Evidence On Android’s Blackberry Messenger Using NIST Mobile Forensic Method,” Int. J. Comput. Sci. Inf. Secur., vol. 3, no. 5, pp. 29–36, 2017.

[2] I. Riadi, A. Fadlil, and A. Fauzan, “Evidence Gathering and Identification of LINE Messenger on Android Device,” Int. J. Comput. Sci. Inf. Secur. (IJCSIS), vol. 16, no. June, pp. 201–205, 2018.

[3] U. Kumar Singh, C. Joshi, U. Neha Gaud, and U. Chanchala Joshi, “A Framework for Digital Forensic Investigation using Authentication Technique to maintain Evidence Integrity,” Int. J. Comput. Appl., vol. 154, no. 6, pp. 975–8887, 2016.

[4] R. Ayers, S. Brothers, and W. Jansen, “Guidelines on mobile device forensics,” NIST Spec. Publ., vol. 1, no. 1, p. 85, 2014.

[5] R. Umar, I. Riadi, and G. Maulana, “A Comparative Study of Forensic Tools for WhatsApp Analysis using NIST Measurements,” Int. J. Adv. Comput. Sci. Appl., 2017.

[6] T. Sutikno, L. Handayani, D. Stiawan, M. A. Riyadi, and I. M. I. Subroto, "WhatsApp, viber, and telegram: Which is the best for instant messaging?," Int. J. Electr. Comput. Eng., 2016.

[7] I. Riadi and A. Firdonsyah, “Forensic Investigation Technique on Android ’ s Blackberry Messenger using NIST Framework,” Int. J. Cyber - Secur. Digit. Forensics (IJCSDF) Soc. Digit. Inf. Wirel. Commun., vol. 6, no. 4, pp. 198–205.

[8] S. Saleem, O. Popov, and I. Baggili, "A method and a case study for the selection of the best available tool for mobile device forensics using decision analysis," Digit. Investig., 2016.

[9] A. K. Kubi, S. Saleem, and O. Popov, "Evaluation of some tools for extracting e-evidence from mobile devices," 2011 5th Int. Conf. Appl. Inf. Commun. Technol. AICT 2011, no. 10, 2011.

[10] R. Ruuhwan, I. Riadi, and Y. Prayudi, "Evaluation of integrated digital forensics investigation framework for the investigation of smartphones using soft system methodology," Int. J. Electr. Comput. Eng., 2017.

[11] N. Widiyasono, I. Riadi, and A. Luthfi, "Investigation on the services of private cloud computing by using ADAM Method," Int. J. Electr. Comput. Eng., vol. 6, no. 5, pp. 2387–2395, 2016.

[12] E. Benkhelifa, B. E. Thomas, L. Tawalbeh, and Y. Jararweh, "Framework for Mobile Devices Analysis," Procedia Comput. Sci., vol. 83, pp. 1188–1193, 2016.

[13] K. Curran, A. Robinson, S. Peacocke, and S. Cassidy, "Mobile Phone Forensic Analysis," Int. J. Digit. Crime Forensics, vol. 2, no. 2, pp. 1941–6210, 2010.

[14] J. Beckett and J. Slay, "Digital forensics: Validation and verification in a dynamic work environment," Proc. Annu. Hawaii Int. Conf. Syst. Sci., no. February 2014, 2007.

[15] R. Umar, I. Riadi, and G. M. Zamroni, "Mobile Forensic Tools Evaluation for Digital Crime Investigation," Int. J. Adv. Sci. Eng. Inf. Technol., vol. 8, no. June, pp. 949–955, 2018.

[16] National Institute of Standards and Technology, "Mobile Device Tool Specification Version 2.0," 2016.

[17] Y. Guo, J. Slay, and J. Beckett, "Validation and verification of computer forensic software tools-Searching Function," Digit. Investig., vol. 6, no. SUPPL., 2009.

Moving from Heterogeneous Data Sources to Big Data: Interoperability and Integration Issues

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Abstract—**Heterogeneous databases are now facing an emerging challenge of moving towards big data. These databases are adhoc polyglot systems, complex, and NoSQL tools which are semantically annotated. Integration of these heterogeneous databases are becoming very challenging because big data analytics is integrating human and machines contexts. In this paper, an attempt is made to study heterogeneous databases and their interoperability issues and integration issues, and their impact on analysis of data. The data science has grown exponentially and a new paradigm has emerged which is of integration of heterogeneous data to big data. Information, knowledge and decision making become easier but the size of databases has grown and it became big data.**

Keywords—Heterogeneous databases; interoperability; integration; big data; analytics and intelligence

I. Introduction

This paper presents a new novel approach for integrating database systems and unifying processing while preserving heterogeneity among databases. Instead of using interface techniques this approach uses database connection techniques, which is more flexible and available. Since 1980th till now, several heterogeneous distributed database models have been developed. The early models, the models that were generated before 1990th, such as R* [1] SDD-[2], SIRIUS-DELTA [3], Distributed INGRE [4], ADDS [5], IMDAS [6], and MERMAID [7], presented good ideas, but they were never commercially successful [8; 9]. The new models, designed after 1990, such as Mariposa [10], DB2 UDB [11] and Sybase for extensible data management [12], in additional to the new generation of the early models, are trying to realize the value of the new advantages of the computers, the networks, and the DBMSs. They are also providing heterogeneous distributed systems and unified processing, which have become more complex, because of the continuous growth of several commercial hardware and software products.

1) The limitation of the current models: Most of these models focus on providing heterogeneous distributed systems under certain components. No model can provide standard approach for developing the distributed system under the rapid changes we face today. AS we can see there is a large body of applications, data, and enterprises that run on variety of computers and networks, which cannot be unified by a model that is designed to solve a certain kind of heterogeneity under a certain concept i.e. a limited solution for a global problem. So these models cannot be considered as standard solutions for the distributed processing unless all the heterogeneous and the unified components are static, which is not the case in the situation we face today.

In a sense most of all these models are projects that were generated to satisfy a certain purpose; so they look like an independent particular solution, which cannot be extended to cover integrated systems.

Most of these models do not address the principles introduced by distributed database such as fragmentation, and replication techniques.

2) The gap between research and application: Researchers have developed techniques for handling distributed problems. A large body of research work has been produced in areas such as distributed queries processing and optimization (as example: [13; 14]); distributed location (as example: [15; 16]); distributed replication (as example: [17; 18; 19]); and distributed concurrency control (as example: [20; 21]). Today the situation became more complex; a large body of enterprises has been distributed on the networks, which generate tremendous amounts of data. Applications and computerized products are generated so fast and distributed on different sites using variety of software and hardware, which provide difficulties in compatibility and load balancing among various data marts, especially as the number of systems is growing continuously. This situation causes more complexity in heterogeneous and unified processing. Furthermore, new problems are coming up, the problems of cocupling and integrating data, enterprises, and information, which can be difficult for the existing models to solve. Therefore, new approach is needed to handle this situation. The approach which, can build a heterogeneous distributed models that can provide a standard solution to the distributed processing, the solution which can work on all kinds of data, application, and enterprises, with ability to integrate several systems and enterprises, and ability to facilitate the continuously growing computing advantages and complexity.

Thus, this paper is to present new approach for the heterogeneous distributed database systems integration and shows the role of this approach in moving from Heterogeneous Data Sources to Big Data, the approach:

- acts as a standard approach for developing integrated distributed system under complexity and heterogeneous components,
- provides unified processing,
- permits the use of distributed database techniques such as fragmentation, replication and allocation.
- provides the heterogeneous distributed database capabilities such as schema integration, distributed query processing, and distributed transaction management.
- and provide a frame work for applying big data processing.

II. The Proposed Approach

This section describes the proposed two Approaches for Heterogonous Distributed Database Systems Integration **(**AHDDI**)**, which are top down and bottom up approach.

```
Procedure AHDDI
Begin
Top down:
    While (there is undivided problem) Do
    {
    Problem ⇒ sub-problems {divide-conquer}
    }
    while (there is unsolved sub-problem) Do
    {
     sub-problem ⇒ smaller-sub-system                 1
     smaller-sub-systems-solving:
        - Smaller-subsystem-DBMS (S-DBMS)
        - Application.
     }
bottom up:

    Linking the S-DBMSs ⇒ one midd-DBMS (M-DBMS)          2
    Add new application ⇒ get sibling solution

    While (not reaching the top level)
     {
        Combine M-DBMSs ⇒ one upper-DBMS (U-DBMS)         3
        Add new application ⇒ get upper sibling
        solution
     }
    Add new application ⇒ get final solution
    Add interface application ⇒ unify the system
End
```

Fig. 1. The Methodology.

The AHDDI algorithm:

Figure (1) illustrates the general idea of AHDDI algorithm. It gives the logical process and it explains the use of DBMS in linking the system components. While the numbers (1), (2) and (3) refer to the steps in which the distributed database techniques are provided, hence in (1) vertical fragmentation and allocation are provided, in (2) horizontal fragmentation and replication are provided, and in (3) hybrid fragmentation and replication are provided.

III. Divide-Conquer Algorithm

Divide and conquer approach is applied, where AHDDI splits the problem into several smaller sub-instances. Then it independently solves each of the sub-instances and then combines the sub-instance solutions yielding a solution for the original instance.

Divide-Conquer algorithm guarantees that a final solution is obtained by combining the independent solutions of the components. [22] [23]

AHDDI uses the following Divide-Conquer algorithm:

Re Divide an instance of size n into r sub-instances each of size n/k. (where k is the divide factor)

Solve these sub-instances.

Combine these sub-solutions.

So the recursion algorithm can follow this rule (*equation 1*):

$$\boldsymbol{a_n = c a_{n/k} + f(n)} \quad c \neq k \text{ [22][23]} \tag{1}$$

n : the size of the problem.(total number of the parts).

an : total number of steps needs to obtain the n-parts.

c : is a constant indicating the weight of the step

k : the divide factor (n/k: the size of the part).

f(n) : the function(the problem).

For example: if we want to divide each instance into 2 sub-instances (k=2), and if we have certain problem (f(n)=1) with equal levels (c=1) then our equation can be as follow (*equation2*) :

$$a_n = (2a_{n/2}) + 1 \tag{2}$$

We can recursively solving this problem as follows:

$$(2a_{n/2}) = [2^2 a_{n/2^2}] + 2$$

$$[2^2 a_{n/2^2}] = 2^3 a_{n/2^3} + 2^2$$

$$2^{k-1} a_{n/2^{k-1}} = 2^k a_{n/2^k} + 2^{k-1}$$

Assuming large n and summing:

$$a_n = n a_1 + \sum_{i=0}^{k-1} 2^i$$

According to Divide-Conquer Rule if we put $a_1 = 1$ as initial conditions then: [23].

$$\text{Then } a_n = n + 1 \tag{3}$$

Which is means we need n+1 steps for recursively dividing instants of size n to n sub-instances with the same size of parameters. This means n+1 tasks are required to solve problems of size n (*equation 3*)

IV. Software Architecture

AHDDI is generated using the bottom up technique. This is done by using divide-conquer rule to reach the lowest level systems (smallest subsystems). When we reach the smallest subsystems then we start working in these subsystems, which are located in bottom of the system, and then go up combining subsystems to obtain finally the whole system. All subsystems at the same level, which have the same parent, are combined to automatically obtain the solution for the parent system. Two steps did the combination of these systems (figure 2).

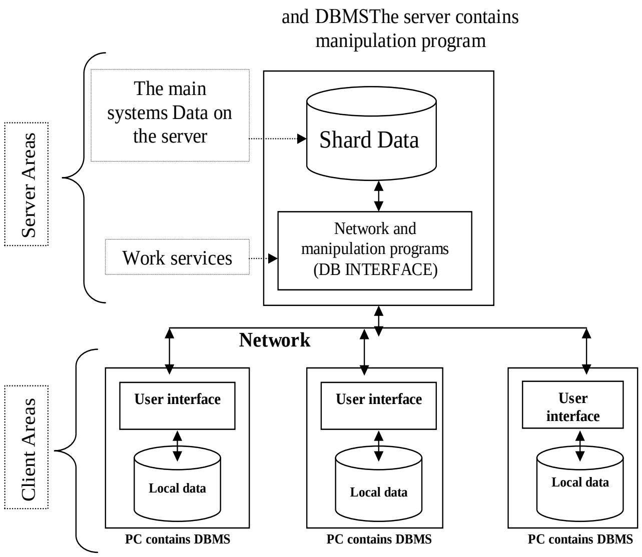

Fig. 2. AHDDI First Level Structure.

V. AHDDI Data Replication

It is important, for some applications, to replicate the data in different sites. For example, when we apply the AHDDI in the education environment we find that the academic subjects and syllabuses are needed to be used in different systems, such as, the students' academic record, the departments information system, and the registrations system, while these kinds of data are not frequency updated it will be better for the system to replicate these data in each user's local machine. Replication can be one of the successful factors in distributed models.

It is easy for AHDDI designer to implement all replication mechanisms (Eager or/and Lazy) because no more than one user can (simultaneously) create or update the same data. This is due to the fact hat AHDDI implements the bottom-up technique built on divide conquer rule.

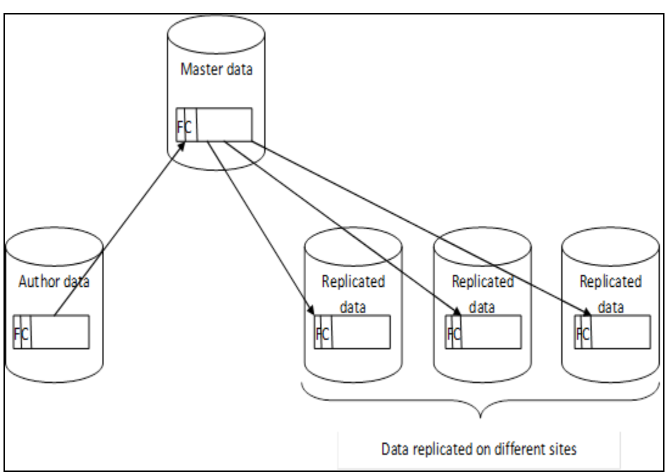

Fig. 3. AHDDI Data Replication.

AHDDI recommended that: any static data, not frequently updated data and archive data, must be replicated on any system that uses this data. This replication can be handled easy because; in AHDDI any data is actually master data in only one subsystem constitutes assistant data to the other subsystems. As example in educational system the academic subjects are master data in academic subject subsystem and its assistance data for all the college sub system such as, the timetable and the registration system. Therefore, this data is administrated by one user or one subsystem administrator and the replication of this data on other subsystem can be done by putting the master data on the global area and make a copy of it on each other subsystem data. So the author user's transaction can then access this data directly from its local machine (figure 3).

VI. Application Layer for Global Processing

The main function of this layer is to map the main system data on the subsystems machines, so this layer is available on each subsystem server, and through this layer the AHDDI queries can make access to main system data.

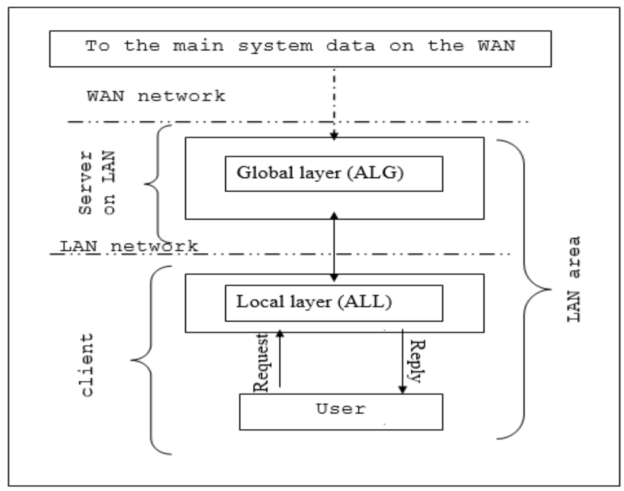

Fig. 4. AHDDI Communication.

```
{Example: linking Oracle DBMS}
Private cn As ADODB.Connection {ADO connection unit}

Public Sub condb()
{Connect to Oracle database}
Set cn = New
ADODB.Connection With cn
        .ConnectionTimeout = 3 { the wait time till the 30 sec. original time is finished}
        .CursorLocation = adUseClient
End With
{open table, using the ODBC DSN }
cn.Open "DSN=ORACLE;UID=SCOTT;PWD=tiger;"
End Sub

{Example: linking SQL-Server DBMS}
Private Sub Form_Load()
Dim cn1 As Connection
Dim r1, r2 As Recordset
Dim s1 As String
Set cn1 = New Connection {Connect SQL-
Server DBMS } cn1.Open "DSN=pubs"
{Specified an ODBC DSN } Set r1 = new
Recordset
r1.Open "Emp", cn1 , adOpenForwardOnly, adLockReadonly
{open table} do Until r1.EOF   s1=r1("name")
        …
        …
loop
End Sub
```

Fig. 5. Data Linking Algorithm (algorithm that used for linking the two layers and make data available in the place of the user application).

The application layer for global processing establishes a link to the main system's DBMS by bringing the name of a server (directory) on each subsystem server and letting the location of the main system DBMS available to each AHDDI queries (figure 4).

These two layers cause limitation to the work space and allow the manipulation of the queries looks like one machine process (transparent), hence these two layers make all the AHDDI data be available in the place of the user application. The algorithm that used for handling this process is illustrated in figure (5).

VII. Big Data Architecture

There was a shift in paradigms from RDBMS to AHDDI. Now data management and processing becoming more challenging because of nature of data, type of data, volume of data, and data become big data. Now complex NoSQL tools with semantically annotations are becoming popular to handle this big data. Architecture and design of databases are changing accordingly with technologies available to handle big data. Data variety, volume and access pattern, data migration from existing systems and integration in the new systems also very challenging task. Data analytics and analytical tools need to be integrated in this big data architectures and design because data modelling and management need them consistently.

Data Acquisition, storage, and analysis of huge data is becoming very complex and expensive process so most of the big companies working on their project called big data. It provides solution in terms of data value, velocity, variety and volume. Requirement of running web services over cloud has tremendously increased and it also facilitated the growth of big data. The sources of data generation is increasing like IoT and it compels big data platforms to grow. MPI, MapReduce and Dryad are the major big data tools that used for handling big data and the comparison will make it clear which tool is better than the other. Deployment, Resource management, scheduling, level of programming support, data storage, task handling, portioning, communication and fault tolerance are some of the issue which are solved by big data tools. In figure (6), an example of Oman is given, it shown how various heterogeneous data sources creating data and now it is moving towards Big Data.

TABLE I. Various Components of Big Data

Value Traditional data service Resource Pool Numeric Data types Content format Data **consumers**	**Velocity** Inquiry analysis Data Collections Analysis Processing
Variety Text, graphics, image, sound and animation data Real time Batch Oriented On demand	**Volume** Virtual Resource Pool Distributed Storage Meta Data Master Data Historical Data

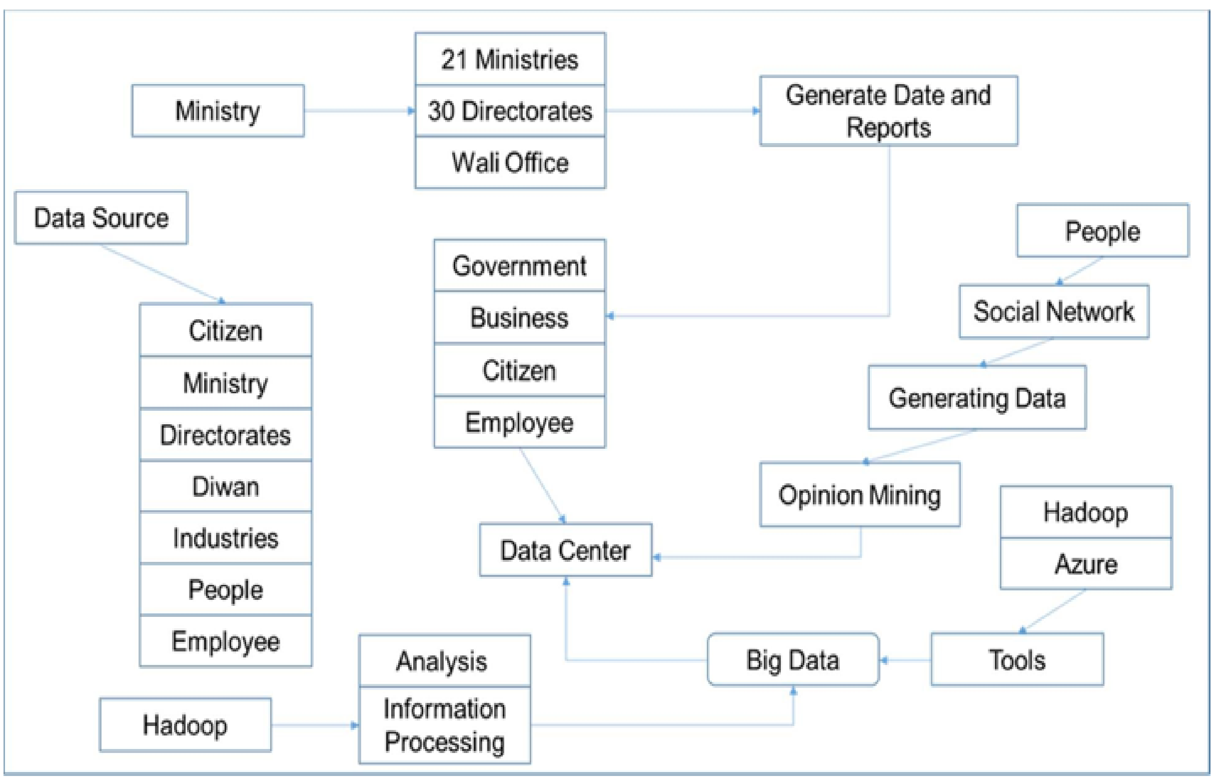

Fig. 6. From Heterogeneous Databases to Big Data (Data Origination and Management).

Figure 6:Data Origination and Management from Heterogeneous Databases to Big Data

Table 1 given below shows various components of big data and various operations happening in these components

VIII. Results and Discussion

It is proposed to use the DBMS to combine these sub-tableinstances, and because it start from the bottom of the system, fragmentations are generated automatically. Thus, the top systems databases carry the combined data that accumulated from several sub systems. Accordingly, in our model all fragmentations are obtained within the model methodology. Moreover, this is done without any conspicuous difficulties. In this approach the work is handled on the smaller subsystems, in the bottom of the system, and each one of these subsystems concern a specific task. Thus most of the queries are processed in the local machine, only the updating process and some synchronous work affect the remote data. Therefore, these techniques minimize the network traffic. In this approach only the owner subsystem is allowed to update its data, because each task is handled by a particular subsystem. This results in the simplification of the query processing and in the elimination of the updating problems. It is demonstrated that this approach can provide both kinds of the replication mechanisms, Eager and Lazy. In addition to that we can combine these two replication mechanisms. This provides more flexibility in AHDDI models, by applying the suitable technique for the suitable data. In this paper we propose that this approach can build an expandable model. The expandable model that can add new systems or application to the existing model or/and can be developed using ready application.

This approach can solve the integration problems by: combining applications of organization and result unified system and by the ability of integrating applications that do not belong to subsystems. This combination provides integration of the organization data as well as the integration of the applications because this is done by using the DBMS as tools to link the application data. This will guarantee that the new technologies are provided on these combined applications because this methodology can be applied as long as there is DBMS and there are protocols that can connected several DBMS, to provide heterogeneous database system, such as ODBC and JDBC , which is make avail of several kind of DBMS. An integrated model with integrated data. An information network, by linking more than one information system to form a WAN. The traditional data was kept in files, then it moved to networked, then hierarchal, then relational, object oriented, object relational, warehouses, then mining now it is becoming big data. Processing, values, consumers, data sources all changed with due course of time. Now big data is real time processing, on demand and continuous.

IX. Conclusion

In this paper, we claim that AHDDI is a suitable model for generating information networks of various sizes. Examples of such networks that arise in practice are: unity between universities, national library system, public sector departments, and national or international organizations. Hence, using AHDDI technique it will be easy to link any kind of application's database in one WAN network, and then users can analyzing and accessing this data using any big data tools, which is indicate that this approach can be a suitable way for moving from heterogeneous data sources to big data.

The paper presents a conceptual solution to the movement from heterogonous database to big data, that can be used for solving difficulties of moving from databases to big data, and whether databases can address the big data problems. Most of those who have taken this aspect believe that databases cannot handle massive data problems for example [24] and [25], therefore most of the previous solutions try to provide new database that can be applicable to handle bid data problems such as [26] and [27]

References

[1]- Thomas, G. Thompson, G., Chung, C., Barkmerer, E., Carter, F., Templeton, M., Fox, S., and Hartman, B. 1990. “Heterogeneous Distributed Database systems for Production use”. ACM computer Surveys, Vol. 22, No. 3, pp.237-266 Sept.

[2]- Bernstein, P., Goodman, N., Wong, E., Reeve, C., and Rothnie, J. 1981. “Query processing in a system for distributed database systems(SDD-1)”. ACM Trans. Database Sys.6, 4 (Dec.), pp. 602-625.

[3]- Kossmann, D. 2000. “The State of the Art in Distributed Query Processing”, ACM Computing Surveys; Dec; Vol. 32,4; ABI/INFORM Global, pp. 422-469.

[4]- Srinivasa, R. 2002. “Network-Aided Concurrency Control in Distributed Databases”. Ph.D. thesis, University of Virginia.

[5]- Breitbart, Y., Olson, P., and Thompson, G. 1986. "Database integration in a distributed heterogeneous database system". In Proceedings of the International Conference on Data Engineering (Los Angeles, CA, Feb. 5-7). IEEE, Washington, D.C., pp. 301-310.

[6]- Barkmeyer, E., Mitchell, M., Mikkilineni, K., Su, S. Y. W., and Lam, H. 1986. “An architecture for an integrated manufacturing data administration system”. NBSIR 863312, Md. 86, National Bureau of Standards, Gaithersburg.

[7]- Templeton, M., WARD, P., and LUND, E. 1987. “Pragmatics of access control in Merand”. Q. Bull. IEEE Comput. SOC. Tech. Committee Data Eng. 10, 3, pp. 33-38, Sept. International Conference on High Performance Computing, pp. 126-131.

[8]- Stonebraker, M., Aoki, M., Pfeffer, W., Sah, A., Sidell, J., Staelin, C. and Yu, A. 1996. “Mariposa: A wide-area distributed database system” The VLDB Journal, Springer-Verlag, 5: pp.48-63.

[9]- Kossmann, D., Franklan, M., and Drach, G. 2000."Cache Investment: Integrating query optimization and dynamic data placement". ACM Trans. Data System.

[10]- Andrew S. Tanenbaum and Herbert Bos 2014. “Modern operating systems”. PEARSON.

[11]- Carey M., Laura M., James K., and Berthold R. 1998. “Data Access Interoperability in the IBM Database Family”. Bulletin of the Technical Committee on Data Engineering, Special 38 Issue on Interoperability, Vol 21 No.3, September.

[12]- Litwin, W. et al. 1982. “SIRIUS System for Distributed Data Management,” in Distributed Databases”. H.J. Schneider (ed.), North-Holland.

[13]- Kemme, B., Alonso, G. 2000. “A New Approach to Developing and Implementing Eager Database Replication Protocols”. ACM Transactions on Database Systems, v25 i3, p333.

[14]- Ives, Z., Florescu, D., Friedman, M., Levy, A., and Weld, D. 1999. "An adaptive query execution engine for data integration". In Proceedings of the ACM SIGMOD Conference on Management of Data (Philadelphia, PA, USA), pp.299-310, June.

[15]- Chin A. 2001. “Incremental Data Allocation and ReAllocation in Distributed Database Systems”. Journal of Database Management, Jan-March v12 i1 pg. 35.

[16]- Hegazi, Mohamed Osman Ali. "A conceptual foundation and integration database designing model." Journal of Computer Science 10.3 (2014): 376-381.

[17]- EL Abbadi, A. and Toueg, S. 1989. "Maintaining availability in partitioned replicated 17 databases". ACM Trans. Database Syst. 14, 2 (June), pp. 264-290.

[18]- Agrawal, D. and EL Abbadi, A., and Steinke. R. 1997. "Epidemic algorithms in replicated databases (extended abstract)". In Proceedings of the 16th ACM SIGACT-SIGMOD- SIGART Symposium on Principles of Database Systems (PODS '97, Tucson, AZ, May 12 14), A. Mendelzon and Z. M. Ozsoyoglu, Chairs. ACM Press, New York, NY, pp. 161-172.

[19]- Hegazi, Mohamed Osman Ali. "An Approach for Designing and Implementing Eager and lazy Data Replication." methodology 110.6 (2015).

[20]- Olson, S., Oledereder, R., Shaw P., and Yach, D. 1998. “The Sybase Architecture for Extensible Data Management”. Bulletin of the Technical Committee on Data Engineering, 15 Special Issue on Interoperability, Vol. 21 No.3, Sep.

[21]- Gray J. and Reuter A. 1992. “Transaction Processing: Concepts and Facilities”. Morgan-Kaufmann. 41,4; ABI/INFORM Global. pg.578.

[22]- Rosen, K. Discrete Mathematics and Its Applications 4/E, 2003. http://people.cs.vt.edu/~irchen/4004/pdf/discreteMath/chapt53.pdf,

[23]-Tucker A. 1995. “Applied Combinatory”. 3rd ed. John Wiley & Sons, Inc., New York, U.S.A.

[24]- Madden, Sam. "From databases to big data." *IEEE Internet Computing* 3 (2012): 4-6.

[25]- Labrinidis, Alexandros, and Hosagrahar V. Jagadish. "Challenges and opportunities with big data." *Proceedings of the VLDB Endowment* 5.12 (2012): 2032-2033.

[26]- Deng, Jia, et al. "Imagenet: A large-scale hierarchical image database." *Computer Vision and Pattern Recognition, 2009. CVPR 2009. IEEE Conference on*. Ieee, 2009.

[27]- Moniruzzaman, A. B. M., and Syed Akhter Hossain. "Nosql database: New era of databases for big data analytics-classification, characteristics and comparison." arXiv preprint arXiv:1307.0191 (2013).

An Evaluation of the Proposed Framework for Access Control in the Cloud and BYOD Environment

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***Abstract*—As the bring your own device (BYOD) to work trend grows, so do the network security risks. This fast-growing trend has huge benefits for both employees and employers. With malware, spyware and other malicious downloads, tricking their way onto personal devices, organizations need to consider their information security policies. Malicious programs can download onto a personal device without a user even knowing. This can have disastrous results for both an organization and the personal device. When this happens, it risks BYODs making unauthorized changes to policies and leaking sensitive information into the public domain. A privacy breach can cause a domino effect with huge financial and legal implications, and loss of productivity for organizations. This is a difficult challenge. Organizations need to consider user privacy and rights together with protecting networks from attacks. This paper evaluates a new architectural framework to control the risks that challenge organizations and the use of BYODs. After analysis of large volumes of research, the previous studies addressed single issues. We integrated parts of these single solutions into a new framework to develop a complete solution for access control. With too many organizations failing to implement and enforce adequate security policies, the process needs to be simpler. This framework reduces system restrictions while enforcing access control policies for BYOD and cloud environments using an independent platform. Primary results of the study are positive with the framework reducing access control issues.**

Keywords—Bring your own device; access control; policy; security

I. Introduction

Bring your own device (BYOD) is the trend where employees use personal handheld devices for work as well as for personal use [1-3]. Employees own the devices so they take them home each day. Organizations with cloud network systems usually allow the use of BYODs for accessing data and enterprise applications. This has huge advantages for both employees and employers. One study estimated there will be more than one billion BYODs used for work in 2018 [4]. Another study said 95% of participants used personal handheld devices to perform work functions [5]. More and more people are using BYODs because of the benefits. It boosts morale, productivity, employee satisfaction and job ownership as well as work flexibility and mobility [6].

This raises organizational challenges, in particular, device and network security. Using BYODs means organizations have poor control over them without adequate security policies. Organizations have concerns about unauthorized access to cloud-based applications that bypass company policies [6]. This is referred to as 'shadow IT' where activities take place on a company network without specific organizational approval. The use of BYODs also risks employees accessing social media during work hours contrary to company policy. BYODs in the workplace exposes companies to greater security risks; in particular, the heightened risk of cyber-attack as it is hard to control access out of hours [7].

This is a conundrum for organizations as they need to consider user privacy and rights along with protecting networks from attacks. Some organizations get the balance between controlling BYODs for work and personal use right. Others' monitoring practices can violate an employee's personal privacy and rights when using personal handheld devices for personal reasons. It is important BYOD users understand their rights [8]. It is possible for employers to access private information without permission under the guise of management practices without good security mechanisms in place. This will cause problems for employees and employers if the process for managing access control to enterprise applications after hours is not transparent [9].

Employees have the right to use personal devices in any manner they like as long as they do not breach company policies. Unknowingly they can download malware and malicious applications, which can have a negative effect on corporate networks as well as their own devices. 'Keyloggers, malware, and cyber-attacks have greatly increased the potential for unauthorized access to, and information theft from, endpoints' [10]. With most organizations and personal devices vulnerable [10-12], risks increase when staff bypass system limitations by rooting or jailbreaking devices to access off-limit areas. This threatens personal devices and the cloud network with a malicious attack when transferring, processing, and storing data.

Organizational risks escalate when there are no access policies. These policies need permission from owners to check devices for viruses, spyware, and malware before connecting to its system.

Windows, Android, and IOS mobile operating systems are all vulnerable to cyber-attack (Table I) [13]. Malware collects and leaks sensitive data, tracks users, and changes authorization policies (Fig. 1) [14], which means a high degree of vulnerability. No operating system is immune from attack and organizational solutions need to be compatible on all operating systems.

TABLE I. LIST OF DIFFERENT TYPES OF ATTACKS IN DIFFERENT OPERATING SYSTEMS

Name	Attack(s)	Mobile OS
Zeus (Zitmo)	• Mobile Banking Attacks • TAC Thefts • Illegal Transactions	• Symbian • Win Mobile • BlackBerry • Android
DroidDream	• Theft of Private Data • Downloading Malicious Applications	• Android
Android.Bmaster (SmartRoot)	• Revenue Generation • Theft of Private Data	• Android
AnserverBot	• Theft of Private Data	• Android
Ikee.B	• Revenue Generation • Theft of Private Data	• iPhone
TigerBot	• Theft of Private Data • Changing Device Settings	• Android

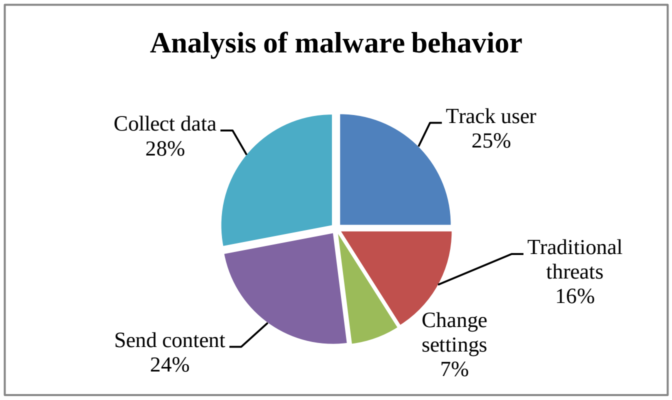

Fig. 1. What malwares do with BYOD devices [29]

Sensitive data is at risk when a personal device is lost or the employee leaves. With more than 9 million smartphones lost or stolen each year [15, 16], this is a considerable challenge. Even when data is deleted from a device and its operating systems, experts can retrieve that data [17, 18].

Many organizations fail to implement appropriate security policies for employees using BYODs. Where organizations do have security policies, they are inadequate because they do not address technical or organizational requirements for information security [19]. This makes controlling personal devices the biggest security risk for companies [20, 21]. Although there are applications available to manage and control personal devices, organizations are not using them in an appropriate way [7].

One study showed these concern BYOD owners when 57% of respondents [22] expressed worry about employers accessing personal devices without their authorization. By far the most concerning issue is the risk of unauthorized access to enterprise systems through BYODs.

In short, BYOD boosts morale, productivity, employee satisfaction and job ownership as well as work flexibility and mobility but it has some issues with employers such as poor controlling, violating an employee's personal privacy and rights, spreading malware and malicious applications, and lacking appropriate security policies for employees using BYODs.

II. RELATED WORK

We investigated the latest BYOD trends to address control systems to protect information security [23]. We analyzed the requirements for developing a suitable access control system and found there are four requirements.

A. *Check BYOD Device Security*

Any solution must meet an organization's security policies, while not breaching user privacy and rights. There has to be the ability to check the security levels installed on each individual device to avoid threats that can change or destroy data. The challenge is to find a solution that does not restrict user access either as it conflicts with the purpose of BYOD. Previous solutions call for device registration before use on a company network. Device registration limits the use of BYODs especially when a device is lost or replaced.

B. *Enforce Access Control Policy*

Mandatory access control is the best mechanism for protecting an organization from the risk of using BYODs. However, restricting access to certain locations or work hours negates the benefits of BYODs for both the employer and the employee. There needs to be minimum requirements for security, authentication, and authorization phases for BYODs to meet. Policy administrators need to set access controls to the resources each user requires. Organizations must then enforce all technical and access control policies.

C. *Platform Independence*

Any proposed solution should be compatible with all BYOD operating systems to reduce the risks from these devices to keep the process simple and flexible.

D. *Secure Access Control Policy*

Developing new policies is of no value without protecting them. Without protection, it risks malicious actions from BYODs that may have downloaded malware that modifies access an access control policy. There are also the risks from external threats that attack data and policies from BYODs. A secure access control policy must protect the process of transferring, processing, and storing data when a BYOD interacts with the cloud environment. There are several solutions that focus on user data without addressing possible side attacks on the cloud.

TABLE II. PREVIOUS APPROACHES COMPARING TO OUR PROPOSED FRAMEWORK

Paper citation	Check BYOD Device Security	Enforce Access Control Policy	Platform Independence	Secure Access Control Policy
[24]	P	Y		
[25]		Y		P
[26]	Y	Y	Y	
[27]	P			P
[28]	Y	Y		P
[21]	P	Y	Y	
Our proposed framework	Y	Y	Y	Y

Y = yes
P = partly

Table II shows an evaluation of how previous approaches compare to our proposed protection framework.

From the literature review, we see previous studies address single issue without providing a complete access control solution. As a result, these solutions are insufficient and require further research. We integrate several parts of these to develop a new solution for BYOD access control. We describe this in Section III. This paper focuses on the technical side of the solution. It does not attempt to develop the required processes a user needs to follow to support an access control policy.

III. Proposed Framework

Cloud services have three main models managed by a cloud manager: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). We propose a new security manager tool called Software as a Service (AaaS) for public cloud providers. The AaaS framework gives any organization's SaaS the ability to use cloud manager to perform security checks before granting BYOD access to the cloud environment. We considered several issues when designing the framework. It was important to make the tool easy to add and use without affecting existing BYOD and cloud environments. We achieved this by limiting operating requirements.

We based the framework on a multi-agent system, because the software runs independently on behalf of a network user. This makes it adaptable, mobile, transparent, and it automatically starts and stops. This reduces the costs and the required resources when a BYOD interacts with other machines. The proposed framework is divided to three parts: the client BYOD, owner device, and the security manager (Fig. 2). Each software agent is explained in this paper.

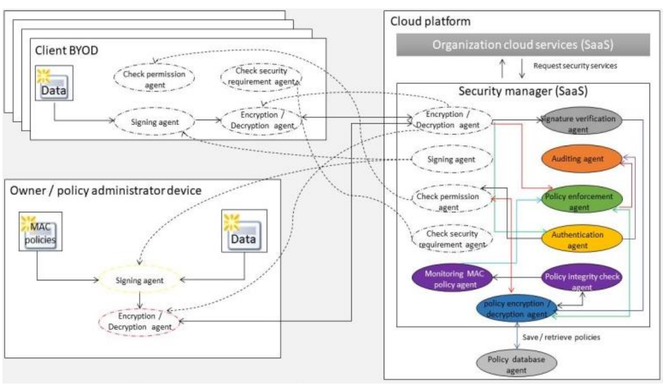

Fig. 2. Our proposed framework for the BYOD and cloud environment

A. *Owner / Policy Administrator Device*

Whoever is responsible for BYOD user access control policy, controls the owner/policy administrator device. This can be the Chief Security Officer (CSO), policy administrator or an organization's owner. The device can be either a personal device or PC with a trusted operating system like Security-Enhanced Linux (SELinux) so they can set security classification levels and the initial data for user access control.

1) *MAC Policy*

The Mandatory Access Control (MAC) policy dictates strict access limits that are difficult to bypass, either intentionally or unintentionally. Using a MAC policy is effective as it assigns a clearance level to every user. It does this by establishing what each user can and cannot access within the system using JavaScript Object Notation language (JSON). There are four categories for users (subjects) and resources (objects), and these are top secret, secret, confidential, and unclassified. The policy administrator determines the user and resource security classification levels according to the MAC. The JSON file and data is encrypted and signed after the data is digitally signed. The following is an example of a JSON file:

```
{
  'Version': '2018-1-17',
  'username': 'John',
    'compartmentalization': {
 'computer science',
    'security classification level':
 'Secret',}
}
```

2) *DATA:*

This includes all resources that we want to upload and store in the cloud.

B. *Security Manager*

The security manager is at the core of the proposed framework. Its function is to manage all the components required for the MAC policy to operate. It is located in the cloud and operates when called on by a SaaS. The framework has four functions: checking BYOD device security, enforcing the access control policy, working with independent platforms, and securing the access control policy. It works in conjunction with the 11 agents.

1) *Controller Agent*

The controller agent is static and manages all other agents. It contains the Application Programming Interface (API) that allows it to communicate with other SaaS in the cloud. The controller agent creates instances from mobile agents and sends them to devices using individual IP addresses.

2) *Check Security Requirement Agent*

The controller agent creates the check security requirement agent. Its purpose is to check all connected devices using an organization's SaaS in the cloud. The check security agent checks whether BYODs meet company security policy requirements for being a trusted device. It does this by checking for up-to-date antivirus software, fingerprints, and a VPN connection and installs an agent manager.

This research uses the requirement for an up-to-date antivirus application as an example. When a device does not have updated antivirus installed, the check security agent provides the user a summary. It will summarize what actions the user needs to take for a BYOD to comply with the organization's security requirements.

3) *Authentication Agent*

Once a device meets security policy requirements, the authentication agent starts. Every user needs a unique identity. The authentication agent validates a user's identity for access to the system using two types of authentication for extra security.

4) Check Permission Agent

Once the authentication agent finishes its verification, the check permission agent searches the database for the security classification assigned to the username. The agent sends the username to the relevant personal device to make a preliminary decision about granting access. It then implements the MAC policy to authenticate the username against the security classification contained within the MAC policy to make a final decision to grant access or not.

The check permission agent functions to speed up the process if user access is denied before it sends a request to the cloud. It also displays to users their permissions when accessing specific resources. For example, users will see permission details such as read only, read and write, against each file when the system grants access. Once a user has access at this level, the next check occurs in the cloud by the 'policy enforcement agent'.

5) Signing and Signature Verification Agents

Signing and signature verification agents are mobile agents. They check a system access request comes from a known user without being modified during transit. It generates digital signatures for every JSON policy file and data requests from data owners or BYOD users (Fig. 3). The signature verification agent within the security manager verifies the digital signature. It compares the decrypted hash value with the original JSON policy and initiated generated hash to verify it is the same. When the values are equal, the message has not been modified.

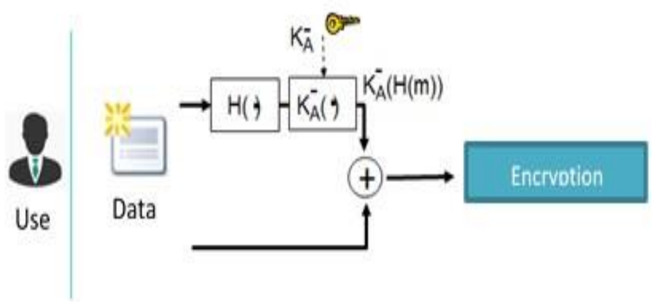

Fig. 3. Generating the digital signature in a BYOD device

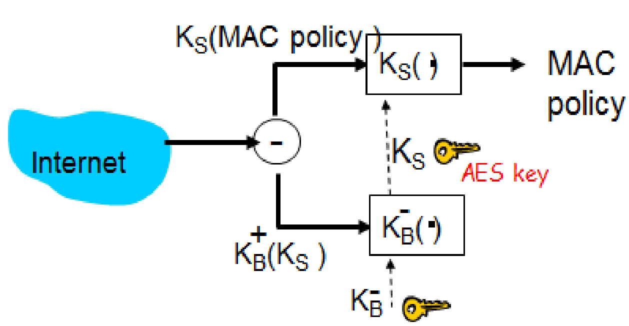

Fig. 4. Decryption of the MAC policy

6) Encryption and Decryption Agent

The encryption and decryption agent makes sure only authorized users and agents access and read the information transmitted. Its function is to keep the information in the message secret. It does this by encrypting and decrypting all transmissions traveling between the security manager and user devices. This agent converts messages into an unreadable format to transmit them. It then reverses the process to convert the messages into a readable format for the user. The agent encrypts messages using an asymmetric algorithm (also known as public-key cryptography). During transmission it exchanges this for a symmetric key (which is the Advanced Encryption Standard (AES)) to decrypt the MAC policy (Fig. 4).

7) Policy Enforcement Agent

The policy enforcement agent is static and its primary function is to enforce access control policies to determine who has access to the cloud. Its purpose is to strengthen access control. The policy enforcement agent implements the MAC policy using the Bell–LaPadula model (Fig. 5) to match the relevant user classification level. It uses the classification level in conjunction with the 'check permission agent' to verify a user has legitimate access and transmissions were not modified during the process.

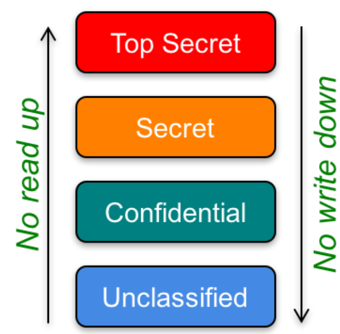

Fig. 5. Bell–LaPadula model

8) Policy Monitoring and Integrity Check Agents

The policy enforcement agent saves a copy of the first hash value generated/updated by the owner. It continuously uses this as a comparison with newly generated hash values for the same MAC policy. These should all be identical. Policy monitoring and integrity checking agents check for modifications to a MAC policy during transmission and has only been sent by the policy administrator. It informs the policy administrator and controller when there is a security breach.

9) Auditing Agent

The auditing agent is static. Its function is to record all successful and failed attempts to access the system. It records all policy enforcement agent decisions about grant and deny access decisions. The auditing agent records username, date, time, access request to what resources, and the decision. This assists the policy administrator to monitor, analyze, and manage regulatory compliance, understand system access denials, and perform disaster recovery to develop the system.

10) Policy Encryption and Decryption Agent

The policy encryption and decryption agent encrypts and decrypts all the data it transmits. It uses the symmetric encryption algorithm (AES) to protect information during the storage and retrieval phases when communicating with the access control database.

11)Policy Database Agent

The policy database agent is static and communicates with other Databases as a Service (DBAAS), database management systems (DBMSs), or distributed database management systems (DDBMSs). This agent exchanges the data as it transmits across different software architecture styles and patterns.

C. Client Byod Device

When a client uses their BYOD to access the cloud environment, the check security requirement agent verifies it meets security policy requirements. Once the BYOD passes and the security agent grant access, three other agents perform their functions when signing in. These are the encryption and decryption, check permission, and signing agents. Clients are not restricted to working from one location or to 'hours of work'. They can work from anywhere at any time. People can use any device as long as it meets security requirements. Clients create and share data according to their classification levels, which the owner has to approve (or reject). The owner grants access by accepting the request.

Sequence diagrams for the proposed access control framework are broken into seven sub-frameworks based on the main tasks. We explain the most important tasks, which are: creating and modifying policies or data by policy administrators; clients creating and modifying data; and monitoring the MAC policy in the security manager.

1) Creating and Modifying Policies and Data

Fig. 6 shows the process for creating and modifying policies and data. To start, the signing agent adds a digital signature to the message when a policy maker creates a new or modifies existing policies or data through the user interface (Fig.6). Then the encryption and decryption agent encrypts the message to transmit it and decrypts it into a readable format for the receiver. A signature verification agent verifies the digital signature. Then the policy enforcement agent implements the MAC policy to accept or deny illegitimate access requests. There are 'save' mechanisms for both the policy encryption and decryption, and the policy database agents. This is so the user can save new and amended policies and data to the system. The 'ack' method in both agents confirms the save process. Finally, the auditing agent records full details of final decisions made by the policy enforcement agent.

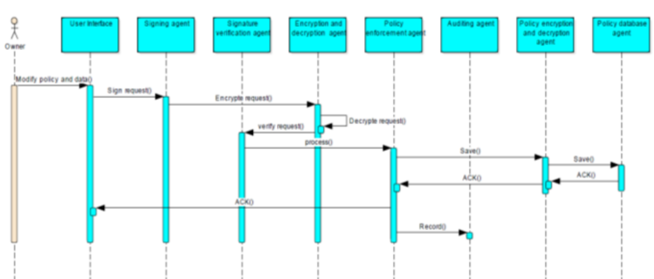

Fig. 6. Sequential diagram for creating and modifying policies or data by policy administrators

When clients try to create or modify data, the permission method makes a preliminary decision about granting access based on the username clearances and security classifications. If permission is granted, the 'signing agent' adds a digital signature to the data (Fig. 7). All data is now encrypted by the encryption and decryption agent before being transmitted across the internet. The agent then decrypts the data when received in the cloud. Next the signature verification agent verifies the digital signature. The policy enforcement agent implements the MAC policy, which denies any illegitimate access requests. The policy encryption and decryption agent and policy database agent save the data. The ack method in each agent confirms the data saving process. Finally, the auditing agent records full details of final decisions made by the policy enforcement agent or by the check permission agent during the preliminary decision.

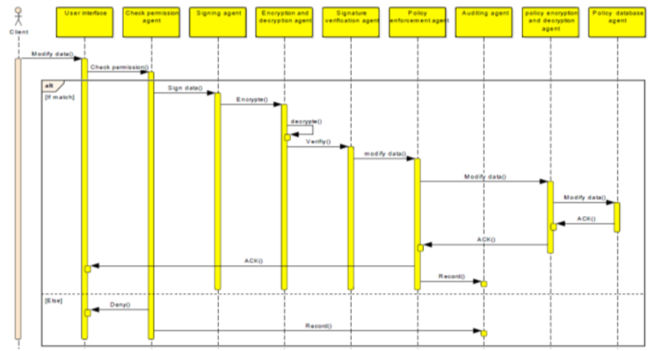

Fig. 7. Sequential diagram for creating and modifying data by clients

2) Monitoring the Mac Policy

Fig. 8 shows the process of monitoring the MAC in the security manager. Monitoring the MAC is the main function for protecting the integrity of policies during the processing and storage phases. This process starts with the controller agent activating the policy integrity check agent. It retrieves the policy from the database using the request hash key method. The reply hash key generates a hash value from the policies requested. The value is sent to the monitoring MAC policy agent for comparison with the original one. If the values match, the process continuously repeats. When they do not match, the monitoring MAC policy agent sends an error message to the controller agent to cease authentication. It records the issue, deletes the existing policies, and sends a message to the owner.

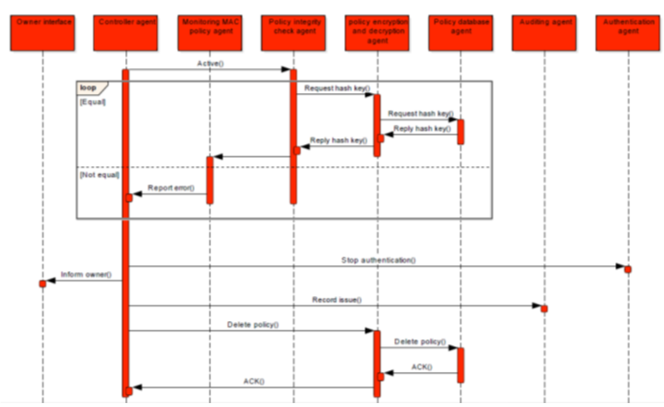

Fig. 8. Sequential diagram for monitoring the MAC policy in the security manager

IV. Implementation And Testing

Implementing and testing the proposed framework is required to verify and validate the solution. It is required to ensure that there is no fault, error or failure in the system. The implemented prototype has two core components. The first is the client and owner application, and the second is the security manager as Software as a Service (SaaS) in the cloud. Mobile agent software is required in these components. There are a variety of agent frameworks can be used, such as Concordia, Aglets, and Jade. In the client and owner BYOD devices, we built an application by using c# and Java in the Microsoft visual studio framework. The JavaScript Object Notation language (JSON) is used in these codes to implement the MAC. We use real BYOD devices based on the Windows operating system to install the app and connect to the cloud. In the security manager, we used the same above environments to build two software as services. One of them is our security manager, and the other one is the organizational software as a service that is connected to our security manager. These two software as services are deployed in the Google cloud platform and use its storage as a database.

Black and white box tests are used first to examine the functionality and structure of the proposed framework. The validation was completed successfully by validating some of the requirements that are used in our proposed framework. We used four cases to test the proposed framework based on potential attacks, as shown in the following (Fig. 9).

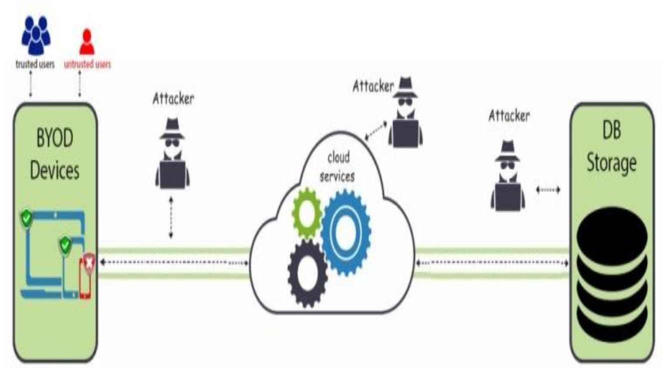

Fig. 9. Potential attacks that may occur in the cloud and BYOD environment

We classified the test into four main sub-tasks. First, trusted and untrusted users and devices testing. Second, access control policy testing. Third, performance and scalability testing. Finally, integrity testing.

1) Trusted and Untrusted Users and Devices Testing

Four different cases can be used to test trusted and untrusted users or devices. These cases cover the possible situations that may occur when users use their BYODs, as seen in (Table 3). These cases are:

Case 1: The use of an untrusted device by trusted and untrusted users.

Case 2: The use of a trusted device with trusted users who want to access legitimate resources.

Case 3: The use of a trusted device with trusted users who want to access illegitimate resources.

Case 4: The use of a trusted device with untrusted users.

TABLE III. Different Cases Of Trusted And Untrusted Users Or Devices

Situation of different cases	**Trusted devices**	**Untrusted devices**
Trusted users access legitimately	Case 2	Case 1
Trusted users access illegitimately	Case 3	Case 1
Untrusted users	Case 4	Case 1

For the first case, the ‘check security requirement agent’ was able to detect an untrusted device that does not meet the organization’s requirement of an updated antivirus program, as seen in (Fig. 10). In this scenario, the application will not be allowed to connect to the cloud.

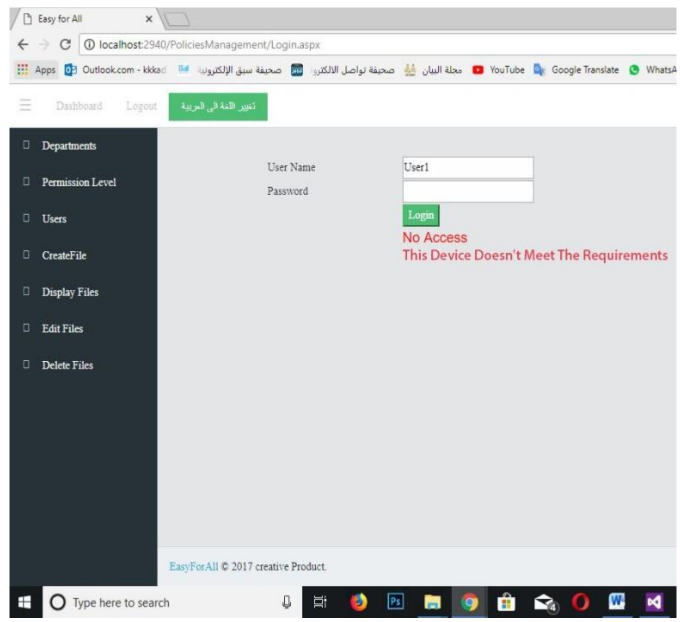

Fig. 10. Interface showing the untrusted BYOD

For the second case, ‘check security requirement agent’ allowed the device to connect to Google cloud because it is a trusted device. Both ‘check permission agent’ and ‘policy enforcement agent’ allowed trusted users to access wanted resources. For case three, the system detects users that want to access illegitimate resources, as shown in (Fig. 11), by verifying the MAC security classification level of the user and comparing it with the security classification level of the wanted resource using the Bell–LaPadula model to gain access. The final case is for untrusted users (i.e., users who do not have permission to access the system and certainly do not have a MAC security classification level). ‘Authentication agent’ can discover these users and prevent them from accessing the system, as shown in (Fig. 12).

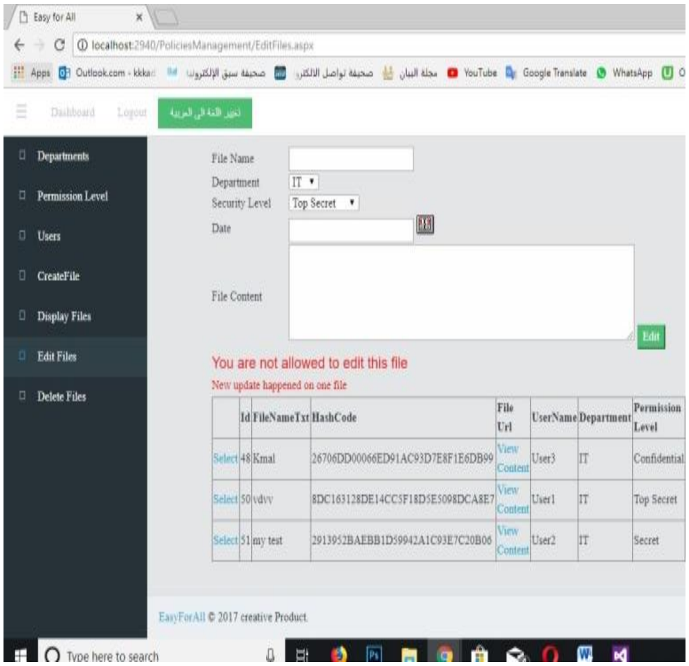

Fig. 11. Interface showing denied access to illegitimate resources

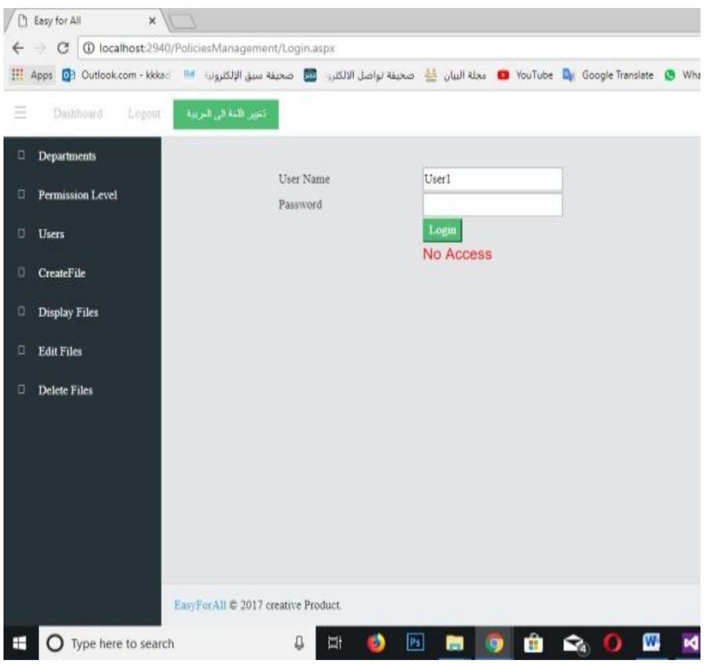

Fig. 12. Interface showing prevention of untrusted user access to the system

2) Access Control Policy Testing

A different access control policy has been tested by simulating different and complex attacks during the transfer, process, and storage phases. During the process and storage phases, the proposed framework faced 10 attacks that modified the access control policy.

Five of them modified during the processing phase, and five of them modified in the database. The hash value changed and was detected by policy monitoring and integrity check agents, as shown in (Fig. 13).

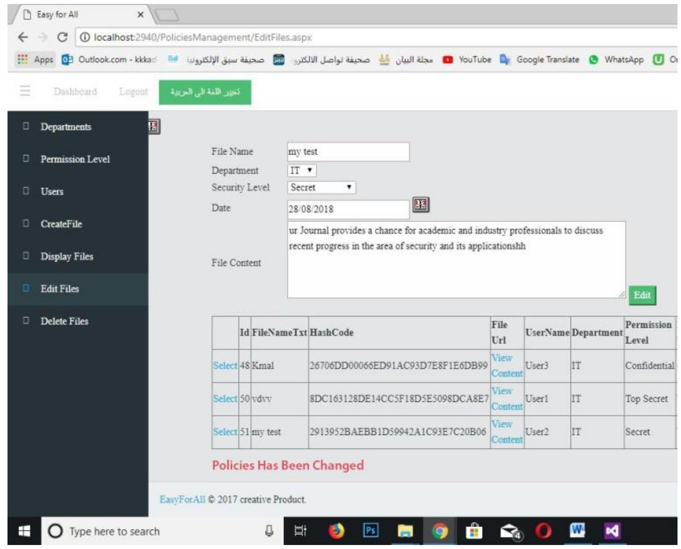

Fig. 13. Interface showing the detection of the changed MAC policy

During the transfer phase, we tested the 20 accesses of the control policy with different characteristics. Five of them had the correct digital signatures, five of them had incorrect digital signatures, five of them had the original cipher text, and five of them had the modified cipher text. Both the encryption and decryption agent and the signature verification agent detected all modified access control policies, as shown in (Fig. 14).

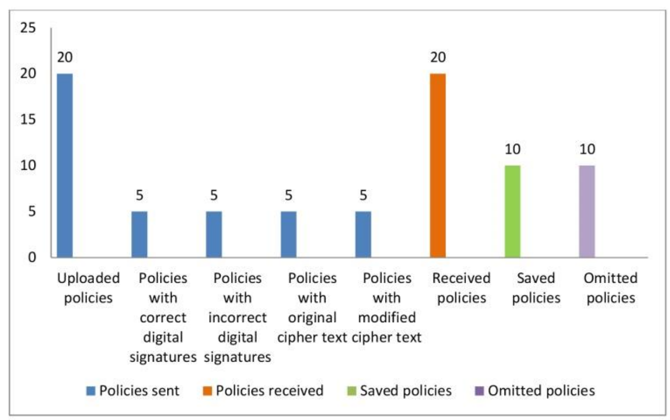

Fig. 14. Statistics shows the number of uploaded policies, received policies, saved policies, and rejected policies

3) Performance and Scalability Testing

To measure performance and scalability, we used different available software based on the required test. Visual Studio 2017 has some useful built-in testing tools that we used to measure the CPU and memory usage. The Google cloud platform also has some useful testing tools for measuring traffic, load, CPU and memory usage, and more. We also used the JMeter tool to test scalability because it is a free open source tool specifically for this type of testing. Below are the results of these different tests with some comments about each test. The discussion and evaluation of the results are in the next chapter. First, we measured the performance with different numbers of users ranging from 1 to 1000 users for the access control enforcement function, as shown in (Fig. 15).

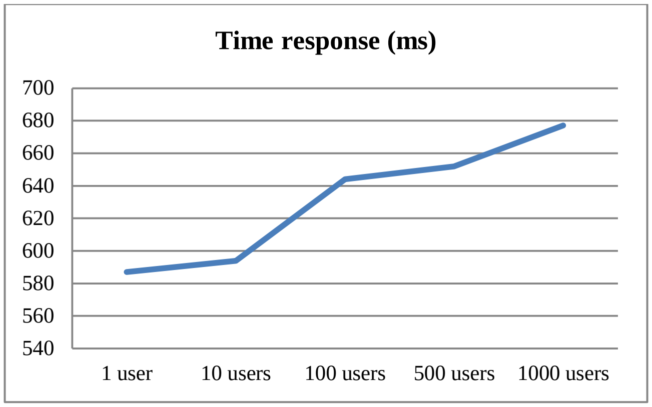

Fig. 15. Performance testing with different numbers of users for the enforcement access function

Fig. 16 shows the time response for each function in the proposed framework, including the time for saving and retrieving data from the database. This test was done in local machines. In addition, we did not calculate the travel time between different machines.

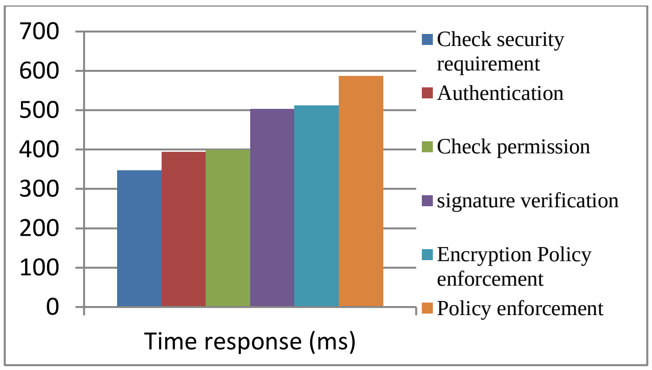

Fig. 16. Time response for each function in the proposed framework

The next test shows the time response for access allowed by the policy enforcement agent and access denied by the check permission agent after the authentication phase and setting up the policies, as shown in (Fig. 17).

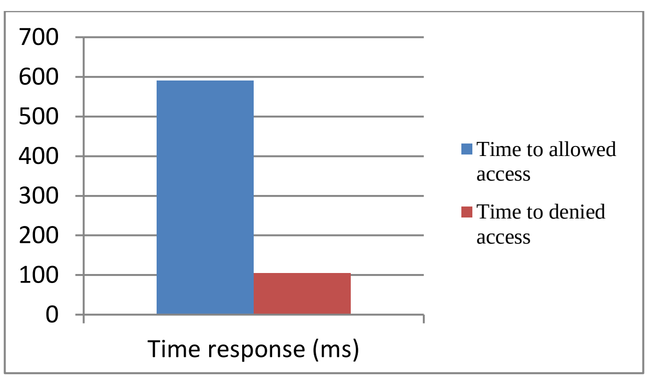

Fig. 17. Time response for allowed and denied access decision

We used a LOADIMPACT tool to test the load time in the cloud when the number of users is increased as seen in (Fig. 18)

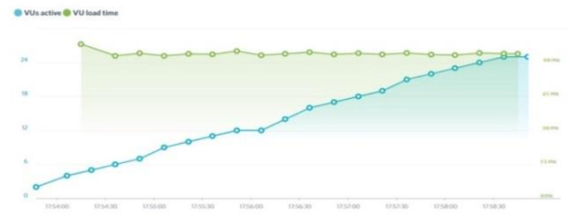

Fig. 18. Load time test for the framework in the cloud with increase of number of users

4) Integrity Testing

Over three weeks, we found 2,860 access requests in the logs. Twenty policy attacks occurred, none of which were successful since they were detected by the system. To measure integrity for a particular type of attack, we need to know the probability that an attack of this type will occur within a given time [29]. The integrity attack is defined as:

Integrity attack = 1 – threat attack (1 – security attack)

The integrity of the software product, integrity, is defined to be the sum, over all attack types, of integrity attack:

Integrity = Σ attack (integrity attack)

In our case, the threat attack is (20/2860) = 0.006993006993007 and the security attack is (0/20) = 0.00, so the integrity is (1- 0.006993006993007 * (1 – 0.00)) = 0.99300699300699 ≈ 1 * 100 = 100%.

V. Discussion And Evaluation

The process of verifying and validating was completed successfully, as planned, by using white and black boxes testing with no faults, errors, or failures in the system. The results can be explained as follows. First, the proposed framework was able to differentiate between trusted and untrusted devices and between trusted and untrusted users. It prevented untrusted devices from connecting to the cloud and prevented untrusted users from accessing the system. It also enforced the access control policies and provided access to legitimate users only. Second, the proposed framework was able to detect attacks that faced access control policies during the transfer, process, and storage phases. It rejected the policies that had been modified after informing the owner of the system.

Third, the performance tests showed a slight increase in the time response when the number of people increased during the process of enforcing access control policies in the local machine. This kind of test examines the scalability of the system. The result is normal due to specific resource consumption, such as CPU and memories. However, the same test was done in the cloud by a LOADIMPACT tool and showed no increase in the time response. This is because the resources in the cloud are scalable, which means the cloud is able to increase the workload on its current hardware resource on demand with an increase in the amount of billing. Fourth, the JMeter testing tool showed the time response for each function in the system. The policy enforcement had the highest time response due to the comparison between the security classification levels of the subjects and objects after retrieval of these data from the database. The encryption and decryption functions had high time responses because of the amount of time the asymmetric algorithm needed to encrypt and decrypt the messages.

Fourth, we reduced the time needed to make the final decision when an illegitimate request occurs due to the functionality of the check permission agent in the same BYOD. However, in the case of legitimate access, it takes more time because the decision comes from the policy enforcement agent in the cloud. Fifth, these tests were performed using Intel Core (TM) i7 -5500U CPU (2.40 GHz) and 8.0 GB DDR3 memory, which shows low performance for one user. Finally, the integrity of the system is high due to its detection of the attacks, which were unsuccessful.

VI. Conclusions

In this paper, we introduce a solution to the access control issues in BYODs and the cloud environment. We aimed to design a solution that maintains the features of BYODs, such as mobility and improved flexibility. This solution is based on four main requirements, which are checking the BYOD device security, enforcing the access control policy, working with independent platforms, and securing the access control policy. We integrate all of these requirements and build our proposed framework based on the multi-agent system due to its adaptability, mobility, transparency, raggedness, and self-start and stops.

Most other existing solutions solve specific issues without comprehensive consideration of the effects of these solutions on the BYOD environment or their users. We attempted to reduce the restrictions and increase the flexibility and mobility with a soft implementation of the policy. We also tried to protect user's privacy by avoiding the use of Mobile Device Management (MDM) solutions. We have also built the first prototype of the system by implementing and testing the proposed framework in real environments. The outcome of verification and validation show excellent results and positive feedback. The future work will increase the performance of allowing access decision and enhance the current framework to support federated cloud computing.

References

[1] Information Commissioner's Office (ICO), 'Bring your own device,' ed, pp. 1-14.

[2] T. Shumate and M. Ketel, 'Bring your own device: benefits, risks and control techniques,' in SOUTHEASTCON 2014, IEEE, 2014, pp. 1-6.

[3] A. V. Herrera, M. Ron, and C. Rabadão, 'National cyber-security policies oriented to BYOD (bring your own device): Systematic review,' in Information Systems and Technologies (CISTI), 2017 12th Iberian Conference on, 2017, pp. 1-4.

[4] M. Dhingra, 'Legal issues in secure implementation of bring your own device (BYOD),' Procedia Computer Science, vol. 78,2016, pp. 179-184.

[5] A. B. Garba, J. Armarego, D. Murray, and W. Kenworthy, 'Review of the information security and privacy challenges in Bring Your Own Device (BYOD) environments,' Journal of Information privacy and security, vol. 11, 2015, pp. 38-54.

[6] P. Beckett, 'BYOD–popular and problematic,' Network Security, vol. 2014, pp. 7-9.

[7] D. Dang-Pham and S. Pittayachawan, 'Comparing intention to avoid malware across contexts in a BYOD-enabled Australian university: A Protection Motivation Theory approach,' Computers & Security, vol. 48, 2015, pp. 281-297.

[8] M. M. Singh, C. W. Chan, and Z. Zulkefli, 'Security and Privacy Risks Awareness for Bring Your Own Device (BYOD) Paradigm,' INTERNATIONAL JOURNAL OF ADVANCED COMPUTER SCIENCE AND APPLICATIONS, vol. 8, 2017, pp. 53-62.

[9] S. Blizzard, 'Coming full circle: are there benefits to BYOD?,' Computer Fraud & Security, vol. 2015, 2015, pp. 18-20.

[10] B. Morrow, 'BYOD security challenges: control and protect your most sensitive data,' Network Security, vol. 2012, pp. 5-8.

[11] A. V. R. Herrera, Mario and C. Rabadao, 'National Cyber-security Policies oriented to BYOD (Bring Your Own Device): Systematic Review,' IEEE 12th Iberian Conference on Information Systems and Technologies (CISTI), 2017.

[12] Checkpoint website. (2014). Security Report. Available: https://www.checkpoint.com/documents/ebooks/security-report-2014/files/assets/common/downloads/Check%20Point%20Security%20Report%202014.pdf. [Accessed: 10- Oct- 2018].

[13] M. Eslahi, R. Salleh, and N. B. Anuar, 'MoBots: A new generation of botnets on mobile devices and networks,' in Computer Applications and Industrial Electronics (ISCAIE), 2012 IEEE Symposium on, 2012, pp. 262-266.

[14] S. Enterprise, 'Internet Security Threat Report 2014,' ed, 2015.

[15] B. Yulianto and R. Layona, 'An Implementation of Location Based Service (LBS) for Community Tracking,' ComTech: Computer, Mathematics and Engineering Applications, vol. 8, 2017, pp. 69-75.

[16] PricewaterhouseCoopers (PWC), 'The Global State of Information Security Survey,' 2015.

[17] N. Zahadat, P. Blessner, T. Blackburn, and B. A. Olson, 'BYOD security engineering: A framework and its analysis,' Computers & Security, vol. 55, 2015, pp. 81-99.

[18] J. Girard, 'Top Seven Failures in Mobile Device Security,' Gartner, 2013.

[19] M. M. Ratchford, 'BYOD: A Security Policy Evaluation Model,' in Information Technology-New Generations, ed: Springer, 2018, pp. 215-220.

[20] J. Thielens, 'Why APIs are central to a BYOD security strategy,' Network Security, vol. 2013, 2013, pp. 5-6.

[21] P. de las Cuevas, A. Mora, J. J. Merelo, P. A. Castillo, P. Garcia-Sanchez, and A. Fernandez-Ares, 'Corporate security solutions for BYOD: A novel user-centric and self-adaptive system,' Computer Communications, vol. 68, 2015, pp. 83-95.

[22] H. Schulze, 'BYOD & Mobile Security Report,' 2014.

[23] K. Almarhabi, K. Jambi, F. Eassa, and O. Batarfi, 'Survey on access control and management issues in cloud and BYOD environment,' International Journal of Computer Science and Mobile Computing, vol. 6, 2017, pp. 44-54.

[24] G. Costantino, F. Martinelli, A. Saracino, and D. Sgandurra, 'Towards enforcing on-the-fly policies in BYOD environments,' in Information Assurance and Security (IAS), 2013 9th International Conference on, 2013, pp. 61-65.

[25] L. L. Bann, M. M. Singh, and A. Samsudin, 'Trusted Security Policies for Tackling Advanced Persistent Threat via Spear Phishing in BYOD Environment,' Procedia Computer Science, vol. 72, 2015, pp. 129-136.

[26] S. Chung, S. Chung, T. Escrig, Y. Bai, and B. Endicott-Popovsky, '2TAC: Distributed access control architecture for' Bring Your Own Device' security,' in BioMedical Computing (BioMedCom), 2012 ASE/IEEE International Conference on, 2012, pp. 123-126.

[27] K. AlHarthy and W. Shawkat, 'Implement network security control solutions in BYOD environment,' in Control System, Computing and Engineering (ICCSCE), 2013 IEEE International Conference on, 2013, pp. 7-11.

[28] U. Vignesh and S. Asha, 'Modifying security policies towards BYOD,' Procedia Computer Science, vol. 50, 2015, pp. 511-516.

[29] G. G. Schulmeyer and J. I. McManus, Handbook of software quality assurance: Van Nostrand Reinhold Co., 1992.

Model Development for Predicting the Occurrence of Benign Laryngeal Lesions using Support Vector Machine: Focusing on South Korean Adults Living in Local Communities

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***Abstract*—The disease is a consequence of interactions between many complex risk factors, rather than a single cause. Therefore, it is necessary to develop a disease prediction model by using multiple risk factors instead of using a single risk factor. The objective of this study was to develop a model for predicting the occurrence of benign laryngeal lesions based on support vector machine (SVM) using ear, nose and throat (ENT) data from a national-level survey and to provide a basis for selecting high-risk groups and preventing a voice disorder. This study targeted 16,938 adults (≥19years) who participated in the ENT examination among the people who completed the Korea National Health and Nutrition Examination Survey from 2010 to 2012. This study compared the prediction power of the Gauss function, which was used for this study, with that of a linear algorithm, that of a polynomial algorithm, and that of a sigmoid algorithm. Moreover, four kernels were divided into C-SVM and Nu-SVM to compare the prediction accuracy of C-SVM with that of Nu-SVM. The 'benign laryngeal lesion prediction model' based on SVM could derive preventive factors and risk factors. The final prediction rate of this SVM using 479 support vectors was 97.306. The fitness results indicated that the difference between C-SVM and Nu-SVM was not large in the benign laryngeal lesion prediction model. In terms of kernel type, the prediction accuracy of Gauss kernel was the highest and the prediction accuracy of the sigmoid kernel was the lowest. The results of this study will provide an important basis for preventing and managing benign laryngeal lesions.**

***Keywords*—Support vector machine; SVM; dysphonia; voice disorder; prediction model; risk factor; data mining**

I. Introduction

Benign laryngeal lesions have a different meaning from laryngeal cancer and it is used to describe voice disease due to the changes in the laryngeal structure such as vocal fold nodules, vocal polyp, intracordal cyst, Reinke's edema, granuloma, sulcus vocalis, and larynx keratosis [1, 2]. Since benign laryngeal lesions lead to structural changes in the larynx including the vocal cords, it ultimately becomes a direct cause of voice disorder.

Roy et al. [3] reported that the prevalence of the laryngeal diseases was 6.6% in the United States as of 2005 and 10% of all Americans experienced a voice problem at least once in their lifetime. Voice is a very important function in maintaining daily life, and maintaining a healthy voice can greatly affect the quality of life particularly for those who use voice for occupations (e.g., teacher). For example, the voice problem of the teachers can cause unnecessary socio-economic costs such as job loss or unemployment due to the loss of their ability to teach [4]. Therefore, it is very important to accurately understand the risk factors and diagnose the earlier for providing appropriate rehabilitation according to the assessment.

It has been reported that voice abuse and the physical stimulation to the vocal cord due to inappropriate speech habits are the most common causes of benign laryngeal lesions [5-13]. Moreover, various other factors such as smoking, drinking, virus, upper airway infection, and laryngopharyngeal reflux are also reported as risk factors [5-13]. The disease is a consequence of interactions between many complex risk factors, rather than a single cause [7, 14]. Therefore, it is necessary to develop a disease prediction model by using multiple risk factors instead of using a single risk factor [12]. Nevertheless, studies evaluating the risk factors for the laryngeal disease have mostly focused on single risk factors [15].

Lifestyle heavily influences the occurrence and rehabilitation of benign laryngeal lesions [15]. Moreover, even if surgical treatment is successfully conducted, it is likely to reoccur if the factor negatively affects the voice is not removed [15]. Additionally, although the shapes of lesions on the vocal fold are similar, different treatments must be performed depending on the etiology. Therefore, it is important to identify the complex risk factors in order to fully understand the cause of the disease and to make accurate diagnosis and treatment.

Machine learning based on the supervised learning such as support vector machine (SVM) has been used as a method to identify complex risk factors of diseases [16-18]. SVM is known to have the better predictive power in classifying binary data such as the presence of disease than the decision tree method or the artificial neural network (ANN) method [19-24]. Nevertheless, the voice disorder prediction models based on SVM, which mostly uses acoustic analysis indices, have been mainly utilized to evaluate laryngeal diseases [25, 26]. There are not enough studies examining prediction models reflecting the health behaviors and sociodemographic characteristics.

The objective of this study was to develop a model for predicting the occurrence of benign laryngeal lesions based on SVM using ear, nose and throat (ENT) data from a national-level survey and to provide a basis for selecting high-risk groups and preventing a voice disorder. Construction of our study is as follows. chapter II explains study sample and analyzed variables and chapter III defines SVM and explains the procedure of model development. Lastly, chapter IV presents discussion and direction for future research.

II. Methods

A. Data Source

This study targeted adults (⩾19years) who participated in the ENT examination among the people who completed the Korea National Health and Nutrition Examination Survey (KNHANES) from 2010 to 2012. This study was approved by the Research Ethics Committee of Honam University (IRB Number: 1041223-201801-HR-40). The KNHANES extract samples from sampling plots by using the proportional allocation systematic sampling method, which stratifies the administrative districts and dwelling types of the national regional classes. Therefore, the samples were proportional to the population. This study selected 16,938 adults (7,703 males, 9,235 females), who were 19 years or older and completed the health questionnaire, ENT examination questionnaire, and the laryngeal endoscopy.

B. Measurements

Benign laryngeal disease in this study were defined as vocal nodules, laryngeal polyps, intracordal cysts, reinke's edema, laryngeal granuloma, glottic sulcus and laryngeal keratosis [10]. The explanatory variables were age(19-39, 40-59, 60+), gender, occupation, educational level, Income, smoking, high-risk drinking, and self-reported voice problems. Occupations were classified into economically-inactive, non-manual and manual. Levels of education were classified as elementary school graduates and lower, junior high school graduates, high school graduates and college graduates and over. Levels of income for households were classified into four quartiles.

III. Analysis Methods

A. Development of Prediction Model using SVM

The difference between the groups by the prevalence of benign laryngeal lesions was tested by chi-square test. The prediction model for benign laryngeal lesions was developed using SVM. SVM is a machine learning algorithm that finds the most optimal decision boundary by linearly separating the hyperplane after converting the learning data to a higher dimension through nonlinear mapping [27]. The concept of SVM is shown in Figure 1.

For example, A=[a, d] and B=[b, c] are non-linearly separable in the two-dimensional space. If they are mapped in the three-dimensional space, they have a linearly separable characteristic. Thus, data containing two classes can always be separated in hyperplanes when the appropriate nonlinear mapping is used with sufficiently large dimensions [28]. Consequently, SVM is very accurate because it can model the complex nonlinear decision-making areas and it tends to have less over-fitting than other models, which is an advantage [29].

The objective of SVM is to find the interface that maximizes the margin (Fig. 2). For the convenience of calculation, the algorithm will be explained by minimizing the half of the reciprocal of squared half margin.

max2‖w‖2→min12‖w‖22max2‖w‖2→min12‖w‖22

The meaning of the above equation is as follows. The observations above the plus-plane satisfy y=1y=1 and wTx+bwTx+b is larger than 1. On the other hand, the observations below the minus-plane are y=−1y=−1 and wTx+bwTx+b is smaller than -1. When these two conditions are combined, it can be converted to the following constraint.

yi(wTxi+b)≥1

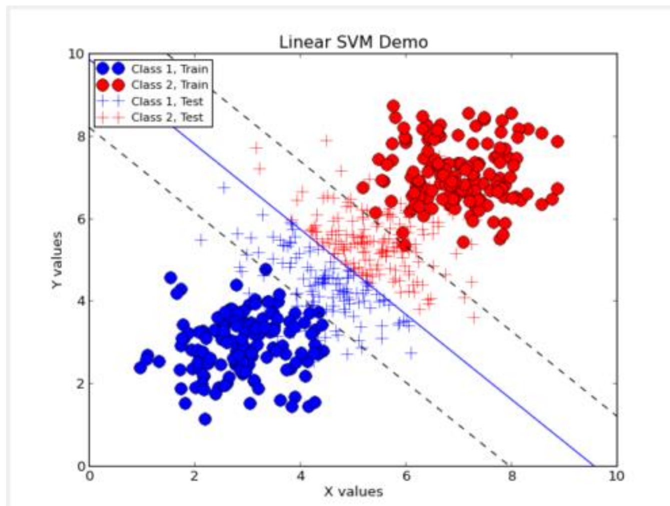

Fig. 1. Concepts of SVM, Source: MTECH Project [30].

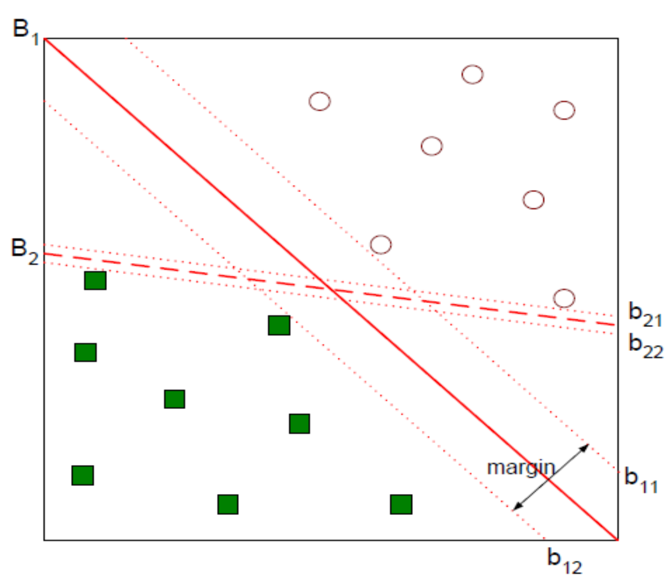

Fig. 2. Maximum Margin Classifiers.

```
> model <- svm(Species~., data=LD)
> model
Call:
svm(formula = Species ~ ., data = LD)
Parameters:
SVM-Type: C-classification
SVM-Kernel: radial
cost: 1
gamma: 0.25
Number of Support Vectors:
> table(pred, LD$Species)
predict(object, newdata, decision.values = FALSE,
probability = FALSE, ..., na.action = na.omit)
#object
Object of class "svm", created by svm.
#newdata
An object containing the new input data
# p <- predict(m, test, type = "response")
>plot(cmdscale(dist(LD[,-5])), col = as.integer(LD[,5]),
pch = c("o","+")[1:150 %in% model$index + 1])
library(kernlab)
LDmodel <- ksvm(Species ~ ., data = LD,
type = "C-bsvc", kernel = "rbfdot",
kpar = list(sigma = 0.1), C = 10,
prob.model = TRUE)
svm_problem prob = new svm_problem();
ArrayList pointsList = iv.getPointsList();
svm_node[][] nodes = new svm_node[2][pointsList.size()];
for (int i = 0; i < pointsList.size(); i++) {
float point = pointsList.get(i);
nodes[0][i] = new svm_node();
nodes[0][i].index = i;
nodes[0][i].value = point;
}
for (int i = 0; i < pointsList.size(); i++) {
float point = pointsList.get(i);
nodes[1][i] = new svm_node();
nodes[1][i].index = i;
nodes[1][i].value = point+5;
}
prob.l = 2;
prob.y = new double[] { 1, 2 };
prob.x = nodes;
svm_parameter param = new svm_parameter();
libsvm.svm.svm_check_parameter(prob, param);
svm_model model = libsvm.svm.svm_train(prob, param);
System.out.println(libsvm.svm.svm_predict(model, nodes[1]));
```

Fig. 3. SVM Algorithm Source of R Program.

When new data is entered, the observations are substituted into yi(wTxi+b−1)yi(wTxi+b−1). If the answer is larger than 0, it is predicted as 1 category. If it is smaller than 0, it is predicted as -1 category. The analysis is performed by using R version 3.4.2. Figure 3 presents the SVM algorithm source of R program. This study chose a radial basis function (Gauss function) that uses the parameter C (unit cost) in the SVM algorithm. This study compared the prediction power of the Gauss function, which was used for this study, with that of a linear algorithm, that of a polynomial algorithm, and that of a sigmoid algorithm. Moreover, four kernels were divided into C-SVM and Nu-SVM to compare the prediction accuracy of C-SVM with that of Nu-SVM.

IV. Results

A. The General Characteristics of Subjects

The general characteristics of 16,938 subjects were analyzed by using frequency analysis (Table 1). The ages of the subjects were distributed as 31.4% for 19-39 years old, 36.9% for 40-59 years old, and 31.7% for the 60 years and older. The 54.5% of subjects were women and 45.5% of them were men. In terms of occupation, the not economically active population was 44.1%, non-manual workers were 31.9%, and manual workers were 23.9%. The education level of subjects was elementary school graduate and below (39.2%), middle school graduate (11.5%), high school graduate (26.2%), and college graduate and above (23.1%). The 68.7% of subjects were nonsmokers, the 15.5% of them were former smokers, and 15.8% of them were current smokers. The 32.4% of subjects experienced the high-risk drinking during the past one year. The prevalence of subjective voice disorder was 7% and the prevalence of benign laryngeal lesions was 1.8%.

B. The Potential Causes of Benign Laryngeal Lesions

The general characteristics of subjects by the prevalence of benign laryngeal lesions and the potential causes of benign laryngeal lesions are presented in Table 2. The results of chi-square test showed that the subjects with benign laryngeal lesions and those without benign laryngeal lesions were not significantly different in all variables (i.e., age, gender, income level, occupation, education level, smoking, and high-risk drinking) except voice disorder. The prevalence of benign laryngeal lesions was significantly higher in subjects with subjective voice disorder (9.8%) than in those without subjective voice disorder (2.1%, p<0.05).

C. *Major Predictors based on SVM*

Table 3 shows the 'function weight' of SVM based on Gaussian Kernel algorithm. It is impossible to simply compare the magnitude (priority) of influence on the function weight of SVM by a variable. However, it is possible to identify if a major predictor variable has a positive relationship with a disease or a negative relationship with a disease. The ‘benign laryngeal lesion prediction model’ based on SVM could derive preventive factors and risk factors.

Risk factors were people perceiving voice problem subjectively, age between 40 and 59, 60 years old or older, female, occupation (non-manual worker and manual worker), high school graduate (the highest level of education), and high-risk drinking.

TABLE I. GENERAL CHARACTERISTICS OF SUBJECTS, %

Variables	Subcategory	Total (n=16,938)
Age	19-39	31.4
	40-59	36.9
	60+	31.7
Gender	Male	45.5
	Female	54.5
Income (quartile)	First quartile	17.3
	Second quartile	26.9
	Third quartile	28.8
	Fourth quartile	27.0
Job	Economically inactive population	44.1
	Non-manual worke	31.9
	Manual worker	23.9
highest level of education	Elementary school graduation	39.2
	Middle school graduate	11.5
	High school graduation	26.2
	College graduate	23.1
Smoking	Non smoker	68.7
	Past smoker	15.5
	Current smoker	15.8
High-risk drinking	No	67.6
	Yes	32.4
Subjective voice disorder	No	93.7
	Yes	7.0
Benign laryngeal lesions	No	98.2
	Yes	1.8

Preventive factors were people not-perceiving subjective voice problem, the income level second quartile (medium-low), third quartile (medium-high), and fourth quartile (high) than the income level first quartile (low), middle school graduate and college graduate (the highest level of education), and former smokers and nonsmokers than smokers. The final prediction rate of this SVM using 479 support vectors was 97.306.

TABLE II. THE GENERAL CHARACTERISTICS OF SUBJECTS BY THE PREVALENCE OF BENIGN LARYNGEAL LESIONS AND THE POTENTIAL CAUSES OF BENIGN LARYNGEAL LESIONS, N (%)

Variables	Subcategory	Benign laryngeal lesions		p
		No (n=16,636)	Yes (n=302)	
Age	19-39	3,974 (98.1)	79 (1.9)	0.564
	40-59	4,688 (98.2)	84 (1.8)	
	60+	4,023 (98.4)	67 (1.6)	
Gender	Male	7,564 (98.2)	139 (1.8)	0.862
	Female	9,072 (98.2)	163 (1.8)	
Income (quartile)	First quartile	2,840 (98.4)	47 (1.6)	0.605
	Second quartile	4,421 (98.4)	73 (1.6)	
	Third quartile	4,712 (98.2)	88 (1.8)	
	Fourth quartile	4,421 (98.0)	88 (2.0)	
Job	Economically inactive population	5,426 (98.4)	87 (1.6)	0.178
	Non-manual worke	3,907 (97.9)	83 (2.1)	
	Manual worker	2,939 (98.3)	51 (1.7)	
Highest level of education	Elementary school graduation	6,022 (98.2)	108 (1.8)	0.142
	Middle school graduate	1,768 (98.8)	22 (1.2)	
	High school graduation	4,029 (98.3)	70 (1.7)	
	College graduate	3,535 (97.9)	76 (2.1)	
Smoking	Nonsmoker	10,566 (98.4)	176 (1.6)	0.158
	Past smoker	2,372 (98.0)	49 (2.0)	
	Current smoker	2,423 (97.9)	52 (2.1)	
High-risk drinking	No	6,752 (98.2)	125 (1.8)	0.985
	Yes	3,231 (98.2)	60 (1.8)	
Subjective voice disorder	No	10,357 (97.9)	224 (2.1)	<0.001
	Yes	721 (90.2)	78 (9.8)	

D. Major Predictors based on SVM

Table 3 shows the 'function weight' of SVM based on Gaussian Kernel algorithm. It is impossible to simply compare the magnitude (priority) of influence on the function weight of SVM by a variable. However, it is possible to identify if a major predictor variable has a positive relationship with a disease or a negative relationship with a disease. The 'benign laryngeal lesion prediction model' based on SVM could derive preventive factors and risk factors. Risk factors were people perceiving voice problem subjectively, age between 40 and 59, 60 years old or older, female, occupation (non-manual worker and manual worker), high school graduate (the highest level of education), and high-risk drinking. Preventive factors were people not-perceiving subjective voice problem, the income level second quartile (medium-low), third quartile (medium-high), and fourth quartile (high) than the income level first quartile (low), middle school graduate and college graduate (the highest level of education), and former smokers and nonsmokers than smokers. The final prediction rate of this SVM using 479 support vectors was 97.306.

TABLE III. FUNCTION WEIGHT OF SVM BASED ON GAUSSIAN KERNEL ALGORITHM

Perceiving voice problem subjectively	.007
Not-perceiving subjective voice problem	-.007
Age between 40 and 59	.029
60 years old or older	.034
Female	.019
Income level second quartile (medium-low)	-.017
Income level third quartile (medium-high)	-.023
Income level fourth quartile (high)	-.045
Non-manual worker	.008
Manual worker	.005
Middle school graduate	-.003
High school graduate	.011
College graduate	-.011
Former smokers	-.029
Nonsmokers	-.001
High-risk drinking	.004
Number of Support Vector: 679	

E. The Accuracy of Benign Laryngeal Lesion Prediction According to the SVM Classification Algorithm

The accuracy of benign laryngeal lesion prediction according to the SVM classification algorithm is shown in Table 2. One of the SVM's disadvantages is that the fitness of the model varies by the type of kernel. Therefore, this study compared the Gaussian kernel (used for this study), linear, polynomial, and sigmoid algorithms in order to confirm the prediction accuracy of the models according to various kernel types. Additionally, these four algorithms were divided into C-SVM and Nu-SVM and the prediction accuracy of each algorithm was compared with each other. The fitness results indicated that the difference between C-SVM and Nu-SVM was not large in the benign laryngeal lesion prediction model. In terms of kernel type, the prediction accuracy of Gauss kernel was the highest and the prediction accuracy of the sigmoid kernel was the lowest.

TABLE IV. THE ACCURACY OF BENIGN LARYNGEAL LESION PREDICTION ACCORDING TO THE SVM CLASSIFICATION ALGORITHM, %

Type of SVM	Type of kernel			
	Linear	Polynomial	Gaussian	Sigmoid
C-SVM	96.582	95.825	97.306	94.858
Nu-SVM	96.431	95.767	97.120	93.158

V. DISCUSSION

This study developed a benign laryngeal lesion prediction model based on SVM by using the highly reliable ENT examination data. The results of this study revealed that subjective voice problem perception, 40 years and older, female, occupation, high school graduate, and high-risk drinking were risk factors of benign laryngeal lesions. The preventive factors of benign laryngeal lesions were people not perceiving subjective voice problem, above the second quartile, middle school graduate and college graduate (highest level of education), former smokers, and nonsmokers. Numerous previous studies that evaluated the risk factors of voice disorder reported that sociodemographic characteristics such as gender [13], age [6], and occupation [3,4,31,32], drinking [2], and smoking [31,15] were the risk factors of voice disorder. These results support the results of this study. One interesting finding of this study was that middle school graduate and college graduate were the preventive factors of benign laryngeal lesions. It was speculated that the middle school graduate had a low risk of benign laryngeal lesions because they were mostly manual workers engaging in simple labor. Byeon & Lee (2010) [33] analyzed the prevalence of benign laryngeal lesions, similar to this study, and reported that simple manual workers (e.g., maids, cleaners, and construction workers) had a low voice disorder prevalence. Byeon & Lee (2010) [33] argued that it was because they had a low probability to abuse their voice because they worked along and did repetitive jobs. It will be necessary to conduct a longitudinal study that will demonstrate the causality among the highest level of education, occupation, and voice disorder.

Another finding of this study was that the prediction accuracy of C-SVM's Gaussian kernel was the highest when the prediction accuracies of the eight SVM classification algorithms were compared after dividing Gaussian kernel, linear kernel, polynomial kernel, and sigmoid algorithms into C-SVM and Nu-SVM. The performance of the nonlinear SVM is largely determined by a kernel function and the parameters consisting of the kernel [28]. Kuo et al. [34] also reported that the Gaussian kernel algorithm had high prediction accuracy. The Gaussian kernel is to map in the specific space with infinite dimensions. It is believed that using Gaussian kernel-based C-SVM will be effective in predicting binomial variables.

VI. Conclusion

The results of this study will provide an important basis for preventing and managing benign laryngeal lesions. It will be required to systematically manage the high-risk groups in order to prevent benign laryngeal lesions.

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References

[1] H. D. Soni, S. Gandhi, M, Goyal, and U. Shah, Study of clinical profile of benign laryngeal lesions. International Journal of Medical Science and Public Health, vol. 5, no. 4, pp. 656-660, 2016.

[2] H. Byeon, A population-based cross-sectional study of alcohol consumption and risk of benign laryngeal disease in Korean adults. Journal of Voice, vol. 30, no. 4, pp. 443-447, 2016.

[3] N. Roy, R. M. Merrill, S, D. Gray, and E. M. Smith, Voice disorders in the general population: prevalence, risk factors, and occupational impact. The Laryngoscope, vol. 115. no. 11, pp. 1988-1995, 2005.

[4] A. A. Assunção, I. B. Bassi, A. M. de Medeiros, C. de Souza Rodrigues, and A. C. C. Gama, Occupational and individual risk factors for dysphonia in teachers. Occupational Medicine, vol. 62, no. 7, pp. 553-559, 2012.

[5] H. Byeon, The factors that affects the experience of discrimination in children in multi-cultural families using QUEST algorithm: focusing on Korean language education. Asia-pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology, no. 4, vol. 2, pp. 303-312, 2014.

[6] H. Byeon, The prediction model for self-reported voice problem using a decision tree model. Journal of the Korea Academia-Industrial cooperation Society, vol. 14, no. 7, pp. 3368-3373, 2013.

[7] P. N. Carding, S. Roulstone, K. Northstone, and ALSPAC Study Team. (2006). The prevalence of childhood dysphonia: a cross-sectional study. Journal of Voice, 20(4), 623-630, 2006.

[8] N. R. Williams, Occupational groups at risk of voice disorders: a review of the literature. Occupational Medicine, vol. 53, no. 7, pp. 456-460, 2003.

[9] M Behlau, F. Zambon, A. C. Guerrieri, and N. Roy, Epidemiology of voice disorders in teachers and nonteachers in Brazil: prevalence and adverse effects. Journal of Voice, vol. 26, no. 5, pp. 665.e9-18, 2012.

[10] R. M. B. De Alvear, F. J. Barón, and A. G. Martínez-Arquero, School teachers' vocal use, risk factors, and voice disorder prevalence: guidelines to detect teachers with current voice problems. Folia Phoniatrica et Logopaedica, vol. 63, no. 4, pp. 209-215, 2011.

[11] H. Byeon, Relationships among smoking, organic, and functional voice disorders in Korean general population. Journal of Voice, vol. 29. No. 3, pp. 312-316, 2015.

[12] H. Byeon, and Y. Lee, Laryngeal pathologies in older Korean adults and their association with smoking and alcohol consumption. The Laryngoscope, vol. 123, no. 2, pp. 429-433, 2013.

[13] H. Byeon, Gender differences in risk factors of benign vocal fold disease in Korea: the fifth Korea National Health and Nutritional Examination Survey. Logopedics Phoniatrics Vocology, vol. 41, no. 2, pp. 85-91, 2016.

[14] V. Kontis, C. D. Mathers, J. Rehm, G. A. Stevens, K. D. Shield, P. R. Bonita, L. M. Riley, V. Poznyak, and M. Ezzati, Contribution of six risk factors to achieving the 25× 25 non-communicable disease mortality reduction target: a modelling study. The Lancet, vol. 384, no. 9941, pp. 427-437, 2014.

[15] H. Byeon, The risk factors of laryngeal pathology in Korean adults using a decision tree model. Journal of Voice, vol. 29, no. 1, pp. 59-64, 2015.

[16] B. Zheng, S. W. Yoon, and S. S. Lam, Breast cancer diagnosis based on feature extraction using a hybrid of K-means and support vector machine algorithms. Expert Systems with Applications, vol. 41, no. 4, pp. 1476-1482, 2014.

[17] H. Byeon, A prediction model for mild cognitive impairment using random forests. International Journal of Advanced Computer Science and Applications, vol. 6, no. 12, pp. 8-12, 2015.

[18] H. Byeon, H. Jin and S. Cho, Development of Parkinson's disease dementia prediction model based on verbal memory, visuospatial memory, and executive function. Journal of Medical Imaging and Health Informatics, vol. 7, no. 7, pp. 1517-1521, 2017.

[19] A. Begue, V. Kowlessur, U. Singh, F. Mahomoodally, and S. Pudaruth, Automatic Recognition of medicinal plants using machine learning techniques. International Journal of Advanced Computer Science and Applications, vol. 8, no. 4, pp. 166-175, 2017.

[20] A. Amri, I. A'Fifah, A. R. Ismail, and A. A. Zarir, Comparative performance of deep learning and machine learning algorithms on imbalanced handwritten data. International Journal of Advanced Computer Science and Applications, vol. 9, no. 2, pp. 258-264, 2018.

[21] H. Byeon. Developing a model to predict the occurrence of the cardio-cerebrovascular disease for the Korean elderly using the random forests algorithm. International Journal of Advanced Computer Science and Applications, no. 9, vol. 9.

[22] H. Byeon, H. Development of prediction model for endocrine disorders in the Korean elderly using CART algorithm. Development, vol. 6, no, 9, 2015.

[23] H. Byeon, and H. W. Koh, A feature analysis of risk factors for stroke in the middle-aged adults. International Journal of Advanced Computer Science and Applications, vol. 6, no. 12, pp. 95-99, 2015.

[24] H. Byeon, Chi-square automatic interaction detection modeling for predicting depression in multicultural female students. International Journal of Advanced Computer Science and Applications, vol. 8, no. 12, pp. 179-183, 2017.

[25] P. Saidi, and F. Almasganj, Voice disorder signal classification using m-band wavelets and support vector machine. Circuits, Systems, and Signal Processing, vol. 34, no. 8, pp. 2727-2738, 2015.

[26] M. Shahbakhi, D. T. Far, and E. Tahami, Speech analysis for diagnosis of Parkinson's disease using genetic algorithm and support vector machine. Journal of Biomedical Science and Engineering, vol. 7, no. 4, pp. 147-156, 2014.

[27] G. Raho, R. Al-Shalabi, G. Kanaan, and A. Nassar, A. Different classification algorithms based on Arabic text classification: feature selection comparative study. International Journal of Advanced Computer Science and Applications, vol. 6, no. 2, pp. 23-28, 2015.

[28] I. Steinwart, and A. Christmann, Support vector machines, Springer Science & Business Media, New York, 2008.

[29] T. S. Furey, N. Cristianini, N. Duffy, D. W. Bednarski, M. Schummer, and D. Haussler, Support vector machine classification and validation of cancer tissue samples using microarray expression data. Bioinformatics, vol. 16, no. 10, pp. 906-914, 2000.

[30] MTECH Project, http://www.mtechprojects.org/linear-svm-projects.html

[31] H. Byeon, The association between lifetime cigarette smoking and dysphonia in the Korean general population: findings from a national survey. Peer J, vol. 3, pp. e912, 2015.

[32] H. Byeon, H. Occupational risks for voice disorders: Evidence from a Korea national cross-sectional survey. Logopedics Phoniatrics Vocology, vol. 42, no. 1, pp. 39-43, 2017.

[33] H Byeon, and Y. Lee, Prevalence and risk factors of benign laryngeal lesions in the adult population. Communication Sciences & Disorders, vol. 15, no. 4, pp. 648-656, 2010.

[34] B. C. Kuo, H. H. Ho, C. H., Li, C. C. Hung, and J. S. Taur, A kernel-based feature selection method for SVM with RBF kernel for hyperspectral image classification. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 7, no. 1, pp. 317-326, 2014.

Construction Project Quality Management using Building Information Modeling 360 Field

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***Abstract*—A quality management process plays a vital role in the success of engineering and construction projects. The management process needs to be effective and efficient if projects are to be completed on time and within the project's budget. Many construction projects' quality management processes are paper-based, which makes them time-consuming and inefficient. The next generation of Building Information Modeling (BIM) is the BIM-cloud. The BIM-cloud can help to enhance the effectiveness of a quality management process; it can also save an organization time and money. This paper proposes a quality management model based on cloud computing, mobile devices, and the Autodesk BIM 360 Field software. This software functions as a platform for gathering, managing and controlling the quality of the management data. The process is then applied to a real project in Vietnam to verify the benefits and barriers of using the BIM 360 Field for a construction project.**

Keywords*—*BIM 360 field; cloud computing; project management; quality management

I. Introduction

Construction projects are unique, because they serve the business production and meet human's basic demands [1-3]. As a result, the quality of a construction and engineering project directly influences the stable development and effectiveness of the socioeconomic factors of the national economy [4-7]. Additionally, in a fiercely competitive market economy, an improvement in the management quality has always been considered a crucial leading issue for construction companies [8]. To ensure a high quality project, a quality management process must be performed during all stages of a project (e.g., survey, design, the organization of the construction process, the maintenance of the project) [9, 10]. The construction process is the most complicated process. This is because the quality control process, at this stage, is also complicated; therefore, it is easy to make mistakes [11]. Good project quality management helps contractors save money on materials, workers, and equipment. It would also enhance the contractor's reputation in the market.

To ensure a high-quality management process, the collection and processing of information and the interaction between project stakeholders must be constant and accurate. Hence, the project management process involves an enormous amount of information. Consequently, the development of a system that could access and grasp project information quickly, effectively, and accurately is extremely urgent and necessary.

The Autodesk Building Information Modeling (BIM) 360 Field is the next generation BIM. It combines iPads, mobile devices, cloud computing, and the BIM model [12-15]. This research applied the Autodesk BIM 360 Field to enhance the efficiency of the management quality for construction projects in Vietnam. This is a new approach used to support quality assurance activities to improve the productivity so the construction projects are effectively managed.

II. Literature Review

A high quality construction project meets all of the stipulated demands of a project (e.g., technical requirements, time, expenditures, stability degrees, safety, environment) [16]. The process of producing a high quality product begins when the construction idea is developed and continues throughout all construction processes (e.g., planning, project creation, surveys, design, construction, acceptance, delivery) [17, 18]. To ensure a high project quality, the quality management process must be performed during all stages of the project life cycle [19]. Amongst them, the construction stage is considered the most complicated, as it accounts for the largest proportion of the project's cost (70 – 80%). The control process and quality management during this stage are the most difficult tasks [20, 21].

According to the Vietnamese Government's Decree No. 15/2013 ND-CP, construction quality management includes the following steps: (i) choosing a contract and creating and approving a construction method; (ii) checking the initial work conditions, (iii) building, supervising and accepting the project; (iv) developing the construction documents and file storage. In traditional construction quality management approaches, the supervision, acceptance, and storage of documents are often a paper-based process. A paper-based process is a time-consuming, cost-consuming process. It is also difficult to control the quality of [22]. Therefore, the application of information technology using the BIM 360 Field in construction organization, supervision, quality acceptance, and the creation and storage of documents on the server is exceptionally crucial.

Currently, the BIM is acknowledged and developed widely in the construction industry for all types of projects (e.g., apartments, tall buildings, hotels, industrial houses, production, infrastructure works, and transportation projects) [14, 23, 24]. The BIM is a process used to develop an information model. It involves designing, building and operating a construction project [25]. As an umbrella database covering the entire life cycle of a project, the BIM includes logical relationships regarding the space, size, quantity, material, and features of the work components. The ability to combine work division information with the information regarding the norms, unit prices, construction progress, operations, and maintenance regime is becoming more and more crucial in the construction sector to optimize the design, building and project management process [26].

The BIM 360 Field is a program developed by the BIM-Cloud platform [27]. It integrates a 3D smart model and mobile technologies with cloud computing technology [28]. The BIM 360 Field is applied to the execution stage of a project. It assists with the cooperation, combination, and management of work information that is occurring quickly, enhancing the effectiveness of work quality management and saving time and expenditures [29]. We could apply the BIM-Cloud to the entire life cycle of a project, from planning and project formation, to the survey, design, execution, acceptance, project handover, and work dismount [30, 31]. All data relating to the project would be uploaded to the cloud. Project participants (e.g., investors, consultancy companies, contractors) would obtain available preset access rights to easily access the necessary data.

Cox et al. [32] proposed a process using the Hand Base on a personal computer to perform the acceptance stage of the construction project. Its benefits are to reduce tasks relating to papers, to create a management report and to distribute information quickly and effectively. Chen and Kamara [22] recommended a mobile computing process to manage the information at the work site. The model includes mobile devices, wireless networks, and other mobile applications to perform the information management process in a construction project. Chuang et al. [33] built a system using server software and cloud computing techniques to develop a virtual system. This virtual system was used to observe and operate a BIM 3D model through the website without any limits regarding time or space. This system creates conditions for the communication and the distribution of information between the parties taking part in the project.

Moran [34] conducted experimental research on actual projects. Some projects used the BIM 360 Field and some did not. Moran [34] proved that the usage of the BIM 360 Field based Vela Systems helps parties taking part in the project to save time, money and expenditures. They also improve the construction quality of the work. This is due to the reduction of the amendment and remade activities. Sawhney and Maheswari [35] proposed a process where the BIM-Cloud would supervise the data during the design process. The project manager could check the data of each design engineer that was uploaded to the server. Jiao et al. [36] recommended the usage of the BIM-Cloud Augmented Reality, a virtual reality technology, to observe and manage data in the field of design and the work execution of projects in Shanghai and China. This model integrates the usage of a 3D website and cloud technology through BIM connections and social networking services.

Davies and Harty [37] described the deployment of "Site BIM" in a hospital project. The main contractor developed the "BIM-Enable" tools, allowing employees to use a notebook to access the information regarding the design, quality report photographs, and working progress in the field. The "Site BIM" system includes five main parts: 1) notebook, 2) combined 3D BIM models, 3) a data management system (DMS), 4) "Site dBase" application software, and 5) the office project system (including the infrastructure and relevant software).

Fernandes [38] proposed a process using the BIM 360 Field for relevant parties taking part in the construction project (e.g., contractors, investors, consultants, project managers). At the same time, the author also pointed out three groups of benefits acquired from the application of the BIM 360 Field in the project, including: (i) information (good interaction and fast update of project information), (ii) operation (notification system improvement and process streamlining), (iii) management (better management of parties taking part in the project on the basis of the cloud, and the removal of traditional paper-based tasks), and (iv) quality (reduction of project costs due to the reduction of reworked tasks and the commitment of better quality).

Zhang et al. [39] proposed a BIM-Service on the private cloud. This is the place where the parties who are taking part in the project store relevant information on their private server. This model supported project stakeholders to set, manage and transfer BIM data effectively, as well as secure the information. Tsai et al. [8] proposed an effective construction project acceptance method through the BIM model on the basis of the cloud platform. In this model, the supervisors easily take photos created from the BIM model and construction information to quickly complete the inspection tasks..

Gleason et al. [40] studied three software supporting construction projects: Bluebeam, BIM 360 Field, and Latista.

The authors concluded that Bluebeam is suitable for small construction companies, while BIM 360 Field is the best choice for companies performing BIM in large-scale projects. Latista is an optimized choice for companies not using BIM, but that are still able to perform complicated tasks. No matter what the software is, the primary aim is to improve productivity, to increase information interactions, and to reduce remade tasks and delay in a construction project. This study also gave out a quality assurance process with the assistance of mobile devices and software.

III. Research Methodology and Results

In this investigation, a process is proposed by applying the BIM 360 Field in the assistance of a construction quality assurance activity. The BIM 360 Field was applied in a residential construction project in District 2 of Ho Chi Minh city in Vietnam. This project includes 02 mutual underground basements and 04 housing blocks; the scale goes from 22 to 25 floors. There were 605 apartments for living and 16 commercial apartments. This project is in the process of the structural execution of a typical floor and a combination of completed construction.

TABLE I. Project Quality Management Process

Without BIM 360 Field	With BIM 360 Field
Subcontractor	
1. To perform the work according to method drawings and approved shop-drawings; 2. To check the quality and the compatibility of the execution activities; 3. To send internal acceptance requirements to the main contractors to determine if they are meeting quality and compatibility requirements; 4. To amend and to modify the inappropriate faults required by the main contractor. .	1. To perform the work according to method drawings and approved shop-drawings; 2. To amend and modify the inappropriate faults required by the main contractor. 3. To photograph the fault amendment. To synchronize the BIM 360 Field System. The information would be automatically updated for the main contractor to perform the acceptance for the NCRs closure.
Main contractor	
1. To perform the internal acceptance with the subcontractor. If the result is passed, an acceptance requirement would be sent to the Consultant and the Investor; by contrast, an analysis of the reasons and amendment methods would be performed to require the subcontractor to modify and remedy them. 2. When receiving NCRs from the Supervision Consultant and Investor, the analysis of the reasons must be performed. The solutions must be submitted to the Supervision Consultant and Investor for approval. 3. When the remedy is approved, it would be employed for the amendment and modification of the subcontractor. 4. To perform the internal acceptance with a subcontractor, and in case it is passed, the acceptance requirement for NCRs closure would be performed together with the Supervision Consultant and the Investor.	1. When receiving NCRs from the Supervision Consultant and the Investor, the analysis of the reasons must be performed. The solutions must be submitted to the Supervision Consultant and the Investor for approval. 2. When the solutions are approved, the main contractor would make updates on the BIM 360 Field and allocate the NCRs position. The subcontractor shall be responsible for the amendment and completion deadline. 3. The representative of the contractor would sign and close the NCRs if the amendment meets the demands.

The collected data would be analyzed to determine the benefits and difficulties of applying the BIM 360 Field in the project's management quality. To assure better quality, it is necessary to control the inputs and outputs carefully. The input of quality is the acceptance of tasks. The output is the control of the inappropriateness of work in comparison with the technical drawings (e.g., no conformance reports (NCRs)). Regarding the old acceptance process, an acceptance checklist is critical. This checklist would be held at the work site to perform the acceptance process. With the BIM 360 Field, it is possible to perform the acceptance on an iPad (Table 1).

The performance process applied the BIM 360 Field and involved seven steps:

Step 1. Performing the preparation and training for the project stakeholders

Step 2. Project administration would modify the BIM user and decentralize the rights. This involves the following five steps:

- Setting the general information of the project
- Setting the types of issues and the main reasons
- Setting the checklist and the forms for acceptance on the BIM 360 Field system
- Setting the types of tasks
- Setting the types of reports

Step 3. Pointing out the problems and defects necessary to remedy the image and the faulty position. Allocating the performer and the time of the execution (Figure 1).

Step 4. The information would be automatically updated on the BIM 360 Field; the subcontractor would remedy and amend. The subcontractor would then take a picture of the amended defects and update the system.

Step 5. When there was a requirement to accept on the system, the main contractor would perform the acceptance process. If it is passed, an electronic signature would be signed, and the issue, or NCRs, would be sealed.

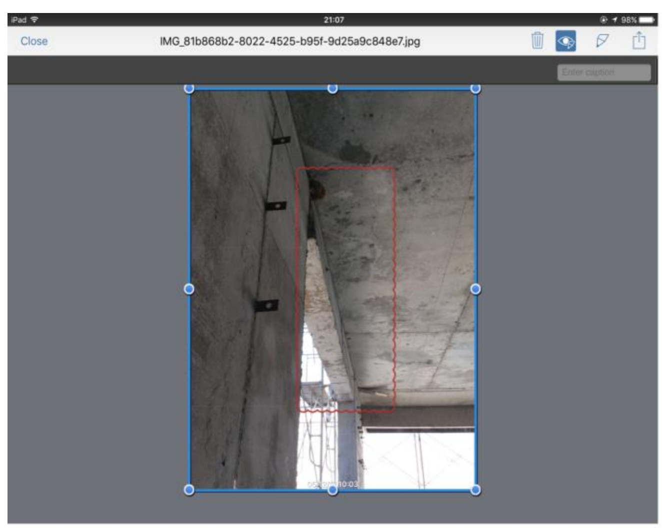

Fig. 1. Create Issues on BIM 360 Field System by iPad.

Step 6. Publish the project quality management report presented in TABLE II, according to the causes.

The employment of the BIM 360 Field in the actual project has resulted in the following benefits to the company, as follows:

- saving 2.5 hours per day, thanks to the simplified working process; and
- saving paper, because the new procedure is mainly acceptance through iPad (Figure 2).

TABLE II. PROJECT QUALITY ROOT CAUSE

No.	Cause	Issues	Percent
01	Low-quality formwork with insufficient supervision and control	22	5%
02	Dismounting of formwork, post, scaffold, method steel, and sanitation	25	5%
03	Shop drawings shall not present or insufficiently	15	3%
04	Formwork installation is not standard	63	13%
05	Not using the approved method	12	3%
06	Due to the differences between the drawings and the structure	66	14%
07	The position of the formwork to the columns and the incorrect wall	17	4%
08	The position of the formwork is not in accordance with the geodetic level	65	14%
09	There is a formwork bulge; the formwork is crooked	144	30%
10	Amendment method not meeting demands	21	4%
11	Concreting method and surface flat method	16	3%
12	Due to workers' handicraft and careless supervision	9	2%
Total		475	100%

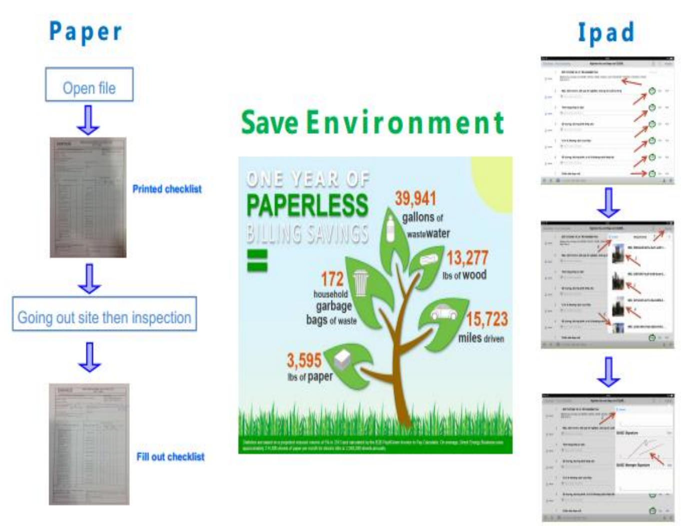

Fig. 2. Saving Papers by using iPad.

- Access to the project document at any time and any place, thanks to data storage on the cloud;
- Analyzing the core reasons leading to the poor construction quality works. From that basis, the project managers could propose solutions to remedy timely to avoid the repetition situation (e.g., the fault regarding the quality of the project exploiting, due to the formwork not being assured (30%)). It is recommended that project managers place more focus on the execution of the work and the formwork acceptance process;
- To observe and to supervise the project from anywhere. Additionally, the project manager could access the project information that is updated daily through the system synchronization on the cloud.
- To observe the problems relating to the quality and remedy defects; to recognize the defective positions, so that there would be control over the remedy and the amendment.
- To have data as a basis for the evaluation of the subcontractor's capacity. In particular, at the time of executing the project, the defects caused by the subcontractor are found to account for 57%. As a result, the project manager should pay more attention to the execution activities, inspection, and supervision of the subcontractor.

Despite the many benefits of the application of the BIM 360 Field in construction quality management, there are also some difficulties. Through the results of the BIM 360 Field applied in the actual projects, it was determined that employees apply the report submitted to managers as follows:

- Some employees do not get used to the new working style, so they still work slowly for about 01 month when performing a project.
- Continuously changing and instable human resources; as a result, this project needs time to retrain new employees. In particular, for the first 3 months of executing a project, the department of safety directed 2 employees to other projects.
- Department at the construction site allocated 3 employees to other projects. This also causes difficulties to the operation of the BIM 360 Field.
- The new project is only applied by the main contractor and the subcontractor, without extension for the owner and the consultancy company.

IV. CONCLUSION

The BIM 360 Field is a modern approach which could improve the effectiveness of construction project quality management. This is a new method used to control project quality in Vietnam to replace the traditional acceptance method. However, the application of the BIM 360 Field also experiences some specific difficulties and challenges. As a result, great effort is really necessary to change the old mindset, so that the aim of the application of the BIM 360 Field could be reached. In reality, the research contributed a tool to contractors that supports effective construction quality assurance in a convenient and easy manner. Thanks to this technology application, the company could perform project quality management and update project progress anywhere and anytime. In this way, the management effectiveness could be improved, the cost would decrease, and the competitiveness could be increased. Regarding the theoretical basis, this research also aims to contribute to the guidelines to the BIM 360 application to perform construction project quality management.

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REFERENCES

[1] P. T. Nguyen, T. A. Nguyen, Q. L. H. T. T. Nguyen, V. D. B. Huynh, and K. D. Vo, "Ranking project success criteria in power engineering companies using fuzzy decision-making method," International Journal of Advanced and Applied Sciences, vol. 5, no. 8, pp. 91-94, 2018.

[2] N. T. V. N. Phong, Nguyen; Luan Hong, Pham; Thu Anh, Nguyen; Quyen Le Hoang Thuy To, Nguyen; Vy Dang Bich, Huynh, "Application of supply chain management in construction industry," Advances in Science and Technology Research Journal, journal article vol. 12, no. 2, 2018.

[3] A. Khelifi and K. H. Hyari, "A Mobile Device Software to Improve Construction Sites Communications" MoSIC," International Journal of Advanced Computer Science and Applications, vol. 7, no. 11, pp. 51-58, 2016.

[4] N. T. Phong, V. Likhitruangsilp, and M. Onishi, "Developing a stochastic traffic volume prediction model for public-private partnership projects," in AIP Conference Proceedings, 2017, vol. 1903, no. 1, p. 060010: AIP Publishing.

[5] N. T. Phong and N. L. H. T. T. Quyen, "Application fuzzy multi-attribute decision analysis method to prioritize project success criteria," AIP Conference Proceedings, vol. 1903, no. 1, p. 070011, 2017.

[6] N. L. H. T. T. Quyen, T. N. Phong, and D. B. H. Vy, "A hybrid multi criteria decision analysis for engineering project manager evaluation," International Journal of Advanced and Applied Sciences, vol. 4, no. 4, pp. 49-52, 2017.

[7] L. D. Nguyen, T. K. N. Nguyen, D. Q. Tran, and C. Villiers, "Productivity in Daytime and Nighttime Construction of Urban Sewer Systems," Journal of Construction Engineering and Management, vol. 140, no. 7, p. 04014021, 2014.

[8] Y.-H. Tsai, S.-H. Hsieh, and S.-C. Kang, "A BIM-enabled approach for construction inspection," in Computing in Civil and Building Engineering (2014), 2014, pp. 721-728.

[9] L.-C. Wang, "Enhancing construction quality inspection and management using RFID technology," Automation in Construction, vol. 17, no. 4, pp. 467-479, 2008.

[10] L. Chen and H. Luo, "A BIM-based construction quality management model and its applications," Automation in Construction, vol. 46, pp. 64-73, 2014.

[11] F. Y. Y. Ling and T. T. D. Bui, "Factors affecting construction project outcomes: case study of Vietnam," Journal of Professional Issues in Engineering Education and Practice, vol. 136, no. 3, pp. 148-155, 2009.

[12] A. M. Gaber, S. Mazen, and E. E. Hassanein, "Comparative Study for Software Project Management Approaches and Change Management in the Project Monitoring & Controlling," International Journal of Advanced Computer Science and Applications, vol. 7, pp. 259-264, 2016.

[13] M. Ashraf et al., "A Study on Usability Awareness in Local IT Industry," International journal of advanced computer science and applications, vol. 9, no. 5, pp. 427-432, 2018.

[14] J. Matthews, P. E. Love, S. Heinemann, R. Chandler, C. Rumsey, and O. Olatunj, "Real time progress management: Re-engineering processes for cloud-based BIM in construction," Automation in Construction, vol. 58, pp. 38-47, 2015.

[15] L. Nguyen, A. Koufakou, and C. Mitchell, "A smart mobile app for site inspection and documentation," in Proceedings of ICSC15-The Canadian Society for Civil Engineering 5th International/11th Construction Specialty Conference, University of British Columbia, Vancouver, Canada, 2015.

[16] A. A. Bubshait and T. H. Al-Atiq, "ISO 9000 quality standards in construction," Journal of Management in Engineering, vol. 15, no. 6, pp. 41-46, 1999.

[17] D. Arditi and H. M. Gunaydin, "Total quality management in the construction process," International Journal of Project Management, vol. 15, no. 4, pp. 235-243, 1997.

[18] L. Duy Nguyen, S. O. Ogunlana, and D. Thi Xuan Lan, "A study on project success factors in large construction projects in Vietnam," Engineering, Construction and Architectural Management, vol. 11, no. 6, pp. 404-413, 2004.

[19] Y. Luo, Cooperative Design, Visualization, and Engineering. Springer, 2007.

[20] T. A. Nguyen and P. T. Nguyen, "Explaining model for supervisor's behavior on safety action based on their perceptions," ARPN Journal of Engineering and Applied Sciences, Article vol. 10, no. 20, pp. 9562-9572, 2015.

[21] P. T. Nguyen, P. Van Nguyen, Q. L. H. T. To Nguyen, and V. D. B. Huynh, "Project success evaluation using TOPSIS algorithm," Journal of Engineering and Applied Sciences, Article vol. 11, no. 8, pp. 1876-1879, 2016.

[22] Y. Chen and J. M. Kamara, "Using mobile computing for construction site information management," Engineering, construction and architectural management, vol. 15, no. 1, pp. 7-20, 2008.

[23] P. T. Nguyen, T. A. Nguyen, N. T. H. Ha, and T. N. Nguyen, "Facilities management in high rise buildings using building information modeling," (in English), International Journal of Advanced and Applied Sciences, Article vol. 4, no. 2, pp. 1-9, Feb 2017.

[24] M. El-Mekawy, A. Östman, and I. Hijazi, "An evaluation of IFC-CityGML unidirectional conversion," International Journal of Advanced Computer Science and Applications, vol. 3, no. 5, pp. 159-171, 2012.

[25] S. Azhar, "Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry," Leadership and management in engineering, vol. 11, no. 3, pp. 241-252, 2011.

[26] D. Bryde, M. Broquetas, and J. M. Volm, "The project benefits of building information modelling (BIM)," International journal of project management, vol. 31, no. 7, pp. 971-980, 2013.

[27] B. McGuire, R. Atadero, C. Clevenger, and M. Ozbek, "Bridge information modeling for inspection and evaluation," Journal of Bridge Engineering, vol. 21, no. 4, p. 04015076, 2016.

[28] C. Eastman, P. Teicholz, R. Sacks, and K. Liston, BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors. John Wiley & Sons, 2011.

[29] A. Sattineni and T. Schmidt, "Implementation of mobile devices on jobsites in the construction industry," Procedia Engineering, vol. 123, pp. 488-495, 2015.

[30] J. Wong, X. Wang, H. Li, and G. Chan, "A review of cloud-based BIM technology in the construction sector," Journal of information technology in construction, vol. 19, pp. 281-291, 2014.

[31] J. Wang et al., "Integrating BIM and LiDAR for real-time construction quality control," Journal of Intelligent & Robotic Systems, vol. 79, no. 3-4, pp. 417-432, 2015.

[32] S. Cox, J. Perdomo, and W. Thabet, "Construction field data inspection using pocket PC technology," in International Council for Research and Innovation in Building and Construction, CIB w78 conference, 2002.

[33] T.-H. Chuang, B.-C. Lee, and I.-C. Wu, "Applying cloud computing technology to BIM visualization and manipulation," in 28th International Symposium on Automation and Robotics in Construction, 2011, vol. 201, no. 1, pp. 144-149.

[34] M. S. Moran, "Assessing the benefits of a field data management tool," 2012.

[35] A. Sawhney and J. U. Maheswari, "Design coordination using cloud-based smart building element models," International Journal of Computer Information Systems and Industrial Management Applications, vol. 5, pp. 445-453, 2013.

[36] Y. Jiao, S. Zhang, Y. Li, Y. Wang, and B. Yang, "Towards cloud augmented reality for construction application by BIM and SNS integration," Automation in construction, vol. 33, pp. 37-47, 2013.

[37] R. Davies and C. Harty, "Implementing 'Site BIM': a case study of ICT innovation on a large hospital project," Automation in Construction, vol. 30, pp. 15-24, 2013.

[38] R. P. L. Fernandes, "Advantages and disadvantages of BIM platforms on construction site," 2013.

[39] J. Zhang, Q. Liu, F. Yu, Z. Hu, and W. Zhao, "A framework of cloud-computing-based BIM service for building lifecycle," in Computing in Civil and Building Engineering (2014), 2014, pp. 1514-1521.

[40] B. E. Gleason, P. D. White, K. E. Kumpula, and J.-H. Woo, "The Use of Mobile Devices to Create Value in Quality Management Systems," in 50th ASC Annual International Conference Proceedings, 2014.

Task Scheduling Frameworks for Heterogeneous Computing Toward Exascale

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***Abstract*—The race for Exascale Computing has naturally led computer architecture to transit from the multicore era and into the heterogeneous era. Many systems are shipped with integrated CPUs and graphics processing units (GPUs). Moreover, various applications need to utilize both CPUs and GPUs executive resources, as many of their unique features prove the significant importance and strengths of using each one of the process units PUs. Several research studies consider partitioning the applications, scheduling their execution and allocating them onto the PUs resources. They investigate the important role of optimization and tackle intelligently scheduled tasks on the combination of CPU/GPU architecture CPUs and GPUs cores in achieving the peace of performance and power consumption of Exascale Computing. In this paper, the evolution of heterogeneous computing architectures, the approaches, and challenges toward achieving Exascale Computing, and the various algorithms and techniques used to partition and scheduling tasks are all reviewed. The existing frameworks and runtime systems utilized to optimize performance and improve energy efficiency in desecrates and fused chips in order to attain the objectives of Exascale Computing will also be reviewed.**

Keywords—Exascale computing; heterogenous computing; task scheduler framework

I. Introduction

High-performance computing is the pillar for modern science. Researchers with great computing powers can make an amazing scientific discovery from climate science to combustion science, business analytics for making a good decision, big data analytics, and many others. Therefore, researchers are looking forward to the next generation of high-performance computing, i.e. "Exascale Computing". Exascale Computing achieves 10^{18} flops on real applications constraints to be within the power of 20 megawatts. Therefore, in designing both the hardware and software architecture systems, the challenge is managing the tradeoff between the performance speed-up and energy consumption. One of the most critical aspects in this management between the software and hardware is related to mapping software application to the best-fit hardware resources. Mapping refers to partitioning the application under execution into tasks, prioritizing these tasks, or scheduling them in lists to be allocated on the processors, reducing the execution results after which the user receives the computation results. Arranging this mapping using an efficient optimum algorithm that decreases the limit range of energy consumed and raises performance is considered an NP-problem. There have been a significant number of research studies that look into achieving the optimum solution to the scheduling problem. In this survey, the scheduling approaches and the research existing in the heterogeneous processors are reviewed.

A. Survey Scope and Limitations

The survey is focused on the scheduling framework that plans the tasks on the combination of CPU and general purpose graphical processing unit GPU in both types of desecrate system and on-chip system. As it is impractical to review all the aspects of the published work that are related to the task scheduling frameworks, we consider here some limitations in order to highlight the paper's scope. We focus on the CPUs/GPUs heterogenous architecture. We don't review the heterogenous architecture that are built based on other types of processors or accelerators, as heterogeneous computing may consist of for instance Field Programming Array FPGA cores and CPUs cores. Also, we didn't discuss the scheduler frameworks that consider only multi GPUs nor single GPU. The paper focuses on the task scheduler framework, language libraries, and framework level techniques. The paper considers the software level techniques, therefore, no circuit/ device/ microarchitectural level techniques are reviewed. Our paper aim is to highlight the key research ideas and the main concepts that provide researchers with the insight required to inspire future improvement in the next generation of the high-performance computing "Exascale Computing".

The remainder of the paper is organized as follows; in the next section, some principles regarding the roadmap for exascale capabilities are highlighted. This section also argues if heterogeneous computing is able to achieve an exascale capability. The following section explains the heterogeneous computing principles, where first heterogeneous computing and its types are defined extensively. Then the parallel computing with different types are defined and how it can achieve optimum heterogeneous computing is discussed. Afterward, the evolution of several components of processors hardware, such as the increase in transistor numbers, core numbers, registers file, new memory types, and new speed interconnections bus is described. The study also highlights the challenges that may limit software improvement of Exascale Computing. Furthermore, the single chip and multiple chips accompanied with accelerator GPUs as well as the algorithms used in task scheduling frameworks and the research of task scheduling framework in two aspects; performance improvement and energy efficiency all are also reviewed.

II. The Roadmap for Exascale

Figure 1 illustrates the roadmap for Exascale Computing. In 2013, the biggest supercomputers such as Titan in the USA or Tsubame KFC Tokyo Tech were 2.5GFlops/W and 4.5GFlops/W, respectively [1,2,3] where heterogeneous computing is used. Both also use K20 GPU, but Tsubame KFC does several improvements as opposed to Titan, one of which is changing the ratio CPU/ GPU, as energy consumption mostly goes more to the GPU and less to the CPU. Thus, one way of thinking to reach exascale is to improve 20PFlops, 10Wand 10^7threads so as by 2023, it will have been duplicated 50times to get 1000GFlops besides only duplicating twice the power consumption. Hence, power efficiency must go up to 25 times of the 2013 range. This efficiency is derived from process technology, better h/w, and s/w architecture and circuits, in addition to utilizing, parallelize and improving the thread from 10^7 to 10^{10}.[1].

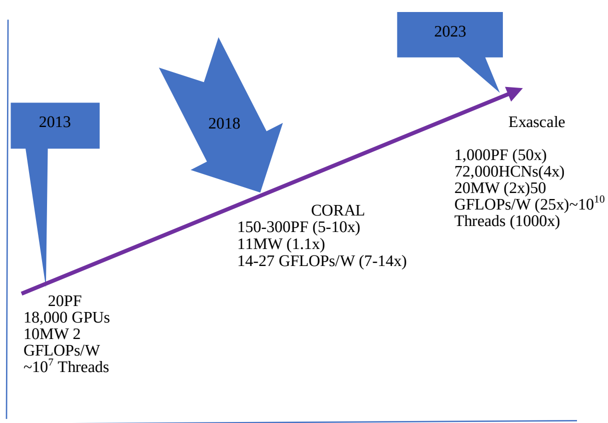

Fig. 1. The Roadmap for Exascale.

The matter that motivates researchers to leverage the heterogeneous Pus (multi CPU cores combined with any many-core accelerator such as GPUs or GFPA) collaboration to achieve high-performance computing. This way, we can benefit from the advantages of each and leverage the intelligent combination of both so as to achieve exascale performance and power consumption.

III. The Heterogeneous Computing, Principals, and Types

Nowadays, instead of CPU versus GPU debates, researchers, programmers, and computer architects are exploring PUs paradigm to find different approaches for computing and programming on efficient algorithms. This paradigm, which is known as Heterogeneous Computing (HC), refers to the utilization of the strength of diverse processing cores to maximize performance. The combinations vary from the CPUs with graphics processing units (GPUs), (see Fig4) to field programmable gate arrays (FPGAs) or both or Cell Broadband Engine Architecture (CBEA), Heterogeneous Computing (HC). Strengthening the combination architectures and accomplishing load balancing are the main targets to tone with the needs of each application, by refraining from idle time for both Processing Units (PUs). Some processors achieved more heterogeneous integration by fabricating them on the same chip as a system on chip (SoC), Such as AMD Llano [3], Intel Sandy Bridge, and Ivy Bridge [4]. One example of heterogeneous Multi-Processor System-on-Chip (MPSOC) is the Samsung Exynos[5]. The Samsung Exynos architecture consists of 4Arm Cortex-A7 (little), 4Arm Cortex-A15 (big) and ArmMali-T628GPU cores. As modern embedded systems become gradually based on MPSoC, developers are motivated to adapt algorithms and techniques that convey this hardware evolution.

A. *From Parallel to Heterogeneous Computing Principles and Challenges*

One of the key techniques in the HC is tuning the work scheduler to leverage the parallelism efficiently. The modern hardware of single node architecture has several parallelism layers by which the performance of our program can be optimized. Here, the different types of parallelism in a single node equipped with an accelerator such as GPU are mentioned. The type of the parallelism varies based on the type of connection between the unit processing and its types.(Figure 2 and 3 illustrates the types of parallelism. At the highest level is the Multi-chip parallelism, when there is more than one physical processor chip connected by a bus in the same computer. In this type, the resources and components, specifically the system memory, are shared. The communication between the cores is by the Peripheral Component Interconnect Express (PCIe) bus. The second level of parallelism is Multi-core on-chip parallelism, which is similar to the multi-chip parallelism, except that there is a single chip that combines the processor cores. In this type, the processor units share the resources that are a single chip, thus the communication is much better as when using the on-chip cache. This makes communications even less costly. When an accelerator such as GPU is connected To CPU cores on-chip, we refer to it as an Accelerated Processing Unit (APU) or heterogeneous Multi-Processor Systems-on-Chips (MPSoCs). This type is also called an integrated/fused system in contrast to the first type that is a conventional discrete system. The third type is Multi-context (thread) parallelism, where a single core is able to initialize multiple execution contexts and switch between them with reasonable or no overhead. In a multi-context system, a task can be executed on each context and in this case, there would be a separate hardware program counter for each execution context. When the processor unit is able to perform the order for one or more instructions per cycle, it then achieves the Instruction Parallelism level (ILP), which requires using multiple instruction units. HCS leverages several types of parallelisms and combines between these techniques in order to decrease the cycle per instruction and increase the efficiency of the utilization of resources.[6]

Following are several techniques used for HPC and examples for these approaches: we will start by mention the ILP techniques.

Hardware pipelining, this technique is applied when the processor unit gives one instruction order or more per cycle simultaneously in the pipeline. Next, the Vector parallelism, when there is an array of arithmetic units over which an order is duplicated. Also, Very long instruction words (VLIWs) technique used in particular architectures. [6]

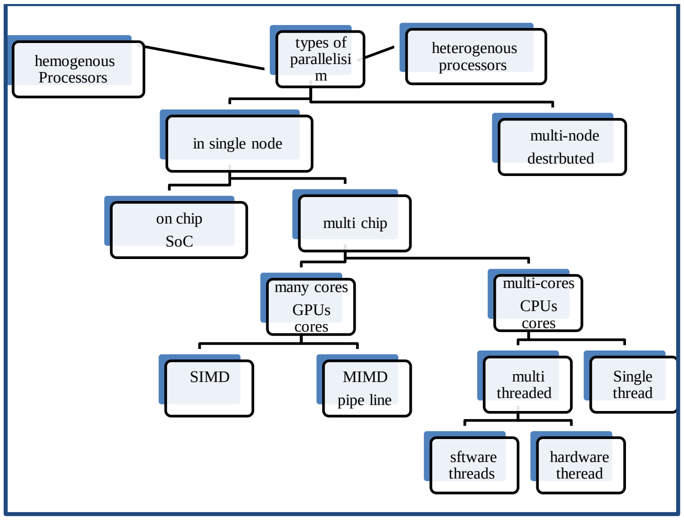

Fig. 2. Levels of Parallelism.

There are also some other techniques that can solve memory latency such as:

Hardware multi-threading :when the execution units are shared by set of execution contexts. If memory demands stall occur the CPU instantaneously switches between these contexts , declining the effect of latencies. This ought not to be confused with software threads, as the different execution contexts normally are stored in main memory.[6]

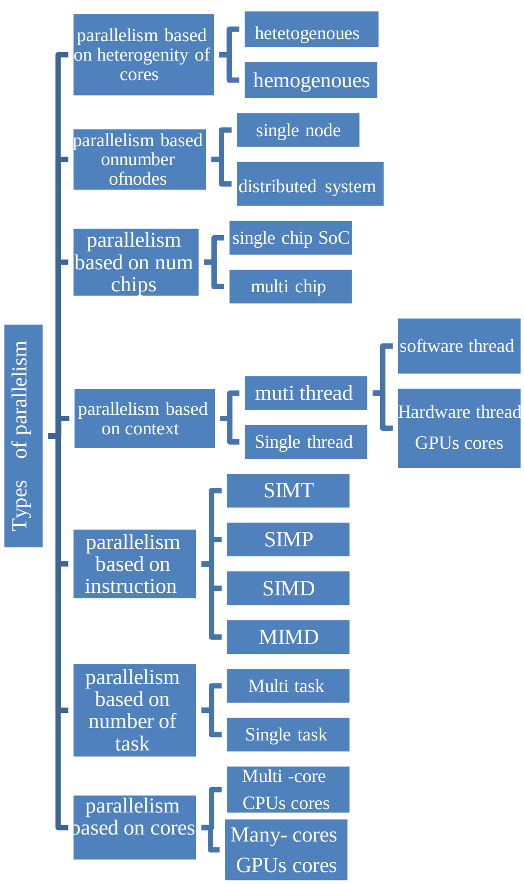

Fig. 3. Types of Parallelism.

Out-of-order execution: in some cases, latencies caused by data dependencies are minimized by reordering the instructions stream execution statically by the compiler. Otherwise, the penalty of this latency in that the conventional systems cause processor stalls.[6]

Such techniques are frequently combined, making program execution complex and tough to predict.

Data and task parallelism are different sorts of parallelism. Task-parallel methodology approximately views the problem as a set of tasks with clearly characterized communication patterns and dependencies. Pipelining could be a representative model. On the other hand, data-parallel methodology roughly views the problem as a set of operations carried out on clusters of data in a generally uniform fashion. The focus of this paper is on the combination of CPU/GPU architecture, CPUs and GPUs. The extremely diverse architectures and programming models of every type of the heterogeneous architecture present quite a few challenges in accomplishing such collaborative computing. Due to the interaction amid CPUs and GPUs in a heterogeneous system, performance optimization and energy efficiency depend on considering the characteristics of both the Pus. For this cause, usual techniques of CPU-only or GPU-only optimization might not work efficiently in a heterogeneous system. Hence, novel techniques are obligatory so as to realize the potential and opportunities of heterogeneous computing and shift towards the objectives of exascale performance.

IV. Prospects and Difficulties of Heterogeneous Computing Towards Exascale Computing

A. *Evolution of Hardware Architecture of PUs*

Table 1 reviews the hardware architecture development during the last few years. Some of the main parameters affecting the performance and the energy consumption are considered. We also take into account the transistor counts, number of cores, hardware or software manage caches, types of memory and bandwidth.

TABLE I. Hardware Evolution Recent 10 Years

parameter	Before	Now
Transistor Count	CPUs:1B transistors	Oracle SPARC M8 CPU >10Bon a chip[7].
		Stratix(FPGA)30B transistors.[7,8]
	GT200 GPU 1.4B transistors	GTX TITAN X GPU contains8B transistors [9].
Number Of Cores	GTX 280has 240 core	GTX TITAN=3072 cores Oracle Cranks up the Cores to 32 with Sparc M8 Chip.[10]
Managed Caches,	GPUs only software- managed caches, GT200 no L2	Large hardware -managed caches. Fermi GPU only had768KB LLC, the Kepler GPU had1536KB LLC, and the Maxwell GPU had2048KB LLC.[11]
3D Stacking	No	NVIDIA's Pascal GPU [11] Intel's Knights Landing [12].
Interconnect Bandwidth	The bottle neck in performance of CPUs and GPUs [13 and 14].	NVLink, offer 5to 12× bandwidth[11]

1) Examples of heterogeneous architecture computers: Here are examples of well-known heterogeneous computing architectures:

Xeon Phi:.[14] Knights Landing

The second-generation Phi.[14]

CBEA [15,16]

Nvidia GPU[11]

FPGA[8]

Finally, it can be said that there had been several approaches for achieving exascale capabilities through heterogeneous computing such as [17] it is evident —via these trends— that the never-ending evolution process of hardware architecture of both CPUs and GPUs is still ongoing.

2) Motivations for heterogeneous computing: Although utilizing GPU and FPGA as stand-alone devices appears promising, there is a number of compelling reasons for shifting towards a heterogeneous computing approach:

Each one of the AUs has a unique strength along its weakness aspects, (See fig.4). By combining AUs with different architecture, we aim to leverage the pros of each AU and overcome the cons. A modern multi-core CPUs usually own several tens of cores. These cores are caricaturized by multi-instruction and out of order issue cores. They also operate at high frequency. In addition, caches' size has increased in a way that eliminates most of the single thread execution latency caused by memory and cache miss late penalty.

Therefore, we consider CPUs suitable for latency-critical applications and memory intensive instructions. Contrast to GPU architecture, which is characterized by using a huge number of in-order cores, these cores use shared control, shared memory, and smaller cache size for each Stream multi-processor with lower frequency. Consequently, GPUs are appropriate for throughput-critical applications [18]. Therefore, it is reasonable to use a heterogeneous architectural system that consists of two or more types of cores, and schedule the application tasks between those cores; each task to the best fit or suitable type of execution unit. This way, we optimize the performance more than if we only use traditional CPU or GPU alone [19].

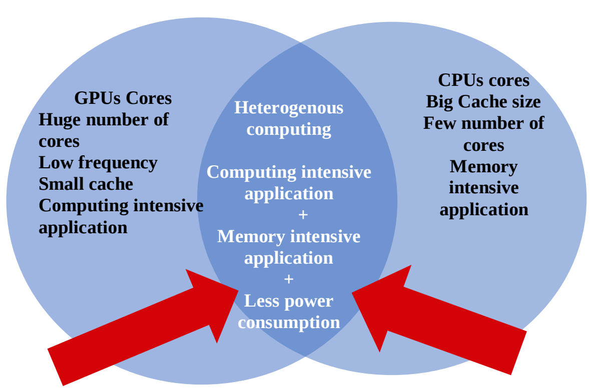

Fig. 4. Heterogenous Computing Advantages.

Mapping algorithm to best fit Pu's characteristic. When a user needs to schedule data transfers intensive applications, in some cases the branch difference or the time, uninterrupted execution are not allowed for GPU cores. On the other hand, performance is improved if CPUs are used. This does not only happen for diverse applications, but CPUs are also superior for diverse phases in single application. The matter that motivates to look at both sides in equality, both CPUs and GPUs. [20,21,22]. For example, it is eligible for developers to consider CPUs efficiency for processing short list queries contrast to GPUs that are efficient to process queries of long list. [23]

Exascale Computing is characterized by 10^{18} flops/s on real applications within the power of 20 megawatts. It assess requires using best fit scheduling and resource utilization improvement. Using GPUs alone or CPUs alone is considered a waste of resource as the average of utilization is low. For example, when allocating the task to GPU, the CPU starts initializing the kernel and keeps waiting idle for GPU computing results. [19]. Furthermore, when GPU is used for memory intensive tasks, memory bandwidth is considered the bottleneck which led to energy consumption and the utilization is even low [24,25]. Scheduling tasks intelligently on heterogeneous architecture enables the elimination of this problem [26,27]. Therefore, the June 2017 Green500 states the most energy efficient supercomputers, and CPU-GPU heterogeneous systems achieve the top 13 systems in the whole list [2].

CPUs have usually been used as a host for GPU in systems equipped with GPU to administer I/O and scheduling; nevertheless, due to the continuing innovations improvements of CPU performance even further, using its computation capabilities also has happened to be more appealing. Additionally, while numerous initial works report that GPUs supply up to 100× to 1000× speedup, other researchers claim that on applying careful optimizations on both CPUs and GPUs, CPUs may even outperform the performance of GPUs [28,29]. Due to this, different sums of load divisions to CPUs and GPUs can lead to very much dissimilar performance. These findings highlight the significance of utilizing the computational capabilities of CPUs as well.

V. Challenges Toward Achieving Exascale Performance and Energy through Heterogeneous Computing

There is a wide gap between the CPUs and the accelerators GPUs in different aspects such as performance, energy consumption, and efficiency. That gap is related to difference in architecture and programming model. Therefore, there are many considerations and challenge faces when scheduling tasks on such combination. Here, some issues are mentioned briefly:

HCS architecture that may achieve exascale features.

Achieving load balance on both CPU and GPU.

Memory bottleneck, memory bandwidth and size and memory contentions.

There is another concern related to scheduling algorithms such as:

Data partitioning and job partitioning in addition to accounting the data dependencies.

Static verses dynamic algorithms for scheduling and allocating task on heterogeneous cores

Overlapping data transfer and computation algorithms.

Underutilization of GPU multiprocessor and related resources.

Partitioning kernels contrast to partitioning devices.

Calculation systems power affectionately.

In the next section, some of these challenges are discussed and some of the research studies addressing them are mentioned.

VI. Techniques of Workload Scheduling

Tables 2 categorizes the techniques projected for dividing the workload among a CPUs and a GPUs at the stage of an algorithm or through program execution. Scheduling algorithms may classify based on when the scheduling is done, at the compile time or runtime, see Table 2. In the dynamic algorithm, the verdict about operating the subtasks or program phases or code portions on a particular PU is made at runtime. The subtasks that are implemented on a particular PU are already decided before program execution in the static algorithm, the mapping of subtasks to PUs is fixed. Here we review some of the researches that are based on each of the static and the dynamic techniques beside other schedulers that combine the both strategies.

TABLE II. Scheduler Type based on when Occur the Scheduling

Type of scheduling	**Examples of The researches**
Static scheduling	30,31,32,50,67,69,70,..
Dynamic scheduling	34,35,36,77,76,51,49,52,53,68,…
Combine static and dynamic	37,38,39,40,41,42,43,44,45,46,47,48,54,55,56,57,58 ,59,60,61,62,63,64,65,66,67,69,71,72,73,74,75

A. *Static Strategy*

Many Static algorithms have been used for partitioning the tasks to available cores [30]. Qilin scheduler framework uses static algorithm [31]. An adaptive mapping method on heterogeneous parallel processing platforms (HPPPs) is proposed; comprising of one CPU and one GPU. The reason behind Qilin is to make load adjusting on HPPPs, so it maps the divided workload to all processors concurring to their capabilities. First in the offline phase, Qilin tests execution times of a task with different problem (data) sizes, and then it formulates linear regression as the prediction model. Then, in the online phase with the new coming problem dimension, the ideal splitting proportion of workload of task on CPU and GPU is gotten by the model. Then a database recording all of the tasks sampled is created. Qilin investigates the database for the division proportion while dispersing workload on HPPPs. Luke et al. [31] suggest an effective method for workload partition. Although, the approach deals with one CPU and one GPU only, what possesses a limitation of computational workload distribution (CWD) especially on HPPPs consisting of multiple CPUs and GPUs is the number of heterogeneous processors. One more work related to CWD proposes a "waterfall energy consumption model" [32] for power concern. The authors implement a task mapping method, β-migration, on GPU. Tasks could be divided into CPU sub-task and GPU sub-task. In this method, CPU sub-task does not move parts to GPU since CPU sub-task is not proper for GPU. Whereas CPU sub-task and GPU sub-task do not work in a balanced style, the β proportion of GPU sub-task is relocated to CPU.

B. *The Dynamic Strategy*

The dynamic strategy in [33,34,35] shows a mechanism that disperses the workload to processors evenly in the initial state (e.g., the first iteration of a for-loop in a program), and after that collects the execution periods of all processors and re-distribute the workload based on the achieved respective performance measured by minimum code intrusion run-time. Such a strategy can be regarded as a light runtime profiling, so the most important matter of this strategy is how to measure each processor's performance with minimum overhead.

The dynamic strategy, if compared to the static one, cannot reach a precise extent of workload distribution at first for efficient load balancing. Furthermore, the dynamic approach requires data migrations among processors, thus causing communication overhead than a static approach. Therefore, there is a tradeoff between the dynamic and static strategies. However, each one of them is suitable for different circumstances, as will be explained in other cases.

There are many heterogeneous scheduling frameworks that are based on a combination of dynamic and static scheduling algorithms.

Some examples are as follows:

STAR PU

StarPU, is a runtime system capable of performing tasks scheduling over multicore machines qualified with GPU accelerators. StarPU employs a software virtual shared memory (VSM), which achieves a high-level programming interface, and data transfers between processing units is then automated. To enable tasks to be dynamically scheduled, it uses static and dynamic scheduling strategies such as heterogeneous early finish task HEFT in addition to work stealing algorithm in order to get considerable speedups and elevated efficiency over multicore machines with multiple accelerators. In addition, it evaluates the performance of these applications over clusters featuring multiple GPUs per node and MPI could be combined with it. StarPU is a C library that gives an API to explain the application data, capable of submitting tasks that are dispatched and executed transparently over the whole machine in an efficient way and asynchronously.[36,37,38]The main drawbacks regarding StarPU that it does not support independent loops and also recursive parallel algorithms as it does not allow create tasks recursively.

Several researchers built scheduler frameworks on top of StarPU as to extend or improve it such as [39]. They investigate the applicability of throughput enhancement by the co-scheduling of poorly-scaling tasks on sub-partitions of the GPU. This is being done to elevate utilization efficiency. Scalability of GPUs was studied, and the incorporation of this insight to use the CUDA API to partition the GPU.

Sequential task-based programming model was studied by Emmanuel, et al. [40] to achieve efficiencies in multiple nodes scale similar to its successfully efficient on the environment scale of a single node that combined with accelerators supported with OpenMP standard. They extend StaPU with an inner-node data management layer to post communication automatically. They achieve a performance competing with both pure Message Passing Interface (MPI)-based ScaLAPACK Cholesky reference execution and the DPLASMA Cholesky code, which executes a different (non-sequential) task-based programming paradigm.

Common runtime of IBM OpenCL

It enhances the OpenCL programming encounter as it covers up the low details of data movement from the programmer synchronization and automatically runs multiple OpenCL platforms and duplicated components, such as contexts and memory objects. Moreover, it also controls event dependencies cross-queue scheduling.[41]

The GPU And Multi-core Aware (GAMA)

It is a framework to aid computational scientists in the development or porting of data-parallel applications to heterogeneous computing platforms CPU/GPU cores. GAMA is specially designed to efficiently execute irregular applications where it is hard to make the needed estimation to compute the input data sets.[42]. In addition to many others such as QUARK [43], PaRSEC[44], SuperMatrix[45], StarSs[46] and Kaapi[47].

VII. Workload Scheduling Purposes

Answering why a particular scheduling of tasks to PUs is carried out, the following works are classified based on two main criteria -see table3- :

Improving performance.

Improving energy consumption.

First, we survey the research that addresses improving performance.

C. Improving Performance

Scheduling tasks on processors could be induced by the PU characteristic/capability itself and/or the subtasks. In case subtasks are similar, the scheduling then is based on achieving best performance or efficient power consumption or avoiding memory contention or achieving load balance. On the other hand, if the subtasks are different, deciding if a subtask ought to be mapped is based on the computation of an intensive task mapped to GPUs and memory intensive task to CPU.

TABLE III. Classify the Researchs based on the Scheduling Purposes

Type of scheduler based on the purpose of scheduling	**Examples of the researches**
Improve Performance by leverage memory utilization	48,49
Improve performance by improve load balance and resource underutilization	30,31,35,37,40,45,52,53.
Improve performance or in heterogenous SoC embedded	54,5,56,57,58,59,60,61
Improve performance and energy consumption in heterogenous SoC on desktop	62,64,65,63
Improve energy efficiency	70,71.72.73,74,75,76,77

1) Scheduling to concern memory limitations: Some cases exhibit the following: a subtask cannot be mapped on a particular PU; when the memory footprint of a subtask exceeds the memory size of the GPU. For example, the GPGPUs huge data demands costly memory modules, such as GDDR, to sustain high data bandwidth. The high cost poses limitations on the total memory capacity on hand to GPGPUs, and the data needs to be transferred among the host CPUs and GPGPUs. However, the data transfer long latency has resulted in considerable performance overhead. To ease this matter, modern GPGPUs have actualized the non-blocking data transfer, which enables a GPGPU to carry out computing while the data is under transmission. In [48], it is proposed that a capacity aware scheduling algorithm exploits the non-blocking data transfer in modern GPGPUs. By effectively benefitting from the non-blocking transfers, experiments show an average of 24.01% performance improvement when compared to other approaches existing, which only consider memory capacity.

One of the most critical problems in HC is scheduling in the presence of memory contention. This occurs when processors have used concurrency multi CPU cores and many cores as GPU are competing on the available resources such as register files memory and interconnected network that cause the contention. In the presence of memory contention, entirely static scheduling is hard coding and likely fails to solve it [49]. Given that the environment of multiprogramming is changing dramatically, the resources availability and the workload programs behaviors are indeterministic. This has an effect on the right mapping and scheduling of the required tasks. An approach that can adjust the mapping decision concurring to the dynamic computing environment is what is needed, by taking into account the target program behavior. To resolve the memory contention, Luk et al in [31] incorporate offline profiling to decide the best partitioning between the CPU and GPU as Grewe and O'Boyle [50] apply machine learning techniques to forecast the ideal partitioning. Both approaches arrived at promising results but only under the assumption that no other programs are operating on the system. Ravi et al. [51] use a dynamic "task farm" method for task mapping where the task is partitioned into chunks of a fixed number, and one chunk is sent to each device. When a device is done processing, it calls for a new chunk. However, this dynamic approach achieves poor performance in the presence of GPU contention. Another approach was used in [49] where they use runtime information and the code features of the program under execution to make the task partitioning prediction to achieve the best dynamic task scheduling. The good point in this dynamic scheduler is the low overhead and it avoids the penalty of long online searching.

2) Scheduling to prevent resource underutilization: In reality, the majority of GPU applications do not utilize all of the available components in a system efficiently, either entirely failing in using a component or using it to a limited fragment of its full potential. This underutilization can harm both energy efficiency and performance. Some research related the underutilization of GPU to the penalty of CPU/GPU communication and coordinate. Consequently, they reduce the CPU/GPU interaction and synchronization aiming to improve the performance improves the energy consumption. Boyer [52] studied the iterative algorithms that are implemented and found that it causes the underutilization of the GPU resources, since they produce a high overhead of CPU/GPU arrangements. Thus, he presented several strategies to be applied when implementing such algorithms. Applying these strategies would improve the performance and reduce the communication overhead. He also applied dynamic algorithms for allocation parallel kernels and efficiently utilized the available resources and achieved the load balance between the cores. Moreover in allocation kernels on GPU stream multi processors the kernels are usually executed sequentially, one kernel a time even in systems with multiple powerful devices.

Some other framework schedulers harnessing kernel partitioning to achieve the load balance on GPUs and improve the performance. One of the heterogeneous systems that used kernel partitioning is done by Ghose et al[53]. They present an in-depth analysis of control flow divergence of OpenCL kernels. Since branches have a significant impact on OperCL kernel performance, the author uses divergence as a guide to partition a kernel across CPU and GPU. A machine learning model is trained by using the amount of divergence in a program; then this model is used to predict unseen program's optimal partition. Splitting a kernel into parts and spreading these parts into distinct devices can be done statically or dynamically. But most of these research studies are not heterogeneous computing systems, and thus they are out of our scope.

3) Scheduling for achieving load balance: The load balancing across the resources in the system is the most important goal of the scheduler's framework which considers performance improvement. As load balancing enhances the overall system performance, there are various approaches for achieving this. Some approaches focus on the static algorithms and arrange the balancing plan during the compile time such as heterogeneous early finish time HEFT [30,31]. Other research studies use dynamic strategies such as work stealing or work share algorithms[35,37,40,45]. On the other hand, some research studies relate the solution for imbalance load to resource underutilization. Therefore, they consider improving resource utilization as mentioned in a previous point.

In the next section, the research studies that consider scheduling tasks on heterogeneous multiprocessor system-on-chip (MPSoC), aiming to improve the performance or energy consumption or both, are discussed.

D. Scheduling Tasks on Heterogeneous Multiprocessor System-on-chip (MPSoC)

Nowadays, MPSOC is considered a hot topic, where there have been many pieces of research introducing different approaches. [54,55, 56, 57, 58, 59, 60, 61]. The work mostly considered Samsung Exynos 5422 SoC which utilizes 4 big and/or 4 little cores that possess the same instruction set architecture ISAs [55, 57, 60]. Nonetheless, the majority of the effort was applied to the identical type of cores [58, 59, 60, 61]. In spite of that, there were a number of endeavors to parallelize both big and LITTLE cores [55], exploit cores are inapplicable with this approach having diverse ISAs such as CPU and GPU for the reason that they handle instructions in many ways. A number of studies were conducted to develop the MPSOC on desktop platforms [62, 63, 64,65]. Task scheduling and harmonization between CPU/GPU cores using such platforms cores require additional consideration. In [63], an algorithm to improve the throughput was proposed. The algorithm divides both the power budget and the workload between the CPU/GPU cores of an AMD Trinity single chip heterogeneous platform, using the same AMD platform by [64], but memory dispute occurs due to access of the same bank in different patterns by the CPU and GPU. In addition, in [62], partition considered the work and mapped them to threads between the CPU/GPU cores but that did not revolve around the energy FreeOCL [66]; a similar open source framework is used for the Arm CPU that acts as both the host processor and an OpenCL device. This provides concurrent use of CPU and GPU to carry out the application threads, but in [67,69], a static dividing is performed by using all the CPU and GPU cores. Researchers of [68] established that the influence of temperature-induced variability on circuit lifetime can be elevated due to stress and exceed over the value estimated bearing in mind the circuit average temperature. The researcher presents a simulation framework for the BTI degradation analysis of DVFS designs that considers thermal profiles under the Dynamic Thermal Management (DTM) system influence.

In [54] they divide the workload on CPU/GPU savings of the average temperature of the chip while keeping performance needs. A lower thermal behavior exhibits an enhanced long-term reliability (lifetime) of the SoC. Grasso et.al.[69] focus on analyzing the embedded GPU ARM Mali-T604 GPU. They used an OpenCL Full Profile support and investigated the utilization and optimization techniques that efficiently leverage the hardware resources. They implemented and evaluated the frame work and concluded that ARM Mali GPU Compute Architecture was able to achieve the performance and energy consumption that allows them to be a good candidate for future HPC systems.

E. Energy-Aware Scheduling Frameworks

There have been several types of research that optimize scheduling algorithms aiming to reduce the energy consumption [70,71,72,73,74,75,76,77,78]. Some use a static algorithm such as a generic algorithm. In [76] they introduce new chromosome structure to implement a generic algorithm that adapts to schedule scalable and various tasks in efficient energy consumption. Instead of individual tasks and machines, it is based upon groups of alike tasks and machines. This fresh arrangement is highly scalable and divided into three phases. The first two phases of the algorithm exhibit near-constant execution time notwithstanding of the number of tasks to be listed or the figures of machines in the system. Only the final phase of the algorithm is dependent upon the number of tasks and machines; this could be relieved by executing the phase for only a subset of the solutions from the last population.

Some others use algorithms that schedule the tasks in a way that controls the system energy consumption at a certain point of time. Other research studies aim to schedule tasks while keeping the system energy at a limit given range and prevent the system energy overloaded. This point of keeping a system in a limit range of energy is critical to achieving the exascale systems constraints. One of those uprising techniques is "Power capping", which is used to control power consumption in a data center in a certain period of time. In [77] the researchers study the impact of power variation of scheduling multi programming concurrently. They present an efficient algorithm for power capping.

VIII. Conclusion

Recently, the use of different processors simultaneously, such as CPU cores combined with different accelerators GPUs cores, for achieving efficiency in performance and energy control of Exascale Computing, has been intensively researched. Heterogeneous computing emerges as a promise paradigm. Different approaches were proposed to leverage heterogeneous computing toward Exascale Computing. Several of these approaches have been reviewed in this paper. Also, the evolution of hardware and the various approaches proposed for partitioning, scheduling and allocating the workload on the heterogeneous architecture, desecrate systems and fused systems or heterogeneous SoC were discussed as well. These research studies are done with two main goals: performance improvement and energy efficiency. In conclusion, we confirm the need for accommodating software development along with the quick evolution of the hardware. In our review, a huge gap has been found between the algorithms improvements to utilize the available hardware resources and the evolution in hardware. Tuning the scheduling techniques and the combining of algorithms by exploring other software techniques to reduce the underutilization of the accelerators resources -specifically GPUs resources is bound to decrease this gap.

References

[1] https://youtu.be/IIzjMr4f-8U

[2] https://www.top500.org/green500/lists/2017/11/

[3] A. Branover, D. Foley, M Steinman. AMD fusion APU: Llano. IEEE Micro, 32, 2(2012), 28–37.

[4] M. Yuffe, E. Knoll, M. Mehalel, J. Shor, and T.Kurts.. "A fully integrated multi- CPU, GPU and memory controller 32nm processor". In Proceedings of the IEEE International Solid-State Circuits Conference Digest of Technical Papers (ISSCC'11). 264–266. Damaraju et al. 2012

[5] Exynos 5 Octa (5422). (2016). www.samsung.com/exynos/

[6] A. R. Brodtkorb, C. Dyken, T.R. Hagen, J. M. Hjelmervik, and O.O. Storaasli, "State-of-the-art in Heterogeneous Computing," Scientific Programming, vol. 18, no. 1, pp. 1-33, 2010. doi:10.3233/SPR-2009-0296

[7] https://www.nextplatform.com/2017/09/18/m8-last-hurrah-oracle-sparc/

[8] "Altera's 30 billion transistor FPGA". Gazettabyte. 28 June 2015. Retrieved 24Jan 2017. http://www.gazettabyte.com/home/2015/6/28/alteras-30-billion-transistor-fpga.html

[9] http://www.enterprisetech.com/2018/03/13/oracle-cranks-cores-32-sparc-m8-chip/.

[10] https://www.techpowerup.com/gpudb/2632/geforce-gtx-titan-x

[11] https://www.nvidia.com/en-us/data-center/pascal-gpu-architecture/

[12] https://ark.intel.com/products/codename/48999/Knights-Landing

[13] K. Barker, K. Davis, A. Hoisie, D. Kerbyson, M. Lang,S. Pakin and J. Sancho, Entering the petaflop era: The architecture and performance of Roadrunner, in: Supercomputing, November 2008, IEEE Press, Piscataway, NJ, USA, 2008, pp. 1–11

[14] https://www.intel.com/content/www/us/en/products/processors/xeon-phi/xeon-phi-processors.html

[15] http://searchdatacenter.techtarget.com/definition/IBM-Roadrunner

[16] https://gizmodo.com/5090737/ibm-roadrunner-tops-cray-as-the-official-worlds-fastest-supercomputer

[17] Schulte, M.J., Ignatowski, M., Loh, G.H., Beckmann, B.M., Brantley, W.C., Gurumurthi, S., Jayasena, N., Paul, I., Reinhardt, S.K. and Rodgers, G., 2015. Achieving exascale capabilities through heterogeneous computing. IEEE Micro, 35(4), pp.26-36.S.

[18] Mittal. A survey of techniques for managing and leveraging caches in GPUs. Journal of Circuits, Systems, and Computers (JCSC) 23, 8 (2014).

[19] Mittal S, Vetter JS. A survey of CPU-GPU heterogeneous computing techniques. ACM Computing Surveys (CSUR). 2015 Jul 21;47(4):69

[20] H. Hong; Z. H.B. Hong. Dynamically tuned push-relabel algorithm for the maximum flow problem on CPU-GPU-hybrid platforms. In Proceedings of the 2010 IEEE International Symposium on Parallel & Distributed Processing (IPDPS'10). 1–10.

[21] A. Nere, S. Franey, A. Hashmi, and M. Lipasti. 2012. Simulating cortical networks on heterogeneous multi-GPU systems. J. Parallel and Distrib. Comput. 43, 7 (July 2012), 953–971.

[22] J. Shen, A.Varbanescu, H. Sips, M. Arntzen, and D. G. Simons. Glinda: A frameworkfor accelerating imbalanced applications on heterogeneous platforms. In Proceedings of the ACM International Conference on Computing Frontiers. ACM, New York, NY, Article 14. 2013

[23] S. Ding, J. He, H. Yan, and T. Suel.. Using graphics processors for high performance IR query processing. In Proceedings of the 18th International Conference on World Wide Web (WWW'09)P.421–430 ,2009

[24] M. Daga, A. M. Aji, and W. Feng. On the efficacy of a fused CPU+ GPU processor (orAPU) for parallel computing. In Symposium on Application Accelerators inHigh-Performance Computing(SAAHPC). IEEE, 141–149. 2011.

[25] K. L. Spafford, J. S. Meredith, S. Lee, D. Li, Philip C. Roth, and J. S. Vetter. The tradeoffs of fused memory hierarchies in heterogeneous computing architectures. In Proceedings of the 9th Conference on Computing Frontiers. 103–112. 2012.

[26] I. Gelado, J. E. Stone, J. Cabezas, S. Patel, N. Navarro, and W. W. Hwu. An asymmetric distributed shared memory model for heterogeneous parallel systems. In ACM SIGARCH Computer Architecture News, 38 1 (March 2010), 347–358. 2010.

[27] Q. Hu, N. A. Gumerov, and R. Duraiswami. Scalable fast multipole methods on distributed heterogeneous architectures. In Proceedings of the 2011 International Conference for High Performance Computing, Networking, Storage and Analysis. ACM, New York, NY, Article 36. . 2011

[28] J. Gummaraju, L. Morichetti, M. Houston, B. Sander, B. R. Gaster, and B. Zheng. 2010. Twin peaks: A software platform for heterogeneous computing on general-purpose and graphics processors. In Proceedings of the 19th International Conference on Parallel Architectures and Compilation Techniques (PACT'10). ACM, New York, NY, 205–216.

[29] V. W. Lee, C. Kim, J. Chhugani, M. Deisher, D. Kim, A. D. Nguyen, N. Satish, M. Smelyanskiy, S. Chennupaty, P. Hammarlund, R. Singhal, and P. Dubey.. Debunking the 100X GPU vs. CPU myth: An evaluation of throughput computing on CPU and GPU. In Proceedings of the 37th Annual International Symposium on Computer Architecture (ISCA'10). ACM, New York, NY,P 451–460. 2010

[30] D. Grewe and Michael F. P. O'Boyle.. A static task partitioning approach for heterogeneous systems using OpenCL. In Proceedings of the 20th International Conference on Compiler Construction:Part of the Joint European Conferences on Theory and Practice of Software. Springer, Berlin, P 286–305. 2011

[31] C.-K. Luk et al., "Qilin: Exploiting Parallelism on Heterogeneous Multiprocessors with Adaptive Mapping," in the 42nd Annual IEEE/ACM International Symposium on Microarchitecture. MICRO-42, pp. 45–55, 2009.

[32] W. Liu et al., "A Waterfall Model to Achieve Energy Efficient Tasks Mapping for Large Scale GPU Clusters," in the IEEE International Symposium on Parallel and Distributed Processing Workshops and Phd Forum, IPDPSW, pp. 82–92, 2011.

[33] A.P.D. Binotto et al., "Towards dynamic reconfigurable load-balancing for hybrid desktop platforms," in the IEEE International Symposium on Parallel & Distributed Processing Workshops and Phd Forum, IPDPSW, pp. 1–4, 2010.

[34] I. Galindo et al., "Dynamic load balancing on dedicated heterogeneous systems," In Recent Advances in Parallel Virtual Machine and Message Passing Interface, Springer, pp. 64–74, 2008.

[35] C. Augonnet, J. Clet-Ortega, S. Thibault and R. Namyst, "Data-Aware Task Scheduling on Multi-accelerator Based Platforms," 2010 IEEE 16th International Conference on Parallel and Distributed Systems, Shanghai, 2010, pp. 291-298.doi: 10.1109/ICPADS.2010.129

[36] Augonnet Cdric et al., "StarPU: a unified platform for task scheduling on heterogeneous multicore architectures", Concurrency and Computation: Practice and Experience, vol. 23.2, pp. 187-198, 2011.

[37] C. Augonnet et al. "StarPU: a unified platform for task scheduling on heterogeneous multicore architectures". In: Concurrency and Computation: Practice and Experience 23.2 (2011), pp. 187–198.

[38] Augonnet Cdric et al., "StarPU: a unified platform for task scheduling on heterogeneous multicore architectures", Concurrency and Computation: Practice and Experience, vol. 23.2, pp. 187-198, 2011.

[39] Janzén, J., Black-Schaffer, D., & Hugo, A. (2016, October). Partitioning GPUs for Improved Scalability. In Computer Architecture and High Performance Computing (SBAC-PAD), 2016 28th International Symposium on (pp. 42-49). IEEE.

[40] Agullo, Emmanuel, et al. "Achieving high performance on supercomputers with a sequential task-based programming model." IEEE Transactions on Parallel and Distributed Systems (2017).

[41] Stone, J. E., Gohara, D., & Shi, G. (2010). OpenCL: A parallel programming standard for heterogeneous computing systems. Computing in science & engineering, 12(3), 66-73.

[42] João Barbosa. GAMA framework: Hardware Aware Scheduling in Heterogeneous Environments. Tech. rep. Computer Science Dept., University of Texas at Austin, Sept.2012.7

[43] YarKhan, J. Kurzak, J. Dongarra, "QUARK UsersGuide: QUeueing And Runtime for Kernels", UTK ICL, 2011.

[44] G. Bosilca, A. Bouteiller, A. Danalis, M. Faverge, T. Hrault, J. Dongarra, "PaRSEC: A programming paradigm exploiting heterogeneity for enhancing scalability", Computing in Science and Engineering, vol. 15, no. 6, pp. 3645, Nov. 2013.

[45] E. Chan, F. G. Van Zee, P. Bientinesi, E. S. Quintana-Orti, G. Quintana-Orti, R. Van de Geijn, "SuperMatrix: a multithreaded runtime scheduling system for algorithms-byblocks", 13th ACM SIGPLAN Symposium on Principles and practice of parallel programming, pp. 123132, 2008.

[46] J. Planas, R. M. Badia, E. Ayguad, J. Labarta, "Hierarchical task-based programming with StarSs", International Journal of High Performance Computing Applications, vol. 23, no. 3, pp. 284299, 2009.

[47] T. Gautier, X. Besseron, L. Pigeon, "Kaapi: A thread scheduling runtime system for data flow computations on cluster of multi-processors", 2007 International Workshop on Parallel Symbolic Computation ser. PASCO 07, pp. 1523, 2007.

[48] H. W. Liu, H. K. Kuo, K. T. Chen and B. C. C. Lai, "Memory capacity aware non-blocking data transfer on GPGPU," SiPS 2013 Proceedings, Taipei City, 2013, pp. 395-400.doi: 10.1109/SiPS.2013.6674539

[49] Grewe D., Wang Z., O'Boyle M.F.P. (2014) OpenCL Task Partitioning in the Presence of GPU Contention. In: Cașcaval C., Montesinos P. (eds) Languages and Compilers for Parallel Computing. LCPC 2013. Lecture Notes in Computer Science, vol 8664. Springer, Cham

[50] Dominik Grewe and Michael F.P. O'Boyle. A static task partitioning approach for heterogeneous systems using opencl. In CC, 2011.

[51] 40]Vignesh T. Ravi, Wenjing Ma, David Chiu, and Gagan Agrawal. Compiler and runtime support for enabling generalized reduction computations on heterogeneous parallel configurations. In ICS, 2010.

[52] Boyer, M. (2013). Improving Resource Utilization in Heterogeneous CPU-GPU Systems (Doctoral dissertation, Ph. D. thesis, University of Virginia, Virginia).

[53] Ghose, A., Dey, S., Mitra, P., & Chaudhuri, M. (2016, February). Divergence aware automated partitioning of OpenCL workloads. In Proceedings of the 9th India Software Engineering Conference (pp. 131-135). ACM.

[54] Weber Wachter, Eduardo, Merrett, Geoff V., Singh, Amit and Al-Hashimi, Bashir (2017) Reliable mapping and partitioning of performance-constrained OpenCL Applications on CPU-GPU MPSoCs At 15th IEEE/ACM Symposium on Embedded Systems for Real-Time Multimedia, Seoul, Korea, Republic of. 15 - 20 Oct 2017.

[55] Ali Aalsaud, Rishad Shafik, Ashur Rafiev, Fie Xia, Sheng Yang, and Alex Yakovlev.2016. Power–Aware Performance Adaptation of Concurrent Applications inHeterogeneous Many-Core Systems. In Proceedings of the 2016 International Symposium on Low Power Electronics and Design (ISLPED '16). ACM, New York NY, USA, 368–373. https://doi.org/10.1145/2934583.2934612

[56] Karunakar Reddy Basireddy, Amit Singh, Geoff V. Merrett, and Bashir M. Al-Hashimi. 2017. ITMD: run-time management of concurrent multi-threadedapplications on heterogeneous multi-cores. In Conference on Design, Automationand Test in Europe 2017 (DATE'17). https://eprints.soton.ac.uk/406291/

[57] Kiran Chandramohan and Michael F.P. O'Boyle. 2014. Partitioning Data-paralle Programs for Heterogeneous MPSoCs: Time and Energy Design Space Exploration.In Proceedings of the 2014 SIGPLAN/SIGBED Conference on Languages,Compilers and Tools for Embedded Systems (LCTES '14). ACM, New York, NY, USA,73–82. https://doi.org/10.1145/2597809.2597822

[58] B. Donyanavard, T. MAijck, S. Sarma, and N. Dutt. 2016. SPARTA: Runtime task allocation for energy efficient heterogeneous manycores. In 2016 International Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS).1–10.

[59] Gangwon Jo, Won Jong Jeon, Wookeun Jung, Gordon Taft, and Jaejin Lee. 2014.OpenCL Framework for ARM Processors with NEON Support. In Proceedings of the 2014 Workshop on Programming Models for SIMD/Vector Processing (WPMVP '14). ACM, New York, NY, USA, 33–40. https://doi.org/10.1145/2568058.2568064

[60] J. Ma, G. Yan, Y. Han, and X. Li. 2016. An Analytical Framework for Estimating Scale-Out and Scale-Up Power Efficiency of Heterogeneous Manycores. IEEE Trans. Comput. 65, 2 (Feb 2016), 367–381. https://doi.org/10.1109/TC.2015.2419655

[61] E. Del Sozzo, G. C. Durelli, E. M. G. Trainiti, A. Miele, M. D. Santambrogio, and C. Bolchini. 2016. Workload-aware power optimization strategy for asymmetric multiprocessors. In 2016 Design, Automation Test in Europe Conference Exhibition (DATE). 531–534.

[62] Kenzo Van Craeynest, Aamer Jaleel, Lieven Eeckhout, Paolo Narvaez, and Joel Emer. 2012. Scheduling Heterogeneous Multi-cores Through Performance Impact Estimation (PIE). In Proceedings of the 39th Annual International Symposium on Computer Architecture (ISCA '12).

IEEE Computer Society, Washington, DC, USA,213–224. http://dl.acm.org/citation.cfm?id=2337159.2337184

[63] Indrani Paul, Vignesh Ravi, Srilatha Manne, Manish Arora, and Sudhakar Yalamanchili. 2013. Coordinated Energy Management in Heterogeneous Processors.In Proceedings of the International Conference on High Performance Computing,Networking, Storage and Analysis (SC ’13). ACM, New York, NY, USA, Article 59,12 pages. https://doi.org/10.1145/2503210.2503227

[64] Hao Wang, Vijay Sathish, Ripudaman Singh, Michael J. Schulte, and Nam Sung Kim. 2012. Workload and Power Budget Partitioning for Single-chip Heterogeneous Processors. In Proceedings of the 21st International Conference on Parallel Architectures and Compilation Techniques (PACT ’12). ACM, New York, NY, USA,401–410. https://doi.org/10.1145/2370816.2370873

[65] Hao Wang, Ripudaman Singh, Michael J. Schulte, and Nam Sung Kim. 2014.Memory Scheduling Towards High-throughput Cooperative Heterogeneous Computing. In Proceedings of the 23rd International Conference on Parallel Architectures and Compilation (PACT ’14). ACM, New York, NY, USA, 331–342. https://doi.org/10.1145/2628071.2628096

[66] FreeOCL: Multi-platform implementation of OpenCL 1.2 targeting CPUs.(2017). Retrieved 2017 from https://github.com/zuzuf/freeocl

[67] A. Prakash, S. Wang, A. E. Irimiea, and T. Mitra. 2015. Energy-efficient execution of data-parallel applications on heterogeneous mobile platforms. In 2015 33rd IEEE International Conference on Computer Design (ICCD). 208–215. https://doi.org/10.1109/ICCD.2015.7357105

[68] H. Chahal, V. Tenentes, D. Rossi, and B. M. Al-Hashimi. 2016. BTI aware therma management for reliable DVFS designs. In 2016 IEEE International Symposium on Defect and Fault Tolerance in VLSI and Nanotechnology Systems (DFT). 1–6. https://doi.org/10.1109/DFT.2016.7684059

[69] I. Grasso, P. Radojkovic, N. Rajovic, I. Gelado, and A. Ramirez. 2014. Energy Efficient HPC on Embedded SoCs: Optimization Techniques for Mali GPU. In 2014IEEE 28th International Parallel and Distributed Processing Symposium. 123–132. https://doi.org/10.1109/IPDPS.2014.24

[70] M. Oxley, S. Pasricha, H. J. Siegel, A. A. Maciejewski, J. Apodaca,D. Young, L. Briceno, J. Smite, S. Bahirat, B. Khemka, A. Ramirez,and Y. Zou, “Makespan and energy robust stochastic static resource allocation of a bag-of-tasks to a heterogeneous computing system,” IEEE Transactions on Parallel and Distributed Systems, vol. 26, no. 10, pp.2791–2805, Oct 2015.

[71] M. Halappanavar, M. Schram, L. de la Torre, K. Barker, N. Tallent, and D. Kerbyson, “Towards efficient scheduling of data intensive high energy physics workflows (works ’15),” in 10th workshop on Workflows in Support of Large-Scale Science, Nov 2015, pp. 1–9.

[72] R. Friese, B. Khemka, A. A. Maciejewski, H. J. Siegel, G. A. Koenig, S. Powers, M. Hilton, J. Rambharos, G. Okonski, and S. W. Poole,“An analysis framework for investigating the trade-offs between system performance and energy consumption in a heterogeneous computing environments,” in 22nd Heterogeneity in Computing Workshop (HCW 2013), in the proceedings of the IPDPS 2013 Workshops & PhD Forum (IPDPSW), May 2013.

[73] K. M. Tarplee, R. Friese, A. A. Maciejewski, H. J. Siegel, and E. Chong,“Energy and makespan tradeoffs in heterogeneous computing systems using efficient linear programming techniques,” IEEE Transactions on Parallel and Distributed Systems, vol. 26, 2015.

[74] K. M. Tarplee, R. Friese, A. A. Maciejewski, and H. J. Siegel, “Scalable linear programming based resource allocation for makespan minimization in heterogeneous computing systems,” Journal of Parallel and Distributed Computing, vol. 84, pp. 76–86, 2015.

[75] Friese, Ryan D. "Efficient genetic algorithm encoding for large-scale multi-objective resource allocation." In Parallel and Distributed Processing Symposium Workshops, 2016 IEEE International, pp. 1360-1369. IEEE, 2016.

[76] Feng, Y., Li, G., & Sethi, S. P. (2018). A three-layer chromosome genetic algorithm for multi-cell scheduling with flexible routes and machine sharing. International Journal of Production Economics, 196, 269-283.

[77] Shoukourian H, Wilde T, Auweter A, Bode A. Power variation aware configuration adviser for scalable hpc schedulers. InHigh Performance Computing & Simulation (HPCS), 2015 International Conference on 2015 Jul 20 (pp. 71-79). IEEE.

[78] S. Mittal and J. S. Vetter. A survey of methods for analyzing and improving GPU energy efficiency. ACM Computing Surveys 47, 2, Article 19 (2015).

Heterogeneous HW/SW FPGA-Based Embedded System for Database Sequencing Applications

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***Abstract*—Database sequencing applications including sequence comparison, searching, and analysis are considered among the most computation power and time consumers. Heuristic algorithms suffer from sensitivity while traditional sequencing methods, require searching the whole database to find the most matched sequences, which requires high computation power and time. This paper introduces a dynamic programming technique based-on a measure of similarity between two sequential objects in the database using two components, namely frequency and mean. Additionally, database sequences that have the lowest scores in the comparison process were excluded such that the similarity algorithm between a query sequence and other database sequences is applied to meaningful parts of the database. The proposed technique was implemented and validated using a heterogeneous HW/SW FPGA-based embedded system platform. The implementation was partitioned into (1) hardware part (running on logic gates of FPGA) and (2) software part (running on ARM processor of FPGA). The validation study showed a significant reduction in computation time by accelerating the database sequencing processes by 60% comparing to traditional known methods.**

Keywords—Database; sequence comparison; dynamic programming; FPGA

I. Introduction

Sequence analysis, comparing, alignment, or any sequence computing application are common concepts in a variety of research fields. The rapid analysis of Protein and DNA sequences, in Biology, is performed on large databases of sequences in order to search for close matches in specific sequences, such as a protein that has been discovered recently [1], [2], [3], [4]. If the sequences were correlated, then new drugs would be created, and the invention of better techniques could be possible in order to treat the disease.

"String Editing" [5], which is a form of sequence comparison, is used, in Computer Science, as error correction mechanism similar to the one found in spell checkers and file comparators. The way it works is by comparing and searching through a large sequence database of words for a particular one. Sequence comparison is also used to find the Longest Common Subsequence (MLCS) between two input strings [6]. Using Sequence Comparison in Social Science [7], [8], [9], [10], involves a broad selection of topics, such as national histories and daily life careers. In video processing, a video's temporal and spatial info that is contained in a frame sequence, are aligned to find the repeated contents in a video's stream [11]. In the previously mentioned applications, the time consumption is high, since they rely on the comparison of a specific sequence with a huge sequences database. Approximate solutions can be found via the use of Heuristic algorithms, which are problematic since they are sensitive and my trim searches which may result in missing some important homologies, unexpectedly. However, deterministic algorithms can guarantee that the optimal comparison result is returned from the two sequences as they are based on dynamic programming principles. In these algorithms, a query sequence, which is the sequence under search, is compared with every sequence in the database. A similarity score will be computed for every comparison process. The higher the score, the closer is the database sequence to the query.

Dynamic programming based algorithm breaks down the large computing problems into a smaller subset of problems, where each one's result depends dynamically on the other. The end results are presented in a time which is proportional to the product of the two lengths of both sequences under comparison, such as if n represents the query sequence's length, and m represents that of the database sequence, the optimal alignment from the previous algorithms will be provided in n x m steps. Hence, we can conclude that searching a whole database will grow the computational time in a linear fashion with respect to the size of the database.

Powerful and efficient techniques have been suggested to compute these huge amounts of data in a more realistic time using the FPGAs [12], [13]. The authors of [14] proposed a Recursive Variable Expansion (RVE) based technique and implemented it on the FPGA. In [15], the authors partitioned the database sequences into two sections based on the sequence length by running the short sequences on the CPU and the long sequences on the GPU. In [16], the authors combined a sequence alignment algorithm with linear space complexity using a GPU. The authors in [17] have suggested a measurement of similarities across two web pages, as well as a clustering method of the web sessions via a Fast Optimal Global Sequence Alignment algorithm (FOGSAA). In [18], the authors provided a comparative analysis of the various optimization strategies of the Smith-Waterman algorithm and contributed to the dynamic programming of sequence alignment and the implementation in FPGA. [19] presented a run-time efficient hardware-software partitioning technique for FPGAs. [20] presented a method to approximate dynamic programming for direct model predictive control (MPC) of current reference tracking in power electronics and the FPGA implementation is validated on a variable speed drive system with a three-level voltage source converter.

Every previous application and submission has used the similarity measures to find how close the objects are to each other. This object may be a sequence database, a string file, a stream of a video, or a webpage. Objects consist of various frequently reoccurring letters (codes) and are sequences in a database.

In this research, we suggest new similarity measures (similarity functions as we refer to them) that are based upon the mathematical parameters; the mean of the codes in the sequences on the database, and their frequency. We can reduce the required time to measure the similarity of two objects (database sequences) by using our similarity functions. Also, we will present a new efficient technique that reduces the computational time required to compute similarities between the entire database sequences and the query sequence by the exclusion of the sequences which obtain a low score in the comparison process. In such cases, we have to apply dynamic programming algorithm on part of the database and not on the entire database. We also develop a heterogeneous HW/SW FPGA-Based Embedded System which exploits the new features of the Xilinx ZYNQ-7000 series, by partitioning the implementation into (1) hardware part (running on logic gates of FPGA) and (2) software part (running on ARM processor of FPGA). As the sorting part of the technique requires more computations, we run it on ARM processor of FPGA, while we leave the part which can be parallelized to be run on logic gates of the FPGA. Using our technique, we can size-down the comparison application time by 60% with respect to the traditional methods. The selling point in this technique is the ability to use it in conjunction with the currently available methods to prove their validity.

As a case study, we apply our technique to the dynamic programming based algorithm the Needleman-Wunsch [21].

Our contributions are as follows:

1) Proposing new similarity functions to measure the similarity between two objects based on mathematical parameters.

2) Minimizing the computation time required for database sequence computing application by proposing a novel technique.

3) Heterogeneous HW/SW FPGA-Based embedded system is proposed which executes the hardware part of the technique on the logic gates of FPGA, and the software part on the ARM processor of FPGA

The following sections in this paper will be organized as the following. Section II will demonstrate the sequential applications via applying the traditional methods. Section III demonstrates our similarity functions. Section IV will introduce the time complexity and the reduction of the computational time of our technique.

The proposed FPGA implementation is presented in Section V. The experimental results are presented in Section VI. We conclude this paper in Section VII.

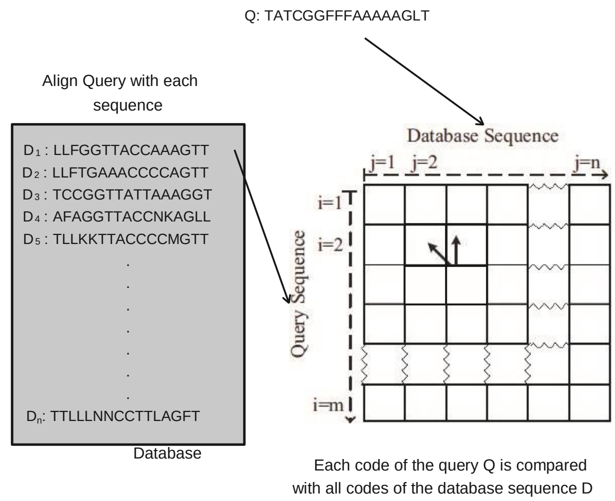

Fig. 1. The Sequential Alignment, where every Element (Code) of the Query Sequences has to be Compared to every Element in the Database Sequences.

II. Sequencing Applications using Traditional Methods

Traditional methods align two sequences together and compute an alignment score (AS) that represents the amount of similarity between them. In order to search for a query sequence in a database, the query should be aligned with every sequence in a database. Every alignment process compares every element (code) of a query sequence with every element in a database (as mentioned in Figure 1). Based on the results of the comparison, an alignment score is calculated, where it can be a match or a mismatch. In the case of a mismatch, any of the three operations can be performed; insertion, deletion, or substitution. A gap can be added to the sequences to make them closer to each other. The scores of these operations are predefined. The alignment score (AS) of every alignment process between the database and query is computed using the following formula:

$$AS = (\#of\ matches\ \times match\ score) + (\#of\ gaps\ \times gap\ score) + (\#\ of\ mismatches\ \times mismatch\ score) \quad (1)$$

Mismatches are usually negative along with the gap scores, however matches are positive scores. Hence, we can understand that the matches increase the alignment score, whereas gaps and mismatches decrease it. The scores of each are given as input parameters. The optimal number of every score can be calculated via the use of any dynamic programming based algorithm, just like the Needleman-Wunsch algorithm [21]. Then, a matrix containing the scores is generated. It has the dimensions of m x n (where m is the query sequence length and n is the database sequence length). The optimal score in every element of this matrix is calculated by adding the previous score to the current match score while subtracting the gap penalties. Every element can be positive, negative, or 0 value, according to the predefined score.

When the T matrix is full, we use a method called trace back to determine the optimal sequence alignment score from the scoring matrix. This method remembers the position in the scoring matrix the provided the best score so far. This position can align, or be next to a gap, depending on the traceback matrix's information. Multiple maximum alignments may exist. As mentioned earlier, the time required to obtain the optimal alignment of both sequences (one database sequence and the query) is proportional to the product of their lengths, which is n x m steps.

III. Our Proposed Similarity Functions

This section shows the new similarity measures we proposed, or similarity function, as we call them. These functions rely on the mathematical parameters; the mean of each database sequence's codes, and their frequency. Since every sequence contains different reoccurring codes, we introduce the **"Frequency Function",** which is our first similarity function. It relies on the code frequencies for every sequence. This frequency represents the number of the repeated codes in a sequence. This indicates the similarity between both sequences. As an example, when the frequency of the codes is close one to another, then the two sequences may be similar.

Most of the time, the sequence may contain multiple varying codes, and in order to realize the similarities between the two sequences, we find the frequency difference score (FDS). This score is the sum of the absolute values of the differences between the two sequences for each type of code.

Mathematically, the FDS of the database sequence 'D' and the query sequence 'Q' is defined using the following formula, considering that both of them have an alphabet of 'n' codes:

$$FDS = |Freq\_code\_1(Q) - Freq\_code\_1(D)| + |Freq\_code\_2(Q) - Freq\_code\_2(D)| + |Freq\_code\_3(Q) - Freq\_code\_3(D)| + \cdots + \cdots + |Freq\_code\_n(Q) - Freq\_code\_n(D)| \quad (2)$$

Where "$Freq\_code\ 1(Q)$" is the frequency of code 1 in the query sequence. "$Freq\ code\ 1(D)$" is the frequency of code 1 in the database sequence, etc.

The first function we proposed does not always yield a correct output. For example, when two sequences have a close number of code frequencies, but they are distributed differently among these two sequences, the frequency score will not be the correct measurement of similarity.

So, we introduce a 2nd function, dubbed as the **"Mean Function"**. The mean, or the average, is obtained via the division of the sum of codes by the number of observations, as defined in the following formula:

$$\bar{X} = \frac{\sum_{i=1}^{i=n} x_i}{n} \quad (3)$$

In our case, it is better to locate a central code concentration location. This is a good indication of similarities between two sequences. For example, if the mean is close to that of another sequence, it is a good indicator of the possibility of a similarity. When the sequence has varying codes, we compute the mean difference score (MDS) to find if a similarity exists among them, as defined in the FDS. This function, as well, does not always yield the correct output. As an instance, when two sequences have a close mean to each other but the number is not the same, the "Mean Score" is not correct to identify the similarity.

Because of the two problems, we suggest our third function, which we refer to as the **"Frequency+Mean Function".** The new score FMDS is the sum of both, the FDS and MDS. This is a good indication of a similarity since it considers both, the number of codes and their concentration.

IV. Sequencing Applications using Our Technique

In this section, we are going to propose our new efficient technique in order to size-down the required computational time for sequencing applications. Our technique uses the similarity functions we introduce in section III in order to compute the similarity between a query sequence with every database sequence.

The database in a sequencing application has huge amounts of sequences (as described in Section I). In order to align the sequence of the query (Q) to everyone in the database (D), we apply dynamic programming based algorithms on every pair, as described in section II.

Our technique filters the database where it gets rid of the sequences that are not close to the query from the searching process, so the algorithm is applied to the sequences that are similar to the query.

Our technique identifies the similarity functions and keeps them close to each related sequence. This procedure may require huge amount of time since the database may include huge amount of sequences, which is done off-line (independent from the comparison process). Hence, the time does not matter since we perform it only once to prepare our database for future comparison processes.

Our technique computes the scores of FDS, MDS, and FMDS when the query sequence has to be compared with the database sequences. Next, it sorts the sequences in the database in accordance to the difference score (DS) they produce, where the lower scores (closer to the query sequence) are at the top of the database.

Next, it applies dynamic programming-based algorithms on the sequences that have a low score, which was identified in the previous step. The sequences resulting in high difference scores are omitted from the search. This gives us the best alignment in a reasonable amount of time. The upcoming section will demonstrate how fast this technique is with respect to the traditional methods by demonstrating the time complexity.

A. Complexity of our Technique

As the dynamic programming based algorithm uses dynamic programming, the complexity that results to align one sequence is *O(m x n)*. This can be multiplied by the number of sequences 's' in a database, which will result in *O(m x n x s).*

In the case of our presented technique, let's assume that we have *c* different codes. In order to compute the distribution of these *c* codes in the query sequence, we have to scan it along its length. If its length is assumed to be m, then m steps are required to perform the scan. Computing the DS between the query and a sequence on the database requires c steps to subtract for the *c* codes, and *c-1* steps for the summation process. If *s* is the sequences amount, then the steps we need are *((2c-1) x s)* steps to calculate the difference score. Sorting the *s* scores via the use of QuickSort requires (*s x log s*) steps.

If we select 50% of the sequences in the database to apply the dynamic programming based algorithm on, then performing this step requires m x n x s/2 steps.

The total number of steps required in our technique is

$$(m + (2c - 1) \times s + s \times \log s) + (m \times n \times \frac{s}{2}) \quad (4)$$

i.e., the complexity is $O(m \times n \times s/2)$.

As an example, assuming a query length m of 500, and s = 10000, each sequence in this database has a length n of 500. Performing the comparison on the query sequence with all the sequences in the database using the traditional methods requires 500 x 500 x 10000 = 2500000000 steps, 2,500 Million. However, via the use of our technique, codding the data with 4 different codes requires:

500 + (7 x 10000) + (10000 x log 10000) + (500 x 500 x 5000) = ≈ 1250 Million steps.

Our technique saves 50% of the required time to align the sequences using the traditional methods.

V. FPGA-based Embedded System Design

The ZedBoard FPGA prototyping board, from Xilinx[1], is used to implement our embedded design. The board contains Zynq-7000 All Programmable SoC FPGA[2], which is released by Xilinx into the market, as a new series of products. The Zynq-7000 FPGA combines ARM dual-core 1GHz Cortex-A9 MPCore Processing System (PS) that comes with a high-performance memory system, with Xilinx 28 nm Programmable Logic (PL). Our technique has some parts which can be run in parallel, such as computing FDS, MDS, or FMDS for each sequence. These computations are sequence independent and therefore, they can be run in parallel using the logic gates of the FPGA. On the other hand, our technique has another part which needs powerful computations such as sorting the database sequences based on their similarity score. This part can be run on the ARM processor of the FPGA. By partitioning the implementation, we exploit the new features of Xilinx Zynq7000 series to design heterogeneous HW/SW FPGA-Based embedded system.

A. FPGA Implementation

To implement the embedded design of our technique on the FPGA prototyping board, different software/hardware tools are used. The software tools are the MATLAB and the SDK (Software Development Kit), and the hardware tool is the Vivado from Xilinx[3]. The MATLAB software is used to compute the frequency and mean of each code of the sequences.

The Xilinx Vivado design suite is used to instantiate all required IPs for our embedded design and to build interfaces between them. It synthesizes the complete design, implements it, and generates the bit-stream to be downloaded on the FPGA for verification. The SDK is used to write the software application (sorting algorithm), in C programming language, to be run on one of the two ARM processors. It initiates the IPs and transfers the required information to/from DDR memory.

Figure 2 shows the schematic of our embedded design which contains different IP blocks:

- "DMA IP" (Direct Memory Access)
- "Processing System IP"
- "FMDS IP"

The "DMA IP" is used to transfer Data from the DDR memory to other parts of the system, and vice versa through the interface "M AXI HP0" of "Processing System IP". This will increase the data throughput and will offload the processor from tasks that involve memory transfers.

The "Processing System IP" includes the ARM processor, the processor System Reset, the DDR memory controller, and the AXI interconnects. All these components are combined together to simplify the schematic as shown in Figure 3.

The "FMDS IP" (Frequency+Mean Difference Score) includes the FDS (Frequency Difference Score) IP and the MDS (Mean Difference Score) IP. Each of these blocks is a two-input subtractor. Their outputs are summed up using two-input adder to give the Frequency+Mean Difference Score. The computed frequency and mean values of each sequence are stored in the DDR memory of the ZedBoard. The implementation starts by initiating the FMDS and DMA IPs by the ARM processor through the interfaces M00 AXI and M01 AXI, of the Processing System IP, respectively (see Figure 2). The ARM processor transfers the stream of frequency and means values from the DDR memory to the "FMDS IP" through M AXIS MM2S interface of the DMA. The "FMDS IP" computes the absolute values of the frequency difference scores using FDS IP and the mean difference scores using MDS IP.

[1] Digilent, Inc. Website: www.zedboard.org. 2016
[2] Xilinx, Inc. 7 Series FPGAs Overview. Volume 1. Number 15. 2014
[3] Xilinx, Vivado Design Suite - HLx Editions. www.xilinx.com/products/design-tools/vivado.html. 2016

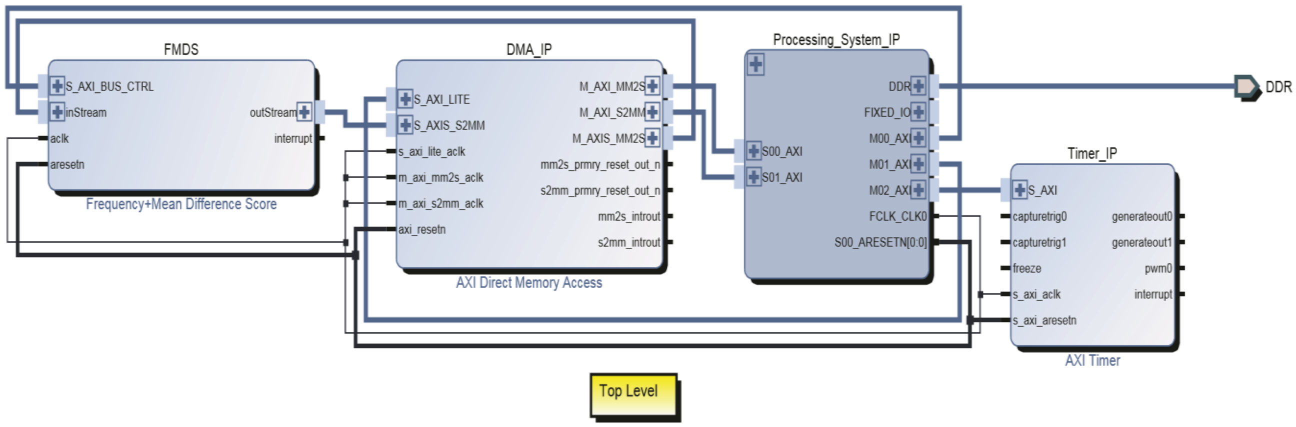

Fig. 2. Schematic of our Embedded Design Implemented in Xilinx Vivado.

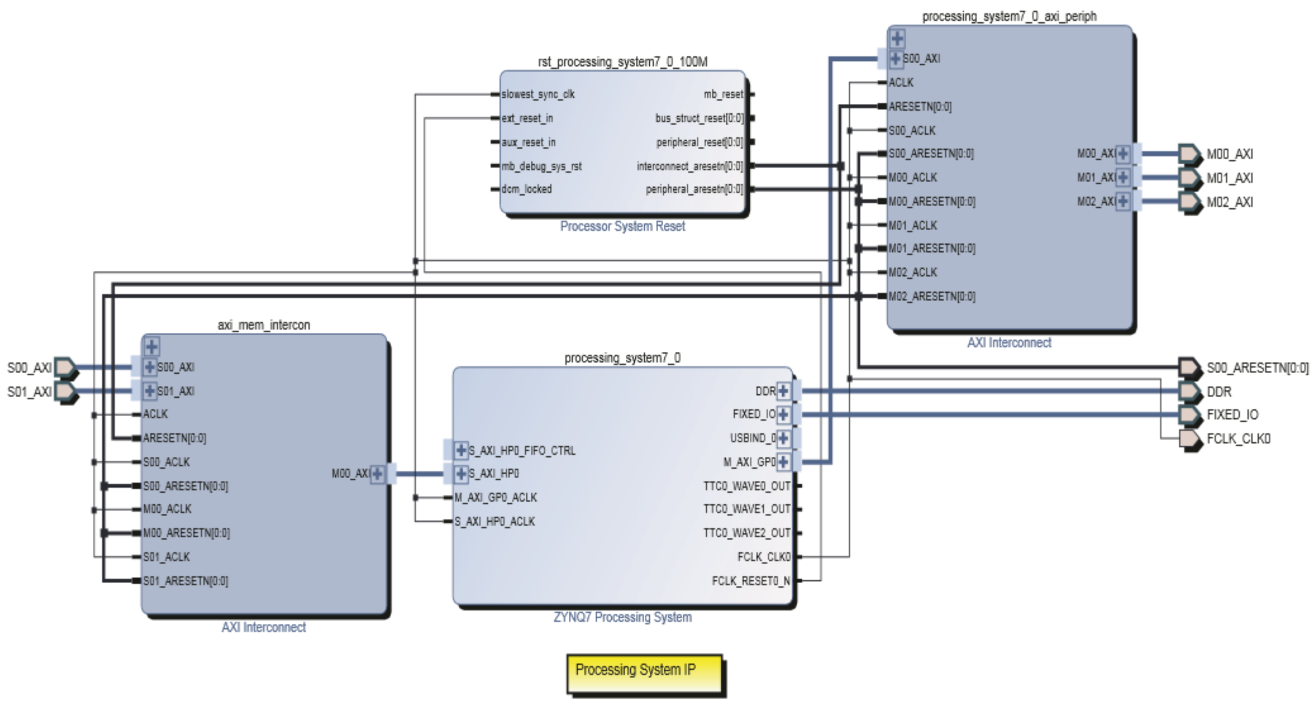

Fig. 3. Schematic of our Embedded Design Implemented in Xilinx Vivado.

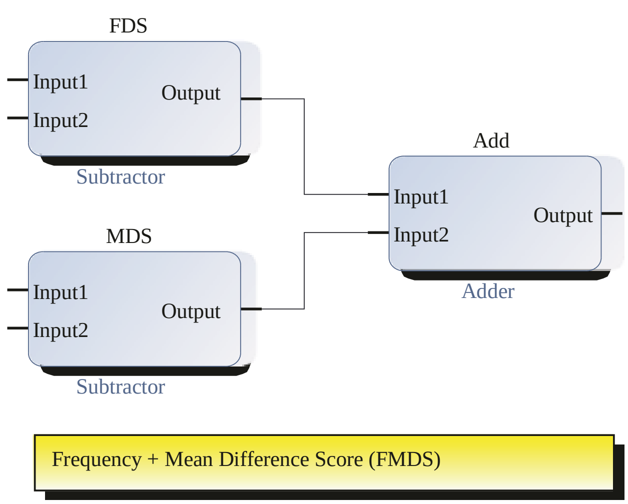

Fig. 4. Schematic of our Embedded Design Implemented in Xilinx Vivado.

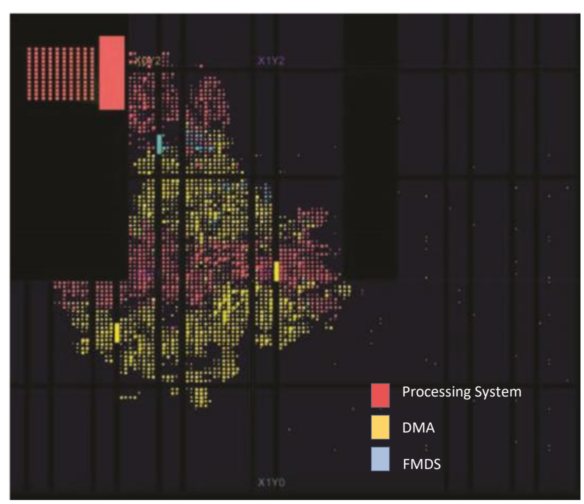

Fig. 5. FPGA Floorplan for the Embedded System Design.

TABLE I. FPGA RESOURCES UTILIZATION OF OUR EMBEDDED DESIGN

Resources	Utilization	Available	Utilization (%)
FF	7303	106400	6.86
LUT	5921	53200	11.13
Memory LUT	280	17400	1.61
BRAM	3	140	2.14
BUFG	1	32	3.12

Those scores are added to get the frequency+mean difference scores (see Figure 4). The output of the "FMDS IP" is then transferred back to the DDR memory through the M AXIS S2MM interface of the DMA. The sorting algorithm, which is running on the ARM processor, is used to sort the sequences based on their score.

B. FPGA Resources Utilization

We implement our design on a Xilinx Zynq-7000 All Programmable SoC (XC7Z020-CLG484) Artix-7 FPGA using Zedboard. All IPs are clocked using a 100 MHz frequency clock signal which is generated by the processing system. Table I summarizes the FPGA resources utilization of our embedded system. For example, less than 12% of the slice Look-up tables and less than 7% of the Flip-Flops registers are utilized. In the fact, the most resources are dominated by the processing system IP and the DMA, as shown in Figure 5. This figure shows the floorplan placement of the different IPs: the processing system IP is marked in red, the DMA in yellow and the FMDS IP in blue.

VI. EXPERIMENTAL RESULTS

In this section, we present the experimental results of our technique. For evaluation, DNA sequences of the database DNA Data Bank of Japan (ddbj)[4] were used. 100000 sequences of the length of 400 nucleotides were selected as a case study. Our technique is compared with the optimal sequence alignment Needleman-Wunsch Algorithm[5]. Random sequences were selected as a query to test our technique using different similarity functions.

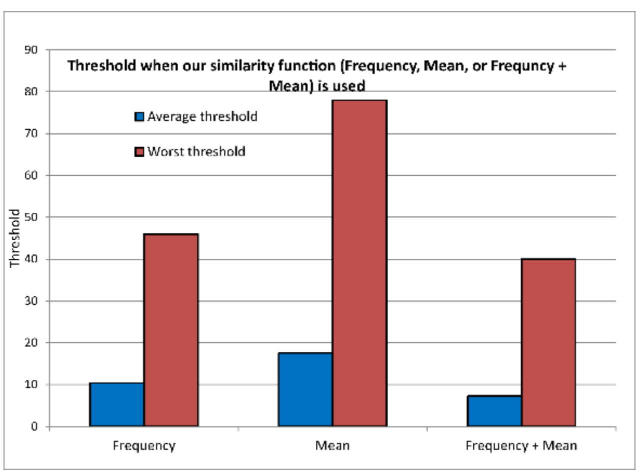

Fig. 6. Average and Worst thresholds when our Similarity Functions: Frequency, Mean, or Frequency + Mean is used.

[4] DDBJ Center, http://www.ddbj.nig.ac.jp/

5 National Center for Biotechnology Information, "Basic Local Alignment Search Tool", blast.ncbi.nlm.nih.gov/Blast.cgi

Figure 6 shows the threshold when our similarity functions, Frequency, Mean or Frequency + Mean is used. In this figure, we define a new parameter called "Threshold". The threshold refers to the number of sequences we need to apply Needleman Wunsch Algorithm on them (using our technique).

The first similarity function used in Figure 6 is "Frequency". The maximum threshold among all tested queries is 46. This is the worst case in which we need to apply the Needleman-Wunsch Algorithm on 46 sequences. The average threshold of the "Frequency" similarity function is 10.4.

When our similarity function "Mean" is used (second bars in Figure 6), the maximum threshold (worst case) and the average among all other queries is 78 and 17.5, respectively.

Looking at the obtained results, we find that using a similarity function alone (no combinations) does not yield good results. This is because two sequences are to have a close number of code frequencies (but distributed differently among both of them). Here, the FDS is not a correct measurement of similarity. Also, when two sequences have close Mean, but their frequency is different. Here, MDS is not a correct measure. Therefore, a combination of both yields better results, as shown in the third bars of Figure 6. The worst case threshold (maximum) among all the other cases in this function, and the average threshold become 40 and 7.2 respectively. Hence, the use of FMDS yields the best outcome. Or, when our technique is to be used on the best 40% sequences, applying the Needleman-Wunsch algorithm is enough to obtain a maximum alignment score. Figure 7 shows the details of distributing the threshold through all experiments when the similarity function "Frequency + Mean" is used.

As shown, in 66% of the experiments, the maximum threshold is less than 10, i.e., it exists in the top 10% of the database. It is between 10 and 20 in 15% of the experiments, while, it is between 20 and 30 in 10% of the experiments, and between 30 and 40 in the rest.

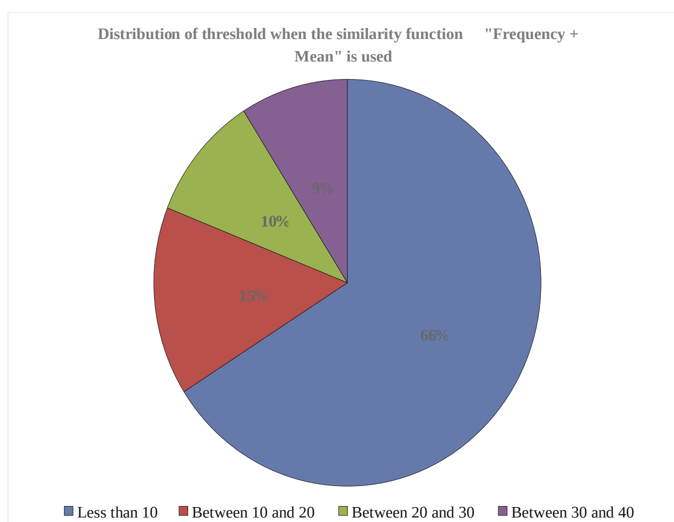

Fig. 7. Distributing the threshold through all Experiments when the Similarity Function: Frequency + Mean is used.

Fig. 8. The Error Rate Resulted from Removing Sequences from the Database.

When the technique is applied to less than 40% of sequences in the database, the result will not be correct for all experiments, because the sequence that has the lowest DS is not the sequence that has the highest similarity score. The result will be different depending on how many sequences are omitted from the database.

Figure 8 provides the rate of error that results when we omit sequences from the database. The x-axis represents the percentage of the sequences which have been removed from every database for all experiments. The y-axis represents the number of the wrong cases that result when we omit sequences from the database. For instance, when 99% of database sequences are removed, there will be 61% of wrong cases and only 39% cases with correct results. Decreasing the percentage of removed sequences decreases the error rate, and the correct cases number increases. If the percentage of the omitted sequences is 60%, and 40% of the database remains, then no wrong cases will be available. This is considered as the best case in accordance with the database size and time of execution. Omitting fewer sequences will not have an effect on the results, but will increase the size of the database, which increases the analyzation time.

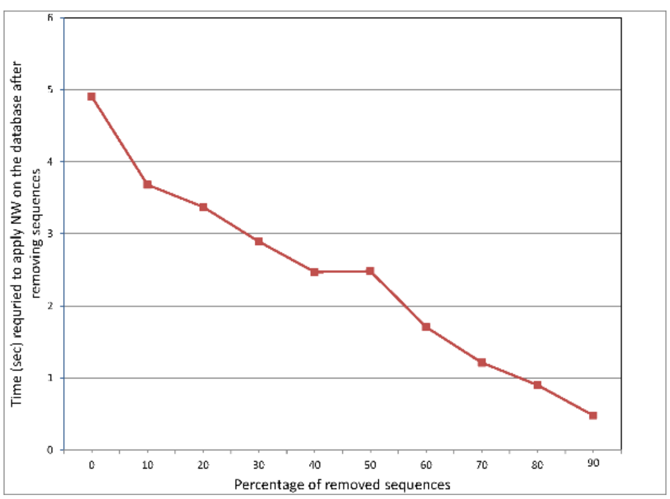

Fig. 9. The Effect of Removing the Sequences on the Execution Time.

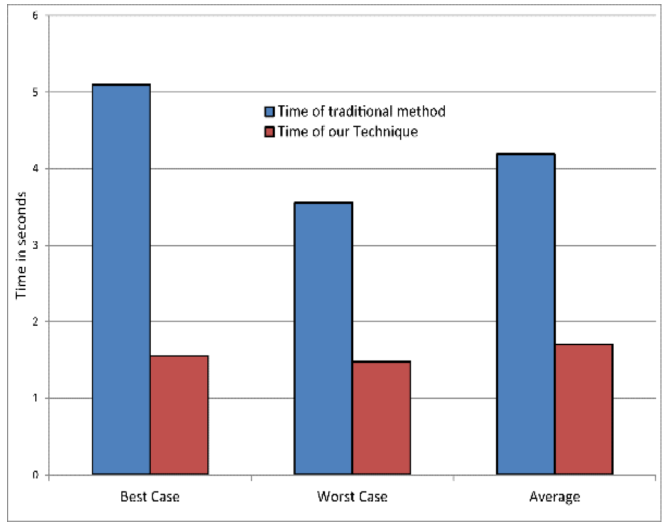

Fig. 10. Execution Time Comparison between Traditional Methods and the Proposed Technique.

Figure 9 demonstrates the impact of omitting more sequences on the time needed to obtain the highest similarity score sequences. Using traditional methods by applying the Needleman-Wunsch Algorithm on the entire sequences in the database, requires 5.9 seconds to obtain the best solution. Increasing the number of sequences omitted will not reduce execution time, however, it will increase the error rate, as seen in Figure 8.

Figure. 10 shows a comparison between the execution time of traditional methods and our technique. In this figure, The x-axis shows the best, worst and average cases through all sequences of the database. The y-axis shows the execution time in seconds. The blue bar shows the time for traditional methods while the red one shows the time for our technique which applies NW algorithm on selected 40% of the database sequences. The first bars show the best case in which the time difference is the best (70% improvement), while the worst difference is shown in the second bars (58% improvement). The third bars represent the average of all experiments. Here, the time of execution via the use of our technique is improved by 60% in respect to that of the traditional methods. (The average of the traditional methods is 4.18 seconds, while our technique has a 1.7 seconds average time.) We obtained this result because we have excluded 60% of the sequences before applying the Needleman-Wunsch Algorithm.

VII. CONCLUSIONS

The paper introduced an efficient and novel algorithm to measure the similarity between two sequences in a large database. The proposed technique computes the difference score for each sequence of the database and selects sequences that have the highest scores. Dynamic programming is then applied on selected sequences. The proposed method was implemented and tested on the HW/SW FPGA-based embedded system using the Zedboard FPGA prototyping board. The performance of the proposed method was compared with other traditional methods. The comparison study showed that our proposed method over performed other methods by 60% in term of computation time.

REFERENCES

[1] T. F. Smith and M. S. Watermann. Identification of common molecular subsequence. Journal of Molecular Biology. Pages 196197, 1981

[2] Talal Bonny, Accuracy/Speed Trade-off Technique for Dynamic Programing Based Algorithms, IEEE 5th International conference on Electronic Devices, Systems and Applications (ICEDSA), Ras Al Khaimah, United Arab Emirates. December 2016

[3] Talal Bonny, M. A. Z. and Salama, K. N. An adaptive hybrid multiprocessor technique for bioinformatics sequence alignment. In the 5th Cairo International Conference on Biomedical Engineering. pages 112115, 2010

[4] Talal Bonny and Bassel Soudan, Filtering Technique for High Speed Database Sequence Comparison, IEEE International Conference on Semantic Computing (ICSC 2015), Anaheim, California, USA. February 2015.

[5] S. Kim, Y. J. Yoo, J. So, J. G. Lee and J. Kim., Design and Implementation of Binary File Similarity Evaluation System. International Journal of Multimedia and Ubiquitous Engineering, Vol.9, No.1. Pages 1-10, 2014

[6] Jiaoyun Yang, Yun Xu, Yi Shang, Guoliang Chen. A space-bounded anytime algorithm for the multiple longest common subsequence problem. IEEE Transactions on Knowledge and Data Engineering, 2014.

[7] B. Halpin and T. W. Chan. Class Careers as Sequences: An Optimal Matching Analysis of Work-Life Histories. European Sociological Review 14(2). Pages 111-30, 1998

[8] L. Lesnard. Optimal Matching And Social Sciences. Working Paper, Centre de Recherche en Economie et Statistique. Institut Nationale de la Statistique et des Etudes Economiques, Paris, France. 2006

[9] G. Pollock. Holistic Trajectories: A Study of Combined Employment, Housing and Family Careers by Using Multiple-Sequence Analysis. Journal of the Royal Statistical Society: Series A 170(1). Pages:167-83, 2007

[10] P. F. Marteau. Time Warp Edit Distance with Stiffness Adjustment for Time Series Matching. IEEE Transactions on Pattern Analysis and Machine Intelligence. Pages 306-318. 2008

[11] Manal Al Ghamdi and Yoshihiko Gotoh. Alignment of nearly-repetitive contents in a video stream with manifold embedding. In IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Pages 1255-1259, 2014

[12] Talal Bonny, "Performance Optimization of the Database Sequencing Applications", International Journal of Computer Applications, volume 112 - number 5, February 2015.

[13] Talal Bonny, "A Hybrid Heuristic/Deterministic Dynamic Programing Technique for Fast Sequence Alignment", International Journal of Advanced Computer Science and Applications, volume 6 - issue 8, August 2015.

[14] Z. Nawaz, M. Nadeem, J. van Someren, and K.L.M. Bertels. A parallel fpga design of the smith-waterman traceback. In Field-Programmable Technology (FPT), 2010 International Conference on, pages 454-459, Beijing, China, December 2010.

[15] M. Affan Zidan, T. B. and Salama, K. N. High performance technique for database applications using a hybrid gpu/cpu platform. IEEE/ACM 21st Great Lake Symposium on VLSI. pages 8590, 2011

[16] E. F. de O.Sandes and A.C.M.A. de Melo. Retrieving smith-waterman alignments with optimizations for megabase biological sequences using gpu. Parallel and Dis- tributed Systems, IEEE Transactions on, 24(5):1009-1021, 2013.

[17] A. Chakraborty and S. Bandyopadhyay. Clustering of web sessions by FOGSAA. In IEEE Recent Advances in Intelligent Computational Systems (RAICS). Pages 282-287. 2013

[18] Xin Chang, Fernando A. Escobar, Carlos Valderrama, Vincent Robert. Optimization strategies for Smith-Waterman algorithm on FPGA platform. International Conference on Computational Science and Computational Intelligence (CSCI), 2014.

[19] Kratika Garg, Yan Lin Aung, Siew-Kei Lam, Thambipillai Srikanthan. Modelsim simulation for real-time stereo matching using DP algorithm. The 28th IEEE International Conference on System-on-Chip (SOCC), 2015.

[20] Bartolomeo Stellato, Paul J. Goulart. Real-time FPGA implementation of direct MPC for power electronics. IEEE 55th Conference on Decision and Control (CDC), 2016.

[21] S. Needleman and C. A. Wunsch. General method applicable to the search for similarities in the amino acid sequence of two sequences. Journal of Molecular Biology. Pages 443453, 1970

Convolutional Neural Network Hyper-Parameters Optimization based on Genetic Algorithms

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***Abstract*—In machine learning for computer vision based applications, Convolutional Neural Network (CNN) is the most widely used technique for image classification. Despite these deep neural networks efficiency, choosing their optimal architecture for a given task remains an open problem. In fact, CNNs performance depends on many hyper-parameters namely CNN depth, convolutional layer number, filters number and their respective sizes. Many CNN structures have been manually designed by researchers and then evaluated to verify their efficiency. In this paper, our contribution is to propose an innovative approach, labeled Enhanced Elite CNN Model Propagation (Enhanced E-CNN-MP), to automatically learn the optimal structure of a CNN. To traverse the large search space of candidate solutions our approach is based on Genetic Algorithms (GA). These meta-heuristic algorithms are well-known for non-deterministic problem resolution. Simulations demonstrate the ability of the designed approach to compute optimal CNN hyper-parameters in a given classification task. Classification accuracy of the designed CNN based on Enhanced E-CNN-MP method, exceed that of public CNN even with the use of the Transfer Learning technique. Our contribution advances the current state by offering to scientists, regardless of their field of research, the ability of designing optimal CNNs for any particular classification problem.**

Keywords*—Machine learning; computer vision; image classification; convolutional neural network; CNN hyper parameters; enhanced E-CNN-MP; genetic algorithms; learning accuracy

I. Introduction

Image classification is an important task in computer vision involving a large area of applications such as object detection, localization and image segmentation [1-3]. The most adopted methods for image classification are based on deep neural network and especially Convolutional Neural Networks (CNN). These deep networks have demonstrated impressive and sometimes human-competitive results [4,5]. CNN deep architecture can be divided in two main parts [6]. The first part, based on convolutional layers CNN, offers the ability of features extraction and input image encoding. Whereas, the second one is a fully connected neural network classifier which role is to generate a prediction model for the classification task. A CNN model is described by many hyper-parameters specifically convolutional layers number, filters number and their respective sizes, etc.

Many researchers proposed different CNN models such as AlexNet, Znet, etc. To improve the network accuracy some of them choose to increase the depth of the network [7]. Others propose new internal configurations [8]. Although, these state-of-the-art CNNs have been shown to be efficient, many of them were manually designed.

During our research, we note that a miss configured values of CNN hyper-parameters namely the network depth, the number of filters and their respective sizes dramatically affect the performance of the classifier. In addition, manually, enumerating all the use cases and selecting optimal values for these hyper-parameters is almost impossible even with a fixed number of convolutional layers. Through contributions held in this paper we propose an innovative approach, labeled Enhanced Elite CNN Model propagation (Enhanced E-CNN MP), to automatically learn optimal CNN hyper-parameters values leading to a best CNN structure for a particular classification problem. Our approach is based on Genetic Algorithms (GA) known to be meta heuristic methods for non-deterministic problem resolution. Each CNN candidate solution structure, is encoded as an individual (chromosome). To search for the best fit individual, the proposed method is based on "The elite propagation" through the whole GA process.

The designed Enhanced E-CNN MP approach is an innovative approach. Our contribution will allow scientists to design their own CNN based prediction model suitable for their particular image classification problem.

This paper is organized as follows. Section II provides an overview of Convolutional Neural Network. In section III, the Genetic Algorithms paradigm is exposed. Problem statement is presented through section IV. Section V introduces related work. Section VI illustrates the designed Elite CNN Model Propagation (E-CNN-MP) approach based on GAs for CNN hyper parameters optimization. E-CNN-MP simulations and results are presented in section VII. Through section VIII, an Enhanced E-CNN-MP version is proposed. The last section includes our concluding remarks.

II. Deep Learning based on Convolutional Neural Network

A neural network is a mathematical model with a design inspired from biological neurons. This network architecture is divided in layers. Each layer is a set of neurons. The first layer of a neural network is the input layer into which we inject the data to be analyzed. The last layer is the output layer. In a classification problem, it returns a number of classes. Layers on the middle are the hidden layers of the neural network.

As shown in Fig.1, in a neural network, a single neuron has several inputs. Each input connection is characterized by a weight wij. On the activation of the artificial neuron, it computes its state Sj, by summing all the inputs multiplied by their corresponding connection weights. To ensure that the neuron will be activated even when all entries are none, an extra input, called bias B, is added. This extra input is always equal to 1 and has its own weight connection.

To normalize its result Yi (normally between 0-1), the neuron passes it through its activation function [9].

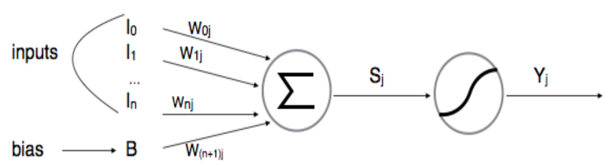


Fig. 1. Neuron Parameters.

CNNs are category of deep neural networks used especially in computer vision area such as image classification [10,11]. The very first CNN was LeNet in 1990 (LeCun et al. 1995). It was the innovative work by Yann LeCun and the result of many successful iterations since the year 1988. This pioneering CNN facilitated propel the field of deep learning. At that time the LeNet architecture was used mainly for character recognition application.

There have been numerous new CNN architectures developed in the recent years. These architectures are improvements over the LeNet using its main concepts. Among these models we quote:

- *AlexNet (2012):* In 2012, Alex Krizhevsky (and others) released AlexNet. It was a deeper and much wider version of the LeNet that won, by a large margin, the difficult ImageNet Large Scale Visual Recognition Challenge (ILSVRC) in 2012.
- *ZF Net (2013)*: The ILSVRC 2013 winner was a Convolutional Network from Matthew Zeiler and Rob Fergus. It became known as the ZFNet. It was an improvement on AlexNet by tweaking the architecture hyper-parameters.
- *GoogLeNet (2014):* The ILSVRC 2014 winner was a Convolutional Network from Szegedy (and others) from Google. Its main contribution was the development of an inception module that dramatically reduced the number of parameters in the network (4M, compared to AlexNet with 60M) [12].
- *VGGNet (2014):* The runner-up in ILSVRC 2014 was the network that became known as the VGGNet. Its main contribution was in showing that the depth of the network (number of layers) is a critical component for good performance.
- *ResNets (2015):* Residual Network developed by Kaiming He (and others) was the winner of ILSVRC 2015.
- *DenseNet (August 2016):* Recently published by Gao Huang (and others). The Densely Connected Convolutional Network has each layer directly connected to every other layer in a feed-forward fashion. The DenseNet has been shown to obtain significant improvements over previous state-of-the-art architectures on five highly competitive object recognition benchmark tasks.

There are four main operations which are the basic building blocks of every CNN [13,14].

1) Convolution
2) Activation function (ReLU)
3) Pooling or Sub Sampling
4) Classification (Fully Connected Layer)

A. Convolution

Convolutional layer derives its name from the convolution operator. The aim of this layer is image features extraction. Convolution conserves the spatial relationship between pixels by learning image features using small squares of input data. Each convolution layer uses various filters to features detection and extraction such as Edge Detection, Sharpen, Blur, etc. These filters are also called 'kernels' or 'feature detectors'. After sliding the filter over the image we get a matrix known as the feature map [15].

In the first convolution layer, the convolution is between the input image and its filters. Filter values are the neuron weights (see (1)).

In deep layers of the network, the resulting image of convolutions is the sum of k^{l-1} convolutions, with k^{l-1} the number of outputs of layer $l-1$ (see (2)).

$$\boldsymbol{\sigma_k^{(l)} = x_k^{(l)}.w_k^{(l)} + b_k^{(l)}} \quad (1)$$

$$\sigma_k^{(l)} = \sum_{i=1}^{i=k^{l-1}} x_{k,i}^{(l)} * w_{k,i}^{(l)} + b_k^{(l)} \quad (2)$$

With $\sigma_k^{(l)}$ the value of the neuron k of the layer l, $x_k^{(l)}$ the input vector of the neuron k, $w_k^{(l)}$ the weight vector and $b_k^{(l)}$ the bias.

In practice, a CNN learns the values of these filters on its own during the training process. Parameters such as number of filters, filter size and network architecture are specified by the scientific before launching the training process. The more number of filters we have, the more image features get extracted and the better the network becomes at features extraction and image classification.

The size of the feature map is controlled by three parameters which are:

- *Depth*: Depth corresponds to the number of filters used for the convolution operation.

- *Stride*: Stride is the number of pixels by which we slide our filter matrix over the input matrix. Having a larger stride will produce smaller feature maps.
- *Zero-padding:* To apply the filter to bordering elements of input image, it is convenient to pad the input matrix with zeros around the border.

B. Activation Function

Once the convolution has been completed, an activation function is applied to all values in the filtered image to extract nonlinear features. There are many activation functions such as the ReLU [16,17] which is defined as $f(x) = \max(0, \sigma)$, the function $tanh$ () [18] or the sigmoid function [19].

The output value $s_k^{(l)}$ of a neuron k of layer l depends on its activation function and is defined as (see (3)) :

$$s_k^{(l)} = f(\sigma_k^{(l)}) \tag{3}$$

with f the activation function and $\sigma_k^{(l)}$ the value of neuron k of layer l. The choice of the activation function may depend of the problem. The ReLU function replaces all negative pixel values in the feature map by zero. The purpose of ReLU is to introduce non-linearity in the CNN, since the convolution operator is linear operation and most of the CNN input data would be non-linear. Result of convolution and ReLU operation is called rectified feature map.

C. Pooling

The pooling step is also called subsampling or down sampling. It aims to reduce the dimensionality of each rectified feature map and retains the most important information.

The two most used methods to apply in this operation are the average or max pooling [20].

After this step of sub-sampling we get a feature map that is defined in (4)

$$I_k^{(l)} = pool(s_k^{(l)}) \tag{4}$$

with $I_k^{(l)}$ the feature map of the layer l, the $pool$ () operation pooling and $s_k^{(l)}$ the output value of the neuron k of the layer l.

The advantages of the pooling function are:

- It makes the input representations (feature dimension) smaller and more manageable.
- It reduces the number of parameters and computations in the network, therefore, controlling overfitting.
- It makes the network invariant to small transformations, distortions and translations in the input image. In fact, a small distortion in input will not change the output of pooling since the maximum/average value in a local neighborhood is taken.
- It helps getting an almost scale invariant representation of input image. This is very powerful since we can detect objects in an image no matter where they are located.

D. Fully Connected Layer

The output from the convolutional and pooling layers of a CNN is the image features vector. The purpose of the fully connected layer is to use these features vector for classifying the input images into several classes based on a labeled training dataset.

The fully connected layer is composed of two parts. The first part consists of layers so-called fully connected layers where all its neurons are connected with all the neurons of the previous and next layers. The second part is based on an objective function. In fact, CNNs seek to optimize some objective function, specifically the loss function. The well-used loss function is the Softmax function [21]. It normalizes the results and produces a probability distribution between the different classes (each class will have a value in the range [0, 1]) [22]. Adding a fully-connected layer allows learning non-linear combinations of extracted features which might be even better for the classification task.

E. Genetic Algorithms

GAs are heuristic solution-search or optimization methods. These techniques were originally inspired from the Darwinian principle of evolution through (genetic) selection.

A GA is based on a highly abstract form of evolutionary processes to give solutions to complex problems. Each GA operates on a population of artificial chromosomes. Each chromosome signifies a solution to the problem to be resolved and has a fitness. A chromosome fitness is a real number measure which represents its performance as a solution of the specific problem.

GA method begins with a randomly generated population of chromosomes. It, then carries out a process of selection and recombination based on each chromosome fitness. Parent genetic materials are recombined to generate child chromosomes producing a next generation. This process is iterated until some stopping criterion is reached. In this way, a GA evolves a best solution to a given problem.

GAs were first proposed by John McCall [23] as a method to find best solutions to problems that were otherwise computationally intractable. McCall's theorem, and the related building block hypothesis, delivered a theoretical basis for the conception of effective GAs. The development and success of GAs have significantly contributed to their adoption in many computational approaches based on natural phenomena. GA is, henceforth, a major part of the wider field of Computational Intelligence such as Neural Networks, Ant Colony Optimization, etc.

F. Genetic Algorithm Structure

A GA is made from a number of "standard" components. This conception facilitated their re-use with trivial adaptation in many different problems. The main components of GA are: chromosome encoding, fitness function, selection, recombination and evolution scheme.

1) Chromosome encoding: In GA a population is a set of chromosomes, which are solution candidates to a particular problem. A chromosome is an abstraction of a biological DNA chromosome. It can be thought of as a combination of genes. For a given problem, a particular representation is used and referred to as the GA encoding of the problem. GA proposes two ways for chromosome encoding:

- A bit-string representation to encode solutions: bit-string chromosomes consist of a string of genes whose allele values are characters from the alphabet {0,1}.
- Value Encoding: chromosome, in direct value encoding, is a string of some values which can be whatever form related to problem such as numbers, real numbers, chars, some complicated objects, etc.

2) Fitness: The fitness function allows to compute and evaluates the quality of a chromosome as a solution to a particular problem. Fitness computation will go on through GA generations measuring the performance of each individual in terms of various criteria and objectives defined by researchers (completion time, resource utilization, cost minimization, etc).

3) Selection: Selection method in a GA is very important as it guides the evolution of chromosomes through generations. This method will permit to make a choice regarding the parent chromosomes to be used for child chromosome creation.

In GA process, chromosome selection for recombination is based on its fitness value. Best fit individuals should have a greater chance of selection than those with lower fitness.

Many selection methods are proposed in literature such as [24]:

- Roulette Wheel (or fitness proportional) selection method which allocates each chromosome a probability of being designated proportional to its relative fitness. This value is computed as a proportion of the sum of all chromosome’s fitness in the population.
- Random Stochastic selection explicitly chooses each individual a number of times equal to its expectation of being selected under the fitness proportional method.
- Tournament selection first chooses two individuals based on a uniform probability and then selects the one with the highest value of fitness.
- Truncation selection first eliminates a fixed number of the least fit chromosomes and, then, picks one at random from the population having.

4) GA Recombination operators: GA recombination method allows the production of offspring with combinations of genetic material from parents chosen through the selection method. This process allows to form members of a successor population based on recombination of chromosomes selected from a source population. Since the selection mechanism is biased towards chromosomes with higher fitness value, this guarantees (hopefully) the evolution to more highly fit individuals in the descendant generations.

There are two main operators for genetic recombination which are:

- Crossover:
- Mutation

Those Genetic operators are nondeterministic in their behavior. Their outcome is also nondeterministic: each happens with a certain probability.

Crossover operator characterizes the fact of mixing genes from two selected parent chromosomes. This recombination allows to produce one or two child chromosomes.

Literature proposes many alternative forms of crossover method:

- One-point crossover generalized to 2- and multi-point crossover operations: the idea is to choose a sequence of crossover points along the chromosome length. Child chromosomes are subsequently created by interchanging the gene values of both parents at each chosen crossover points.
- Uniform crossover creates a child chromosome by picking uniformly between parent gene values at each chosen position.

Crossover algorithms also vary with according to the number of created children through the process.

To ensure a maximum of diversity when creating offspring, all crossover resulted chromosome(s) are then passed on to the mutation process. Mutation operators perform on an individual chromosome to change one or more gene values. The aim of these genetic operators is to increase population diversity and avoid premature convergence to a less optimal solution for a particular problem.

5) Evolution: After the crossover and mutation process, the resulting chromosomes are passed into the descendant population called next generation. This process is then iterated for all upcoming generations until reaching a stopping criteria. Termination conditions can include:

- A solution with minimum criteria is found.
- Fixed number of generations elapsed.
- Due budget such as computation time/money reached.
- The highest level solution's fitness is reaching or converge to a best-fitness solution such that successive generations no longer yield better results.
- Manual inspection that fully satisfies a set of constraints.

Evolutionary schemes depend on the degree to which individuals from a source population are permitted to move on unchanged to the next generation. Evolutionary scheme is an important aspect of GA design. It depends closely on the nature of the solution space being investigated. These schemes vary from:

- Complete replacement, where all next generation chromosomes are generated through selection and mutation.
- Steady state, where the next generation is created by generating one new chromosome at each new population and using it to replace a less-fit individual of the original population.
- Replacement-with-elitism: This is a hybrid complete replacement method since the best one or two individuals from the source population are preserved in the next generation. This scheme avoids individual of the highest relative fitness from being lost through the nondeterministic selection process

G. GA Design

When solving problem is based on GA metaheuristic approach, scientific may make many choices in designing the genetic algorithm. These choices are related to:

- Chromosome encoding;
- Fitness function form;
- Population size;
- Crossover and mutation operators and their respective rates;
- Evolutionary scheme to be applied;
- Appropriate stopping criteria.

Numerous examples of non-classical GAs can be found in literature [25,26]. A typical architecture adopted for a classical GA using complete replacement with standard genetic operators might be as follows:

(S1) Randomly create an initial population of N chromosomes (source population).

(S2) Compute the fitness value, $F(c)$, of each chromosome c in the initial population.

(S3) Create a successor population of N chromosomes as follows:

(S3a) Use selection method to select two parent chromosomes, $c1$ and $c2$, from the previous population.

(S3b) Apply crossover technic to $c1$ and $c2$ with a crossover rate cr to get a child chromosome c.

(S3c) Apply a mutation method to c with mutation rate mr to produce c'.

(S3d) include the chromosome c' to the successor population.

(S4) Replace the source population with the successor population.

(S5) If not reaching stopping condition, return to Step S2.

The flexibility of this standard architecture allows its implementation and refinement by scientific to fit a particular problem to be solved based on of this metaheuristic approach.

III. Problem Statement

In this section we establish the context of the current work according to a previous investigated one. The aim of our research is to design an approach to be used for image classification task. For this purpose, we are interested in machine learning algorithms and specially supervised learning.

Machine learning (ML) is a wide variety of algorithms particularly suited to prediction. ML avoids starting with a data model and rather uses an algorithm to learn the relationship between the response and its predictors. As shown in Fig. 2, ML techniques try to learn the response by observing inputs and responses and finding dominant patterns.

At the end of the training process we get a predictive model which can be used to classify a new input data.

When we use supervised learning algorithms for classification purpose the input variables (X) are a labeled data (for each input from the dataset we know its class or category) and the output variable (Y) represents a category (class). A supervised algorithm aims to learn the mapping function from the input to the output:

$$Y = f(X)$$

The goal is to well approximate the mapping function $f()$ in such a way that for a new input data (X) the algorithm can predict its category (Y). Learning stops when the algorithm achieves an acceptable level of prediction accuracy.

In previous works, we investigated many approaches to design a machine learning framework for image classification. During research, we investigated two approaches:

1) The Bag of Features paradigm and CNN as features extraction and image encoding methods [27,28]. Our experimentation results shown in Fig.3,4 demonstrated how CNN performs better than BoF as features extractor and image encoding technique [30].

Deep Learning approach based on Transfer Learning technique. The pre-trained used CNN is AlexNet [29]. Its architecture is described in Fig.5 [6]. Based on this approach, we reached a classification accuracy of 93.33% [31].

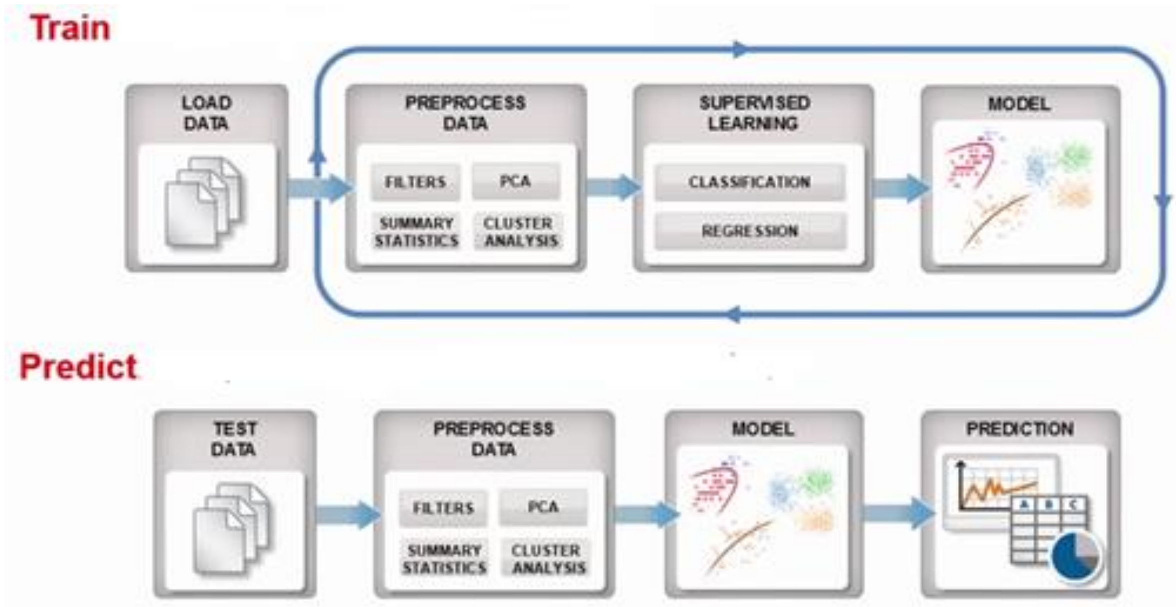


Fig. 2. Machine Learning Framework.

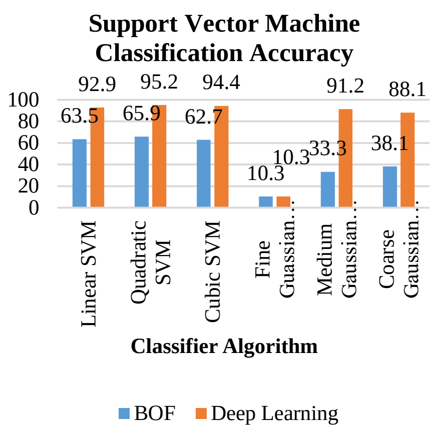


Fig. 3. SVM Classifiers Accuracies.

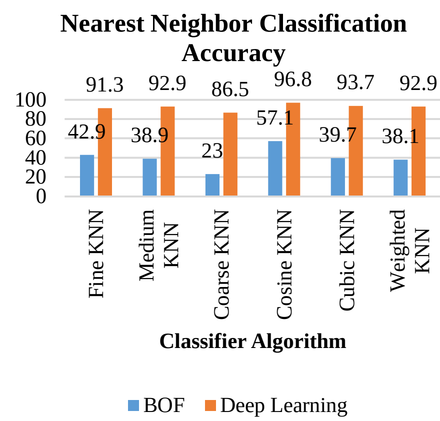


Fig. 4. KNN Classifiers Accuracies.

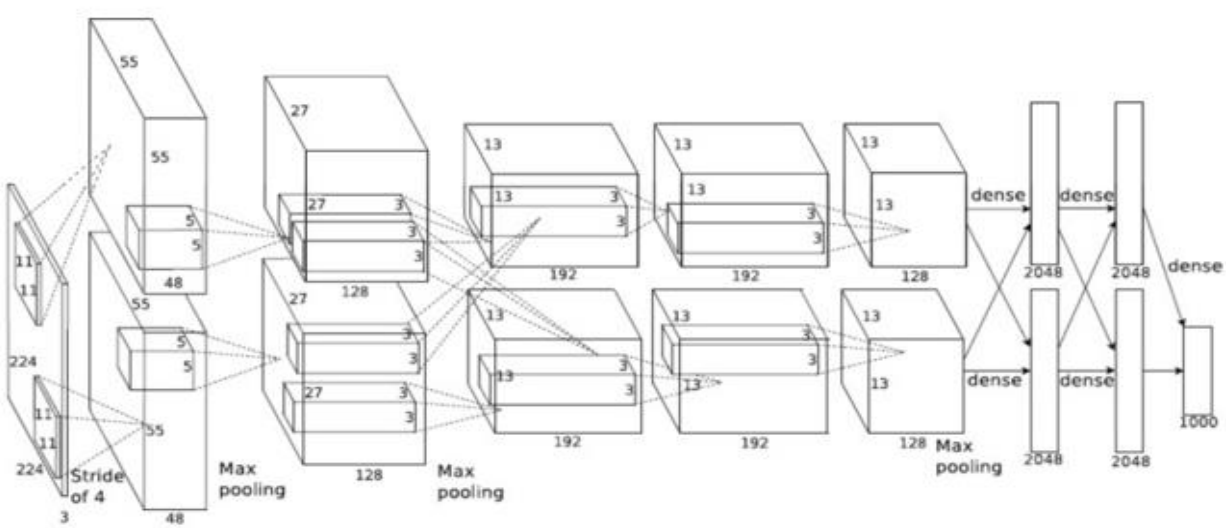


Fig. 5. AlexNet Architecture.

In the current work, our overarching approach is to design our own CNN model for stop sign image classification. The designed CNN will be trained from scratch. For the CNN to be created, many hyper parameters must be defined, such as: CNN depth, filters number per convolutional layer and their respective sizes. To build our network, we, first, choose to follow the same model as the AlexNet one. The CNN model includes 5 convolutional layers each layer is followed by a ReLU and MaxPooling layer. The input image size is 227x227x3. The feature vector resulting from the convolution part of the model has a dimension of 4096, which is a good dimension to encode image for classification task. The fully connected part of the model is composed of three fully connected layers. The first two layers have 4096 neurons. The activation function used is the ReLU. The third layer is a softmax that calculates the probability distribution of the five classes. In the first approach simulation, we put a large number of filters on the convolution layers. This number of filters and their sizes are chosen randomly. For this purpose, we refer to already developed CNNs such as AlexNet.

The CNN designed architecture is represented in Table I.

TABLE I. THE MANUALLY DESIGNED CNN ARCHITECTURE

Layer	Layer Name	Layer Properties
1	Image Input	227x227x3 images with 'zerocenter' normalization
2	Convolution	96 11x11x3 convolutions with stride [4 4] and padding [0 0 0 0]
3	ReLU	ReLU
4	Max Pooling	3x3 max pooling with stride [2 2] and padding [0 0 0 0]
5	Convolution	256 5x5x96 convolutions with stride [1 1] and padding [2 2 2 2]
6	ReLU	ReLU
7	Max Pooling	3x3 max pooling with stride [2 2] and padding [0 0 0 0]
8	Convolution	384 3x3x256 convolutions with stride [1 1] and padding [1 1 1 1]
9	ReLU	ReLU
10	Convolution	384 3x3x384 convolutions with stride [1 1] and padding [1 1 1 1]
11	ReLU	ReLU
12	Convolution	256 3x3x384 convolutions with stride [1 1] and padding [1 1 1 1]
13	ReLU	ReLU
14	Max Pooling	3x3 max pooling with stride [2 2] and padding [0 0 0 0]
15	Fully Connected	4096 fully connected layer
16	ReLU	ReLU
17	Fully Connected	4096 fully connected layer
18	ReLU	ReLU
19	Fully Connected	256 fully connected layer
20	Softmax	softmax
21	Classification Output	crossentropyex

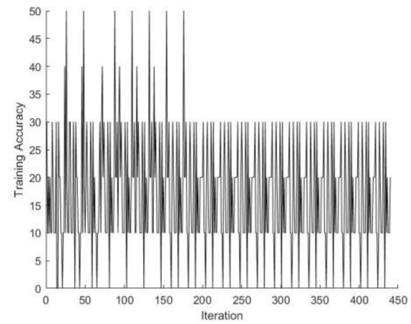


Fig. 6. Manually Designed CNN Training Accuracy (≅30%).

Many popular image datasets can be used for CNN training including MNIST [32], CIFAR10 [33], Caltech-256 [34], ImageNet [6], etc. CNN training from scratch requires a large amount of computational resources. In our experimentations we choose the Caltech-256 dataset including 256 object categories containing a total of 30607 images. For training step, we use 70% of the whole dataset and leave 30% for the test process and accuracy computing.

Fig.6 shows the training accuracy progress through iterations.

The accuracy of the manually designed model is too bad and not exceed a **30.8%.** The main issue of this model is that the value of its hyper parameters are not optimum for our stop sign image classification problem.

In this stage of research, we have to solve a problem with N variables corresponding to the CNN hyper parameters while ensuring a good learning accuracy. In order to optimize the values of these variables we design a solution based on a genetic algorithm approach well known for nondeterministic problem resolution.

IV. RELATED WORK

For decades, neural networks have proved their ability in machine learning. To increase network performance, some researches are based on deeper networks [35,36] while others propose adding highway information [37,38].

One of the most challenging aspects of deep networks is how to configure them and search for their hyperparameter values. To address this problem, some proposed methods include the use of stochastic depth [39,40] or dense convolutional networks [41]. However, the limit of these approaches is that all proposed deep network structures are deterministic which limits the flexibility of the models and consequently motivates us to design an automated search for optimal CNN hyperparameters for a given classification task.

In fact, searching for optimal deep network hyperparameters can be led through different strategies:

- Random configuration inspired from literature and intuition.
- Grid search by trying a systematic exploration across the layer number and nodes per layer.

- Exhaustive search by trying all possible combinations for hyperparameter values.
- Heuristic search such as genetic algorithm or Bayesian optimization.

Reference [42] shows that a simple random search gives better results than grid search, particularly for high-dimensional problems with low intrinsic dimensionality. In [43] and [44], proposed methods are based on Bayesian optimization process and yield better performance. In this paper we investigate a heuristic search. Our strategy is based on genetic algorithm well known for non-deterministic problem resolution. Our work aims to design and experiment a competitor new GA encoding method for CNN structure search.

V. Proposed Approach: Elite CNN Model Propagation (E-CNN-MP)

To design an optimal CNN model for our classification problem, we design a GA based approach labeled “Elite CNN Model Propagation” (E-CNN-MP). The main structure of a GA method is adopted. We, then, develop a specific method for chromosome encoding, chromosome recombination and fitness function.

In this section, we describe the E-CNN-MP modules that allow to evolve optimum hyper-parameters of a CNN for sign stop image classification problem. In the proposed framework, each chromosome is a candidate solution representing a CNN architecture. The training process error is chosen as the fitness function of a chromosome. In this case the GA based solution aims to compute the optimal hyper-parameters value giving the less error and consequently the higher classification accuracy.

A. Chromosome Encoding

In the designed approach, each chromosome represents a solution to the problem. For a CNN with D_p convolutional layers (CNN depth), the genetic algorithm inputs are $2*D_p$ variables to be optimized through the GA process. These variables are D_p pairs of values (Filter Number per Layer FNL, Filter Size per Layer FSL). The value encoding scheme of a chromosome (individual in a population) is illustrated in Fig.7.

Filters Number/Convolutional Layer$_i$					Filter Size/Convolutional Layer$_i$				
FNL_1	FNL_2	FNL_3	…	FNL_{Dp}	FSL_1	FSL_2	FSL_3	…	FSL_{Dp}

Fig. 7. Chromosome Encoding.

B. Population Initialization

GA population is a set of C individuals . Each individual is represented by a vector with length l (GA variables number).

To initialize the first population P, we use an uniform randomized values in the defined intervals:

$$P = \{I_l^c\}_{c \in [1..C]}$$

With: $\begin{cases} C: Number\ of\ chromosomes\ in\ population \\ l: Number\ of\ variables \end{cases}$

These values will be modified through mutation and crossover when discovering competitive structures during the genetic process. Each initialized individual will be evaluated. For this purpose, we compute its fitness score which is the classification error of the corresponding CNN. Our approach aims to search for the optimum individual which minimizes the fitness function and subsequently the classification error. Computing individual fitness is realized through a whole CNN training and evaluation process which requires heavy computation. For all simulations we use a single GPU. To evaluate the designed approach, generations of eight individuals are used. This number can be generalized and scaled up if we dispose more resources.

C. Selection Method

At the beginning of every generation creation, we apply a selection method. A successor generation P' of a source generation P is defined as follows:

1) A fraction fe of elite individuals from P propagated to P'. These individuals are the fit individuals with lower fitness function value (CNN classification error) over the whole generation P.

2) A fraction fc of P', other than elite children, that are created by crossover.

3) The remaining individuals to form the new generation are chosen randomly. This ensures the population diversity and avoids that the genetic algorithm converges rapidly.

Our selection approach aims to eliminate the least fit individuals from each generation.

To select parents of crossover children we perform a roulette method. During this step, we simulate a roulette wheel, in which the section area of the wheel corresponding to an individual i is proportional to the individual's expectation E_i.

In a population of size C, for an individual of fitness value $score_i$, its expectation is computed as follows:

$$E_i = \frac{score_i}{sum}$$

With:

$$sum = \sum_{j=1}^{C} score_j$$

The method generates, then, a random number in the interval $[0, sum]$. The individual whose segment spans the random number is chosen. This process is repeated until the preferred number of children to be created is reached.

D. Crossover Method

Crossover is a basic operator used in GA for producing new children which will have some parts of both parent’s genetic material. In the proposed approach a scattered crossover technique is used. For a child creation we:

1) Select 2 parents by the use of the selection method.

2) Generate a random binary vector of length l (l: the length of a chromosome).

3) To form the child, we use the gene from the first parent if the vector value is 1 and the gene from the second parent if the vector value is 0.

E. Mutation Method

Mutation method is applied on children created by crossover mechanism. The genetic algorithm applies small random changes in each child. Mutation offers population diversity and allows the genetic algorithm to explore a broader space.

Our mutation method is a two-step process:

1) Randomly select the fraction of the child vector to be mutated according to a probability rate p_r. In practice p_r is often small. This small value guarantees that the mutation operator preserves the good properties of a chromosome while exploring new possibilities. In our experimentation we choose a p_r equal to 0.01.

2) Replace each selected entry (chromosome gene) by a random number chosen from its corresponding range.

F. Termination of the GA

A GA approach is known to be a stochastic search method. The specification of a convergence criteria is sometimes problematic as the fitness function value may remain unchanged for a number of generations before a superior individual is found. In our approach, we choose to terminate the GA process after an already specified number of generations to avoid materials saturation. Then, we verify the quality of the best individual fitness and if necessary we restart the GA process with the initialization of a fresh search. The GA Fitness Function.

In this work we are optimizing CNN hyper-parameters for image classification task. Each individual corresponds to a plausible configuration of a CNN. It specifies its number of filters and their respective sizes. The fitness function or $score$ of an individual is computed via the CNN training from scratch based on an input dataset D. In our approach, the classification error is used as individual score.

The input dataset D is divided in a $TrainingDS$ and $estDS$.

The $accuracy$ of training is computed as: $\frac{Number\ of\ well\ classified\ images\ in\ TestDS}{size(TestDS)}$

The individual $score = 100 - accuracy$

G. Designed Algorithms

According to the previously exposed GA methods, the E-CNN-MP main algorithm is described in **Algorithm 1**. This algorithm returns the best individual and the corresponding CNN for which we save all weights and biases.

The FitnessCNN function used in the main program is the GA fitness function. It is described in **Algorithm 2**. It aims to construct the CNN model according to individual's values generated through the GA process and then operates a from scratch training.

Methods used for successor generations creation are described in **algorithm3**.

Algorithm 1: E-CNN-MP main algorithm

Input: D, convolutional layers number (NumConLayers), Max generations number (MaxG), Generation size N
Output: Best individual Fit*I*, Fit*CNN*
Loading images dataset D
Initialization of the training dataset (TrainingDS), the test dataset (TestDS), Best Accuracy, Fraction of elites (f_e), Fraction of crossover created children(f_c)
Randomly (Uniform distribution) create an initial population P of N chromosomes.
for g **in** 1 **to** MaxG
do
[S_1,S_2 ,..,S_N, BestAccuracy, Fit*I*, Fit*CNN*]← **FitnessCNN** (P, NumConLayers, BestAccuracy, TrainingDS, TestDS);
P'← **Recombination** (P , f_e, f_c);
P←P';
end for;
return Fit*I*;
save Fit*CNN*;

Algorithm 2: FitnessCNN function

Input: Population of **N** chromosomes, NumConLayers, BestAccuracy, TrainingDS, TestDS
Output: Vector of chromosome scores S_i, BestAccuracy, Fit*I*, Fit*CNN*
/*CNN model generation*/
Layers←[imageInputLayer([227 227 3]);
for C in 1 to N
for i in 1 to length(C)/2
FN←C[i];
FS←C[i+length(C)/2];
Layers←concatenate(layers,convolution2dLayer(FS,FN,'padding',FS/2),reluLayer, maxPooling2dLayer(2,'Stride',2));

```
end for;
layers←concatenate(layers, fullyConnectedLayer, reluLayer, fullyConnectedLayer, reluLayer, fullyConnectedLayer(), softmaxLayer ,classificationLayer());
/*From scratch CNN training*/
CNN←training(TrainingDS, layers, trainingoptions);
TestLabel ← classify(CNN, TestDS);
ImageLabel ← TestDS.Labels;
accuracy ← 100*sum(TestLabel==ImageLabel)/size(TestDS);
scores(C) ← 100-accuracy;
if accuracy > BestAccuracy
then
        BestAccuracy←accuracy;
        save(C);
        save(CNN);
 end if;
end for;
return C;
return CNN;
```

Algorithm 3: Successor generations creation algorithm

```
Input: Population of N Chromosomes P, f_e, f_c
Output: Population of N Chromosomes P'
/* Elite individual propagation*/
E←N* f_e;
Select E Elite chromosomes from P and place them in P';
/*Create N' child chromosomes by crossover method*/
N'←N* f_c;
For i 1 to N'
do
initialize a child vector C;
select 2 parents P1 and P2 from P based on roulette method;
randomly generate a binary vector R with length(R)=length(P1);
for j in 1 to length(R)
  do
      if R[j]==1
         then
            C[j]←P1[j]; //choose the first parent gene to be conserved in the child
         else
            C[j]←P2[j]; //choose the second parent gene to be conserved in the child
      end if;
end for;
/*Mutation operation*/
randomly select child gene position i to be mutated:
  i← random (1,length (C));
  randomly select x from the child gene initial range;
C(i)← x;
end for;
/*Randomly generation of remaining individuals in P'*/
N''← N-(E+N');
Inject randomly N'' chromosomes in P' (To guaranty diversity);
Return P';
```

VI. Simulations and Results of E-CNN-MP

The proposed approach for CNN hyper-parameters optimization is executed in a single GPU. The setting of the GA global parameters used for method implementation is synthetized in Table II.

To search for the best CNN model for our particular classification task, the GA process is iterated 5 times and the GA result performance is verified. Table.III shows the individual scores during each GA process.

TABLE II. GA SETTINGS

GA Settings	Value
Number of convolutional layers	5
Number of GA variables to optimized	10
GA population size	8
Individual score	Classification Error
GA stopping criteria is the maximum number of generations	4
Elite individuals fraction	20%
Fraction of children created by crossover	40%

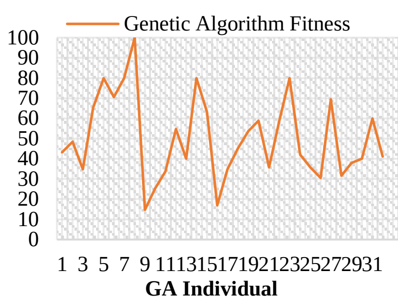
Simulation results are summarized in Table. IV. The best individual reached by the GA process is a CNN model offering **89.47%** accuracy which is not bad. In addition, comparing to the manually designed CNN (Section IV, Table I), it gives better classification accuracy.

Despite this accuracy improvement, we notice that the GA individual scores oscillate a lot through generations giving an accuracy average not exceeding 50%.

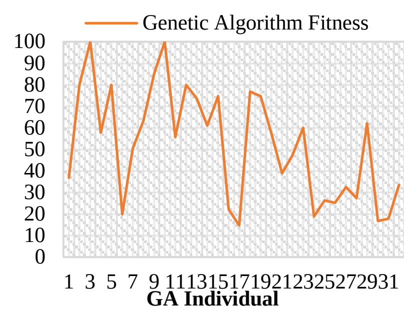
In the following step, the CNN training process is improved to get better classification accuracy values.

TABLE III. GA SIMULATIONS RESULTS BASED ON E-CNN-MP METHOD

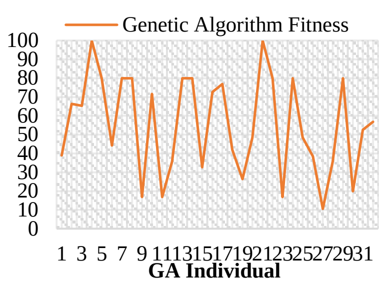
GA Process Iteration N°1



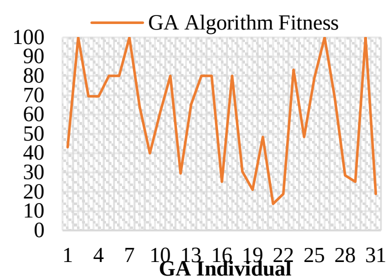
GA Process Iteration N°2



GA Process Iteration N°3



GA Process Iteration N°4



GA Process Iteration N°5

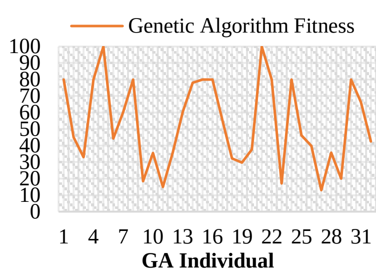


TABLE IV. CLASSIFICATION ACCURACY (ACCU.%) BASED ON E-CNN-MP METHOD

GA process	Max Accu.%	Min Accu.%	Average Accu. %	Best Network Encoding
1	85.27	0	49.81	73 49 61 96 73 18 7 8 7 16
2	85.26	0	47.73	42 75 57 48 76 2 5 11 17 16
3	89.47	0	44.55	80 80 55 70 66 14 4 2 18 2
4	86.32	0	42.11	70 70 60 77 58 17 7 3 6 9
5	87.02	0	46.85	60 73 52 76 61 11 9 3 4 2

VII. ENHANCED E-CNN-MP

Many methods are proposed to optimize a deep neural network training. Some of them try to reduce the sensitivity to network initialization. Among these enhanced initialization schemes, we quote: Xavier Initialization [45], Theoretically Derived Adaptable Initialization [46], Standard Fixed Initialization [6], etc. However, researches demonstrate that these methods have some limits. In fact, Xavier Initialization is not suited for rectification-based nonlinear activations CNN. Although, Theoretically Derived Adaptable Initialization method improves convergence characteristics, it is not confirmed that it led to better accuracy. It is also proven that Standard Fixed Initialization delays convergence because of the gradients magnitude or activations in a deep network final layers [7,47].

Other methods are interested to reduce the internal covariate shift phenomenon produced by variations in the distribution of each layer's inputs due to parameters changes in the previous layer. An "internal covariate shift" problem can dramatically affect CNN training [48]. In fact, during training process when the data is flowing through the CNN, their values are adjusted by the weights and parameters. This procedure makes sometimes the data too big or too small. To largely avoid this problem, the idea is to normalize the data in each mini-batch and not only for input data during the preprocessing step [48]. For each input channel across a mini-batch, activation normalization is, first, performed by subtracting the mini-batch mean and dividing by the mini-batch standard deviation. Input is, then, shifted by a learnable offset β and scaled by a learnable scale factor γ.

To enhance the designed E-CNN-MP approach, a CNN batch normalization is adopted. Comparing to Fig. 6, training accuracy results presented in Fig. 8 show that merely adding batch normalization to our CNN model yields a considerable speedup and achieves higher classification accuracy.

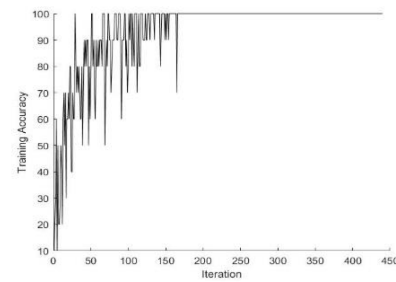


Fig. 8. Training Accuracy based on Bach Normalization Layers.

In the Enhanced E-CNN-MP proposed method, batch normalization layers are incorporated between convolutional layers and ReLU layers. FitnessCNN algorithm is describe in **Algorithm 2'**.

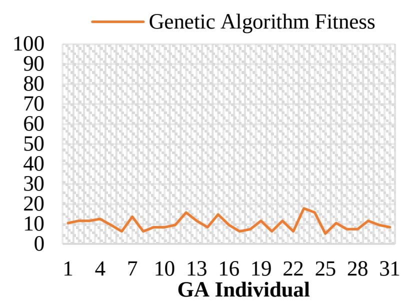
Algorithm 2': FitnessCNN Based on Bach Normalization

Input: **N** chromosomes, NumConLayers, BestAccuracy, TrainingDS, TestDS
Output: Vector of chromosome scores S_i, BestAccuracy, Fit*CNN*
/*CNN model generation*/
Layers←[imageInputLayer([227 227 3]);
for C in 1 to **N**
for i in 1 to length(C)/2
FN←C[i];
FS←C[i+length(C)/2];
/*CNN structure generation with the use of Batch Normalization Layer*/
Layers←concatenate(layers,convolution2dLayer(FS,FN,'padding',FS/2), ***batchNormalizationLayer***, reluLayer, maxPooling2dLayer(2,'Stride',2));
end for;
layers←concatenate(layers, fullyConnectedLayer, reluLayer, fullyConnectedLayer, reluLayer, fullyConnectedLayer(5), softmaxLayer ,classificationLayer());
/*From scratch CNN training*/
CNN←**training**(TrainingDS, layers, trainingoptions);
TestLabel ← **classify**(CNN, TestDS);
ImageLabel ← TestDS.Labels;
accuracy ← 100*sum(TestLabel==ImageLabel)/size(TestDS);
scores(C) ← 100-accuracy;
if accuracy > BestAccuracy
then
BestAccuracy←accuracy;
save(C);
save(CNN);
end if;
end for;
return C;
return CNN;

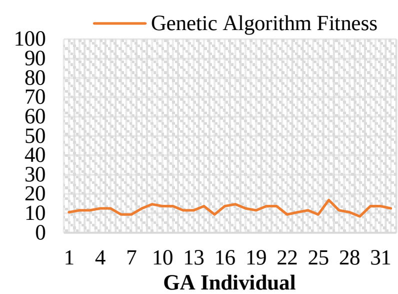
To evaluate the GA process based on this new fitness function. The whole GA process is repeated 5 times. Table. V shows the fitness function values evolution through the GA process iterations. Table. VI synthesizes CNN accuracies got at the end of each GA process iteration. The new CNN structure allows to reach a classification accuracy of **98.94%**. The best fit CNN structure obtained through the Enhanced E-CNN-MP proposed approach is given in Table. VII. All its weights and biases are saved.

TABLE V. GA SIMULATIONS RESULTS BASED ON ENHANCED E-CNN-MP METHOD

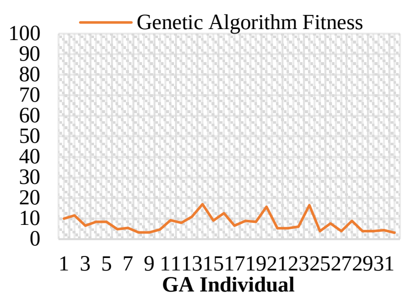
GA Process Iteration N°1



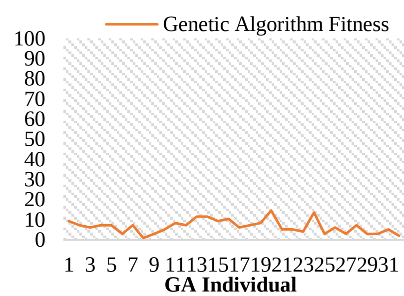
GA Process Iteration N°2



GA Process Iteration N°3



GA Process Iteration N°4



GA Process Iteration N°5

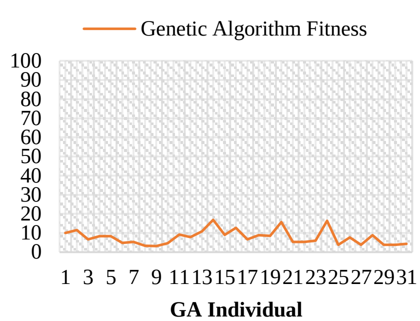


TABLE VI. CLASSIFICATION ACCURACY (ACCU. %) BASED ON ENHANCED E-CNN-MP METHOD

GA process	Max Accu.%	Min Accu.%	Average Accu.%	Best Network Encoding
1	94.74	82.11	89.9	57 98 94 98 38 8 9 7 3 7
2	91.57	83.15	87.89	31 84 50 81 86 13 3 12 20 6
3	94.93	80	87.79	57 98 94 98 37 8 9 7 3 7
4	98.94	85.26	93.25	59 37 81 79 41 19 4 6 17 5
5	96.97	83.11	92.37	60 73 52 76 61 11 9 3 4 2

TABLE VII. BEST FIT CNN STRUCTURE

Layer	Layer Name	Layer Properties
1	Image Input	227x227x3 images with 'zerocenter' normalization
2	Convolution	59 19x19x3 convolutions with stride [1 1] and padding [9 9 9 9]
3	Batch Normalization	Batch normalization with 59 channels
4	ReLU	ReLU
5	Max Pooling	2x2 max pooling with stride [2 2] and padding [0 0 0 0]
6	Convolution	37 4x4x59 convolutions with stride [1 1] and padding [2 2 2 2]
7	Batch Normalization	Batch normalization with 37 channels
8	ReLU	ReLU
9	Max Pooling	2x2 max pooling with stride [2 2] and padding [0 0 0 0]
10	Convolution	81 6x6x37 convolutions with stride [1 1] and padding [3 3 3 3]
11	Batch Normalization	Batch normalization with 81 channels
12	ReLU	ReLU
13	Max Pooling	2x2 max pooling with stride [2 2] and padding [0 0 0 0]
14	Convolution	79 17x17x81 convolutions with stride [1 1] and padding [8 8 8 8]
15	Batch Normalization	Batch normalization with 79 channels
16	ReLU	ReLU
17	Max Pooling	2x2 max pooling with stride [2 2] and padding [0 0 0 0]
18	Convolution	41 5x5x79 convolutions with stride [1 1] and padding [2 2 2 2]
19	Batch Normalization	Batch normalization with 41 channels
20	ReLU	ReLU
21	Max Pooling	2x2 max pooling with stride [2 2] and padding [0 0 0 0]
22	Fully Connected	256 fully connected layer
23	Softmax	softmax
24	Classification Output	crossentropyex with 5 classes

VIII. CONCLUSIONS

In this work CNN is investigated as an image classification method. The performance of such network depends on the setting of its hyper parameters such as the number of convolutional layers, the number of filters per layer and their respective sizes. Our particular problem is to generate a predictive model for sign stop image classification by the use of CNN. First we try to manually design the CNN structure. This approach gives a very poor classification accuracy (≅30%).

As the number of candidate solutions is very large we develop a E-CNN-MP framework, based on GA methods, to search for a best CNN structure. This heuristic method, starts by creating an initial population of potential CNN structure and then evaluates each individual by a “from scratch classification error computing”. For all CNN training we use a reference dataset. During simulations the network is set as a block of convolutional, ReLU and Maxpooling layers. Simulations prove the ability of the GA process to search for the Elite CNN model. This model offers a classification accuracy ≅ 90%. Once we test the well doing of the GA process we try to improve the framework to get better results. Hence, we choose to insert a batch normalization layer after each convolutional layer to improve the quality of the network training. The Enhanced E-CNN-MP performs better than the first designed one. GA simulations allow us to get a pre trained CNN performing an accuracy of 98.94%.

In this article we propose a competitor strategy using the GAs to search for a best CNN structure offering a high-quality pre-trained CNN suitable for stop sign image classification. The designed Enhanced E-CNN MP approach is an innovative approach.

Our contribution will allow scientists from any field of research (biology, medicine, robotic, geology ...) to design their own Convolutional Neural Network (CNN) prediction model suitable for their particular image classification problem.

REFERENCES

[1] A.Karpathy and L. Fei-Fei,. *Deep visual-semantic alignments for generating image descriptions*. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition. (2016), pp. 3128–3137.

[2] R.Bernardi, R.Cakici, D. Elliott, A. Erdem, E. Erdem, N. Ikizler-Cinbis, F. Keller, A. Muscat and B. Plank. *Automatic Description Generation from Images: A Survey of Models, Datasets, and Evaluation Measures*. Journal of Artificial Intelligence Research (JAIR) (2016), pp. 409-442.

[3] D. Garcia-Gasulla, F. Parès, A. Vilalta, J. Moreno, E. Ayguadé, J. Labarta, U. Cortés and T. Suzumura. *On the Behavior of Convolutional Nets for Feature Extraction*. Journal of Artificial Intelligence Research 61 (JAIR) (2018), pp. 563-592.

[4] G. E. Dahl, D. Yu, L. Deng and A. Acero,.*Context dependent pre-trained deep neural networks for large vocabulary speech recognition.* Audio, Speech, and Language Processing, IEEE Transactions on, 20(1) (2012), pp.30-42.

[5] Y. Taigman, M. Yang, M. Ranzato and L. Wolf. *Deepface: Closing the gap to human-level performance in face verification*. In Computer Vision and Pattern Recognition (CVPR) (2014), pp. 1701-1708.

[6] A. Krizhevsky, I. Sutskever, and G. E. Hinton. *ImageNet classification with deep convolutional neural networks.* In Advances in neural information processing systems (2012), pp. 1097–1105.

[7] K. Simonyan and A. Zisserman. *Very Deep Convolutional Networks for Large-Scale Image Recognition*. International Conference on Learning Representations. (2014).

[8] K. He, X. Zhang, S.Ren and J.Sun *Deep Residual Learning for Image Recognition*. Computer Vision and Pattern Recognition. (2016).

[9] F. M. Ham and I. Kostanic. *Principles of Neurocomputing for Science and Engineering.* McGraw-Hill Higher Education. (2000).

[10] Y. LeCun, Y. Bengio and G. Hinton. *Deep Learning.* Nature521(7553) (2015), pp. 436–444. doi:10.1038/nature14539.

[11] S. Srinivas, R. K. Sarvadevabhatla, K. R. Mopuri, N. Prabhu, S. S.Kruthiventi and R. V. Babu, A taxonomy of deep convolutional neural nets for computer vision. (2016). *arXiv 1601.06615.*

[12] C. Szegedy, W. Liu, Y. Jia, P. S. Sermanet, D. Anguelov, D. Erhan, V. Vanhoucke and A. Rabinovich. *Going Deeper with Convolutions* (2014). *arXiv:1409.4842.*

[13] M. D. Zeiler, and R. Fergus. *Visualizing and Understanding Convolutional Networks* (2013). arXiv:1311.2901v3.

[14] A. W. Harley. *An Interactive Node-Link Visualization of Convolutional Neural Networks.* In ISVC (2015), pp. 867-877.

[15] A. W. Dumoulin, and F. Visin, *A guide to convolution arithmetic for deep learning* (2016). arXiv:1603.07285v1.

[16] K. Jarrett, K. Kavukcuoglu, M. Ranzato and Y. LeCun, *What is the best multi-stage architecture for object recognition?*. In Proceedings of the IEEE International Conference on Computer Vision (2009), pp. 2146–2153.

[17] V. Nair and G. Hinton. *Rectified linear units improve restricted boltzmann machines*. In Proceedings of International Conference on Machine Learning (2010), pp. 807–814.

[18] D. Nguyen and B. Widrow. *Improving the learning speed of 2-layer neural networks by choosing initial values of the adaptive weights*. In International Joint Conference on Neural Networks (1990), pp. 21–26 vol.3.

[19] M. Norouzi, M. Ranjbar and G.Mori. *Stacks of convolutional restricted boltzmann machines for shift-invariant feature learning.* In IEEE Transactions on Conference on Computer Vision and Pattern Recognition (2009), pp. 2735–2742.

[20] B. Xu, N. Wang, T. Chen and M. Li. *Empirical evaluation of rectified activations in convolutional network* (2015). arXiv 1505.00853v2.

[21] W. Liu, Y. Wen, M. Scut, Z. Yu and M. Yang. *Large-margin softmax loss for convolutional neural networks.* In Proceedings of the 33rd International Conference Machine Learning (2016), pp. 507–516.

[22] G. Brandon and A. Sigberto. *Real-time American Sign Language Recognition with Convolutional Neural Networks.* Stanford Vision Lab, (2016).

[23] J. McCall. *Genetic algorithms for modelling and optimization.* Journal of Computational and Applied Mathematics (2005), Volume 184, pp. 205-222.

[24] T. Bäck, D. B. Fogel, and Z. Michalewicz. *Handbook of Evolutionary Computation.* IOP Publishing. (1997).

[25] L. Davis. *Handbook of Genetic Algorithms*. Van Nostrand Reinhold, New York (1991).

[26] Z. Michaelewicz. *Genetic Algorithms + Data structures = Evolution Programs* (third ed.), (Springer, Berlin ,1999).

[27] S. Loussaief and A. Abdelkrim. *Machine Learning Framework for Image Classification*. In Sciences of Electronics, Technologies of Information and Telecommunications, SETIT 2016.

[28] S. Loussaief and A. Abdelkrim. *Machine Learning Framework for Image Classification.* In, Advances in Sciences, Technology and Engineering Systems Journal (2018), Vol.3 No. 1, 01-10, ISSN: 2415-6698.

[29] J. Donahue, Y. Jia, O. Vinyals, J. Hoffman, N. Zhang, E. Tzeng and T. Darrell. *A deep convolutional activation feature for generic visual recognition* (2013), CoRR, abs/1310.1531.

[30] S. Loussaief and A. Abdelkrim. *Deep Learning vs. Bag of Features in Machine Learning for Image Classification.* In International Conference on Advanced Systems and Electrical Technologies, IC'ASET 2018.

[31] N. Jmour, S. Loussaief and A. Abdelkrim. *Convolutional Neural Networks for image classification*. In International Conference on Advanced Systems and Electrical Technologies, IC'ASET 2018.

[32] Y. LeCun, L. Bottou, Y. Bengio, and P. Haffner. Gradientbased Learning Applied to Document Recognition. Proceedings of the IEEE, 86(11):2278–2324, 1998.

[33] A. Krizhevsky and G. Hinton. Learning Multiple Layers of Features from Tiny Images. Technical Report, University of Toronto, 1(4):7, 2009.

[34] G. Griffin, A. Holub and P. Perona. Caltech-256 Object Category Dataset. Mars 2007.

[35] K. Simonyan and A. Zisserman. Very Deep Convolutional Networks for Large-Scale Image Recognition. International Conference on Learning Representations, 2014.

[36] C. Szegedy, W. Liu, Y. Jia, P. Sermanet, S. Reed, D. Anguelov, D. Erhan, V. Vanhoucke, and A. Rabinovich. Going Deeper with Convolutions. Computer Vision and Pattern Recognition, 2015.

[37] K. He, X. Zhang, S. Ren, and J. Sun. Deep Residual Learning for Image Recognition. Computer Vision and Pattern Recognition, 2016.

[38] S. Zagoruyko and N. Komodakis. Wide Residual Networks. arXiv preprint, arXiv: 1605.07146, 2016.

[39] L. Xie, J. Wang, W. Lin, B. Zhang, and Q. Tian. Towards Reversal-Invariant Image Representation. International Journal on Computer Vision, 2016.

[40] G. Huang, Y. Sun, Z. Liu, D. Sedra, and K.Weinberger. Deep Networks with Stochastic Depth. European Conference on Computer Vision, 2016.

[41] G. Huang, Z. Liu, and K. Weinberger. Densely Connected Convolutional Networks. arXiv preprint, arXiv:1608.06993, 2016.

[42] J. Bergstra and Y. Bengio. Random search for hyper-parameter optimization. JMLR, 13(1):281–305, 2012.

[43] J. Bergstra, D. Yamins, and D.D. Cox. Making a science of model search: Hyperparameter optimization in hundreds of dimensions for vision architectures. In Proc. Of ICML, pages 115–123, 2013.

[44] F. Hutter, H. Hoos, and K. Leyton-Brown. Sequential model-based optimization for general algorithm configuration. In Proc. of LION, pages 507–523. Springer, 2011.

[45] X. Glorot and Y. Bengio. *Understanding the difficulty of training deep feedforward neural networks*. In Proceedings of the 13th International Conference on Artificial Intelligence and Statistics (2010), pp. 249–256.

[46] K. He, X. Zhang, S. Ren and J. Sun. *Deep residual learning for image recognition* (2015). arXiv 1512.03385.

[47] D. Mishkin and J. Matas. *All you need is a good init.* In Proceedings of the 4th International Conference on Learning Representations (2016), pp. 1–13.

[48] S. Ioffe and C. Szegedy. *Batch Normalization: Accelerating Deep Network Training by Reducing Internal Covariate(2015). arXiv:1502.03167*

E2-Invisible Watermarking for Protecting Intellectual Rights of Medical Images and Records

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***Abstract*—In today's digital era, practice of telemedicine has become common which involves the transmission of medical images and Myhealthrecord (MHR) for higher diagnosis in case of emergency and maintaining integrity, robustness, authentication and confidentiality of such patient's data becomes necessary. Many works has shown that the digital watermarking is one of the solutions but simultaneously, it is known that no complete algorithm is available to fulfil all the requirements of a field. Till the watermarking technique becomes robust, encryption technique can be considered as one of the best solution for protecting the data. Encoding is used for transforming the information in to another form and in the proposed work of digital watermarking (DWM); encoding is combined with encryption and DWM to enhance the protection of data by maintaining the above said constraints. In this paper, DWM for medical images is implemented by joint combination of spatial and frequency domain technique Singular value decomposition-Integer wavelet transform (SVD-IWT) respectively, 64-bit Rivest-Shamir-Adleman (RSA) crypto-technique and new encoding procedure. To avoid the degradation of the medical image which is very essential in the medical field, data payload should be less and is achieved by the use of quick response (QR) code which consumes less space for large information. Finally the proposed system is compared with other traditional methods and also evaluated against various image processing and geometric attacks.**

***Keywords*—Myhealthrecord; SVD; IWT; RSA; QR code; encoding**

I. Introduction

All real time signals are analogous in nature which are easily perceptible and heard by human beings. Butin order to process, transmit and receive over the network, these signals should be in digital form and such real time signals are widely used in many of the applications; one of the main applications is in the field of health care system which strictly prohibits any modifications in the information. But any digitally converted data is reversible in nature and in turn leads to many illegal and fraud activities. In such cases, digital watermarking (DWM) system plays a major role for ensuring security, authenticity and confidentiality. The DWM is implemented in two ways: spatial and transform domain [3] [9]; the transform domain is more robust compared to spatial domain but does not provide complete contribution towards the security of the information. The DWM technique does not avoid the fraud cases but however it can help in preventing and reducing illegal use of the data. So, until the DWM system becomes robust enough to prevent the removal of watermark content from it, the research in this field continues.

Most commonly used and efficient techniques are; Spatial LSB and transform IWT techniques. The SVD technique embeds the WM in the LSB of pixels but does not create serious distortion but is less robust. In DWT, the watermark is embedded in floating point coefficients so that any truncations of the floating point values of the pixels that should be integers may lead to the loss of the watermark information which may in turn lead to the failure of the system. In order to avoid the loss of information IWT technique involves only integer so that there is no loss of information. Thus one of the alternate to increase the robustness of DWM is to combine the positive features of spatial and frequency domain technique [12]. Although the techniques are combined, it cannot avoid the removal and identification of watermark. Therefore the limitation of DWM can be clubbed with encryption [6] and encoding technology to secure the confidential data in the field of health care systems.

Encoding is the process of converting one form of information to another form and this property of encoding is used to hide the original data from the fraud. In this paper, the watermark information is encoded with the help of generation of large value of prime numbers and is done with new proposed algorithm and later encoded message is encrypted using 64-bit RSA crypto algorithm (only for simulation purpose and we can use 1024-bit RSA also). The process of encoding followed by the encryption ensures double blinded security [2] to the information.

Prime numbers are used in both encoding and encryption process and it is very difficult for anyone to predict the large prime factorized value and this property of prime numbers adds the benefit in improving the security.

In the medical field modification of the data is not entertained as it may lead to inappropriate decision even by the specialized doctors and to avoid such cases, data payload should be less and to achieve this quick response code (QR) [7] [15] is used in the proposed watermarking system.

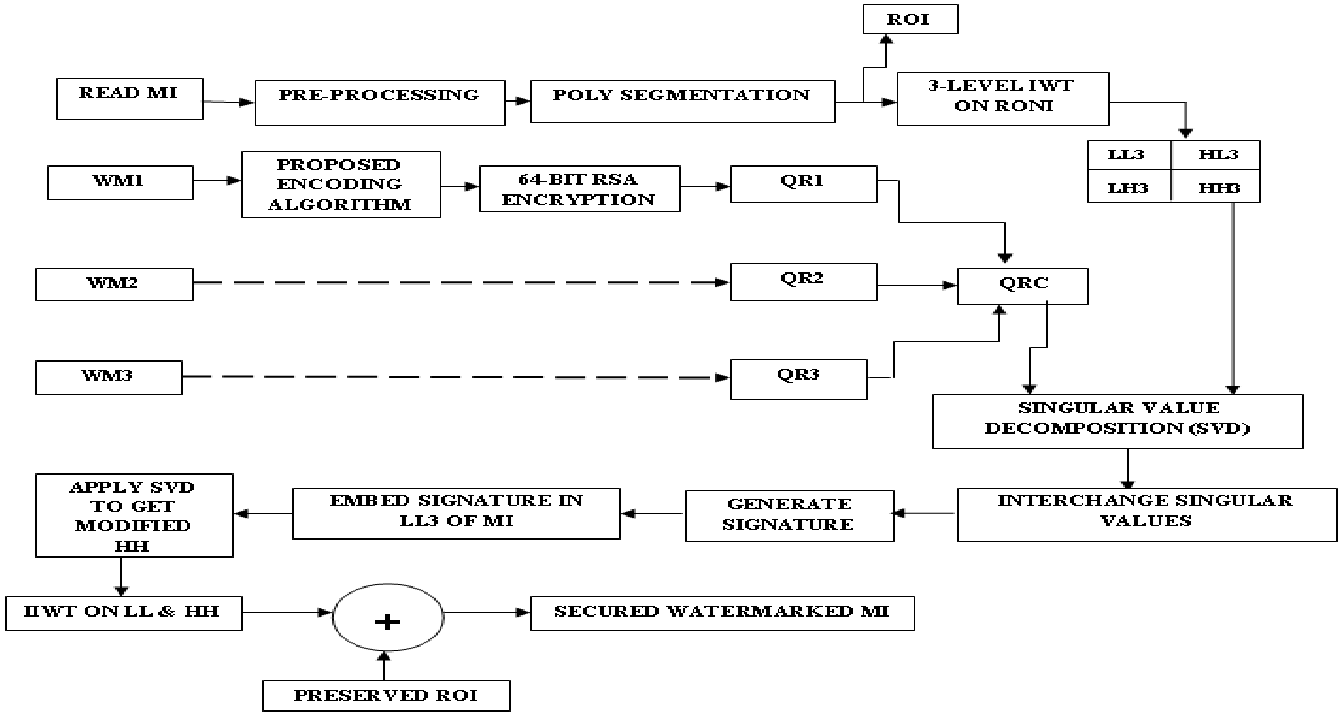


Fig. 1. Proposed Block Diagram of WM Embedding Process.

II. Proposed Algorithm

Here a novel Encoding-Encryption (E2)-based DWM embedding procedure is proposed for MI and is shown in the figure 1. In this work, three different watermarks are used; patient information, patient ID (E-aadhar) and hospital logo. The patient information is encoded using the proposed encoding algorithm followed by 64-bit RSA encryption algorithm. The encrypted patient information is converted to QR code. The same operation can be done with other watermark information also but for simplicity here these steps are performed only with the patient details.

A. Pre-processing Steps at the Scanned MI:

Step1: Read the scanned MI from the database (Cover Image).

Step2: In pre-processing, color image is converted to gray image. The conversion is done as gray scale image is represented by 8-bit value ranging from 0-255. With contrast to RGB MI which is represented by 24-bit, the gray image processing has many advantages such as: complexity of the code is less; speed of computation is very high as it processes only with one channel elements; signal to noise ratio is high compared with 3-channel colour image;

Step3: After the conversion, the image is subjected to polygon based segmentation to separate region of interest (ROI) region and region of non-interest (RONI) region as shown below. Segmentation is necessary in the case of MI so as to avoid the degradation of the diagnosis part. The diagnosis part is considered as ROI and the rest is RONI. Most of the radiologist use polygon based segmentation because of its easiness i.e. it just involves selecting four points on the positive and negative axis as shown in figure2:

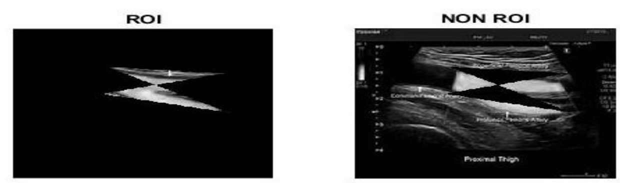


Fig. 2. Polygon Segmentation To Separate ROI & RONI before Embedding Process.

After separating ROI region, the watermark can be embedded in to the RONI region without distorting the useful information.

Step4: This step is explained later in the section of watermark embedding process.

B. Steps Performed at the Watermark:

Step1: Read 3 different watermarks: Patient details (txt, doc, excel), Patient ID (E-aadhar) and hospital logo.

Step2: Apply the proposed encoding algorithm to get encoded message in terms of prime numbers. The encoding algorithm is described below:

1) Read the first watermark i.e. patient detail file K from the database.

2) Read the total length of the characters M and assign it to another variable N for future use.

3) Read each character from the file.

4) Generate a random prime number KL.

5) Using the above value, once again generate random prime numbers for each character.

6) Store the last prime number in a variable key.

7) Divide the entire length in to half.

8) Apply the algorithm as described below

$$for\ i = 1\ toM/2$$
$$enc(i) = (p(i) + p(N) + K(i)) \oplus key$$
$$enc(N) = (p(i) - p(N) + K(N)) \ominus key$$
$$N = N - 1$$

Where

$p(i) -\!\!\rightarrow prime\ number\ of\ ith\ character$
$p(N) -\!\!\rightarrow prime\ number\ of Nth\ character$

Repeat the above process for all characters.

In broad way encoding is considered as a method of transforming the original information in to another form which is easily not understood by common persons. In the encoding procedure mentioned above, the prime numbers are used in the process of addition; subtraction, modulo-2 additions and subtraction are used.

Step3: Apply 64-bit RSA encryption to the encoded message. The RSA encryption technique involves the generation of private key, public key and modulus. The public key can be shared among the doctors while retaining the private key with the patient to maintain confidentiality, authenticity and security.

The procedure for generating the 64-bit key is described below:

a) The encoded message is converted to 64-bit integer data type.

b) Generate the key pair: modulus, public and private key

i. Select two large prime numbers p & q.

ii. Compute modulus $m = p \times q$

iii. Calculate $k = (p - 1) \times (q - 1)$

iv. An integer selection between the range $1 < e < n$ and is used as a public key 'e'.

v. Private key 'd' is generated using integer e and two prime numbers p & q using extended Euclidian algorithm (used to obtain gcd-last non zero remainder).

vi. Later encryption is performed using modulus, public key 'e' and the message as:

$$initialize\ Encrypted\ message = 1$$
$$temppublic = 0$$
$$temppublic = temppublic + 1$$
$$Encrypted\ message = mod((individual\ character\ of\ the\ message \times Encrypted\ message), k)$$
$$if\ (temppubli) = e$$
$$stop\ encryption$$

Step4: QR code is generated using zxing library function for encrypted message to reduce the data payload. QR code is widely used nowadays because of its less space consumption to that of bar code or any other conventional symbol, isotropic property, capacity to hold 7092 characters of data which may consist of numbers, symbols, text, control codes etc both horizontally and vertically and rather than this even if it is damaged it is possible to recover the data from 30 to 35% of the damaged data [4] [5].

Step5: The same procedure may be done for other watermarks also with slight modifications. But in this paper, the steps are performed only for patient details. Rather than this, QR code is generated for other two watermarks. The sizes of patient ID (E-Aadhar) of size 40.4KB of dimension252×365, Hospital Logo of size 3.57 KB with dimension 47×43 and PHR of size 12.47 KB with dimension268×218 are used.

Step6: The generated three different QR code watermarks are concatenated with three different colours R, G and B to differentiate each other.

$$QRC = cat(3, R, G, B)$$

Step7: The concatenated QR code is applied with SVD.

C. Watermark Embedding Process

The procedure for embedding the QR watermark is described below: The process involves the use of frequency domain IWT technique and spatial domain technique SVD [10]. The RONI obtained after segmentation is subjected to 3-level Integer Wavelet Transform (IWT) which is usually considered as Reversible Lifting Wavelet Transform (RLWT). Nowadays IWT is replacing Discrete Wavelet Transform (DWT) as it eliminates the information loss in the fractional part of the data during watermark [1] embedding process as it involves integer to integer transform mapping that does not allow the information loss during the forward and reverse process. The deeper level decomposition is considered, as the 1-level decomposition does not contain much information while the subsequent levels contain more information and less noise. Embedding the watermark in such deeper levels provides more robustness to the system.

a) Apply 3-level IWT to the RONI region of MI which results in four frequency bands as low-low (ll), low-high (lh), high-low (hl) and high-high (hh) followed by SVD operation.

b) Since the high frequency component is less informative, modifying the data in this part does not affect, hence the hh part of MI is used to generate the signature that is to be embedded in ll part of MI. The ll part is chosen for embedding as we know that, the low frequency part is more informative and hiding the data in such part is not easily traceable and thus we can evaluate the robustness of the system.

The signature generation involves the following steps [8]:

i. Apply SVD to the higher frequency band hh of MI and it gives u_i, s_i and v_i.

ii. Apply SVD to the QR code watermark and it gives u_w, s_w and v_w.

iii. Singular component of MI and WM are exchanged to get modified hh band of the MI.

iv. The remaining u_w and v_w components of WM are used along with a random constant key to generate the signature.

v. To generate signature, initially a threshold value is fixed either to 0 or 1 based on the median values of sum of u and v components and reshaped to 1×256 column elements.

vi. Perform XOR operation on the above elements to get 1×512 sized element.

vii. Now this is XORed with a random key selected resulting in signature.

c) The generated signature is embedded in the low frequency band ll of MI.

i. While embedding process, IWT is applied at 3-level decomposition.

ii. The ll3 and hh3 of the above result is reshaped to 1×256 and both are concatenated to get 1×512 sized component.

iii. After concatenation, separate the negative and positive decimals and store the negative values for reconstruction purpose in the later stage.

iv. Again separate the integer and fractional part in the positive decimal part and convert integer part to 32-bit binary.

v. Chose n^{th} bit for embedding signature, in this 20^{th} bit is replaced by the signature.

vi. After performing embedding operation, convert binary to decimal once again and add the fractional part and negative indices stored.

d) Now apply SVD to the modified hh band (which holds singular value of WM) and perform the inverse IWT to this and the result obtained in step c.

e) Combine the above result with preserved ROI to get watermarked MI.

D. Watermark Extraction Process

The watermarked image may be either stored in the database or transmitted over the network, if required for higher diagnosis. At the recipient side, the received image has to be validated by extracting the embedded watermark and reconstructing the original MI. The watermark extraction and reconstruction of MI is done using watermarked image, watermark and a random key as described below:

1) Read the watermarked image from the database, separate ROI & RONI as shown in figure 3 and then apply 3-level IWT to the RONI part.

Fig. 3. Polygon Segmentation to Separate ROI & RONI before Extraction Process.

2) Apply SVD to the watermark image and generate the signature using the received key.

3) Extract the signature from the watermarked image using u and v components of WM and a key (it can be sent over phone or any other method) using the same process as that of signature embedding and signature is generated using the original WM using the same method as that in the watermark embedding process.

4) The generated signature is matched with the extracted signature to get authentication. If both the signatures are matched, then it proves authentication and allows for the next step of watermark extraction.

5) After successful authentication, SVD is applied to the hh frequency band of watermarked MI and the singular value of hh band is extracted.

6) The watermark is constructed with u_w, v_w *components of watermarked MI of step II and result of step V or inverse IWT to get original MI as shown in figure 4.*

7) Later the QR code watermark is decatenated.

After the construction of watermark which is in the QR code is decoded using built in zxing qr code decoder to get the encrypted data. This data is decrypted using 64-bit RSA decryption algorithm and to do this at the receiver a modulus value m and a public key e. The decryption procedure is described below:

a) For decryption, it requires encrypted information, private key and modulus.

b) The same process is carried out as that of encryption except only with respect to private exponent.

Now the decrypted data is passed through the decoding stage which is exactly opposite to that of encoding stage at the transmitter to get the patient detail. The decoding procedure is described below:

$$for\ i = 1\ toM/2$$
$$K(i) = (enc(i) \ominus key) - p(i) - p(N)$$
$$K(N) = (enc(N) \ominus key) - p(i) + p(N)$$
$$N = N - 1$$

8) The RONI part of the watermarked image is combined with the ROI which was separated in step I to get the original MI.

The overall process of generating the patient's MHR is shown in figure 5.

The extracted watermark and reconstructed MI are compared with the original watermark and the original MI respectively and evaluated using the quality metric parameters PSNR, MSE and SSIM. Also the system robustness is verified against various attacks like JPEG compression, Median filter, Wiener filter, and Gaussian filter, Image cropping, Image rotation and Image resize [11] [14].

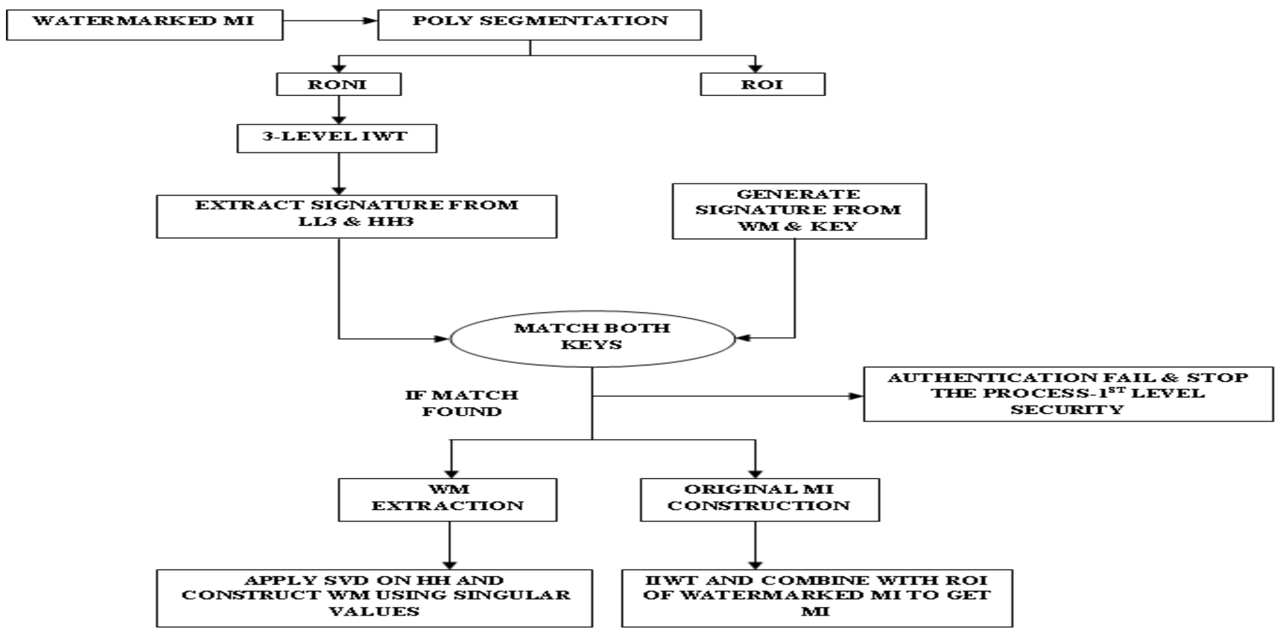


Fig. 4. Block Diagram of Proposed WM Extraction Process.

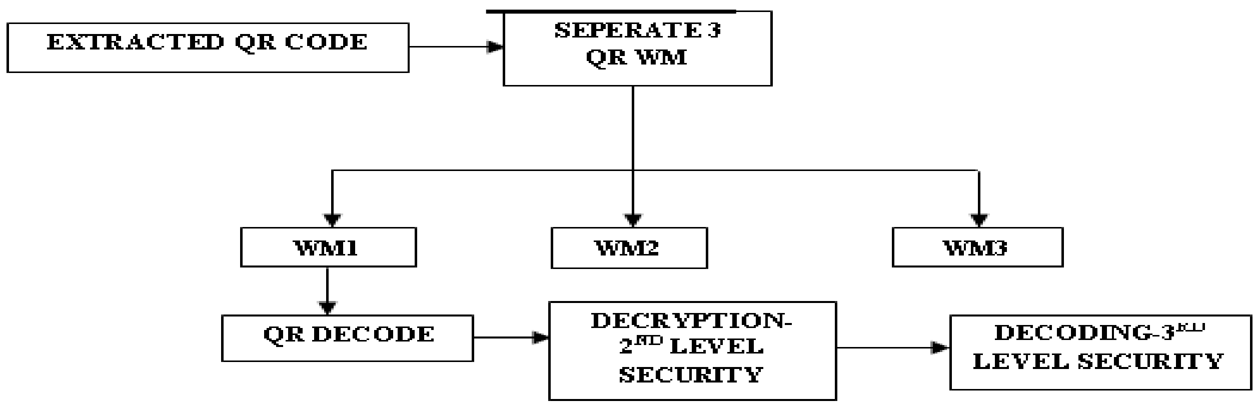


Fig. 5. Block Diagram of Generating the Original Patient Information.

E. Results and Discussion

The proposed algorithm is simulated using Mat lab 2015a. In the proposed work, a combination of spatial domain technique SVD and frequency domain technique IWT together with encoding, encryption and QR code is proposed. The main advantage of SVD is that the singular value of image provides the specifications about the geometry of image such as; left and right singular vectors represents horizontal and vertical details of image whereas the singular values specifies the luminance of the image. And small variations to such vectors will not affect the image quality [13].

On the other hand IWT is used for lossless data compression and also computation speed of IWT is much higher than that of DWT as it does not involve the fractional part. IWT is implemented using the lifting scheme method which consists of 3 steps; split, predict and update. Another main advantage of using IWT is that it is reversible in nature i.e. the image can be reconstructed without any loss as its coefficients are stored without rounding off errors.

Moreover combined use of encoding and encryption doubles the security of the information and QR code can ensemble a bigger data. The US medical images used in the simulation process are collected from the online data base and some of MRI images are collected from SS health care centre.

The result of encoding, QR code generation, encryption and the respective reverse operation are shown in table I and the overall watermark embedding and extraction process is shown in table II. The table III gives the performance evaluation of the proposed system for a single key against other traditional methods.

The table IV & V gives performance evaluation of the system verified for 20 random keys. For evaluation of the system the quality metric parameters PSNR, SSIM, MSE, false acceptance and rejection ratio are considered. The figure 6 shows graph of false acceptance & rejection ratio, decoding correct & wrong information at the receiver side. The table VI gives the evaluation of the system against various image processing & geometric attacks.

TABLE I. RESULTS OF ENCODING, ENCRYPTION AND THE REVERSE PROCESS DURING WM EMBEDDING AND EXTRACTION PROCESSES

Hospital: SS Hitech Health care Doctor In charge: Dr. Sanjay S Name of the Patient: Kavitha K J Date Of Birth: 19/02/1982 Age: 36 years Date of Admission: 19/07/2018 Patient ID: SS_IP_54786_022018 Health Issue: Leg fracture below the ankle Precaution: Rest for 3-weeks a. Patient detail	**Encoded message:** '201036,138225,243711,121578,41379,109004,71983,97310,77308,130178,94803,95117,112154,30922,40577,110832,127047,179003,138216,133674,198552,141419,41683,240182,163414,86754,114428,157685,78031,162234,150935,226699,112038,44230,220975,88469,190356,93159,134568,156734,169615,77390,190780,18133,89214,227257,180464,116703,105147,127966,57832,176844,78332,227284,222710,183575,221407,41702,100190,169155,43657,118564,79041,165331,139236,121734,110123,208611,139251,95050,223271,78714,90726,156066,121328,5705,113702,184712,132129,131112,154105,149129,152416,--------- b. encoded message of (a)
Ciphertext: 1347 1963 301 1963 2989 2969 682 301 2989 84 1347 1347 1325 682 1347 2013 2989 1145 301 301 682 301 1347 301 1325…………. c. encrypted message of (b)	d. QR code of (c)
-Key Pair- Modulus: 4189 Public Exponent: 3 Private Exponent: 2707 **Restored storage:** 1347 1963 301 1963 2989 2969 682 301 2989 84 1347 1347 1325 682 1347 2013 2989 1145 301 301 682 301 …………. e. Decrypted message of (d) after QR decoding	**Decoded Message:** '201036,138225,243711,121578,41379,109004,71983,97310,77308,130178,94803,95117,112154,30922,40577,110832,127047,179003,138216,133674,198552,141419,41683,240182,163414,86754,114428,157685,78031,162234,150935,226699,112038,44230,220975,88469,190356,93159,134568,156734,169615,77390,190780,18133,89214,227257,180464,116703,105147,127966,57832,176844,78332,227284,222710,183575,221407,41702,100190,169155,43657,118564,79041,165331,139236,121734,110123,208611,139251,95050,223271,78714,90726,156066,121328,5705,113702,184712,132129,131112,154105,149129,152416,148386,179904,79056,98751,92727,216716,25261,89962,214886------- f. Decoded information of (e)
Y= Hospital: SS Hitech Health care Doctor In charge: Dr. Sanjay S Name of the Patient: Kavitha K J Date Of Birth: 19/02/1982 Age: 36 years Date of Admission: 19/07/2018 Patient ID: SS_IP_54786_022018 Health Issue: Leg fracture below the ankle Precaution: Rest for 3-weeks g. Reconstructed message	

TABLE II. RESULTS OF WM EMBEDDING AND EXTRACTION PROCESS

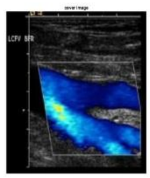
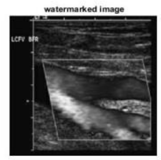
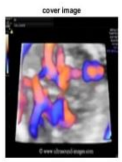
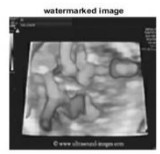
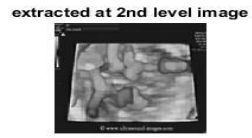
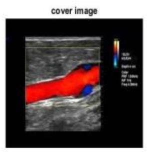
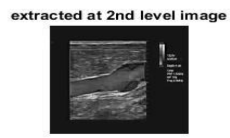
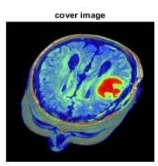
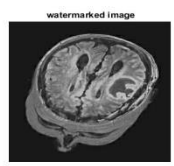
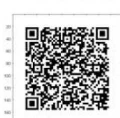
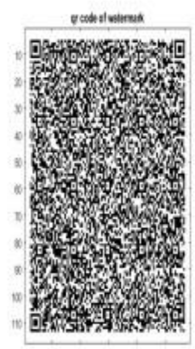
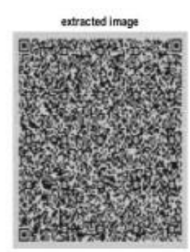
Type of image	***Cover Image***	***Invisible watermark***	***Reconstructed MI***
2-D US			
3-D US			
2-D MRI			
3-D MRI			
WM1, WM2 & WM3	**QR watermark**	**Concatenated watermark**	**Extracted watermark**
File Edit Format View Help Hospital: SS Hitech Hospital Doctor Incharge: Dr. Sanjay S Patient ID:SS_IP_547896_022018 Name: Kavitha K J DOB:19-02-1982 Age:36 years Date of Admission:02-02-1986 Health Issue: Pain_hand_ankle Severeness:Medium Precaution: Do not hold heavy load 	  		

TABLE III. EVALUATION AND COMPARISON OF THE PROPOSED SYSTEM FOR A SINGLE KEY

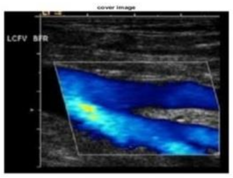
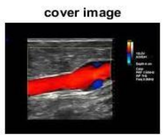
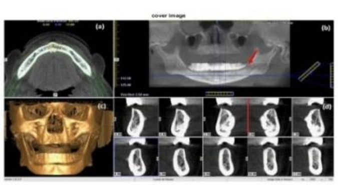
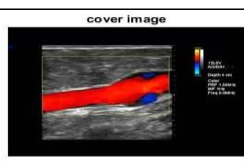
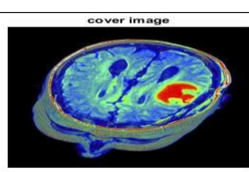
Type of MI	Results of Proposed system with encoding & encryption	IWT-SVD without encoding & encryption	Bit-plane Method	DWT-SVD
	PSNR= 79.117 MSE= 0.0038 NCC= 0.9961 NAE= 0.3549	PSNR= 79.117 MSE= 0.0038 NCC= 0.9961 NAE= 0.3549	PSNR= 49.248110 MSE= 0.8827 NCC= 0.4413 NAE= 0.6315	PSNR= 44.9961 MSE= 2.097 NCC=0.8762 NAE= 0.9810
	PSNR= 75.1518 MSE= 0.0056 NCC= 0.9890 NAE= 0.3559	PSNR= 75.1518 MSE= 0.0056 NCC= 0.9890 NAE= 0.3559	PSNR= 47.677981 MSE= 1.0576 NCC= 0.6976 NAE= 0.7476	PSNR= 44.8512 MSE=2.145 NCC= 0.8903 NAE= 0.9891
	PSNR= 74.0176 MSE= 0. 0061 NCC= 0.9874 NAE=0.03612	PSNR= 74.0176 MSE= 0. 0061 NCC= 0.9874 NAE=0.03612	PSNR= 48.224884 MSE= 0.9970 NCC= 0.6976 NAE= 0.6945	PSNR= 45.004 MSE= 2.070 NCC= 0.8967 NAE= 0.8612
	PSNR= 77.3791 MSE= 0.00581 NCC= 0.9880 NAE= 0.03653	PSNR= 77.3791 MSE= 0.00581 NCC= 0.9880 NAE= 0.03653	PSNR= 54.8284 MSE= 0.8702 NCC= 0.8676 NAE= 0.7951	PSNR= 45.0682 MSE= 2.040 NCC= 0.899 NAE= 0.8524
	PSNR= 73.613 MSE= 0.0072 NCC= 0.9752 NAE= 0.03721	PSNR= 73.613 MSE= 0.0072 NCC= 0.9752 NAE= 0.03721	PSNR= 55.4684 MSE= 0.8920 NCC= 0.7987 NAE= 0.8211	PSNR= 44.7503 MSE= 2.195 NCC= 0.8941 NAE= 0.7853
	PSNR= 74.613 MSE= 0.00260 NCC= 0.9652 NAE= 0.03721	PSNR= 74.613 MSE= 0.00260 NCC= 0.9652 NAE= 0.03721	PSNR= 52.132 MSE= 0.8672 NCC= 0.7852 NAE= 0.7217	PSNR= 42.113 MSE= 2.7214 NCC= 0.7952 NAE= 0.7291
	PSNR= 72.0173 MSE= 0.0142 NCC= 0.9321 NAE= 0.03721	PSNR= 72.0173 MSE= 0.0142 NCC= 0.9321 NAE= 0.03721	PSNR= 53.161 MSE= 0.7275 NCC= 0.6752 NAE= 0.721	PSNR= 43.263 MSE= 2.6525 NCC= 0.6092 NAE= 0.7721

TABLE IV. SSIM, PSNR AND MSE VALUES FOR 20 SECRET KEYS

Keys	SSIM	PSNR	MSE
1	0.9967	75.004	0.070
2	0.9905	74.949	0.096
3	0.997	78.996	0.074
4	0.9908	77.880	0.130
5	0.9889	76.750	0.195
6	0.9938	79.011	0.066
7	0.9920	80.843	0.148
8	0.9990	81.814	0.162
9	0.9963	77.004	0.070
10	0.9031	82.866	0.137
11	0.9412	81.019	0.063
12	0.9913	79.926	0.108
13	0.9962	78.941	0.100
14	0.9895	77.736	0.202
15	0.9859	80.821	0.159
16	0.9933	79.063	0.040
17	0.9899	82.949	0.097
18	0.9920	78.851	0.145
19	0.9974	79.934	0.104
20	0.9877	80.996	0.074

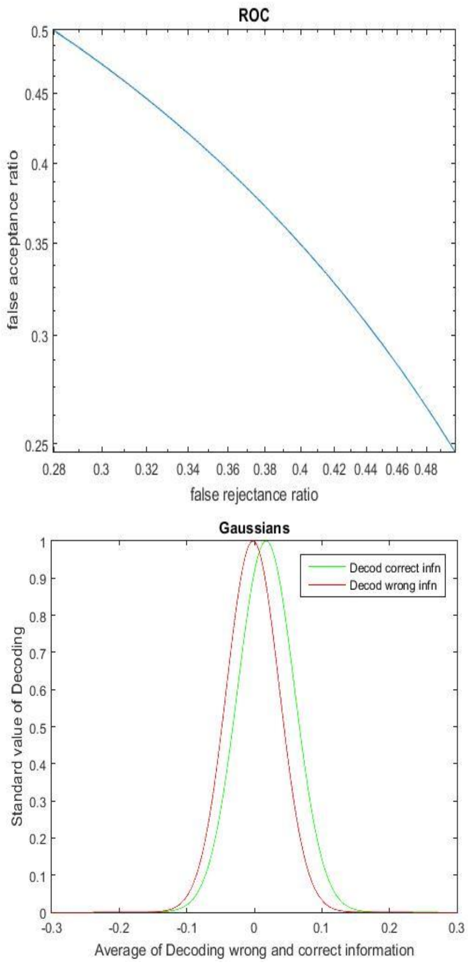


Fig .6. False Acceptance & Rejection, Average of Decoding Wrong And Correct Information.

TABLE V. FALSE POSITIVE AND FALSE NEGATIVE VALUE FOR 20 KEYS

Keys	Pfa	Pfr
1	0.5	0.320
2	0.489	0.329
3	0.478	0.338
4	0.468	0.347
5	0.458	0.356
6	0.447	0.365
7	0.437	0.374
8	0.426	0.384
9	0.416	0.393
10	0.406	0.403
11	0.396	0.412
12	0.385	0.422
13	0.375	0.431
14	0.365	0.441
15	0.356	0.451
16	0.346	0.460
17	0.336	0.470
18	0.327	0.480
19	0.317	0.490
20	0.308	0.5

TABLE VI. EVALUATION OF THE PROPOSED SYSTEM AGAINST VARIOUS ATTACKS

Various attacks	PSNR(db) for Attacked watermarked image & Original watermarked image	
JPEG ATTACK	**69.27**	
MEDIAN FILTER	**Filter size**	
	[3 3]	84.7833
	[6 6]	77.5902
	[10 10]	75.514
WEINER FILTER	[3 3]	78.7029
	[6 6]	77.9213
	[10 10]	77.2466
GAUSSIAN FILTER	Q=0.5	91.93
	[3 3]	
	[6 6]	88.997
	[10 10]	78.997
PEPPER & SALT	71.3563	
SHARPEN	72.3563	
ROTATION WITH ±90°	71.099	

F. Conclusion

In the proposed work, robust blind reversible DWM technique has developed which includes 3-level security. The main idea behind this technique is to protect the original patient's information from third parties. In this methodology, one may not be easily able to identify the information as it ensures three stages of security level viz.; extraction & decoding the information from QR code followed by decryption and decoding processes. Moreover the system shows more robustness against various attacks and the quality of the MI is maintained even for large data payload.

In a single QR code a maximum of 3KB of data may be embedded and hence a new method of storing maximum data and thus reducing the data payload is to be found in future.

REFERENCES

[1] M. Malonia et.al "Digital Image Watermarking using Discrete Wavelet Transform and Arithmetic Progression technique," *2016 IEEE Students' Conference on Electrical, Electronics and Computer Science (SCEECS),* Bhopal, 2016, pp. 1-6.

[2] C. Zhang, et.al, "Digital Image Watermarking Algorithm with Double Encryption by Arnold Transform and Logistic," *2008 Fourth International Conference on Networked Computing and Advanced Information Management,* Gyeongju, 2008, pp. 329-334.

[3] C. Su, J. Huang, C. Shih, and Y. Chen, "Reversible and Embedded Watermarking of Medical Images for Telemedicine," pp. 145–150, 2015.

[4] Kavitha K. J, Shan P., An efficient medical image watermarking technique using integer wavelet transform and quick/fast response codes,(InPress),IJISTA,Inderscience publication.

[5] J. Chen, W. Chen, and C. Chen, "Identification Recovery Scheme using Quick Response (QR) Code and Watermarking Technique," vol. 596, no. 2, pp. 585–596, 2014.

[6] C. Engineering and C. Engineering, "a security technique based on watermarking and encryption FOR," pp. 3–6, 2015.

[7] Y. Guo, et.al, Optimised blind image watermarking method based on firefly algorithm in DWT-QR transform domain. *IET Image Processing*, 2017 June, 11(6), pp. 406-415.

[8] Kavitha K. J, Shan P. B. Joint Digital Water Marking for Medical Images for Improving Security. Biomed Pharmacol J 2018;11(2),pp.863-870.

[9] Maity, et.al, Robust and Blind Spatial Watermarking In Digital Image. *ICVGIP*. 2002.

[10] Alirezanejad, et.al. Improving the performance of spatial domain image watermarking with high boost filter. *Indian Journal of Science and Technology* ,2014,7(12),pp. 2133.

[11] Lee, et.al, Analysis of Attacks on Common Watermarking Techniques. IEEE, Electrical and Computer Engineering Department University of British Columbia, Canada V6T1Z4.

[12] Sarkar, et.al, Digital Watermarking Techniques in Spatial and Frequency Domain. *arXiv preprint arXiv: 1406.2146* (2014).

[13] Z. Nana, Watermarking algorithm of spatial domain image based on SVD. *2016 International Conference on Audio, Language and Image Processing (ICALIP),* Shanghai, 2016, pp. 361-365.

[14] Chun-Shien et.al, Media hash-dependent image watermarking resilient against both geometric attacks and estimation attacks based on false positive-oriented detection. *IEEE Transactions on Multimedia*, 2006 August, 8(4), pp. 668-685.

[15] K. J. Kavitha and B. P. Shan, Implementation of DWM for medical images using IWT and QR code as a watermark, 2017 Conference on Emerging Devices and Smart Systems (ICEDSS),doi={10.1109/ICEDSS.2017.8073698},pp.252-255.

AUTHOR'S PROFILE

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Dr. Priestly B Shan, presently working as Principal,Eranad Knowledge City-Technical Campus, Manjeri, Kerala. He also worked as a Dean in Royal College of Engineering,India, as a Professor in AmalJyothi College of Engineering, Kottayam, India,StJosephs College of Engineering, India and Muthayammal Engineering College. He got his Master degree fom Anna University,India and Philosophy of Doctorate in the field of Medical Imaging from Anna University in the year 2010,Chennai,tamilanadu.He has also done Msc Applied Psychology, Psychology from Bharathidasan University. He was IEEE member and Life Member in ISTE, IETE and IACSIT. He has also accomplished a research project on 4D ultra sound.

A Hybrid Background Subtraction and Artificial Neural Networks for Movement Recognition in Memorizing Quran

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***Abstract*—Movement change beyond the duration of time and the variations of object appearance becomes an interesting topic for research in computer vision. Object behavior can be recognized through movement change on video. During the recognition of object behavior, the target and the trace of an object in a video must be determined in the sequence of frames. To date, the existence of object on a video has been widely used in different areas such as supervision, robotics, agriculture, health, sports, education, and traffic. This research focuses on the field of education by recognizing the movement of Quantum Maki Quran memorization through a video. The purpose of this study is to enhance the existing computer vision technique in detecting the Quantum Maki Quran memorization movement on a video. It combines the Background Subtraction method and Artificial Neural Networks; and evaluates the combination to optimize the system accuracy. Background Subtraction is used as object detection method and Back propagation in Artificial Neural Networks is used as object classification. Nine videos are obtained by three different volunteers. These nine videos are divided into six training and three testing data. The experimental result shows that the percentage of accuracy system is 91.67%. It can be concluded that there are several factors influencing the accuracy, such as video capturing factors, video improvements, the models, feature extraction and parameter definitions during the Artificial Neural Networks training.**

Keywords*—Movement recognition; computer vision; Quran memorization movement; background subtraction; back propagation; artificial neural networks

I. Introduction

Computer vision has been subject to excel in the world of research and development of information technology industry. The change in movement beyond the duration of time and variations in the appearance of an object becomes an interesting topic to study in today's computer vision. The movement changes of the objects are supposed to be able to be detected and recognized by an advance system. This recognition is useful to understand the object movement behavior through a video camera. To detect moving objects on a video, the target and trace of objects must be determined in a sequence of video frames.

There are some important obstacles to consider for detecting objects on a video, such as the appearance of a background or another object that is similar to the focus of objects [1], the shadows on top of the focus of the object, and noise caused by several highlights [2]. Despite these obstacles, the object recognition technique on a video has been widely used in several fields, such as supervision [3], robotics [4], [5], agriculture [6], health [7], sports [8], education [9], and traffic [10]. This research is proposed to contribute in the field of education.

Most object movement detection techniques on a video use Background Subtraction method, the combination of it or the modified one. In total, we found that there are at least 30 references; one of them is [11] that uses a method with an optimal result of object detection. There are other methods that we found in the literature such as Feature Extraction [7], [12], Histogram of Oriented Gradients [13], [14], Neural Networks [15], [16], Face Detection Module [17], Fuzzy Inference System [18], Naïve method [9], Probabilistic method [19], Directed Acyclic Graph [20] with various results of object detection.

Object analysis means classifying objects based on their behavior. Objects can be classified by various techniques, such as matching the pattern [3], [21], system learning and Artificial Neural Networks [22], control comparison and fuzzy logic [23], and others. The Artificial Neural Networks is considered as the best technique, since it can adapt and learn better when environment changes.

To the best of our knowledge, the study that uses Background Subtraction method as object detection method and Artificial Neural Networks as object classification method is rare. There is only one related study [24] that combines these two methods. However, the study concludes that the accuracy of the proposed system is 84.6%. The result contradicts with the theoretical textbook [25] which requires the minimum accuracy of the system in Artificial Neural Networks with Back Propagation algorithm to be 90%. We argue that the increase of the accuracy may serve to fill the gap.

Quran is the holy book for Muslim. It is the source of truth and guidance to human life (Chapter *Al-Baqoroh*: 2) [26]. For this reason, Muslims has complete obligations to practice the contents of the Quran. To ease the practice, it is suggested to memorize the contents as much as possible. There are some techniques in memorizing Quran used by Huffadz, i.e. a person who memorize Quran. The memorization is believed to start from the creation of Prophet Adam (Chapter *Al-Baqoroh*: 31) [26]. Nowadays, there are many methods that can be chosen in memorizing Quran. One of the methods is the sign method which is innovated by Huffadz who emphasizes in memorizing in different ways. The famous example of sign method is the Quantum Maki. Quantum Maki uses body movements to translate the meaning of the Quran verses word by word. Due to the nature of Quantum Maki method, we believe that it can be improved by computer vision.

This research aims at achieving system accuracy above 90% by combining two methods in order to better recognize the memorization of the Quantum Maki Quran. To achieve the goal, it is required that the distribution of data uses the hold-out method which has 70% training data and 30% test data. This method is important for stratified random sampling which randomizes data to produce proportional training and test data used in this research.

To speed up the process, however, this research is limited to the use of one chapter in Quran, namely *Al-Ikhlas* and the detected movement for memorizing Quran is in a standing position. Another limitation of this research is that the image is automatically cropped with predetermined size to standardize the process, although the consequence is that it is difficult to obtain specific parts from particular object for everyone. Moreover, the reliability of the data sets is important for movement recognition in memorizing Quran. Hence, this research uses a green color background to accommodate colorful video recognition in mp4 format.

II. THEORITICAL FRAMEWORK

Background subtraction is a method to seek particular objects in an image by comparing existing images with a background model. Modeling the background subtraction is sensitive to object motion recognition. Background subtraction detects any objects by separating background and moving foreground objects; which is computed by using the formula in

$$R(x,y) = I(x,y) - B(x,y) \tag{1}$$

Where R is the result of background separation, I is an object that is explored in position change, and B is the object background.

During the movement recognition, the Background Subtraction method is used as object detection and Artificial Neural Network is used as object classification. There are two features to represent the movement of objects during the memorization that involves body and hand movements. They are metric and eccentricity. Metric is a quantity that represents the roundness of particular object and eccentricity is the ratio calculation between two axes; i.e. major and the minor axis, in the shape of the object. In addition, the movement is recorded as a video before processed into the system.

Although the background subtraction method is considered as suitable for separating the background with moving objects, there is a possibility of another moving object or the shadow of the object that is detected as a foreground. The basic idea of this method is |frame (n) - background| > threshold. If there is a pixel n (the shadow of the object) that meets the equation, then the pixel is classified into a group of pixel objects, whereas the others are considered as background.

Artificial Neural Networks is a well-known artificial intelligence technique based on the mechanism of human neural networks. It is formulized by modeling human neural networks in mathematical formula with the three basic assumptions. First, the information is processed within several elementary neurons as elements. Second, the signals of information flow in and out through the path between neurons. This path is called connectors. Third, the connection between two neurons is given a weight that strengthens or weakens the signal.

The output is obtained from neuron by calculating activation function. This function; which is usually not a linear function, is computed based on the summation of the received inputs. A threshold is utilized to compare the amount of output. The structure of Artificial Neural Networks is conceptually represented in Fig. 1.

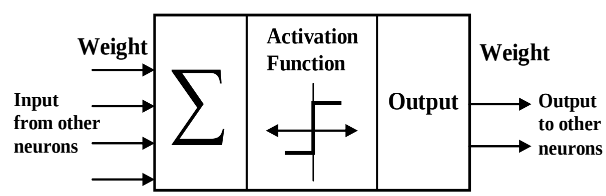

Fig. 1. Artificial Neural Networks Structure.

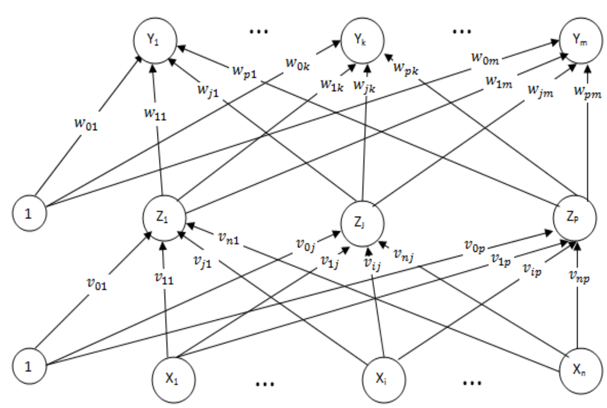

Fig. 2. Back Propagation Subtraction Process.

Back propagation is one of the algorithms in Artificial Neural Networks. This algorithm is commonly used to change the weights connected to neurons in the hidden layer. Back propagation uses an output error to change its weight in backward direction [25].

Back propagation has several units in one or more hidden layers. Fig. 2 illustrates the back propagation architecture with *n* input pieces (plus a bias), a hidden layer consisting of *p* units (plus a bias), and an output unit.

A. *The Sign Movement of Quantum Maki*

The Quantum Maki is a sign movement in memorizing Quran by exploiting human body, mainly by using hand movement. This movement is developed by a husband and wife Huffadz, who successfully memorized the whole chapters of Quran, in accordance with Chapter *An-Nahl* verse 78 and Chapter *Yaasiin* verse 65 [26].

This movement is slightly different from BISINDO [27] and considerably different from SIBI [28]. The main difference is that the Quantum Maki movement does not only use hand movements, but also other limb movements in particular circumstances. For an example, to illustrate the word *al-aqdaam* is by patting the foot with both hands. Basically, the Quantum Maki is based on a movement that generally represents the meaning of the Quran verse. To illustrate the movement, several examples are captured in Fig. 3.

In general, each word in Quran verse has its own meaning and movement. However, there are several verses that are too long to memorize by using the movement. In order to facilitate the memorization, one movement is used. Additionally, to understand and remember the movement easily, general movements are repeated for other verses. For an example, the word *robbi* in the phrase of *birobbil falaq* is indicated by the hand up. In any verses and chapters, the movement for the word *robbi* remains the same.

Fig. 3. The use of Sign Movement of Quantum Maki.

III. METHODOLOGY

To streamline the research, a conceptual methodology is required. Fig. 4 shows the methodology of the research which is divided into two stages. The first stage is data collection which starts from interviewing the creator of the movement to get the sample data from the primary source and to validate the result of the experiments.

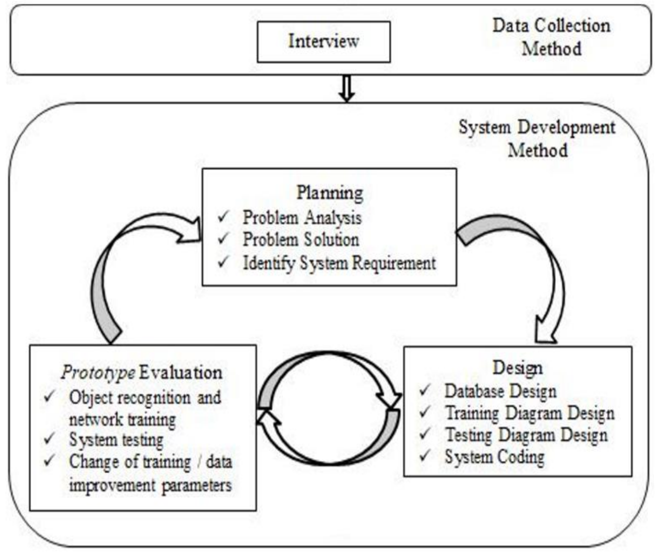

Fig. 4. Research Methodology.

The second stage is system development which emphasizes on the prototyping method to speed up the coding. To achieve the minimum value of error, the prototype is tested several times and its parameter is modified.

The training and testing diagrams are designed to detail system development. Fig. 5 shows training process diagram, while Fig. 6 shows testing process diagram. Several processes in these two diagrams are the same. For each process, the discussion is provided together with the result of its implementation to ease the understanding.

The training and testing diagrams start from video capturing which is conducted by three volunteers with a standing position. The result is inputted into the system together with its attributes, such as video dimension, frames, and duration. In background subtraction, object and background are separated through the following processes:

1) *Frame separation*: It is the process of separating each frame on a video in seconds. Frame attributes are separated and adjusted based on video duration.

2) *Image sequen*ce: It is the process of separation between objects and background. The selected object is used to process the segmentation, while the background is ignored. The RGB values of each frame are converted to HSV and their binary digit values are converted with XOR to eliminate negative value in truth table. The result is gray scale that is then transformed into binary digits by using the formula in

$$Binary(i,j) = \begin{cases} 1, & if\ Gray(i,j) > 0 \\ 0, & if\ Gray(i,j) < 0 \end{cases} \tag{2}$$

3) *Noise removal*: It is the process of removing noise on the object that is already separated from the background by using Median Filter formula, as in

$$f(x,y) = \underset{(s,t)\in S_{xy}}{\text{median}} \{g(s,t)\} \tag{3}$$

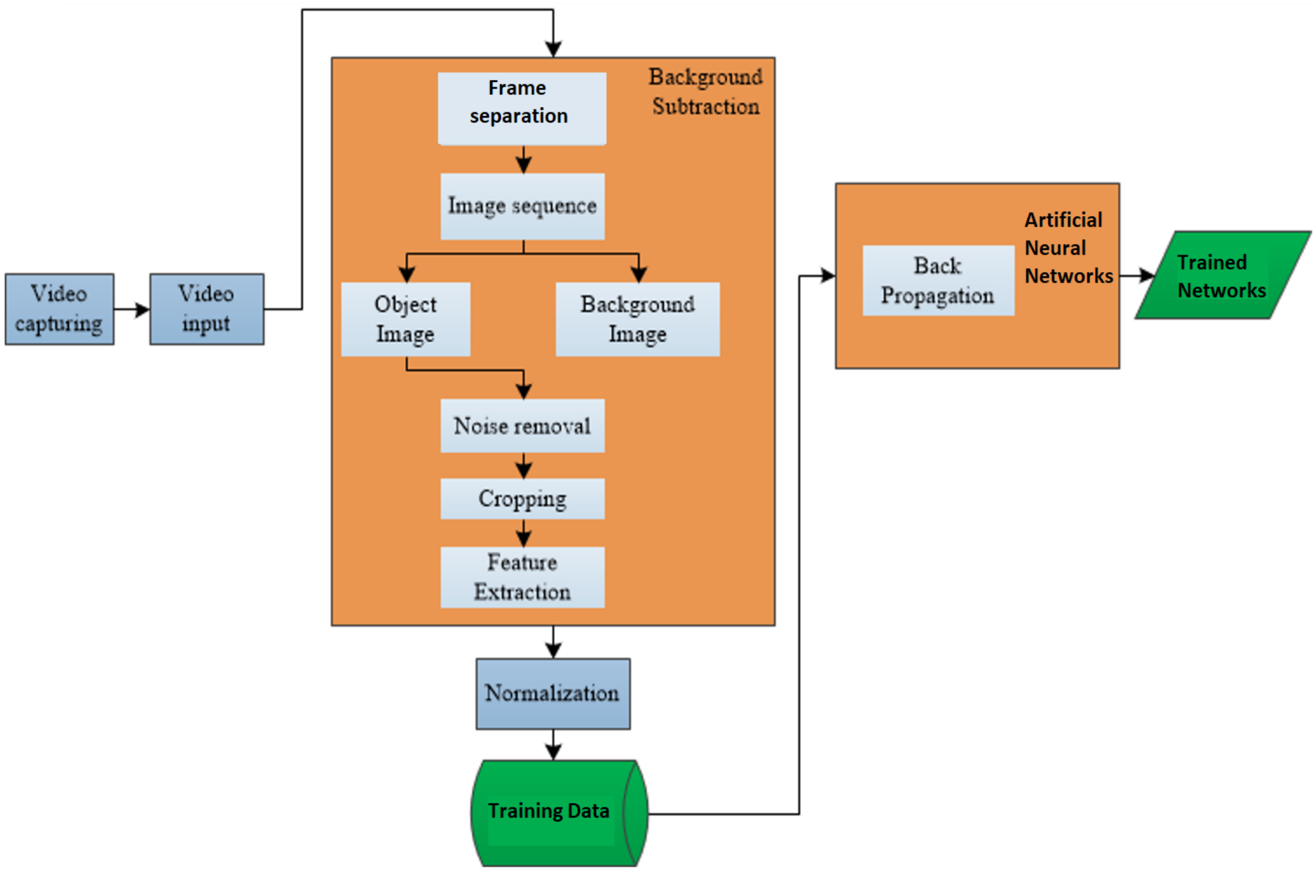

Fig. 5. Training Process Diagram.

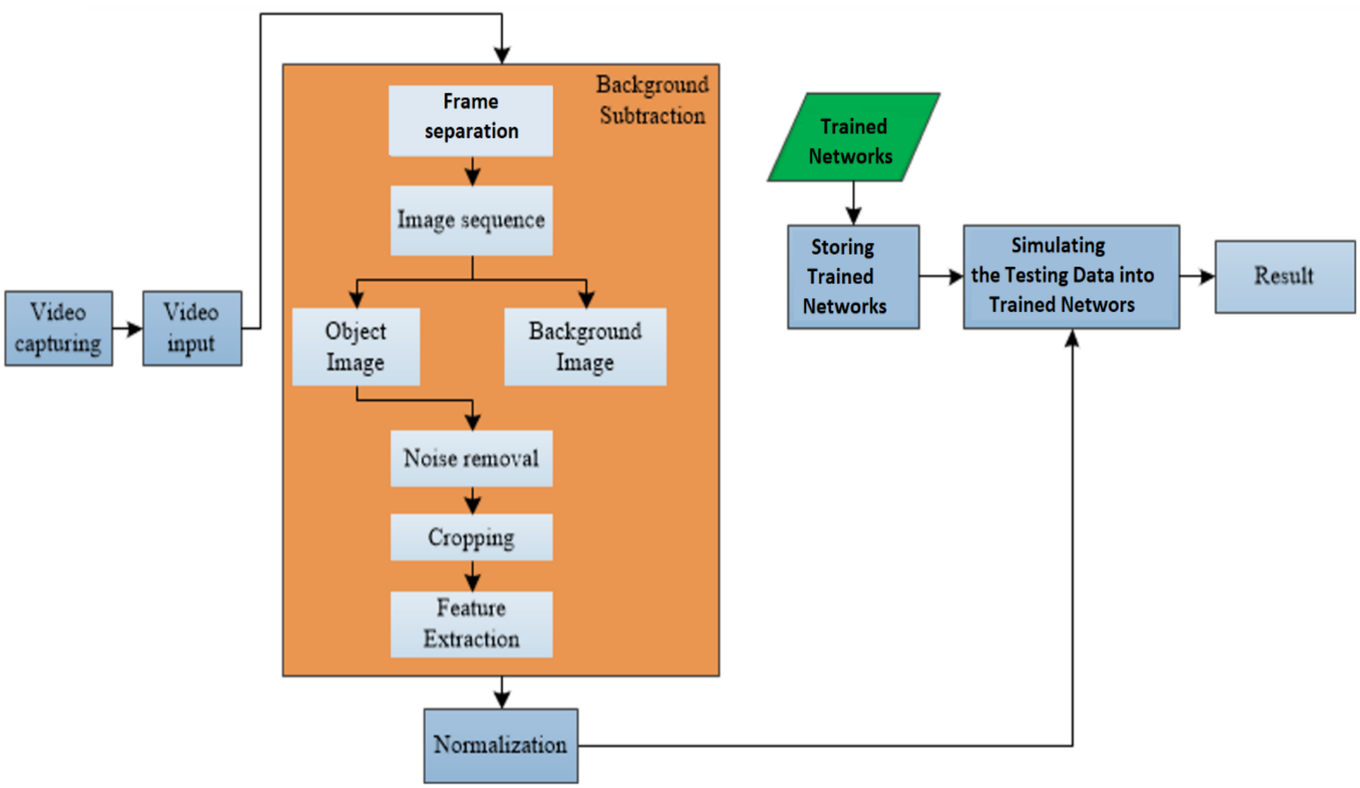

Fig. 6. Testing Process Diagram.

4) Cropping: It is an automatic process of taking specific parts from particular object. This research uses an arbitrary cropping size of 170x170 pixels to automate and speed up the whole process.

5) Feature extraction: It is a process of taking features from particular object. There are two features used in this paper: Metric and Eccentricity; which are also used in [29]. The mathematical equation for the Metric feature extraction is represented in

$$M = \frac{4\pi * A}{P^2} \tag{4}$$

Where M is metric value, A is object area, and P is object size.

The equation of Eccentricity feature extraction is in

$$e = \sqrt{1 - \left(\frac{b}{a}\right)^2} \tag{5}$$

Where e is eccentricity value, a is length of major ellipse foci, and b is length of minor ellipse foci.

The sample result of Background Subtraction processing is illustrated in Fig. 7.

Normalization is the process of normalizing the value of object features. The average value of the two features are selected and calculated by using the formula in

$$\bar{X}(m) = \frac{\sum fe(m)}{N} \tag{6}$$

Where m is a feature (*metric* and *eccentricity*), $\bar{X}(m)$ is a feature value in each frame, $\sum fe(m)$ is the number of feature value in each frame, and N is the number of frame.

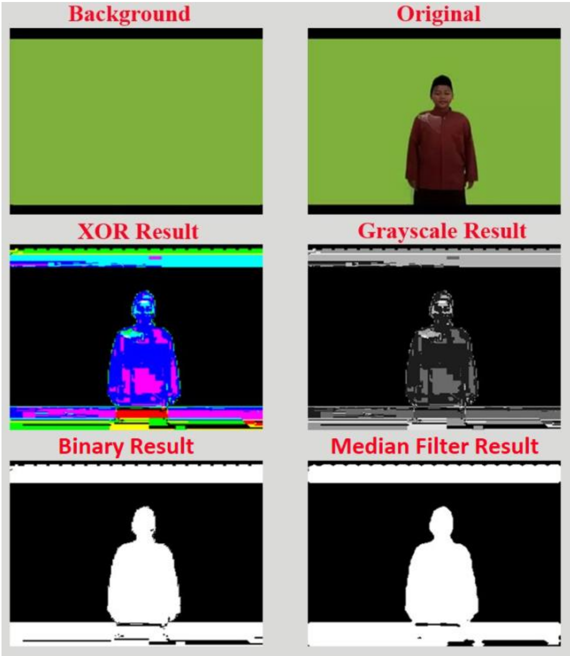

Fig. 7. Background Subtraction Output in One Frame.

IV. Evaluation and Discussion

Artificial Neural Networks is the process of training and dataset classification which leads to be recognized by the system. Back Propagation is the algorithm that is used for training. There are nine videos available in this research. Six videos are used as training data and three videos used as testing data. The training data that have been processed are shown in Table I. The training parameters of the Artificial Neural Network used in this research are shown in Table II.

TABLE I. Input Value, Target Data and Training Data

Data	Target	1	2	3	4
1	*Metric*	0.5707734	0.4466702	0.5800725	0.5115093
	Eccentricity	0.8088200	0.7554581	0.7944091	0.7990654
2	*Metric*	0.5794906	0.4797728	0.5774935	0.5159322
	Eccentricity	0.8088360	0.7408384	0.7875225	0.7850985
3	*Metric*	0.5381068	0.4471097	0.5383233	0.4761612
	Eccentricity	0.7825329	0.7473362	0.7395582	0.7372278
4	*Metric*	0.5968912	0.4525911	0.5808415	0.5124966
	Eccentricity	0.8125884	0.7575972	0.7982806	0.7947707
5	*Metric*	0.5757907	0.4296351	0.5949379	0.5151999
	Eccentricity	0.8064739	0.7075989	0.7908770	0.7864578
6	*Metric*	0.5393527	0.4505028	0.5338850	0.4326231
	Eccentricity	0.7798373	0.7489395	0.7397976	0.7162581
Attribute	Verse	One	Two	Three	Four
	Meaning	Say, "He is Allah, [who is] One,	Allah, the Eternal Refuge.	He neither begets nor is born,	Nor is there to Him any equivalent

TABLE III. PARAMETERS OF BACK PROPAGATION TESTING

Parameter Name	Values
Hidden Layer	24
Looping (Epoch)	11500
Learning Rate	0.05
Error Value	0

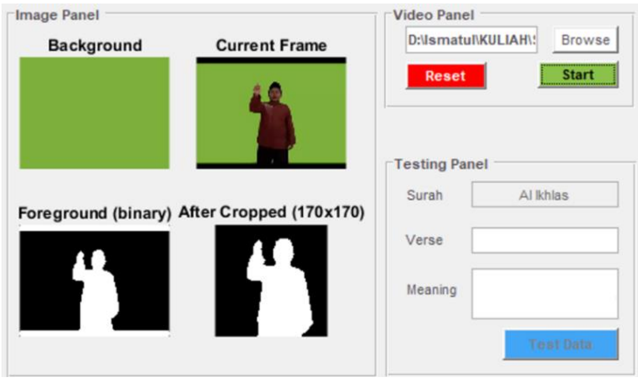

Fig. 8. Trial Process Interface.

The trial process has the same steps as the training process has. However, the normalized data are required to be simulated to the network. Fig. 8 shows the interface of the developed system to accommodate the trial process. The result is divided into current frame, background, foreground in binary, and after cropped image. This interface enables users to evaluate the trial result effectively. The trial results of other six testing data are available in Table III.

All testing data for each movement are tested into a network that has been previously trained. The trial was done 12 times with 11 movements were correctly detected and one movement was incorrectly detected. In other words, the percentage of accuracy system in detecting the Quantum Maki Quran memorization movement is 91.67%. The accuracy percentage is calculated by using the equation in

$$accuracy = \frac{amount\ of\ correct\ test\ data}{amount\ of\ test\ data}\ x\ 100\% \qquad (7)$$

The equation is generally used by other existing works. Hence, it is not required to replicate and compare the experiment from other existing works. This is also because the implementation of this research is different from others in term of its unique requirement and process.

V. CONCLUSION

Detecting the movement during Quantum Maki Quran memorization has three main processes, namely the introduction of objects (Background Subtraction), the training of Artificial Neural Networks (Back Propagation) and the trial process.

The trial process is used to seek the accuracy of the system in recognizing the movement of Quran memorization on the data demonstrated by three different volunteers. The system accuracy results in 91.67% that fulfils the minimum requirement for Artificial Neural Networks. Several factors are considered as influencing the accuracy, such as video capturing, models demonstration, video editing, feature extraction, and Artificial Neural Networks parameters.

The future works include more detected object movements in memorizing the Quantum Maki Quran. It is also suggested to use other methods such as Gaussian Filter to detect the movement in memorizing the Quantum Maki Quran as comparison, to use other extraction features that are adapted to the complexity of the Quantum Maki Quran memorization movement, to compare the accuracy of the Background Subtraction method with other methods, to use other algorithms of training to classify the movement of objects in memorizing the Quantum Maki Quran, to group similar movements to identify better. There is also an expectation to include more chapters in Quran to improve the reliability of the system.

TABLE IV. TESTING DATA TRIAL RESULT

No	**Video Name**	**Movement**	**Input**		**Trial Output**	**Result**
			Metric	*Eccentricity*		
1	Faris-capture-1.mp4	1	0.5807734	0.8088200	0.9470	verse-1
		2	0.4466702	0.7554581	2.0296	verse-2
		3	0.5800725	0.7944091	3.1292	verse-3
		4	0.5115093	0.7990654	3.9514	verse-4
2	Mizar-capture-1.mp4	1	0.5794906	0.8088360	0.8730	verse-1
		2	0.4797728	0.7408384	2.1135	verse-2
		3	0.5774935	0.7875225	3.0652	verse-3
		4	0.5159322	0.7850985	3.9589	verse-4
3	Azzam-capture-1.mp4	1	0.5381068	0.7825329	0.7156	verse-1
		2	0.4471097	0.7473362	1.8845	verse-2
		3	0.5383233	0.7395582	3.1824	verse-3
		4	0.4761612	0.7372278	2.0850	verse-2

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REFERENCES

[1] M. Tiwari, “A Review of Detection and Tracking of Object from Image and Video Sequences,” Int. J. Comput. Intell. Res., vol. Volume 13, pp. 745–765, 2017.

[2] R. kishor Gupta, “Object Detection and Tracking in Video Image,” National Institute of Technology Rourkela, 2014.

[3] J. Qu, Z. Liu, and W. He, “Video Pedestrian Detection Based on Orthogonal Scene Motion Pattern,” Math. Probl. Eng., vol. 2014, no. 1, p. 8, 2014.

[4] H.-B. Zhang, F. Guo, M. Zhang, Y. Lin, and T.-C. Hsiao, “Human motion correction and representation method from motion camera,” J. Eng., vol. 2017, no. 7, pp. 370–375, 2017.

[5] A. S. Prabuwono, M. A. Burhanuddin, and S. M. Said, “Autonomous contour tracking using staircase method for industrial robot. In Control, Automation,” Robotics and Vision, 2008. ICARCV 2008. 10th International Conference on, pp. 2272-2276. IEEE, 2008.

[6] P. Christiansen, L. N. Nielsen, K. A. Steen, R. N. Jørgensen, and H. Karstoft, “DeepAnomaly: Combining Background Subtraction and Deep Learning for Detecting Obstacles and Anomalies in an Agricultural Field,” Sensors (Switzerland), vol. 16, no. 11, p. 21, 2016.

[7] X. Yang, X. Niu, Z. Liu, Y. Zhao, G. Zhang, W. Liang, and W. J. Li, “Accurate extraction of the self-rotational speed for cells in an electrokinetics force field by an image matching algorithm,” Micromachines, vol. 8, no. 9, p. 17, 2017.

[8] H. Tian, and W. X. Jun, “Sensors & Transducers Study on the Detection of Moving Target in the Mining Method Based on Hybrid Algorithm for Sports Video Analysis,” vol. 181, no. 10, pp. 16–22, 2014.

[9] G. N. Rao, P. Jagadeeswara Rao, R. Duvvuru, S. Bendalam, and R. Gemechu, “An Enhanced Real-Time Forest Fire Assessment Algorithm Based on Video by Using Texture Analysis,” Perspect. Sci., vol. 8, pp. 618–620, 2016.

[10] N. Yaghoobi Ershadi and J. M. Menéndez, “Vehicle Tracking and Counting System in Dusty Weather with Vibrating Camera Conditions,” J. Sensors, vol. 2017, p. 9, 2017.

[11] I. Vujović and I. Kuzmanić, “Wavelet Energy and The Usefulness of its Powers in Motion Detection,” Adv. Electr. Comput. Eng., vol. 17, no. 2, pp. 61–70, 2017.

[12] G. Yao, T. Lei, J. Zhong, P. Jiang, and W. Jia, “Comparative Evaluation of Background Subtraction Algorithms in Remote Scene Videos Captured by MWIR Sensors,” Sensors, vol. 17, no. 9, 2017.

[13] H. Tian, and W. X. Jun, “Sensors & Transducers Study on the Detection of Moving Target in the Mining Method Based on Hybrid Algorithm for Sports Video Analysis,” Sensors & Transducers, vol. 181, no. 10, pp. 16–22, 2014.

[14] A. P. Dias, M. F. Silva, and R. Guedes, “Identification of Marks on Tires Using Artificial Vision for Quality,” International Journal for Quality Research, 2015.

[15] R. Tapu, B. Mocanu, and T. Zaharia, “DEEP-SEE: Joint Object Detection, Tracking and Recognition with Application to Visually Impaired Navigational Assistance,” Sensors, vol. 17, no. 11, p. 2473, 2017.

[16] N. Shu, Z. Gao, X. Chen, and H. Liu, “Computational Model of Primary Visual Cortex Combining Visual Attention for Action Recognition,” PloS one, vol. 10, no. 7, 2015.

[17] A. K. Skelin, T. G. Supuk, and M. Bonkovic, “Visual Peoplemeter: A Vision-Based Television Audience Measurement System,” Adv. Electr. Comput. Eng., vol. 14, no. 4, pp. 73–80, 2014.

[18] J. Ren, Y. Chen, L. Xin, and J. Shi, “Lane Detection in Video-Based Intelligent Transportation Monitoring via Fast Extracting and Clustering of Vehicle Motion Trajectories,” Math. Probl. Eng., vol. 2014, p. 12, 2014.

[19] R. I. Hammoud, C. S. Sahin, E. P. Blasch, B. J. Rhodes, and T. Wang, “Automatic Association of Chats and Video Tracks for Activity Learning and Recognition in Aerial Video Surveillance,” Sensors (Switzerland), vol. 14, no. 10, pp. 19843–19860, 2014.

[20] S. Mangale, R. Tambe, and M. Khambete, “Object Detection and Tracking in Thermal Video Using Directed Acyclic Graph (Dag),” ICTACT J. Image Video Process., vol. 8, no. 1, pp. 1566–1574, 2017.

[21] N. A. Mailani, and V. Amrizal, “Comparative Analysis of the Accuracy of Backpropagation and Learning Vector Quantisation for Pattern Recognition of Hijaiyah Letters,” IEEE 6th Int. Conf. Inf. Commun. Technol. Muslim World, 2016.

[22] A. A. Mol, L. S. Martins-Filho, J. D. S. da Silva, and R. Rocha, “Efficiency parameters estimation in gemstones cut design using artificial neural networks,” Comput. Mater. Sci., vol. 38, no. 4, pp. 727–736, 2005.

[23] A. H. Aghamohammadi, A. S. Prabuwono, S. Sahran, and M. Mogharrebi, “Solar cell panel crack detection using particle swarm optimization algorithm,” Pattern Analysis and Intelligent Robotics (ICPAIR), 2011 International Conference on, vol. 1, pp. 160-164. IEEE, 2011.

[24] E. Khoramshahi, J. Hietaoja, A. Valros, J. Yun, and M. Pastell, “Real-time recognition of sows in video: A supervised approach,” Inf. Process. Agric., vol. 1, no. 1, pp. 73–81, 2014.

[25] R. J. Schalkoff, Artificial Neural Networks. New York: McGraw-Hill, 1997.

[26] M. T. U. D. Al-Hilali, and M. M. Khan, Translation of the Meanings of the Noble Quran in the English Language. King Fahd Complex for the Printing of the Holy Qur’ãn, 2018.

[27] T. Handhika, R. I. M. Zen, D. P. Lestari, and I. Sari. "Gesture recognition for Indonesian Sign Language (BISINDO)," Journal of Physics: Conference Series, vol. 1028, no. 1, p. 012173. IOP Publishing, 2018.

[28] A. Rahagiyanto, A. Basuki, and R. Sigit, “Moment Invariant Features Extraction for Hand Gesture Recognition of Sign Language based on SIBI,” EMITTER International Journal of Engineering Technology, vol. 5, no. 1, pp.119-138, 2017.

[29] J. J. Athanesious, and P. Suresh, “Systematic Survey on Object Tracking Methods in Video,” Int. J. Adv. Res. Comput. Eng. Technol., p. 24, 2012.

Evaluation of Distance Measures for Feature based Image Registration using AlexNet

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***Abstract*—Image registration is a classic problem of computer vision with several applications across areas like defence, remote sensing, medicine etc. Feature based image registration methods traditionally used hand-crafted feature extraction algorithms, which detect key points in an image and describe them using a region around the point. Such features are matched using a threshold either on distances or ratio of distances computed between the feature descriptors. Evolution of deep learning, in particular convolution neural networks, has enabled researchers to address several problems of vision such as recognition, tracking, localization etc. Outputs of convolution layers or fully connected layers of CNN which has been trained for applications like visual recognition are proved to be effective when used as features in other applications such as retrieval. In this work, a deep CNN, AlexNet, is used in the place of handcrafted features for feature extraction in the first stage of image registration. However, there is a need to identify a suitable distance measure and a matching method for effective results. Several distance metrics have been evaluated in the framework of nearest neighbour and nearest neighbour ratio matching methods using benchmark dataset. Evaluation is done by comparing matching and registration performance using metrics computed from ground truth.**

Keywords*—Distance measures; deep learning; feature detection; feature descriptor; image matching

I. Introduction

Every image is identified with its unique and discriminating features which are used as interesting points. Features of an image can be edges, blobs, corners and contours of the objects. Feature extraction forms an integral part of several vision-based applications such as image matching, object tracking, classification etc. The aim of image matching is to map the feature points from one image to corresponding points of another image of the same scene. Matches have to be robust to handle the distortions caused due to noise, changing illumination, reflection, area of projection etc. Image matching is fundamental to image registration which aims at computing the spatial transformation between two images.

Conventional image registration methods are broadly divided into area based and feature based methods [1]. Area based approaches find transformation by optimizing an objective function which is defined based on the error between the similarities of pixel properties of images. Similarity measures such as normalized cross correlation, mutual information are commonly used. Feature based approaches rely on computing similarity between descriptors computed around key points. Several handcrafted feature detection and description algorithms such SIFT, SURF, MSER etc. [2, 3, 4] have been used for the purpose. Spatial transformation between the images is estimated from the matched key points using RANSAC [5]. Performance of feature-based image matching depends to a great extent on the suitability of feature detection and descriptor towards kind of images and deformation [6, 7].

Deep learning is gaining importance in the field of machine learning and is able to provide solutions to several issues of computer vision such as image classification [8]. Among the several deep network architectures such as Deep Belief Network, Convolution Neural Network (CNN), Deep stacking Network, DBoM, Deep Q-Network etc. CNN is gaining attention in the field of imaging. CNN's are formed using multiple layers of convolution, activation, pooling arranged in a hierarchy. The output of these layers forms as input to layers which are typically designed to serve applications such as recognition, tracking, localization etc. The effectiveness of CNN's is because feature extraction process is part of training unlike classical approaches where handcrafted features are used to train only the learning algorithm.

CNN's enable to extract features of an image at different granularities; beginning layers extract basic features, such as lines, borders, and corners, while next level layers exhibit higher features, such as object portions, parts, or the whole object. Outputs from activation layers prior to fully connected layers are being used as features descriptors across different applications. Convolution neural network models like LeNet, AlexNet, VGGNet, ZFNet, GoogleNet, ResNet are being increasingly used as global features, by computing the vector for entire image, in retrieval kind of applications [9, 10, 11, 8, 12]. More recently activation outputs of pretrained CNN's are being used as local feature descriptors. Key points are detected in an image and region around key point is given as input to a CNN to get the feature vector. This paper explores the use of AlexNet features for image registration application.

Section2 describes about the background survey conducted on distance measures used in various applications and use of CNNs, Image registration approach adopted is discussed in Section 3. Section 4 explains data and our approach towards implementation, Section 5 presents evaluation and results, conclusion is part of Section 6.

II. Background Work

Convolution Neural Networks (CNN's) are being successfully applied in solving several problems of computer vision and natural language processing. First attempt on CNN, LeNet [13], revealed outstanding results in document recognition. Graph Transformer Network with CNN has been used to classify high-dimensional patterns of handwritten characters with more flexibility. Network framed by Alex Krizhevsky, et al. AlexNet, has been trained and tested for classification of high-resolution images, with results better than conventional feature extraction methods like SIFT. In large scale visual recognition experimentation, CNN has shown exceptional performance with VGGNet[10], GoogleNet[14] and many more [8, 12].

CNN eliminates the need of manual feature extraction methods, as the features are extracted directly from images which are learned while network in trained. CNN models which have been trained for applications like visual recognition have been used as feature extractors for several other applications. For example, activations of fc6 layer of AlexNet are proved to improve vehicle image detection and classification [15]. Recently AlexNet features are used in wound tissue analysis and improved version applied for scene classification [16]. ImageNet features are used in classification of earth observation [17].

CNN features are being effectively used in other typical computer vision problems. For example, scene classification based on classical AlexNet extracted features and used along with SVM and regression model [18]. Image retrieval based on AlexNet fc8 layer features admit good recall rate and fusing the fc6 features of LeNet and fc8 features of AlexNet are proved to be good in [19]. Features of multiple layers from AlexNet are used in object-oriented classification of remote sensing images, proving that fully connected layer features give good results when compared with convolution layers and are more expressive than spectral or texture features [20]. Klemen Grm in [21] conducted experimentation for face recognition application comparing various CNN models such as AlexNet, VGGNet, GoogLeNET, etc. Pre-trained AlexNet is used for speech emotion recognition representing speech features as images [22]. Similarly, NLP problems like automatic speech recognition for phonetic classification [23] are also solved with CNN. We have studied the performance of features extracted from fully connected layers of AlexNet when used for image registration.

The performance of most of the applications mentioned previously depends on the computation of similarity between the feature vectors. Conventional approaches using hand crafted features needed to find a suitable similarity measure depending on the application and type of images being employed. Table I lists some of the works reported. It can be observed that choosing suitable distance measure is necessary even when similar features are used across different applications. Hence when features extracted from pre-trained convolution layers of CNN's are employed choice of similarity measure affects the performance of applications. We have tested the effect of distance measure in image registration when features are extracted from convolution layers of AlexNet.

TABLE I. List of the Features, Distance Measures used in Applications

Reference	**Application**	**Distance measures compared**	**Features Used**
Yossi Rubner et al. [24]	Image retrieval	EMD, Jeffrey divergence, Chi-square statistic, L1-norm, Euclidean	Colour and texture
JesusAngulo, et al. [25]	Image classification and retrieval	Cityblock differences, Euclidean distance, Chi-square distance, Mahalanobis	Colour and texture
Ivan Laptev et al. [26]	Image matching	Squared difference of Gaussian function	Colour, blob and ridge
Xi Chen et al. [27]	Image matching	Cross affinity distance, SSD, Chamfer, Bhattacharyya	Edge orientation
Tudor Barbu et al. [28]	Image recognition	Euclidean	Colour
A. Melbourne et al.[29]	Image registration	Mutual information	Intensity
Xia et al. [30]	Satellite image indexing	Kullback-leibler Divergence	Shape
AbhjieetKumar Sinha et al. [31]	Image retrieval	Euclidean, Manhattan, Cosine	Colour
Abul Hasnat et a1. [32]	Face similarity	Modified Euclidean, Cosine Manhattan	Colour
Dengsheng Zhang et al. [33]	Image retrieval	Minkowski, L1-Norm, L2-Norm, chi-square statistic, Cosine, Mahalanobis, Quadratic, Histogram Intersection	Contour, region

III. Feature based Image Registration

A classic pipeline for Feature based image registration contains the following steps:

1) Feature detection: To detect a pixel of an image as a feature key point, properties of every pixel (such as gradient) are examined with respect to its neighborhood. To improve the invariance to deformations, detection algorithms have used scale space and affine space of images. Scale invariant feature transform, SIFT [21], detects features at different scales. Difference of Gaussian is applied for a series of smoothed and resampled images to know the local extremas around the interested point which gives stable points further known as key points.

2) Feature description: Each key point is described by a vector of values. A window of size N x N is taken around a key point and given as input to AlexNet[8,11]. Activations from fc6 and fc7 are used as feature descriptors.

3) Matching: Key points of images are matched by computing the similarity between the corresponding feature descriptors. Different distance metrics such as Euclidian, Cosine, Manhattan etc. are used to compute the similarity. Different methods like 1-way nearest neighbor, 2-way nearest neighbor and their ratios are used to determine the correspondences.

4) Transformation estimation: The mapping function parameters are computed by establishing inliers among the feature correspondences. RANSAC is used to compute the homography matrix and the inliers.

A. CNN based Feature Extraction using AlexNet

AlexNet with 5 Convolution layers, 5 relu layers, 5 max pooling layers, 2 fully connected layers or dense layers is used. Images are to be resized to 224x224 and given as input to AlexNet. Layer1, convolution layer convolves the input image 224x224x3 with 96 kernels of size 11x11x3 and with stride 4. Output of the layer is 55*55*96. Rectified linear unit activation and Max pooling functions are used to reduce over fitting and add nonlinearity to the extracted features, and the output is of size 27x27x96. Convolution Layer 2 which contains 128 kernels of size 5x5, stride 1x1, gives output 27x27x128. Similarly, convolution layers 3, 4 and 5 with 384, 384 and 256 filters, each of size 3x3 and stride 1x1 followed by max pool, dropout and padding are applied. Finally, the fully connected layer 6 and 7 gives 4096 features. Layer1 gives edge and blob of the input image, layer2 performs the conjunctions of these ***edges or*** responds to ***corners*** and other ***edge*** or color conjunctions**,** layer3 output is texture of a image, Layer5 identifies object parts, fc6 and fc7gives image features.

B. Distance Measures for Similarity

To find the most suitable distance measure between the images, a comparative study of features with dissimilarity measures is required. In this work, we consider dissimilarity measures like Euclidean, City block, Cosine, Minkowski, and Correlation through which we study the dissimilarity among the features of two images.

Cityblock distance: Measures the path between the pixels based on four connected neighbourhood.

$$Cityblock(p_k, q_k) = \sum_{k=1}^{n} (|p_k| - |q_k|)$$

Euclidean distance: Most commonly used metric to find the difference, calculates the square root of the sum of the absolute differences between two feature points.

$$Euclidean(p_k, q_k) = \sqrt{\sum_{k=1}^{n} (p_k - q_k)^2}$$

Cosine distance: Finds the normalized dot product of the two feature points.

$$Cosine(p_k, q_k) = \sum_{k=1}^{n} \frac{(p_k . q_k)}{\|p_k\| . \|q_k\|}$$

, where • indicates vector dot product

Minkowski distance: Is a generalization of Euclidean Distance.

$$Minkowski(p_k, q_k) = \left((\sum_{k=1}^{n} |p_k - q_k|^r) \right)^{1/r}$$

Correlation distance: The *correlation* of feature two points, p and q, with *k* dimensions is calculated as:

$$Correlation(p_k, q_k) = \sum_{k=1}^{n} \frac{Cov(p_k . q_k)}{Std(p_k) . Std(q_k)}$$

$$Cov((p_k, q_k) = \frac{1}{n} \sum_{k=1}^{n} (p_k - \bar{p}).(q_k - \bar{q}),$$

$$Std((p_k) = \frac{1}{n} \sum_{k=1}^{n} (p_k - \bar{p}), \bar{p} = \frac{1}{n} \sum_{k=1}^{n} (p_k)$$

IV. EXPERIMENTATION

The performance of various distances measures on fc6 and fc7 outputs of AlexNet, for the purpose of image matching and registration is objectively evaluated using benchmark dataset. Our implementation starts with a) detecting features using SIFT, b) describing and extracting features from fc6 and fc7 layers of AlexNet, c) finding differences between the features points by using different dissimilarity measures, d) finding matches using various matching algorithms like nearest neighbour (NN), nearest neighbour ratio (NNR), with one way and two-way matching. Matching performance is noted for various threshold values of 0.3, 0.5 and 0.7 for NN, 1.1, 1.2 and 1.3 for NNR, e) estimating homography matrix from the matches using RANSAC, f) computing the various evaluation measures described in the following section. All the above implementation is done in Matlab and executed on i7 CPU@2.7GHz with 8GB RAM.

A. Dataset

The dataset is freely available at http://www.robots.ox.ac.uk /~vgg/data/data-aff.html which contains 8 subsets of images. Each such subset contains six images, with first image being the original image and the rest of 5 images having different effects like zoom, rotation, illumination, compression, view angle etc. sample images are shown in Fig. 1.

B. Evaluation Measures

Evaluation is conducted at three stages, to find a relevant distance measure among the tested measures such as Eucledian, Cosine etc for the AlexNet features, relevant matching method between NN and NNR, and the suitable features between fc6 and fc7.

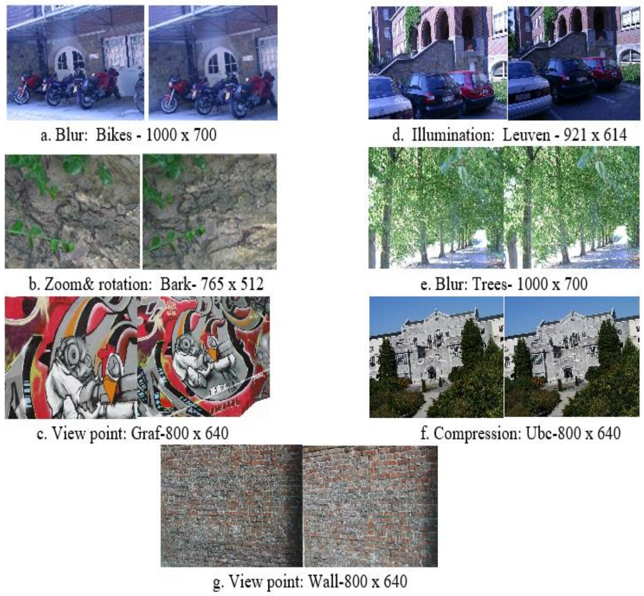


Fig. 1. Sample Images from Graffiti Dataset.

Evaluation is done using ground truth homography matrix by computing the following values:

Keypoint error with ground truth (KE_GH): The distance between the first image keypoint matches which are transformed with ground truth homography matrix in to second image and second image keypoint matches.

True Positive matches (TP): number of correct matches that are found with distance less than 2 pixels when compared with ground truth matches.

Using computed homography matrix (from RANSAC) the following values are computed:

Keypoint error with computed homography (KE_CH): The Distance between the first image keypoint which are transformed with computed homography matrix in to second image and second image keypoint matches. Computed homography matrix is estimated by applying RANSAC.

Inlier Ratio (IR): ratio of the total number of inliers and the total number of matched key points.

Higher the value of TP and IR better the matching whereas low values of KE_CH, KE_GH indicate that registration accuracy is better.

V. Performance and Results

In this segment of the paper we present results obtained and discuss the performance at various evaluation stages. Results are interpreted by comparing images with different deformations (like scale, rotation, zoom, blur, illumination, compression).

A. *Suitable Distance Measure*

In first stage we matched the feature vector of image1 with the other image feature vector by using dissimilarity measures. Various distance measures considered detect correspondences using different thresholds in one/two-way NN and NNR matching techniques.

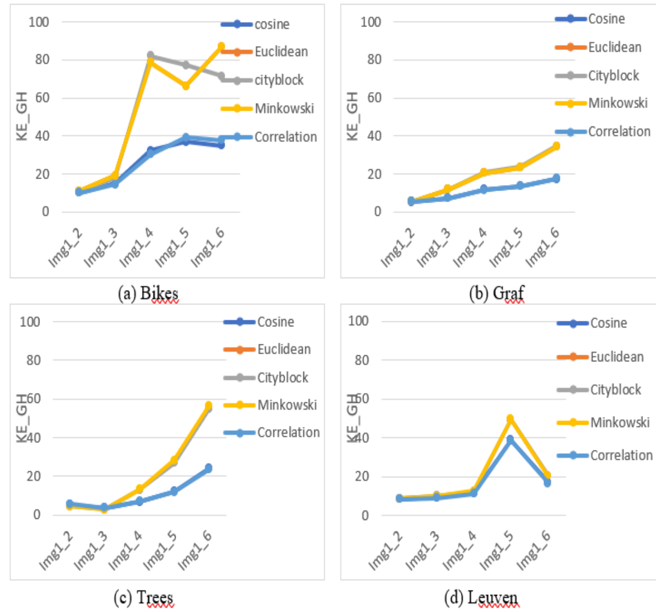


Fig. 2. Key Point Error On Ground Truth Homography for all 5 Images when Matched with First Image using Features of fc6 Layers, 1NNR with Threshold 1.1 for Various Dissimilarity Measures.

The key point error rate between correspondences of the image 1 and image 2 is computed with given ground truth homography matrix and computed homography.

We present the results of 4 different images in Fig. 2. From graphs it can be observed that KE_GH is less between first two images as compared between any other image pair. With any kind of deformation present in the dataset the most similar image is image2. It can be observed that Cosine and Correlation give better performance across deformations when compared to other distance measures.

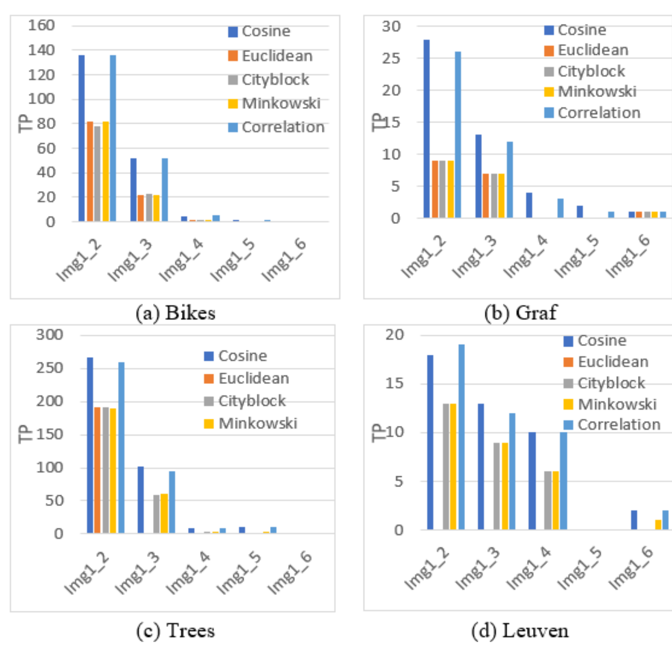
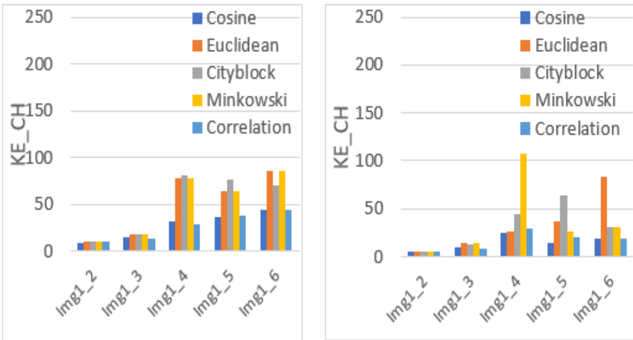
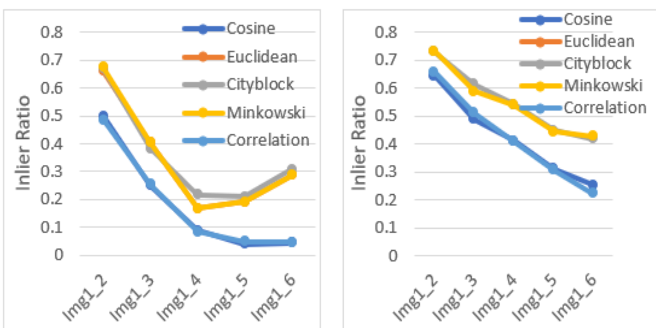


Fig. 3. True Positive Matches for all 5 Images when Matched with First Image using 1NNR with Threshold 1.1 and the Features of fc6 Layers Across 5 Dissimilarity Measures.



(a) Bikes (b) Graf

Fig. 4. Key Point Error for Computed Homography for 5 Images when Matched with First Image using 1NNR with Threshold 1.1 and the Features of fc6 Layers Across 5 Dissimilarity Measures.



(a) Bikes (b) Leuven

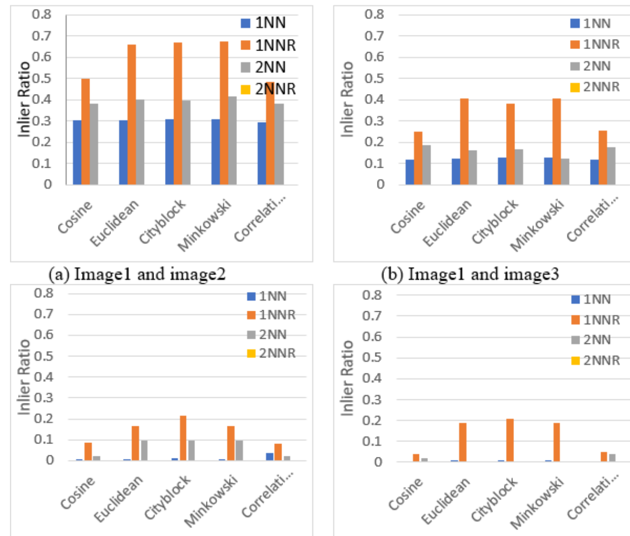
Fig. 5. Inlier Ratio for 5 Images when Matched with First Image using 1NNR with Threshold 1.1 and the Features of fc6 Layers Across 5 Dissimilarity Measure.

Similarly, number of matches, key point error for the computed homography and inlier ratio are presented in Fig. 3, Fig. 4 and Fig. 5 respectively. We used 1-way NNR with threshold 1.1 as the matching technique (we experimented with various thresholds of 1.1, 1.2, 1.3), to find the best dissimilarity measure. From the graphs it can be observed that error rate with respect to both ground truth and computed homography is less in the case of cosine and correlation distance measures. At the same time, we can see that the number of true positives is more (Fig. 3) for all the types of images with cosine and correlation, which are dominating other distance metrics. Cosine is the measure which is consistently performing well, when compared to any other dissimilarity measure.

B. Suitable Matching Technique

We tried to establish the best matching technique based on dissimilarity measure which is found to be the better in the above scenario.

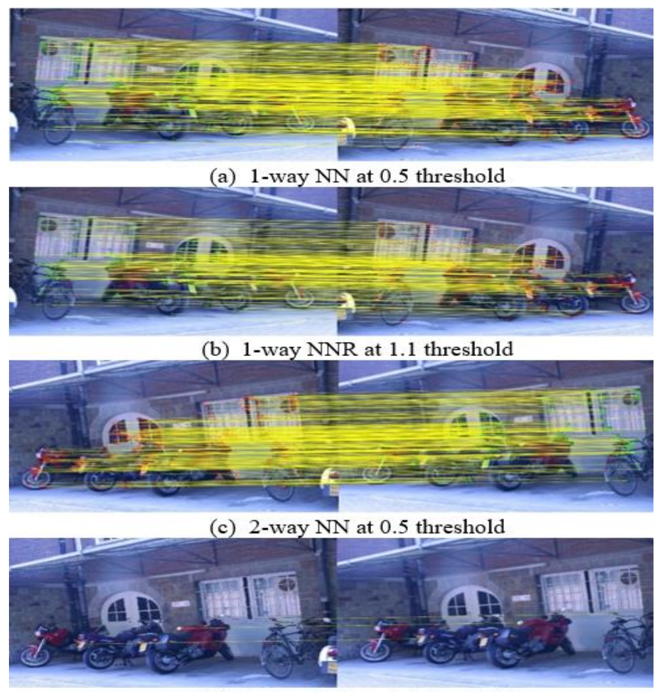
From the results in Fig. 6 it can be observed that 1way NNR and 2way NN are rational, when compared to 1NN and 2 NNR. In some cases, 2 NNR shows high values of inlier ratio, but is not efficient as the number of matches is very less (< 10). Matches obtained for one image pair are shown in Fig.7 and Fig. 8.



(a) Image1 and image2 (b) Image1 and image3

(c) Image1 and image4 (d) Image1 and image5

Fig. 6. Inlier Ratio for 4 Images (from 2 to 5) when Matched with first Image of Bikes using 1NN, 2NN with Threshold 0.5 and 1NNR, 2NNR with Threshold 1.1, for the Features of fc6 Layers Across 5 Dissimilarity Measures.



(a) 1-way NN at 0.5 threshold

(b) 1-way NNR at 1.1 threshold

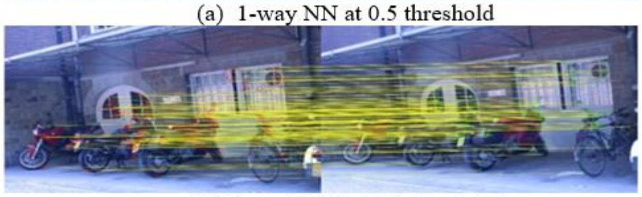
(c) 2-way NN at 0.5 threshold

(d) 2-way NNR at 1.1 threshold

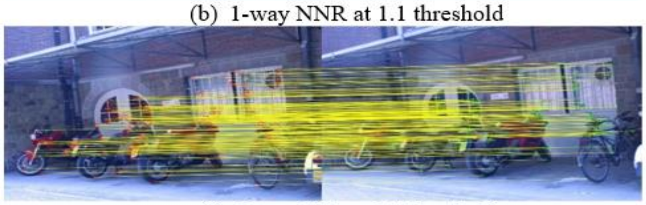
Fig. 7. Matches with Different Matching Techniques of first Image to Second Image of Bikes, with fc6 Features and Cosine Dissimilarity.

It is clearly noticed that the number of correspondences are better in 1-way NN compared to any other matching technique. However, the key point error is less in the case of 2-way NNR as the matched points are accurate when compared to any other matching technique. However, 1-way NNR and 2-way NN error rate is moderate and these matching methods are good across all images of dataset such as ubc, graf, leuven trees and wall. Hence it can be concluded that 1way NNR is best and 2 NN second from matching results of the experiments.

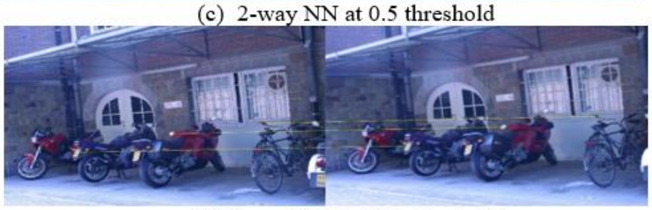
(a) 1-way NN at 0.5 threshold



(b) 1-way NNR at 1.1 threshold



(c) 2-way NN at 0.5 threshold



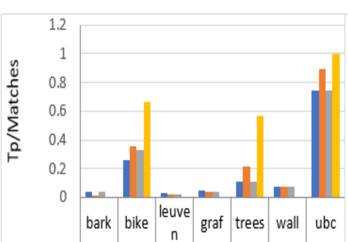
(d) 2-way NNR at 1.1 threshold

Fig. 8. Matches with Different Matching Techniques of First Image to Second Image of Bikes, with fc7 Features and Cosine Dissimilarity.

C. Best Image Features among Fc6 and Fc7

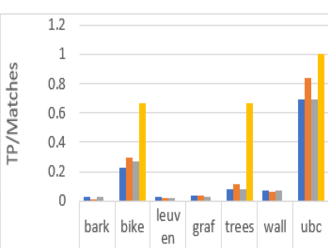
Finally, we test the features of the two layers, fc6 and fc7 of AlexNet to find the better features to be used for Image registration. Based on the above experiments, we present cosine as dissimilarity measure for matching first and second images and present the results in Fig. 9.

Finally, in addition to the dissimilarity and matching measures, we found that instead of fc7 features fc6 layer features are giving quantitatively more matches for the same distance measure consistently.



	bark	bike	leuven	graf	trees	wall	ubc
1_NN	0.0363	0.2631	0.0325	0.0444	0.1066	0.0757	0.7462
1-NNR	0.0089	0.3551	0.0208	0.0393	0.2107	0.074	0.896
2_NN	0.035	0.3318	0.0203	0.0365	0.1062	0.077	0.7413
2_NNR	0	0.6667	0	0	0.5714	0	1

a) fc6 features of AlexNet



	bark	bike	leuven	graf	trees	wall	ubc
1_NN	0.032	0.223	0.032	0.039	0.078	0.069	0.697
1_NNR	0.012	0.292	0.02	0.039	0.111	0.066	0.842
2_NN	0.027	0.266	0.016	0.03	0.078	0.069	0.695
2_NNR	0	0.667	0	0	0.667	0	1

b) fc7 features of AlexNet

Fig. 9. True Positive Matches between first and Second Image Across All Matching Techniques with Cosine as a Dissimilarity Measure.

VI. Conclusion

Trained CNN model, AlexNet, is used as feature extractor for registering images with variations such as zoom, rotation, lighting etc. Outputs of fully connected layers, fc6 and fc7 are used as feature descriptors by giving as input a region around the key point of image, which is detected using SIFT. In order to obtain good registration results, evaluation of various distance measures and matching methods is performed. Objective evaluation measures computed from ground truth are used to compare matching and registration performance. It has been observed that Cosine dissimilarity measure, followed by correlation, consistently gives better matching and registration across images of various deformations. Among the various matching strategies tested, results from one way nearest neighbour ratio with a threshold of 1.1 and two way nearest neighbour with a threshold of 0.8 are promising. Our future work involves verifying the effect of distance measures with other CNNs such as VGG and further to design a deepnet to learn similarity between image features.

References

[1] Barbara Zitova, Jan Flusser, Image Registraion methods: a survey, Elsevier, Image and Vision Computing, 21, pp. 977-1000, 2003.

[2] David G. Lowe, Distinctive Image Features from Scale-invariant keypoints, Internationsl journal of Computer Vision, Vol. 50, no.2, pp91-110, 2004.

[3] Herbert Bay, Andreas Ess, Tinne Turtelaars, and Luc Van Gool, SURF: Speeded Up Robost Features, Computer Vision and Image Understanding (CVIU), Vol. 110, No. 3, pp. 346-359, 2008.

[4] J. Matas, O. Chum, M. Urban, T. Pajdla, Robust Wide Baseline Stereo from Maximally Stable Extremal Regions, Proc. of British Machine Vision Conference (BMVC), pp. 384-396,2002.

[5] Martin A. Fischler and Robert C. Bolles, SRI International, Graphics and Image Processing, Communications of ACM, vol.24, 1981.

[6] Ebrahim Karami, Siva Prasad, Mohamed Shehata, Image Matching Using SIFT, SURF, BRIEF, and ORB, Performance Comparison for Distorted Images, in proc. of the 2015 newfoundland Electrical and Computer Engineering Conf. Canada, Nov 2015.

[7] M. Hassaballah, Aly Amin Abdelmgeid and Hammam A. Alshazly, Image features Detection, description and Matching, Spring Internation Publishing Switzerland, DOI 10.10007/978-3-319-28854-3_2, 2016.

[8] Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "ImageNet Classification with Deep Convolutional Neural Networks." *Advances in neural information processing systems*. 2012.

[9] Zheng-Wu Yuan, Jun Zhang, Feature Extraction and Image retrieval based on AlexNet, 8th ICDIP, china, 2016.

[10] Karen Simonyan and Andrew Zisserman, Very Deep Convolution Networks for large-Scale Image Recognition, published as a Conf. paper at ICLR 2105.

[11] Md. ZahangirAlom, Tarek M.Taha, Christopher Yakopcic, Stefan Westberg, Moahudul Hasan, Brain C Van Esesn, Abdul A. S. Awwal, and Vijayan K.Asari, The History Began fronAlexNet: A Comprensive Survey on DeepLearning Approaches, arXiv:1803.01164, 2018.

[12] Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "ImageNet Classification with Deep Convolutional Neural Networks." Communication of the *ACM, Vol 6, pp.84-90*, 2017.

[13] Yann LeCun, Leon Bottou, YoshuaBengio, and Patrick Haffner, Gradient -Based Learning Applied to Document Recognition, Proc. Of the IEEE, 1998.

[14] Christian Szegedy, Wei Liu, Yangqing Jia, Pierre Sermanet, Scott Reed, Dragmir Anguelov, Dumitru Erhan, Vincent Vanhoucke, Andrew Rabinovich, Going deeper with convolutions, IEEE conference on Computer Vision and Pattern Recognition, DOI: 10.1109/CVPR.2015.7298594, pp.1-9,2015.

[15] Yiren Zhou, Hossein Nejati, Thanh-ToanDo, Nagai-Man Cheung, Lynette Cheah, “Image-based Vehicle analysis using Deep Neural network: A systematic Study”, IEEE International conf. on digital signal processing, 2016.

[16] Lisha Xiao, Qin Yan, Shuyu Deng, Scene Classification with improved AlexNet Model, 12th international conf. on intelligent systems and knowledge engineering, 2017.

[17] Marmanis. D, Datu .M, Esch.T, Stilla. U, Deeplearning earth observation classification using ImageNet Pretrained Networks, IEEE Geo-Science Remote Sensing, 2015.

[18] Jing Sun, Xibiao Cai, Fuming Sun, Jianguo Zhang, Scene Image Classification method based on Alex-Net Model, 3rd international comf. on informative and cybernetics for computational systems, Aug 2016.

[19] Hailong Liu, Baoan Li, XueqiangLv, Yue Huang, Image Retrieval Using Fused Deep Convoluiton features, International congress of Inforamtion and Communication Technology, procedia computer science 107, pp. 749- 754, 2017.

[20] Ling Ding, Hongyi Li, Changmiao Hu, Wei Zhang, Shumin Wang, AlexNet Feature Extraction and Multi-kernel Learning for Object Oriented classification, symposium “Developments, technologies and Applications in Remote sensing”, internatonal Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XLII-3, China, may 2018.

[21] KlemenGrm, VitomirStruc, Anais Aritges, Matthieu Caron, Hazim Kemal Ekenel, Strengths and weaknesses of Deep Learning Models for Face Recognition Against Image Degradations, Submitted for publication to IET Biometrics, oct 2017.

[22] Margaret Lech, Robert S. Bolia, Real Time Speech Emotion Using RGB Image Classification and Transfer Learning, DOI, 10.1109/ICSPCS 2017.8270472, dec 2017.

[23] Hinton. G, Li Deng, Dong Yu, George Dahl, et al. Deep neural networks for acoustic modelling in speech recognition, IEEE signal processing Magazine 29, 82-97, 2012.

[24] Yossi Rubner, Carlo Tomasi and Leonidas J. Guibas, The earth mover’s distance as a metric for image retrieval, International Journal of Computer Vision 40(2), pp 99-121,2000.

[25] Jeaus Angulo and Jean Serra, Morphological Color size distributions for image classification and retrieval, Proc. Of Advanced Concepts for Intelligence Vision Systems, 2002.

[26] Ivan Laptev and Tony Lindeberg, A distance measure and a feature likelihood map concept for scale-invariant matching, International Journal of Computer Vision 52(2/3), pp 97-120,2003.

[27] Xi Chen and Tat-Jen Chem, Learning feature distance measures for image correspondences, IEEE Conf. on Computer Vision and Pattern Recognition, San Diego, CA, 2005.

[28] Tudor Barbu, Adrian Ciobanu, and Mihale Costin, Automatic color-based image recognition technique using LAB-features and robust unsupervised clustering algorithm Advances in Information Science, Circuits and Systems ISBN:978-1-61604-009-2, 2007.

[29] A. Melbourne, G. Ridgway and D. J. Hawkes, Image similarity metrics in image registration, Proceedings of SPIE- the International Society for Optical Engineering, DOI:10.11117/12/840389, 2010.

[30] Xia, G.S.; Yang.W; Delon J; Gousseau . Y; Sun .H; Maitre .H, Structural high-resolution satellite image indexing, In Proc. of the ISPRS TC VII Sym. -100 years, Vienna, Austria, pp. 289-303, 2010.

[31] Abhijeet Kumar Sinha, K. K. Shukla, A study of distance metrics in histogram-based image retrieval, International Journal of Computers and Technology, Council of innovative Research, pp 821-830, 2013.

[32] Abul Hasnat, Santanu Halder, D. Bhattacharjee, M. Nasipuri and D. K. Basu, Comparative study of distance metrics for finding skin color similarity of two color facial images, 2013.

[33] Dengsheng Zhang and Guojun Lu, Evaluation of Similarity Measurement for Image Retrieval, International Conference on Neural Networks and Signal Processing, DOI: 10.1109/ICNNSP.2003.1280752, 2004.

Greedy Algorithms to Optimize a Sentence Set Near-Uniformly Distributed on Syllable Units and Punctuation Marks

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***Abstract*—An optimum sentence set that near-uniformly distributed on syllable units and punctuation marks is important to develop a syllable-based automatic speech recognition (ASR). It is usually extracted from a mother set of millions of unique sentences using Modified Least-to-Most (LTM) Greedy algorithm. The Modified LTM Greedy is capable of minimizing the number of syllables but ignores distributing their frequencies. Hence, two schemes are proposed to minimize the number of syllables as well as to distribute their frequencies near-uniformly. Testing on a mother set of 10 million Indonesian sentences shows that both schemes perform better than the Modified LTM Greedy for two syllable units: monosyllables and bisyllables.**

Keywords*—*read-speech corpus; optimum sentence set; syllable; punctuation marks; Modified Least-to-Most Greedy

I. Introduction

Since the begining 2000, some researchers show that the context-dependent syllable-based ASR systems perform better than the context-independent phone-based ones, as described in [1], [2], and[3]. Today, the promising state-of-the-art ASR called sequence-to-sequence attention-based model is also designed using a syllable-based model [4]. However, the syllable-based ASR needs a much larger read-speech corpus for the training process [5]. Therefore, developing such speech corpus is a challenging issue.

The speech corpus is commonly recorded on a minimum sentence set near-uniformly distributed on both syllable units and punctuation marks for thousands of speakers varying on gender, age, and dialect [6], [7], [8], [9], [10]. Punctuation marks in a sentence affect how it is being interpreted, mostly by differing intonation [11] and [12]. The speakers may use different intonation to make their intentions clear. A sentence ”It's me.” is a monotone statement, while ”it's me?” gives a higher tone for the syllable 'me?'. Hence, a syllable-based ASR needs a read-speech corpus developed using a minimum sentence set balanced on syllables and punctuation marks [13] and [14].

Commonly methods used to extract a minimum sentence set from a mother set are greedy-based algorithms, such as the Least-to-Most (LTM) Greedy Algorithm [15]. This algorithm is then slightly improved to be the Modified LTM Greedy which is capable of extracting a minimum sentence set in quite fast execution time [16]. But, the Modified LTM Greedy only concentrates on minimizing the number of phonetic units but ignores balancing their frequencies.

In this paper, the Modified LTM Greedy is adapted to extract a minimum sentence set from a mother set of around 10 million sentences based on their syllable. Two additional schemes are proposed to make the Modified LTM Greedy capable of extracting a minimum sentence set, near-uniformly balanced on both syllables and punctuation marks, to be used to develop a state-of-the-art syllable-based ASR. Both additional schemes are carefully designed to minimize the number of syllables as well as to balance their frequencies.

II. Greedy Algorithms

The Modified LTM Greedy algorithm described in [16] performs well to extract a phonetically-rich sentence set. Unfortunately, it just focuses on minimizing the number of phonetic units but ignores balancing their frequencies. Hence, in this paper two additional schemes are proposed to improve the performance of the algorithm in minimizing the number of syllables as well as balancing their frequencies.

A. Modified LTM Greedy Algorithm

The Modified LTM Greedy algorithm produces a sentence set from a mother set by taking the best sentences based on a scoring formula. The pseudocode adapted from [16], with an adjusment to handle syllables instead of phonemes, is described as follows:

1) Let A = mother set, U = all to-be-covered syllables, B = empty set;
2) From U take all syllables with the lowest frequency and put them in U_{sub};
3) From A select all sentences containing at least one syllable in U_{sub} and put them in A_{sub};
4) Compute the score of each sentence in A_{sub} using a formula
$$S_i = \frac{N_i}{T_i}, \tag{1}$$
where S_i is the score for the *i*th sentence, N_i is the number of to-be-covered syllables in the *i*th sentence, and T_i is the number of all syllables in the *i*th sentence;

5) Choose a sentence with the best score and put it in B and remove all syllables contained in the sentence from both U and U_{sub};
6) Repeat step 3 to 5 until U_{sub} is empty;
7) Repeat step 2 to 6 until U is empty.

The pseudocode can be explained in a simple way using some illustrations in Fig. 1 to 5. In these illustrations, the mother set (A) contains only five sentences, as listed in Table I, to make any step in the pseudocode clear.

TABLE I. EXAMPLE MOTHER SET OF FIVE SENTENCES

Number	Sentence in *Indonesian* and (English)
1	*Belajar lagi di rumah* (Study again in home)
2	*Dia belajar video lagi* (He learns video again)
3	*Dia menonton di rumah belajar* (He is watching in the learning house)
4	*Lagi-lagi dia menonton di rumah* (Again he is watching at home)
5	*Menonton video di rumah* (Watching video at home)

In step 1, the Indonesian syllabification model described in [17] is used to generate all syllables contained in each sentence as well as a list of to-be-covered syllables, which contains 14 unique syllables, with their frequencies (U). The minimum set B is empty. Next, in step 2, all syllables with the lowest frequency in U are selected and moved into U_{sub}. In step 3, all sentences containing at least one syllable in U_{sub} are then selected and moved into A_{sub}. Then, in step 4, the score of each sentence in A_{sub} is calculated using the formula in Eq. 1. The second sentence, with 9 out of 10 to-be-covered syllables, has a score of 0.9. Meanwhile, the fifth sentence, with 9 out of 9 to-be-covered syllables, has a higher score of 1.0. Finally, in step 5, the fifth sentence with the best score of 1.0 is chosen, saved into B, and all syllables contained in this sentence are removed from both U and U_{sub}. These steps are repeated until both U_{sub} and U are empty. When both stoping criteria are reached the algorithm produces a minimum set of two sentences, i.e. the fifth and the second sentences, that consits of all 14 unique syllables to-be-covered.

A		
i	**Sentence**	**Syllables contained in the sentence**
1	Belajar lagi di rumah	be la jar la gi di ru mah
2	Dia belajar video lagi	di a be la jar vi de o la gi
3	Dia menonton di rumah belajar	di a me non ton di ru mah be la jar
4	Lagi-lagi dia menonton di rumah	la gi la gi dia me non ton di ru mah
5	Menonton video di rumah	me non ton vi de o di ru mah

U	
Syllable	**Frequency**
de	**2**
o	**2**
vi	**2**
a	3
be	3
jar	3
me	3
non	3
ton	3
gi	4
mah	4
ru	4
di	7
la	7

B	
Number	**Sentence**

Fig. 1. Step 1 of the Modified LTM Greedy algorithm: A = mother set, U = all to-be-covered syllables, B = empty set

U_sub	
Syllable	**Frequency**
de	2
o	2
vi	2

Fig. 2. Step 2 of the Modified LTM Greedy algorithm: take all syllables with the lowest frequency, i.e. 2, and put them in U_{sub}

A_sub		
i	**Sentence**	**Score**
2	Dia belajar video lagi	9/10 = 0.9
5	Menonton video di rumah	**9/9 = 1.0**

Fig. 3. Step 3 and 4 of the Modified LTM Greedy algorithm: select all sentences containing at least one syllable in U_{sub} and put them in A_{sub}, then compute the score of each sentence in A_{sub} using the formula in Eq. 1

B	
i	**Sentence**
5	Menonton video di rumah

U	
Syllable	**Frequency**
a	3
be	3
jar	3
gi	4
la	7

U_sub	
Syllable	**Frequency**

Fig. 4. Step 5 of the Modified LTM Greedy algorithm: choose a sentence with the best score, i.e. 1.0, and put it in B and remove all syllables contained in it from both U and U_{sub}

B	
i	**Sentence**
5	Menonton video di rumah
2	Dia belajar video lagi

U	
Syllable	**Frequency**

U_sub	
Syllable	**Frequency**

Fig. 5. Last steps of the Modified LTM Greedy algorithm, when both U_{sub} and U are empty, produce a minimum set of two sentences

B. Semi LTM Greedy 1

In the first proposed scheme, the Modified LTM Greedy is revised by replacing the step 5 with four new steps below:

1) Let K be a real number in the interval $(0, 1)$;
2) From A_{sub} select the top-score sentences, which have scores $\geq$ (the best score $\times(1-K)$), and put them in a new set D;
3) From D choose a sentence with the maximum number of to-be-covered syllables and remove all syllables contained in the sentence from both U and U_{sub};
4) Clear D.

This proposed scheme can be explained using an illustration in Fig. 6. In this illustration, let K = 0.05. From the mother set (A), which is sorted by the score calculated using the formula in Eq. 1, select the top-score sentences and put them into a new set D. Next, from D choose a sentence with the maximum number of to-be-covered syllables, i.e. 24, instead of the highest score. This scheme is designed to handle the possibility of the Modified LTM Greedy algorithm in taking the local optimum when looking for the best sentence. It will produce a larger sentence set B.

A_{sub}	
i	**Score**
129	8/8 = 1.00
758	14/14 = 1.00
35	17/17 = 1.00
12498	24/25 = 0.96
298	19/20 = 0.95
960725	9/10 = 0.90
5709	17/20 = 0.85
...	...

D	
i	**Score**
129	8/8 = 1.00
758	14/14 = 1.00
35	17/17 = 1.00
12498	**24**/25 = 0.96
298	19/20 = 0.95

Fig. 6. Semi LTM Greedy 1: select the top score sentences in the mother set (A) and then choose a sentence with the maximum number of to-be-covered syllables

C. Semi LTM Greedy 2

In the second proposed scheme, the Modified LTM Greedy is updated by replacing the step 5 with four new steps below:

1) Let K be a real number in the interval $(0, 1)$;
2) Select the top-score sentences, which have scores $\geq$ (the best score $\times(1 - K)$), and put them in a new set D;
3) From D, choose a sentence with the lowest new score calculated using a formula:

$$S_i = \sum f, \tag{2}$$

where f is the frequencies of all have-been-covered syllables in the minimum set *B* and remove all syllables contained in the sentence from both U and U_{sub};
4) Clear D.

This scheme is proposed to overcome the weakness of the Modified LTM Greedy algorithm in balancing frequencies of the syllables. By taking sentences with the lowest frequencies of syllables have been covered in the minimum set *B*, the duplication of syllables should be reduced.

III. Experimental Setup

In this research, a mother set containing 10,000,034 sentences is collected by crawling some newspaper websites. Two dictionaries (phonemic and syllabic-based) of 80K unique words are developed using the Indonesian grapheme-to-phoneme conversion system described in [18] and the Indonesian syllabification system described in [17] respectively. Converting the mother set of 10 M sentences using both dictionaries produces 121,860,535 monosyllables (6,804 unique monosyllables) and 132,445,220 bisyllables (308,710 unique bisyllables).

Using the mother set, some experiments are performed based on two scenarios:

1) Scenario 1: The Modified LTM Greedy. In this scenario, the mother set is extracted using the Modified LTM Greedy for both monosyllable and bisyllable.
2) Scenario 2: The Semi LTM Greedy. In this scenario, the mother set is extracted using the Semi LTM Greedy 1 and the Semi LTM Greedy 2 with K = 0.05, 0.1, 0.2 and 0.33 for both monosyllable and bisyllable. The extracted minimum sentence sets balanced on syllables and punctuation marks are compared to those resulted by the Modified LTM Greedy.

IV. Result and Discussion

Two scenarios described in the experimental setup are tested for both monosyllables and bisyllables to compare their performances. The experiments are conducted using a single processor i5 with 4 GB RAM. The total run time per experiments for the monosyllables is 4 hours while for the bisyllables is 9 hours.

A. Monosyllable

Extraction of the mother set of 10 M sentences using the Modified LTM Greedy produces a sentence set of 6,804 unique monosyllables in 4,056 sentences with the total number of monosyllables is 31,575. The average frequency of syllable $\bar{f} = 4.64$ with the standard deviation $\sigma = 30.91$. Next, extraction of the mother set using the Semi LTM Greedy 1 and the Semi LTM Greedy 2 produce the results illustrated in Table II and Fig. 7.

TABLE II. Extraction of the Mother Set for Monosyllable

Exp.	Method	Tot. Syll.	Tot. Sent.	$\bar{f}$	σ
1	Modified LTM Greedy	31,575	4,056	4.64	30.91
2	Semi LTM 1, $K = 0.05$	31,754	4,030	4.66	31.15
3	Semi LTM 1, $K = 0.10$	31,905	3,985	4.86	32.66
4	Semi LTM 1, $K = 0.20$	33,115	3,950	4.50	31.40
5	Semi LTM 1, $K = 0.33$	34,688	3,956	5.09	34.62
6	Semi LTM 2, $K = 0.05$	31,560	4,087	4.63	29.68
7	Semi LTM 2, $K = 0.10$	31,666	4,160	4.65	29.48
8	Semi LTM 2, $K = 0.20$	32,272	4,277	4.74	28.64
9	Semi LTM 2, $K = 0.33$	33,537	4,471	4.92	28.85

TABLE III. Extraction of the Mother Set for Bisyllable

Exp.	Method	Tot. Syll.	Tot. Sent.	f	σ
1	Modified LTM Greedy	2,453,766	202,157	7.94	83.09
2	Semi LTM 1, $K = 0.05$	2,455,142	201,877	7.95	83.09
3	Semi LTM 1, $K = 0.10$	2,451,017	201,609	7.93	83.00
4	Semi LTM 1, $K = 0.20$	2,466,306	201,840	7.98	83.42
5	Semi LTM 1, $K = 0.33$	2,477,568	201,962	8.02	83.81
6	Semi LTM 2, $K = 0.05$	2,456,045	202,586	7.95	81.64
7	Semi LTM 2, $K = 0.10$	2,460,139	202,786	7.96	81.51
8	Semi LTM 2, $K = 0.20$	2,468,850	203,159	7.99	81.43
9	Semi LTM 2, $K = 0.33$	2,471,132	203,387	8.00	81.15

Table II shows that the Semi LTM Greedy 1 is successful in reducing the total number of sentences, but it increases the total number of syllables as the value of K does. This is probably the case where the algorithm does not really consider the redundancy of syllables when taking the best sentence resulting in a large number of syllables.

On the other hand, the Semi LTM Greedy 2 is capable of reducing the standard deviation of the result set relatively as the K increases, but with the number of sentences increases as the K does. The formula used in the algorithm considers the frequencies of have-been-covered syllables and then takes the sentence with the smallest total frequencies. This prefers to select shorter sentences and make the result set larger. Fig. 7 shows that the Semi LTM Greedy 2 manages to lower the number of occurrences of more dominant syllables.

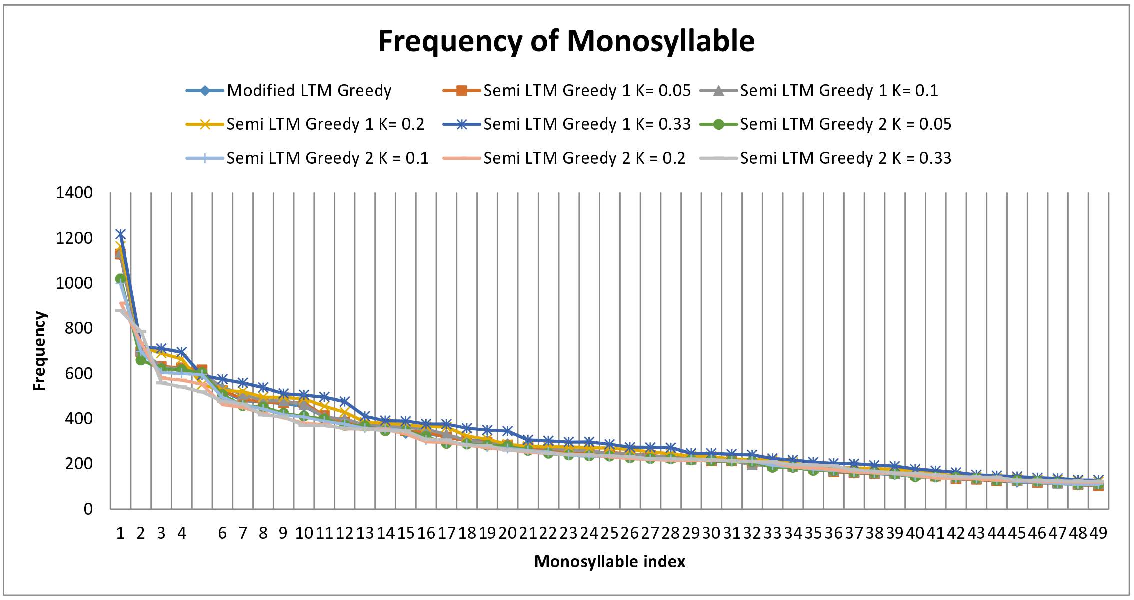

Fig. 7. Frequency of Monosyllable

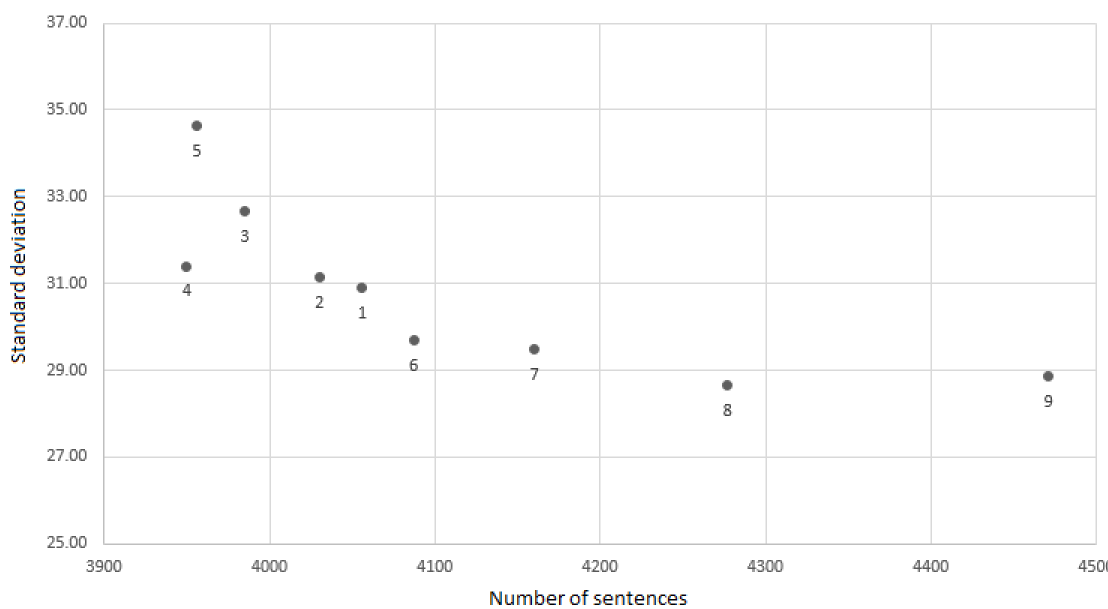

Fig. 8. Visualization of monosyllabic Pareto

A simple Pareto optimization in Fig. 8 shows that: a) Experiment 4 dominates Experiment 5 and 3; b) Experiment 8 dominates result 9; and c) Experiment 1, 2, 4, 6, 7 and 8 do not dominate each other. Hence, it can be concluded that the experiments 1, 2, 4, 6, 7 and 8 are the Pareto optimal set those should be able to be used as the train sets for the syllable-based ASR. The set from Experiment 6 should be used if the train set needs both low standard deviation and number of sentences. Experiment 4 has the smallest number of sentence set and best suited if the system demands as such while the result of Experiment 8 if requires as low standard deviation as possible.

B. Bisyllable

Using the mother set for bisyllables, the Modified LTM Greedy extracts a sentence set of 202,157 unique sentences with 308,710 unique bisyllables. The average frequency of bisyllable $\bar{f} = 8.94$ with the standard deviation $\sigma = 83.09$. Next, extraction of the mother set using the Semi LTM Greedy 1 and the Semi LTM Greedy 2 produces the results illustrated in Table III and Fig. 9.

Table III shows that the Semi LTM Greedy 1 manages to reduce the number of sentences and standard deviation using $K = 0.1$. The scenarios of the Semi LTM Greedy 2 show that it manages to reduce the standard deviation quite well, with the

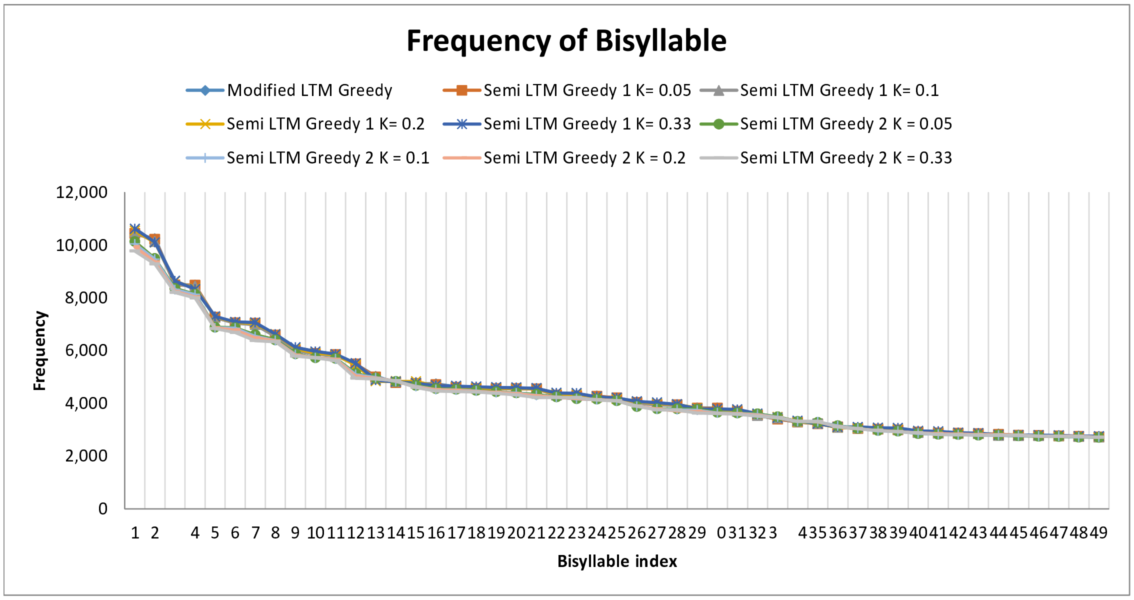

Fig. 9. Frequency of Bisyllable

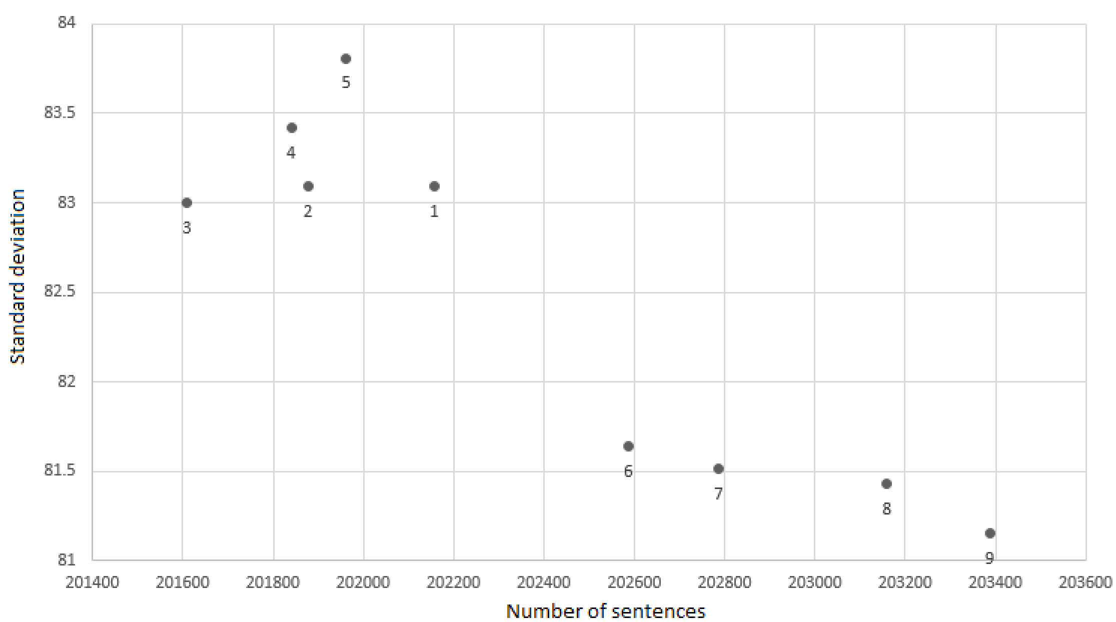

Fig. 10. Visualization of Bisyllable Pareto

scenario using $K = 0.05$ in particular. Increasing K reduces the standard deviation, but increases the number of sentences. Fig. 9 also shows that the Semi LTM Greedy 2 manages to reduce the frequencies of more dominant bisyllables, which should produce lower standard deviation.

A simple Pareto optimization using Fig. 10 shows that: a) Experiment 3 dominated experiments 1, 2, 4, and 5; and b) Experiments 3, 6, 7, 8, and 9 do not dominate each other. Thus, it can be concluded that the experiments 3, 6, 7, 8, and 9 are the optimum Pareto set those should be able to be used as a train set for a syllable-based ASR system. The sentence set from Experiment 6 should be used if the system needs a relatively low standard deviation and total sentences. Experiment 3 produces the set best suited for any system requiring as few sentences as possible, while Experiment 9 if least standard deviation.

V. Conclusion

The Semi LTM Greedy 1 algorithm is capable of reducing the number of sentences in the extracted sentence set, but the Semi LTM Greedy 2 manages to reduce standard deviation significantly. The Semi LTM Greedy 1 reduces more sentences as the K increases. The Semi LTM Greedy 2 reduces more standard deviation as the K increases. A simple Pareto optimization can be used to produce the best sentence set for the designed syllable-based ASR.

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REFERENCES

[1] A. Ganapathiraju and J. Hamaker, "Syllable-based large vocabulary continuous speech recognition," *IEEE Transactions on Speech and Audio Processing*, vol. 9, no. 4, pp. 358–366, 2001.

[2] R. Janakiraman, J. C. Kumar, and H. A. Murthy, "Robust syllable segmentation and its application to syllable-centric continuous speech recognition," in *National Conference on Communications (NCC)*. Chennai, India: Joint Telematics Group of IITs & IISc, jan 2010, pp. 1–5. [Online]. Available: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=5430189

[3] K. Proen, "Designing Syllable Models for an HMM Based," in *International Conference on Speech and Computer*, vol. 1, 2016, pp. 216–223.

[4] S. Zhou, L. Dong, S. Xu, and B. Xu, "Syllable-Based Sequence-to-Sequence Speech Recognition with the Transformer in Mandarin Chinese," in *Interspeech*, 2018.

[5] ——, "A Comparison of Modeling Units in Sequence-to-Sequence Speech Recognition with the Transformer on Mandarin Chinese," *CoRR*, pp. 1–5, 2018.

[6] C. Kurian, "Development of Speech corpora for different Speech Recognition tasks in Malayalam language," in *International Conference on Natural Language Processing*, no. December, 2015, pp. 229–236.

[7] M. Pinnis, A. Salimbajevs, and I. Auzia, "Designing a Speech Corpus for the Development and Evaluation of Dictation Systems in Latvian," in *The Tenth International Conference on Language Resources and Evaluation (LREC)*, 2016, pp. 775–780.

[8] D. Arnold, F. Tomaschek, K. Sering, F. Lopez, and R. H. Baayen, "Words from spontaneous conversational speech can be recognized with human-like accuracy by an error-driven learning algorithm that discriminates between meanings straight from smart acoustic features, bypassing the phoneme as recognition unit," *PLOS ONE*, vol. 12, no. 4, pp. 1–16, 2017. [Online]. Available: https://doi.org/10.1371/journal.pone.0174623

[9] D. Koržinek, K. Marasek, Ł. Brocki, and K. Wołk, "Polish Read Speech Corpus for Speech Tools and Services," in *CLARIN*, 2017, pp. 54–62.

[10] H. Abera and S. H/Mariam, "Design of a Tigrinya Language Speech Corpus for Speech Recognition," in *Workshop on Linguistic Resources for Natural Language Processing*, 2018, pp. 78–82.

[11] J. Kolár and L. Lamel, "On Development of Consistently Punctuated Speech Corpora," in *INTERSPEECH*, 2011, pp. 833–836.

[12] N. Moore, "What ' s the point ? The role of punctuation in realising information structure in written English," *Functional Linguistics*, 2016. [Online]. Available: http://dx.doi.org/10.1186/s40554-016-0029-x

[13] F. Batista, D. Caseiro, N. Mamede, I. Trancoso, L. F. L. D. Sistemas, D. L. Falada, I. Id, and R. A. Redol, "Recovering Punctuation Marks for Automatic Speech Recognition," in *Interspeech*, 2007, pp. 2153–2156.

[14] S. M. Hosseini and H. Sameti, "Creating a corpus for automatic punctuation prediction in Persian texts," in *2017 Iranian Conference on Electrical Engineering (ICEE)*, 2017, pp. 1537–1542.

[15] J.-s. Zhang and S. Nakamura, "An Efficient Algorithm to Search For A Minimum Sentence Set For Collecting Speech Database," in *ICPhS*, 2003, pp. 3145–3148.

[16] Suyanto, "Modified Least-to-Most Greedy Algorithm to Search a Minimum Sentence Set," in *IEEE TENCON*, 2006.

[17] S. Suyanto, S. Hartati, A. Harjoko, and D. V. Compernolle, "Indonesian syllabification using a pseudo nearest neighbour rule and phonotactic knowledge," *Speech Communication*, vol. 85, pp. 109–118, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.specom.2016.10.009

[18] Suyanto and A. Harjoko, "Nearest neighbour-based Indonesian G2P conversion," *Telkomnika (Telecommunication, Computing, Electronics, and Control)*, vol. 12, no. 2, pp. 389–396, 2014.

Data Governance Cloud Security Checklist at Infrastructure as a Service (IaaS)

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***Abstract*—Security checklist is an important element in measuring the level of computing security, especially in cloud computing. Vulnerability in cloud computing become major concern because it will lead to security issue. While security awareness and training can educate users on the severe impact of malware, implementation on data governance and security checklist also can help to reduce the risk of being attacked. Since security checklist is important element to measure security level in cloud computing, data governance can help to manage data right with correct procedure. Due to increasing threats and attacks, service providers and service consumers need to adhere to guidelines and/or checklists when measuring the security level of services and to be prepared for unforeseen circumstances, especially in the IaaS platform. As the IaaS platform lies at the lower level in cloud computing where data are stored, it is vital that IaaS security be given serious consideration to prevent not only data breaches but also data losses. The objective of this paper is to discuss the implementation of security checklist in IaaS layer. In this paper also, several studies related with security assessment and checklist that had been discussed and developed by previous researchers and professional bodies will be discussed. This paper will also discuss the result from interview session that had been conducted by the author with several data centers (DCs) and experts regarding the implementation of security measures in small cloud DCs.**

***Keywords*—IaaS; security checklist; guidelines; threats; cloud computing**

I. Introduction

Cloud computing brings advantages in terms of storage capability [1]–[4]; virtualization [5]–[7]; and cost savings [2]–[4], [8]. These advantages allow users, such as big companies, to invest their profit in business developments rather than having to expand storage space for data and information.

Despite the benefits, cloud computing has drawbacks for companies to consider. These issues of security threats at the data location [1], [4], [7], [9]; external attacks, for instance, by hackers [4], [9]–[11]; as well as advanced persistent threats (APTs) attacks [10], [11], cannot be simply solved with knowledge of information technology (IT) alone.

Many organizations come to realize the importance of data governance after many cases of data breaches occurred. Since most of the cases are due from lack of awareness on procedure to monitor attack at IaaS layer, it is necessary to have person that responsible and able to control the cloud security. According to [12] governance is claimed to be an effective way in managing IT.

[13] claimed that it is very important to implement data governance in the company. The authors stressed out that problems such as lack of integrity, confidentiality and loss of control in data can happen when data governance is not implemented effectively. They also further explained that NIST (National Institute of Standards and Technology) also advised companies who want to move to cloud should have data governance in place because it contained set of rules that can be followed by the data owner.

Several researchers [3], [11], [14], [15] has suggested using a security checklist to measure the security level of cloud computing services (CCSs) or cloud service providers (CSPs). Security checklist guidelines have been developed as a reference for companies, assisting them in their choice of good CSPs for their CCS in their move to cloud computing.

Security in IaaS had been widely discussed by many researchers [6], [16], [17]. Even though all service models in cloud computing may possess the same threat, but since IaaS is a place where all data is stored and where the network connection begin, some sophisticated threat such as APTs can use the vulnerability in IaaS to attack this layer and obtain all access to the whole system. According to [15], [18], [19], attacks in IaaS layer can also affect other layers such as PaaS and SaaS.

The main objective of this paper is to study the assessment, checklists and guidelines for securing the IaaS model layer. This paper also focusses on the threats in cloud computing that can lead to APTs attack in IaaS. At the end of this study, result from research that had been conducted by the author recently will be discussed. The guidelines and checklists proposed and developed by professional bodies and/or researchers are analysed along with the methodologies used. This provides a glimpse of the current practices in IaaS security checklist and how these researchers and professional bodies address the IaaS issues. This paper also discusses security issues in the IaaS service model and how such issues could be identified by researchers.

II. Literature Review

Cloud computing comprises a large pool of computing resources, such as networks, storage, servers, software, applications, data and information. Basically, CCS consists of two models, namely, the Cloud Deployment Model (CDM) and the Cloud Service Model (CSM). When using CCS, users do not use, nor are they given access to, all layers of the cloud. Some parts can only be used and accessed by users, in accordance with their service subscription, with the back-end of the services are under CSP management. For example, when users subscribe to the IaaS service model, they are only allowed to access and use the cloud environment, while the CSP manages the physical infrastructure.

The CDM is the cloud environment used by users. The different types of cloud environment are based on the ownership, size, tenants and level of access to the cloud. The four CDMs currently identified in CCS [13], [20]–[22] are public cloud, private cloud, hybrid cloud and community cloud. Some advantages of the CDM are scalability, cost effectiveness, reliability and accessibility provided an internet connection is in place.

The CSM is how the cloud is made available to users. It is a service to which users subscribe via the CSP to store their data and applications. The three types of CSM are software as a service (SaaS), platform as a service (PaaS) and IaaS. As mentioned earlier in this paper, only security issues in IaaS are explained in detail in this paper.

To understand more about security in cloud computing, several related topics such as security issues in IaaS, data governance, list of the security checklist studied by previous researchers and specific threat focus in this research are discussed in the next section.

A. *IaaS Security Issues*

In this section, several issues in IaaS will be discussed. The issues include vulnerabilities, threats, and attacks. Among CSMs, IaaS is the lowest level. In the traditional data centre (DC), the servers, storage, switches and networking section comprise the basic physical infrastructure. Consumers receive essential infrastructure provided by IaaS, such as virtual servers and storage, so the customer does not have to buy virtual infrastructure and its components.

According to [23], virtualization in IaaS can help consumers expand their storage in an ad hoc manner without involving the addition of new servers or storage capacity. In addition, consumers can have different operating systems (OSs) in virtualized server.

[24] listed several issues related to the IaaS model, such as abuse of cloud computing; insecure application programming interfaces (APIs); internal errors; shared technology issues; data breaches and lost data; hijacking issues; and unknown security profiles. This paper has focused on security in virtual machines (VMs) as virtualization is one of the characteristics and advantages of cloud computing. Some papers that have discussed security threats in IaaS have been reviewed, with the current paper also suggesting some solutions.

Moreover, [16] mentioned data leakage in IaaS, as well as other issues such as lack of monitoring, end-to-end encryption, authentication and authorization, infrastructure hardening and incident response. They include compliance issues, back-up and disaster recovery and lack of provision in the service level agreement (SLA).

Similarly, [10] stated that, as IaaS has multiple users who share the same cloud environment, this could lead to unexpected security breaches from side channel and secret channel attacks. These attacks could come from tenants in the cloud itself or from outside attackers who had obtained access due to errors committed by tenants. [10] also mentioned another cloud computing attack which is more severe and sophisticated, namely, APTs.

[8] indicated that APTs constitute a long-term attack. The attackers enter the system and, by stealth, locate themselves so they can monitor the system's operation. After collecting enough information, they will attack to such an extent that it has a severe effect on the company's business. According to [5], an APTs attack can enter the system through VM vulnerabilities such as a central processing unit (CPU) side timing channel attack, attack through hypervisor, live attack, disk injection, corrupting images, migration attack and control compromise. For tracing the attack path, the researchers used the Bayesian network model.

Another characteristic is that cloud computing is multi-tenant; that is, numerous users share the same cloud environment. Even though being multi-tenant is one of the advantages of cloud computing, it can also be a threat to CCS because all users use the same cloud. Even though it is protected by firewalls, authentication and authorizations, vulnerability is CSP sides may lead to data breaches from another user.

In seeking to solve these issues, researchers have suggested several security checklist checklists that users can use to choose the best services from CSPs or to conduct their own CCS checklist. The solutions suggested by these researchers are discussed in the following section.

B. *Data Governance*

Data governance offers data integrity and consistency where it eliminates silo in the system. As organizations have grown bigger, lots of system and process will be created to fulfil the needs and demands in the organizations. As the result, redundancy and duplication will exist and make the system more complicated. By applying data governance, all data will be categorized and put under specific data owners and will have its own specification. Only data owner will hold the responsibility of the data and can grant access to other users.

This also agreed by [25] where they stated that data governance refer to the authorization and responsibility in data asset management in an organization. However, according to them, this clarification cannot be used in cloud computing context. This is because, managing data in traditional DC is not as complicated as in private cloud DC.

Many researchers advised users to have strong knowledge in cloud computing and governance before moving to the cloud

[26], [27]. This is because, moving to cloud without knowing the risk it will expose users to threats, especially internal threats. Therefore, users need to consult their providers first before proceeding to the next step.

One of security concerns mentioned by [28] is loss of governance by the end user. This also agreed by [29] where problem faced by beginners enterprise users are security, multitenant, lack of integration and expertise and also governance problems. [29] further explained that the main issue of these problems are users who plan to move to cloud did not understand what are cloud is. This is because users did not understand the architecture enough before subscribing to the services.

[28] suggested that the solution for governance and compliance threat issues, are by using audit checklist. This is because, users can use the checklist to check whether they had followed the standard guidelines and policies in data management. This will help them to prevent issues in data management.

[30] mentioned that one of threat in the cloud is loss of governance. In his article, he mentioned about a certain part in SLA which did not cover all parts in cloud service. As discussed by [31], since there is no specific agreement when it comes to providers' side, therefore its widen the gap in security issues. Furthermore, since the data is stored in CSP's server, users may lose control of their data [13].

As further mentioned by [13] there is a need in developing data governance specifically for cloud computing. This is because, currently there many standards or templates developed for data governance, which can only be used in physical DC. They are concerned that the differences between who can control the data is the main issue in data governance for cloud computing. It will also be resulting in privacy and confidentiality issues in cloud computing.

C. Security Checklist

Solutions to improve CCS security have been widely discussed: one method to address this issue is to implement security checklist in the cloud [9], [13], [14], [26]. Moreover, [14] stated that, in CCS, lack of trust was one of the major concerns. The reason is that users do not know where their data are, nor do they know who has and who can access their data. As the data location is unknown in CCS and, unlike on-premises DCs, no physical location exists, many users are not confident with CCS security measures. They are afraid that their data might be accessed by other tenants in the same cloud environment. [8] believed that risk checklists should be conducted regularly to manage the possibility of data leakage. The author added that one attribute needing evaluation is data integrity as this would ensure the security of and restricted access to all personal and confidential data.

Due to the importance of data governance in cloud security and the increasing security threat issues faced by users, many researchers have proposed checklists and frameworks for reference purposes when users are choosing the CSP that is best for them. Table 1 presents security checklists that have been implemented and proposed by several researchers.

These previous studies have focused on identifying IaaS security issues and have suggested solutions and methods that involve the development of checklists or checklists. The different methodologies used by these researchers are discussed in the next section.

TABLE I. SECURITY CHECKLIST

Security Checklist	**Author**	**Title**
This paper focused on the security of multi-tenancy in the IaaS environment. Just as multi-tenancy is one of the advantages of cloud computing, it can also become one of its disadvantages. The reason is that multi-tenancy allows many users in the cloud, in which virtual machines (VMs) must be used to cater for all users. The author also focused on virtual machine (VM) vulnerabilities and how they can lead to threats. The authors therefore suggested security measures to secure the IaaS layer, thus, preventing more threats in future.	[24]	Locking the Sky: A Survey on IaaS Cloud Security
The final contribution of this research paper is a two-layered guidance, audit template and audit manual. The authors proposed a security assurance system for two service models in cloud computing, namely, PaaS and IaaS. The authors used checklist from professional bodies, such as the National Institute of Standards and Technology (NIST), Control Objectives for Information and Related Technology (COBIT) and International Organization for Standardization (ISO), as references when developing their own checklist. In their checklist, Layer 1 is the security control layer and Layer 2 is the audit control layer. This paper also discussed security and privacy risks, possible risks, probability and the potential impact of each risk.	[16]	A Proposed Assurance Model to Assess Security and Privacy Risks in IaaS and PaaS Environments
This paper focused on the security level of four multi-tenants in an IaaS service model named Cloud-Trust. Cloud-Trust estimates high-level security metrics to evaluate the degree of confidentiality and integrity offered by the CSP in their CCS. Here, the authors listed all the possibilities of APT attacks, specifically in the IaaS service model. The authors further argued that APT attacks can go through the VM vulnerabilities in the system. At the end of this study, using the Bayesian network model, they showed how Cloud-Trust accessed the IaaS CCS and the IaaS CSP to estimate the possibilities of APT attacks.	[5]	Cloud-Trust: A Security Checklist Model for Infrastructure as a Service (IaaS) Clouds
The authors developed the checklist for self-auditing purposes. What is different from the other guidelines or checklists available is that companies or users can use the checklist to carry out self-auditing of the cloud service that they have already purchased. The guidelines and checklists can also be used to check the performance of deployment hardware, the network and the configuration context that are running the technology.	[32]	Security Checklist for IaaS Cloud Deployments

Another standard that can be used as reference is ITU (International Telecommunication Union). ITU is under United Nation (UN) that specialized in issues under information and communication technology (ICT). ITU also collaborates with ISO in developing standard in certain areas. Similar to ISO, ITU has 1 recommendation under sub T which is ITU-T X.1601 [33] where it discusses the security framework for cloud computing.

This standard can be used as a second reference since researchers need to purchase to get full documentation for an ISO standard. Therefore, ITU collaborates with ISO to produce another standard which is free and available online.

D. APTs

As had been mentioned in IaaS security issues, APTs is one of advanced threats that can cause severe impact to the system. The severity of APTs attack is to the extent that users will never realize the attackers are already in the system and monitoring them. Attackers also will amend, and modify the code in the system so that they can keep accessing it. By using a simple malware attack, it can create a backdoor for attackers to infiltrate the system. After that, they will change to stealth mode to monitor the system and familiarize with the environment.

APTs are rarely mentioned because some victims don't even know that they were attacked. They will only realize it when they detect large traffic going out of the network, high confidential files were accessed by unauthorized users and most of the files lost.

Some attacks were done due to political issues as one method to know the opponent's weaknesses and planning. Usually, this type of attacks was sponsored by the attacker government itself. While some attacks were done to obtain ransom from the victim.

APTs are different from ransomware where the victim of ransomware knows they were attacked. Ransomware is new types of threat attack that locked victims' files and folders and requesting a ransom from them in order to unlock the files. If not, the attacker will delete the files. However, the victims can ignore the request if they have a backup of the locked files in other places or the information in the locked files are not important. While APTs attack will target the high valuable and confidential information where it will bring severe harm to the victim if the information is deleted or exposed.

[34] discussed about the 7 steps of APTs methods of attack. The first step is research. In this step, the attacker will gather basic information required about their victim. Here, the attacker will identify which internal employee that will be going to help them initiate the attack. Thus, they will start looking all information which they can look into public resources such as online searching, booklet, or any information boards. This is called social engineering.

The next step is preparation. Here, after they collected enough information regarding their victim and who will help them, they will prepare the attack mechanism. The APTs attack mechanism can be started by using malware infected removable devices or phishing infected emails. When the internal employee connected the infected removable device or click on the infected email, it will create a backdoor at the system which allows the attacker to enter the system.

The third step is intrusion. After the backdoor is created, the attacker will enter the system and take control over it. However, they will do that in stealth mode, which their presence cannot be detected by security in the system.

Fourth step is controlling the network. While still in stealth mode, they will change all settings that let them be the administrators and change all the security settings that will allow them to enter the entire network up to the most confidential part. Some attacks will create a simple disturbance in the system so that the system administrator will keep busy clearing the disturbance while the real threats are still in the system.

The fifth step is hiding their presence. Since the attacker already changed most of the system settings, they will keep hiding in the system. This is because, they want to monitor the activities in the network and try to access any possible files and folders. They will delete their activities logs, modify event in the network, and install rootkits to ease them accessing the network.

Next step is gathering data. When they found what they are looking for, they start the extracting process. This is where they will transfer all the data to their network. If security admin staff monitor the network activity, they will notice a large traffic going out from the network. However, since the data was hide and masked as legal or regular traffic, mere security staffs will not notice it.

Last step is maintaining access. If the victims still did not realize that they had been attacked, the attacker will make sure that the backdoor is working properly as usual in case if they want to enter the system again and collect some more data.

III. METHODOLOGIES

Several methodologies have been used to study security issues in cloud computing. Based on the security issues identified, security checklist and checklists were developed. Some methods used to identify security issues are survey and observation on the cloud server. The methods used to design the checklist were via an extensive literature review and focus group discussions. Preliminary research regarding IaaS security was undertaken by [24] in which the authors focused on multi-tenancy issues in IaaS and how vulnerabilities in IaaS can become threats. The authors used a literature review to discuss the security threats in virtual machines (VMs), analyzing the literature review's suggested solutions for future reference.

Meanwhile, [35] traced the development of security issues as well as discussing the main issues raised in previous studies. [35] used a comprehensive taxonomic survey as their methodology while focusing on eight main categories of the CCS security state. The study then identified issues in CCS by evaluating the eight categories.

Another common method used in this type of study is the extensive literature review. The method by reviewing checklists developed by professional bodies and other previous studies. Researchers refer to numerous papers and checklists related to this topic and compare their checklist with the problems that need to be solved.

Many studies [16], [21], [32] have referred to professional bodies when developing their checklist. Examples of these professional bodies are Cloud Security Alliance (CSA); COBIT; NIST; and European Union Agency for Network and Information Security (ENISA). However, most of these professional bodies have developed a security checklist for the whole CCS and not for certain cloud service models (CSMs). Therefore, researchers like [16], who focused on security risks in IaaS and PaaS, only selected a few checklists related to IaaS and PaaS when developing checklists to be used as a reference.

[32] also referred to some of these professional bodies in developing IaaS security checklists. Their study sought to identify the type of IaaS threats before proposing the best solution. In addition to referring to professional bodies, researchers such as [21] referred to previous studies that discussed threats in IaaS as well as to the risks and threats analyzed in the current paper, as mentioned in the previous section.

Some studies used the technical method to analyse IaaS security threats. For example, [5] used the Bayesian network model to detect the attack path by focusing on APT attacks in IaaS. Based on this model, their study calculated the probability of APTs accessing high-value data and the probability of APTs being detected by security system providers or the cloud tenant security system.

Meanwhile, [36] used the fuzzy multi-criteria decision-making technique to conduct risk checklist in cloud computing. Their study proposed risk checklist as a service (RaaaS), in which they adopted and adapted the checklist developed from the above-mentioned professional bodies to solve cloud computing security issues.

Other methods used for studying security issues in cloud computing are interviews and surveys. These methods have been used by some companies, such as [37] and [38], to study security issues in the users' environment and how they managed any attacks that happened within that environment. [39] also used the same method, that is, a systematic literature review and interviews with experts, to address security issues in cloud computing and the gaps identified in previously published checklists.

Furthermore, organizations have participated in cloud security studies by carrying out surveys on CCS security issues, especially in companies that use cloud computing. Organizations, like [40] have conducted interviews with decision makers in business circles, such as digital retailers, venture capital and CSPs, to identify CCS problems and issues.

For the current study, there are 2 methods that will be used in order to investigate the security level in small cloud DC. The first method is extensive literature review (LR). For this method, researchers will study the threats in IaaS layer and how APTs can affect this layer. The researcher also will identify solutions or remediation method to prevent or stop the threats that were proposed by previous researchers. The researcher also will study standards and format in writing checklist from professional bodies such as ISO, CSA and ITU.

After these extensive investigations, a checklist will be designed and used as tools for data collection. For data collection, in-depth interview will be conducted with respondents. There are 2 types of respondents involved in this study, which are small cloud DCs and experts. The objective interviewing small cloud DCs is to investigate the security levels in small cloud DCs and what ate security measurement that had been implemented in the DCs.

This session's focus is to gather information on how the personnel who handle the cloud DC manage its security aspects. Through this session, the current security issues in cloud computing can be investigated, while also studying the current practices that companies have applied to solve these issues. The suitable target respondents for the session would be technicians or staff with responsibility for handling the cloud DC in identified companies.

Next in-depth interview session will be conducted with experts. Experts for this study must fulfilled the criteria decide at the beginning of the study. The criteria that expert must fulfill are he/she must have

- Qualified certification in security or networking and/or
- Have more than 5 years' experience in security and networking.

This session intended to seek advice and opinion from industry experience. This session also is to verify the questions used in the checklist whether it is reliable and can be used to propose a final checklist that will be implemented in one of small cloud DCs. The process of this study is explained in the Fig. 1 below.

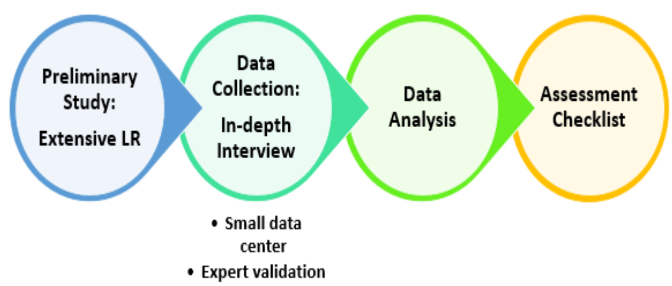

Fig 1. Research Flow Chart.

IV. Threat Checklist

After the checklist is tested at small cloud DC, to measure the level of security in that small cloud DC, a threat checklist needs to be done. This is where the threats and vulnerabilities will be categorized according to their severity. [41] mentioned in their paper that threats ranking is needed to help organization in prioritizing the severity of threats so that they can focus more on which threats they need to be protected from and how they can implement protection methods.

[41], [42] identify 5 factors to be considered when ranking the vulnerabilities, which are (1) identify the risk, (2) estimate

the likelihood, (3) estimate the impact, (4) severity of the risk and (5) prevention method. [41] further explained that severity ranking is based on the organization/user itself. This is because, every organization will have different level of data confidentiality that they want to protect. Therefore, initial engagement with organization is needed to know which threats that will give severe impact to their business operation. In their study, they use Microsoft STRIDE model to define the severity of threats based on the user's preference.

[43] divided the severity of threats and vulnerabilities according to who will affect from it. After that, he categorized the impact of severity by how long the threat could be addressed. If longer time needed, the threat will be categorized as 2 which is high impact and if short time needed, the threat will be put into category 1 which is low impact. After that, he divides the vulnerabilities according to CIA triad and determine the level of severity by giving the CIA score to 2, 4, and 8 respectively.

Next, he assigned the number of probabilities for the vulnerability to happen with low (1), medium (2) and high (4). Lastly, to get the probability score, he multiplies the impact score, severity score and number of probabilities. From that result, he can suggest to the organization which issues they can focus on to make sure the security of cloud service that they implemented.

In [44] they discussed types of methods that had been used in measuring risk for cloud security. They listed 2 types of methodologies which are qualitative and quantitative methods in assessing security risk. At the end of their paper, they proposed their own checklist model with 5 processes which are identification of assets, determination of vulnerabilities, determination of threats, identification of risks and identification of measures.

[45] had published the latest version of critical areas in cloud computing report. In the report, the authors identified 13 domains critical areas in cloud computing. These domains were divided into 2 categories which are governance and operations. The governance domain is addressing the policy and strategic issues in organization, whereas the operations domain is concerning technical security issues and implementation within the organizations.

The critical domains that falls under governance are:

- governance and enterprise risk management,
- legal issues,
- compliance and audit management
- information governance.

While domains that were categorized under operations are:

- management plane and business continuity,
- infrastructure security,
- virtualization and containers,
- incident response,
- notifications and remediations,
- application security,
- data security and encryption,
- identity, entitlement, and access management,
- security as a service
- related technologies.

There are many ways of categorizing the threat severity level when investigating the security level for cloud computing. However, these severity levels must be discussed between CSP and users before the implementation of cloud in the user's organization. This is because, threats can have a different impact, depending on the privacy and confidentiality of certain data and information. Therefore, it is important for an organization to know by themselves first which crucial information in their organization so that they can provide more security in that area.

V. Result and Discussion

This research uses ITU-T X.1601 as the reference. ITU-T provides steps for new researcher to follow as a guideline when developing cloud security checklist, assessment, or guideline. In the article, it suggests 3 steps to follow which is shown in the fig 2 below.

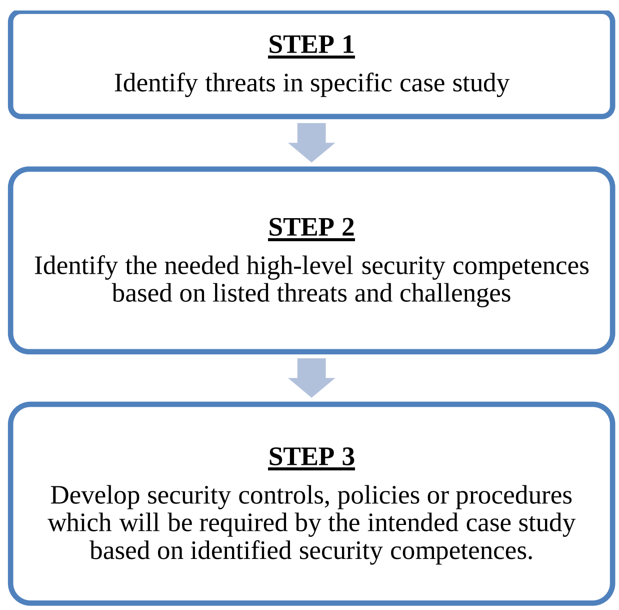

Fig 2. Steps to Develop Checklist.

Based on extensive LR there are 27 threats identified in IaaS layer. This finding is based on reading 130 articles related to IaaS cloud security and threats mentioned in the articles are recorded and calculated. Table II shows the list of threats found in 130 articles related to IaaS security issues.

Then, the next step is to identify the crucial elements in cloud computing that need to be focused when developing the checklist. Among the 130 articles used for this research, 28 of the articles mentioned about important parameters in cloud computing which were identified in the Table III below.

TABLE II. THREATS IN IAAS LAYER

No	Threats	Frequency
1.	VM	59
2.	DOS	34
3.	DDOS	17
4.	Data leakage and loss	31
5.	Data theft	12
6.	Data security and privacy issue	36
7.	Trust issue	7
8.	SLA/Legal issue	12
9.	Shared technology/multi-tenancy	29
10.	Account hijacking	27
11.	Access issues	26
12.	Cloud service providers	24
13.	Malicious attacks	42
14.	Availability and reliability issues	18
15.	Insecure Interfaces and APIs	16
16.	Abuse of cloud	15
17.	Authentication and authorization	33
18.	Man-in-the middle attack	15
19.	Spoofing	6
20.	Injection attack	12
21.	Data breaches	10
22.	Loss of control	7
23.	APTs	3
24.	Malware	10
25.	Phishing	10
26.	Backdoor	8
27.	Social engineering	6

By referring to the table III, it shows there are 3 parameters mostly mentioned in the 28 articles which are availability, confidentiality and integrity. Therefore, for this study, the high-level security components that can be used is the Confidential, Integrity and Availability (CIA) triad.

CIA triad is widely used as reference when developing guideline, checklist or assessment. This is because, it is to ensure the important part of the study area in covered before proposing final checklist/guideline/assessment. CIA triad not only cover cloud security [3] but also cover other information technology (IT) subjects such as advanced threats [68], performance [69], IaaS security [17] and cloud data governance [13].

After that, remediation process suggested by previous researchers were identified and checklist is designed. The questions used in the checklist were referred from the developed checklist by previous researchers and professional bodies. This is to ensure that the questions are following standards that had been used by many researchers.

TABLE III. SECURITY PARAMETERS

No	Author	**Parameter**							
		Availability	**Vulnerability**	**Accessibility**	**Configuration**	**Confidentiality**	**Integrity**	**Reliability**	**Scalability**
1.	[46]	x	x			x			
2.	[47]		x	x	x	x	x		
3.	[48]	x		x		x	x	x	x
4.	[49]	x	x					x	x
5.	[50]	x	x	x	x	x			
6.	[51]			x		x			
7.	[52]	x	x	x	x				
8.	[10]				x				
9.	[1]	x					x		
10.	[53]	x	x	x	x				
11.	[54]	x	x		x	x	x		
12.	[13]	x				x	x		x
13.	[55]	x			x				
14.	[56]	x						x	x
15.	[57]	x	x			x	x	x	x
16.	[58]	x				x	x	x	x
17.	[59]	x		x			x	x	
18.	[60]	x	x				x		x
19.	[61]	x		x		x	x	x	
20.	[62]	x				x	x		x
21.	[12]	x				x	x		
22.	[16]	x				x	x		x
23.	[63]	x				x	x		
24.	[27]					x			x
25.	[64]	x				x	x		
26.	[65]					x	x		
27.	[66]	x				x	x		
28.	[67]	x						x	
Total		**22**	9	8	7	**19**	**16**	8	10

Another focus in this study is the threats in IaaS that may lead to APTs. Table IV shows previous researchers mentioned what are the threats that exist in APTs.

TABLE IV. THREATS IN APTS

No	Author	APTs threats			
		Malware	Trojan	Phishing	Social engineering
1.	[70]	x	x	x	
2.	[71]	x		x	x
3.	[68]	x			x
4.	[72]	x	x	x	x
5.	[73]	x	x	x	
6.	[74]	x			
7.	[75]	x		x	
8.	[38]	x			x
9.	[76]	x			
10.	[77]		x		x
11.	[78]	x			
12.	[79]	x		x	x
13.	[80]	x	x		x
14.	[81]			x	
15.	[82]	x			x
16.	[83]	x		x	
17.	[84]	x			x

As shown in the table IV, all threats mentioned to be existed in APTs also exist in IaaS layer. Therefore, it can be proven that these threats attack can lead to APTs attack in IaaS layer.

A checklist with 27 questions has been developed based on threats identified in IaaS and solutions proposed by previous researchers. An in-depth interview session had been conducted with 3 small DCs. The objective of this in-depth interview is to investigate the security level of cloud IaaS in small DC. 27 questions in the checklist were asked and the analysis was done based on the critical level of the questions. The critical criteria for the questions had been identified by using the critical areas in [45] which had been mentioned above.

Based from the analysis, it shows that the security level from these small cloud DCs is still at low level. This is because, among 17 critical questions in the checklist, these DCs only fulfil 5 critical questions. Therefore, some security recommendations can be suggested for these DCs to be implemented so that the security level can be increased.

After in-depth session with small cloud DCs, another in-depth session was held with experts. As had been mentioned above, this session is to validate the reliability of questions used in the checklist whether it can be used or not. 2 experts were interviewed to get their opinion and advice in this area.

After the interview session is conducted, both experts, Expert 1 (E1) and Expert 2 (E2) agree and accepted the initial checklist that had been developed. However, E2 suggests that the questions should be rephrased and redesigned following the standards. This is because, some of the questions are general to cloud computing since this study is focused on IaaS layer. Therefore, for final development of the checklist, the questions should be specific and focus on IaaS layer.

VI. CONCLUSION

Security in IaaS is a serious issue as IaaS lies at the lower level in cloud computing: both PaaS and SaaS could be affected by any attack at this level. Therefore, it is very important that IaaS security be considered a priority. This would ensure that security in IaaS would be secured to prevent attackers, whether internal or external parties. Based on the review of the current literature, the lack of current security checklist development specifically for the IaaS service model is apparent. Therefore, security checklist needs to be revised and updated as many new threats and malware have been created and modified, thus threatening security in cloud computing technology.

Based on the finding from in-depth interviews with small cloud DCs, it shows that there is lack in security protection at IaaS layer. As had been discussed at the earlier section in paper, IaaS is the most important layer in CSM because this is where all data and information of the system is stored. Therefore, lack of security protection in this layer can bring harm to the system and can expose the system to attackers or APTs.

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REFERENCES

[1] S. Aldossary and W. Allen, "Data Security, Privacy, Availability and Integrity in Cloud Computing: Issues and Current Solutions," Int. J. Adv. Comput. Sci. Appl., vol. 7, no. 4, pp. 485–498, 2016.

[2] Y. Z. An, Z. F. Zaaba, and N. F. Samsudin, "Reviews on Security Issues and Challenges in Cloud Computing," in IOP Conference Series: Materials Science and Engineering PAPER, 2016, p. 10.

[3] J. Kar and M. R. Mishra, "Mitigating Threats and Security Metrics in Cloud Computing," J. Inf. Process. Syst., vol. 12, no. 2, pp. 226–233, 2016.

[4] A. K. Sen and P. K. Tiwari, "Security Issues and Solutions in Cloud Computing," IOSR J. Comput. Eng., vol. 19, no. 2, pp. 67–72, 2017.

[5] D. Gonzales, J. M. Kaplan, E. Saltzman, Z. Winkelman, and D. Woods, "Cloud-Trust-a Security Assessment Model for Infrastructure as a Service (IaaS) Clouds," IEEE Trans. Cloud Comput., vol. 5, no. 3, pp. 523–536, 2017.

[6] B. K. Joshi, M. K. Shrivastava, and B. Joshi, "Security Threats and Their Mitigation in Infrastructure as a Service," Perspect. Sci., vol. 8, pp. 462–464, 2016.

[7] S. N. Kumar and A. Vajpayee, "A Survey on Secure Cloud: Security and Privacy in Cloud Computing," Am. J. Syst. Softw., vol. 4, no. 1, pp. 14–26, 2016.

[8] D. Salazar, "Cloud Security Framework Audit Methods," 2015.

[9] J. Qadiree and T. Arya, "Security Threat Issues and Countermeasures in Cloud Computing," Int. J. Eng. Sceince Innov. Technol., vol. 3, no. 2, pp. 25–29, 2016.

[10] Z. Xu, "Understanding Security Threats In Cloud," Diss. Theses, Masters Proj., 2016.

[11] A. Jadhao, K. Anad, S. Dhar, and S. Mukharia, "Cloud-Trust - A Security Assessment Model for Infrastructure as a Service (IaaS) Clouds," Int. J. Comput. Sci. Trends Technol., vol. 4, no. 5, pp. 110–113, 2016.

[12] V. Khatri and C. V. Brown, "Designing Data Governance," Communications of the ACM, vol. 53, no. 1, p. 148, 2010.

[13] M. Al-Ruithe, E. Benkhelifa, and K. Hameed, "A Conceptual Framework for Designing Data Governance for Cloud Computing," Procedia Comput. Sci., vol. 94, pp. 160–167, 2016.

[14] S. Jafarpour and A. Yousefi, "Security Risks in Cloud Computing : A Review," Int. J. Curr. Eng. Technol., vol. 6, no. 4, pp. 1174–1179, 2016.

[15] B. Lawal, C. Ogude, and K. Abdullah, "Security Management of Infrastructure as A Service in Cloud Computing," African J. Comput. ICT, vol. 6, no. 5, pp. 137–146, 2013.

[16] A. J. Maduka, S. Aghili, and S. Butakorv, "A Proposed Assurance model to Assess Security and Privacy risks in IaaS and PaaS Environments," Annu. Symp. Inf. Assur. (ASIA '17), pp. 61–67, 2017.

[17] N. Rakotondravony et al., "Classifying malware attacks in IaaS cloud environments," J. Cloud Comput. Adv. Syst. Appl., vol. 6, no. 12, pp. 1–112, 2017.

[18] W. Dawoud, I. Takouna, and C. Meinel, "Infrastructure as a Service Security: Challenges and Solutions," pp. 1–8, 2013.

[19] P. Arora, R. C. Wadhawan, and E. S. P. Ahuja, "Cloud Computing Security Issues in Infrastructure as a Service," Int. J. Adv. Res. Comput. Sci. Softw. Eng., vol. 2, no. 1, pp. 1–7, 2012.

[20] B. J. Amali and S. Balaji, "Security Technique Issues in Cloud Computing - A Review," Int. J. Adv. Multidiscip. Res., vol. 4, no. 8, pp. 63–69, 2017.

[21] S. Drissi, H. Houmani, and H. Medromi, "Survey: Risk Assessment for Cloud Computing," Int. J. Adv. Comput. Sci. Appl., vol. 4, no. 12, pp. 143–148, 2013.

[22] R. Yogamangalam and V. S. S. Sriram, "A Review on Security Issues in Cloud Computing," J. Artif. Intell., vol. 6, no. 1, pp. 1–7, 2013.

[23] E. Savolainen, "Cloud Service Models." p. 16, 2012.

[24] L. M. Vaquero, L. Rodero-Merino, and D. Morán, "Locking the sky: A survey on IaaS cloud security," Computing, vol. 91, no. 1, pp. 93–118, 2011.

[25] M. Al-Ruithe and E. Benkhelifa, "Analysis and Classification of Barriers and Critical Success Factors for Implementing a Cloud Data Governance Strategy," Procedia Comput. Sci., vol. 113, no. December, pp. 223–232, 2017.

[26] T. Sommer, T. Nobile, and P. Rozanski, "The Conundrum of Security in Modern Cloud Computing," Commun. IIMA, vol. 12, no. 4, p. 15, 2012.

[27] C. Baudoin et al., "Cloud Security Standards : What to Expect & What to Negotiate Version 2.0," Cloud Stand. Cust. Counc., pp. 1–36, 2016.

[28] F. F. Moghaddam, M. Ahmadi, S. Sarvari, M. Eslami, and A. Golkar, "Cloud Computing Challenges and Opportunities," 1st Int. Conf. Telemat. Futur. Gener. Networks Cloud, pp. 34–38, 2015.

[29] N. Serrano, G. Gallardo, and J. Hernantes, "Infrastructure as a service and cloud technologies," IEEE Softw., vol. 32, no. 2, pp. 30–36, 2015.

[30] A. M. Mohammed, "Securing the Cloud: Threats, Attacks and Mitigation Techniques," 2014.

[31] C. Eric, D. Chris, E. Mike, and G. Jonathan, "Security for Cloud Computing 10 Steps to Ensure Success," Cloud Stand. Cust. Counc., pp. 1–35, 2015.

[32] M. Héder et al., "Security Checklist for IaaS Cloud Deployments," pp. 1–8, 2016.

[33] The International Telecommunication Union, "Series X: Data Networks, Open System Communications and Security," 2015.

[34] J. Vukalović and D. Delija, "Advanced Persistent Threats - Detection and defense," 2015 38th Int. Conv. Inf. Commun. Technol. Electron. Microelectron. MIPRO 2015 - Proc., no. May, pp. 1324–1330, 2015.

[35] D. A. B. Fernandes, L. F. B. Soares, J. V Gomes, M. M. Freire, and P. R. M. Inácio, "Security Issues in Cloud Environments- A Survey," Int. J. Inf. Secur., vol. 13, no. 2, pp. 1–95, 2014.

[36] A. S. Sendi and M. Cheriet, "Cloud Computing: A Risk Assessment Model," 2014 IEEE Int. Conf. Cloud Eng., pp. 147–152, 2014.

[37] Kaspersky, "Consumer Security Risks Survey 2015," Kaspersky Lab, 2016.

[38] Symantec, "Advanced Persistent Threats: A Symantec Perspective," 2011.

[39] Y. Ghanam, J. Ferreira, and F. Maurer, "Emerging Issues & Challenges in Cloud Computing — A Hybrid Approach," J. Softw. Eng. Appl., vol. 5, pp. 923–937, 2012.

[40] Computing Research, "Cloud & Infrastructure Review 2017," 2017.

[41] P. Anand, J. Ryoo, H. Kim, and E. Kim, "Threat Assessment in the Cloud Environment – A Quantitative Approach for Security Pattern Selection," Imcom '16, p. 8, 2016.

[42] Owasp, "OWASP Risk Rating Methodology," Owasp, pp. 1–5, 2013.

[43] F. R. Carlson, "A Security Analysis of Cloud Computing," Ieee, pp. 1–2, 2011.

[44] S. Drissi, S. Benhadou, and H. Medromi, "Evaluation of Risk Assessment Methods Regarding Cloud Computing," 2016, no. June.

[45] R. Mogull et al., "Security Guidance for Critical Areas of Focus in Cloud Computing v4.0," 2017.

[46] K. R. C. Kim, "Cloud computing: challenges and future directions," Trends Issues Crime Crim. Justice, no. 400, pp. 1–6, 2010.

[47] I. Mitchell and J. Alcock, Cloud Security. Fujitsu, 2011.

[48] J. Kar, "Mitigate Threats and Security Metrics in Cloud Computing," vol. 3, no. 4, 2015.

[49] P. Kiminski, "Cyber-Security and Reliability in a Digital Cloud Cyber - Security and Reliability in a Digital Cloud," 2012.

[50] F. Sabahi, "Is Cloud Secure Enough," Int. J. Comput. Theory Eng., vol. 4, no. 6, pp. 926–930, 2012.

[51] G. Nenvani and H. Gupta, "A Survey on Attack Detection on Cloud using Supervised Learning Techniques," Symp. Colossal Data Anal. Netw., 2016.

[52] T. Mather, S. Kumaraswamy, and S. Latif, Cloud Security and Privacy. 2009.

[53] F. Sabahi, "Cloud computing security threats and responses," 2011 IEEE 3rd Int. Conf. Commun. Softw. Networks, pp. 245–249, 2011.

[54] Deloitte, "Cloud Computing: What Healthcare Internal Auditors Need to Know," 2012.

[55] M. Janssen and A. Joha, "Motives for establishing shared service centers in public administrations," Int. J. Inf. Manage., vol. 26, no. 2, pp. 102–115, 2006.

[56] Juniper Network, "Data Center Migration and Risk Mitigation Assessment," 2013.

[57] R. Charanya, M. Aramudhan, K. Mohan, and S. Nithya, "Levels of Security Issues in Cloud Computing," Int. J. Eng. Technol., vol. 5, no. 2, pp. 1912–1920, 2013.

[58] F. Ogigau-Neamtiu, "Cloud computing security issues," J. Def. Resour. Manag., vol. 3, no. 2, pp. 141–148, 2012.

[59] I. Hussain and I. Ashraf, "Security Issues in Cloud Computing -A Review," Int. J, vol. 2243, pp. 2240–2243, 2014.

[60] S. A. Hussain, M. Fatima, A. Saeed, I. Raza, and R. K. Shahzad, "Multilevel classification of security concerns in cloud computing," Appl. Comput. Informatics, vol. 13, no. 1, pp. 57–65, 2017.

[61] R. V. Rao and K. Selvamani, "Data Security Challenges and Its Solutions in Cloud Computing," Procedia - Procedia Comput. Sci., vol. 48, no. Iccc, pp. 204–209, 2015.

[62] Ernest Young, "Building trust in the cloud," no. August, 2013.

[63] W. Huang, A. Ganjali, B. H. Kim, S. Oh, and D. Lie, "The State of Public Infrastructure-as-a-Service Cloud Security," ACM Comput. Surv., vol. 47, no. 4, pp. 1–31, 2015.

[64] P. R. Kumar, P. H. Raj, and P. Jelciana, "Exploring Security Issues and Solutions in Cloud Computing Services – A Survey," Cybern. Inf. Technol., vol. 17, no. 4, pp. 3–31, 2017.

[65] S. Subashini and V. Kavitha, "A survey on security issues in service delivery models of cloud computing," J. Netw. Comput. Appl., vol. 34, no. 1, pp. 1–11, 2011.

[66] S. Singh and V. K. Attri, "State-of-the-art Survey on Security Issues in Cloud Computing Environment," 2016, pp. 1–5.

[67] B. H. Krishna, S. Kiran, G. Murali, and R. P. K. Reddy, "Security Issues In Service Model Of Cloud Computing Environment," Int. Conf. Comput. Sci., vol. 87, pp. 246–251, 2016.

[68] S. Rass, S. König, and S. Schauer, "Defending against advanced persistent threats using game-theory," PLoS One, vol. 12, no. 1, pp. 1–43, 2017.

[69] E. Chew, M. Swanson, K. Stine, N. Bartol, A. Brown, and W. Robinson, "Performance measurement guide for information security," 2008.

[70] F. Li, "A Detailed Analysis of an Advanced Persistent Threat Malware," 2011.

[71] M. A. Siddiqi and N. Ghani, "Critical Analysis on Advanced Persistent Threats," Int. J. Comput. Appl., vol. 141, no. 13, pp. 46–50, 2016.

[72] Kaspersky, "Kaspersky Security Bulletin : KASPERSKY LAB THREAT PREDICTIONS FOR 2018," Kaspersky Secur. Bull., 2017.

[73] B. Rossil, "Advanced Persistent Threats: What are they and why do I care ?," 2015.

[74] The Radicati Group, "Advanced Persistent Threat (APT) Protection Market, 2018-2022," vol. 44, no. 0, 2018.

[75] M. G. Hardy, "APT Dot Gov: Protecting Federal Systems from Advanced Threats," 2011.

[76] D. Sullivan, "Beyond the Hype : Advanced Persistent Threats sponsored by Introduction to Realtime Publishers," 2010.

[77] N. A. Mohamed, A. Jantan, and O. I. Abiodun, "An Improved Behaviour Specification to Stop Advanced Persistent Threat on Governments and Organizations Network," Proc. Int. MultiConference Eng. Comput. Sci., vol. I, 2018.

[78] L.-X. Yang, P. Li, X. Yang, L. Wen, Y. Wu, and Y. Y. Tang, "Security evaluation of cyber networks under advanced persistent threats," no. Pengdeng Li, 2017.

[79] T. Slot, "Detection of APT Malware through External and Internal Network Traffic Correlation," no. March, 2015.

[80] N. Villeneuve and J. Bennett, "Detecting APT Activity with Network Traffic Analysis," 2012.

[81] M. H. Au, K. Liang, J. K. Liu, R. Lu, and J. Ning, "Privacy-preserving personal data operation on mobile cloud—Chances and challenges over advanced persistent threat," Futur. Gener. Comput. Syst., vol. 79, pp. 337–349, 2018.

[82] A. Redondo-hern, A. Couce-vieira, and S. H. Houmb, "Detection of Advanced Persistent Threats Using System and Attack Intelligence," Seventh Int. Conf. Emerg. Networks Syst. Intell., no. July, 2015.

[83] I. Ghafir, M. Hammoudeh, and V. Prenosil, "Defending Against the Advanced Persistent Threat : Detection of Disguised Executable Files," pp. 1–11, 2018.

[84] J. Chen, C. Su, K. H. Yeh, and M. Yung, "Special Issue on Advanced Persistent Threat," Futur. Gener. Comput. Syst., vol. 79, pp. 243–246, 2018.

An Investigational Study and Analysis of Cloud-based Content Delivery Network: Perspectives

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***Abstract*—The content management includes a major technical strategy in the network paradigm of the internet which is called a Content delivery network. The design and the deployment of the CDN shall ensure optimal Quality of services (QoS). This paper aims to brief the taxonomy of the CDN along with its typical architecture. Much latest advancement in smartphones and smart devices which are content hungry require more efficient and reliable mechanism for the cost-effective delivery of the contents irrespective of bottleneck constraints that leads to redesign the entire architecture of CDN on the cloud as CCDN or a new business model of CCDN as a service. The challenges of design for CCDN along with the evolved architecture are discussed in this paper.**

***Keywords*—Content delivery network; cloud computing; distribution network; mobility; scalability; distribution**

I. Introduction

In the era of highly mobile business and competitive environment, any delay in the site/content latency leads to the loss of the business or failure of an intelligent application. The most rapid approach to improvise the application performance is to adopt the Content Delivery Network (CDN) where without having an additional work overhead of updating code or architecture the data can be placed. The evolution approach of (CDN) aims to deliver the content to the end user with optimal Quality of Services (QoS). It is estimated that by 2020 approximately 67% of multimedia content will be forwarded using CDN [1].

CDN is a physically distributed network with surrogate servers and their data centers. The primary objective is to offer high accessibility and high performance to the end-users in order. CDNs provide a huge segment of the Internet content nowadays, containing web things like a) *Graphics* i) text and scripts, *b) Downloadable things* i) Software, ii) Media files, and iii) Documents, c) *Applications* i) E-commerce, ii) Live streaming media, iii) Portals, iv) Social media.

Many of the web objects including text, scripts along with downloadable objects, applications, live streaming media, social media sites, etc. are served through CDNs, and the economics of the CDNs are fulfilled by the content owner [2]. The CDN is the first layer on the internet, and the typical architecture of the CDN includes proxy servers, datacenters, edge servers, origin servers, Domain Name System (DNS) hosted zone, etc. [3]. One of the leading CDN service providers is Akamai, who have deployed tens of thousands of data centers along with edge serves to distribute the content in different geographic locations across the globe. With the rapid growth of content especially multimedia contents, the demand of CDN is increasing so in the competition the CDNs need to assure a very cost-effective, consistent with fault-tolerant architecture that ensures lower latency. There is a sharp shift into the content type which needs to deal with CDNs as it includes both dynamic and static contents including video, metadata, etc., so the content management processes require establishing correlation among the content. The correlation computation demands an additional module for the machine learning which even helps to tags the popularity of the content. The typical architecture design of CDN considers the content type, its granularity along with the characteristics and the distribution. Some of the significant benefits of the CDN are as follows viz. i) media and advertising: the need of propagating different numbers of real-time multimedia streams demands a dedicated communication channel that can be provided by CDN only. The availability and response could be further increased by migrating CDN services over the cloud. ii) e-Commerce: The improvement of the application is carried out by e-commerce companies in order to offer a better quality of service to the client. This is possible by using CDN where 100% uptime associated with the applications can be carried out. iii) Education: The revolutionary in the area of online learning system demands real-time transaction of various forms of course contents along with forum management where thousands of internal threads are operated. Such massive set of information is made available for ensuring an effective knowledge delivery system by CDN, and iv) business-based application: Any business-based application demands a highly smooth and responsive interaction between the users and the service providers (or vendors/merchants). The faster responsiveness of the business-application is feasibly maintained using CDN. However, apart from the above advantages, there are many limitations as well as constraints too, for which reasons; it is worth investigating this topic.

This paper discusses the different perspective of the existing models and research work towards improving the performance of the CDN system. The organization of the paper is as follow: Section II discusses significant taxonomies of CDN followed by a brief discussion of the significance of CDN in Section III. The evolution of the CDN network is briefly discussed in Section IV followed by highlights of some of the research-based approaches in Section V. Finally, research gap is briefed in Section VI while the conclusive remarks of this paper are briefed in Section VII.

II. Essentials of CDN System

The theoretical concept of CDN is quite big enough and there are various taxonomies of it depending on the networking and application demands. It is essential to understand the taxonomies of the CDN that are frequently considered by researchers. For this reason Figure1 highlights the conventional taxonomies of CDN system that are discussed in the work of Stocker et al. [4] which offers an evidence of various forms of CDN system formed by the existing researchers. The different types of CDN are as follows:

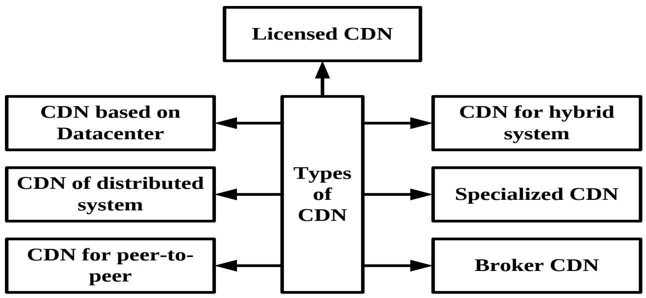

Fig. 1. Types of CDN [4]

By looking into the above Figure1, it is now clear that a different form of networking system demands to utilize different CDN systems. There are CDN systems that are meant for data communication to and from the data center and to the customers using the cloud environment. Peer-to-Peer network also has a dedicated CDN architecture for supporting the exchange of data, which runs completely a different communication protocol. Specialized CDN assists in carrying out a specific on-demand task of communication over better resource availability. Broker CDN assists in explicit communication to achieve a specific performance level using the broker node in the cloud. Finally, hybrid CDN and distributed CDN offers better flexibility to manage an effective data transmission over the distributed network and heterogeneous protocols. The fundamental framework of CDN includes four essential components that can be expressed as an origin server, several surrogate servers, CDN operator and a request redirection mechanism [5]. These components are classified as shown in Figure 2, followed by their discussion:

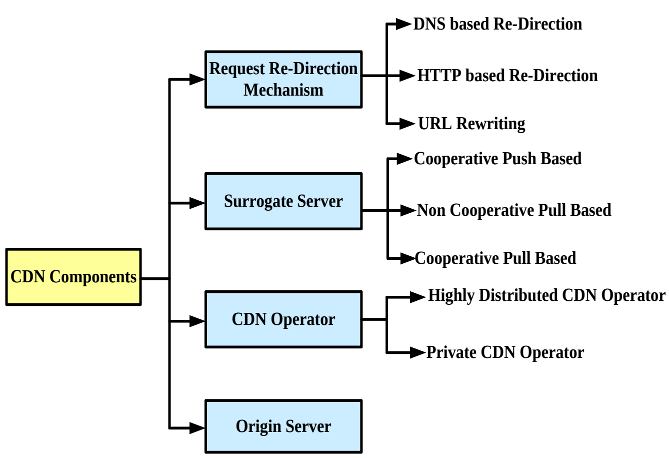

Fig. 2. Classifications of Essential Components in CDN

The essential components in CDN are briefed as follows:

1) *Origin Server:*

The actual contents are reposited over the original server where the data communication is carried out with multimedia providers through a distributed replica server to manage and update a large set of content databases. The replica server plays a role of the media server, cache server or web server. Here, a content provider depends on the CDN operators to globally distribute the contents from the origin server to the user.

2) *CDN Operator:*

The CDN operators are the third party services where the content owner pays to deliver their content to end users and similarly, CDN pays to ISPs and network operator for hosting its servers to their datacenters. Moreover, the CDN operators are run by some branded and commercial organizations. These organizations develop a distributed platform where they provide service for content distribution on rent. The following are the kinds of CDN operators who facilitate services by using different platforms viz. i) highly distributed CDN operator**:** These CDN operators rent their servers in the data centers of the world's leading Internet service providers, and their networks are highly distributed to most parts of the world. This location is also known as Point of Presence (PoP). The Akamai industry is a good example of a highly distributed CDN operator. ii) Private CDN operators: Private CDN operator established its own data center at a specific region where they present content distribution services over a private network. Also, each location being considered as PoP. A Limelight network is an *example of a private CDN operator.*

3) *Surrogate Servers:*

The CDN operators are the responsible for delivering quality aware content to end user by employing or hosting multiples of edge servers in multi-directional ways, and these servers are popularly known's as surrogate servers. The surrogate servers are proxy servers which are much greater than the origin servers that distribute the content to the user on behalf of origins servers of multiple datacenters. The objective of using surrogate servers is to reduce the network traffic, reduce load and to enhance the availability of the content for both end users and devices. Furthermore, the proxies are categorized into the following which is described as i) *Forward proxy:* These proxies are deployed to capture all the web traffic which is found in the ISP network and ii) *Reverse Proxy:* These proxies are deployed to capture the content request which is addressing to origin servers, and this is implemented as CDN's surrogate servers. Typically, a surrogate server utilizes a caching proxy to store data to provide content to users more frequently. The process involves an HTTP request generated based on a request by the user to access the content, and if the content requested by the user is stored locally in the caching proxy, it is referred to as a HIT, where the user gets the respective content from the caching proxy without accessing from the origin server. In case the caching proxy doesn't retain the requested content, then it is referred to the case of MISS. In this case, the content requested by the user is provided from the origin server, and further it stored locally in the caching proxy for future use. The network interconnection and collaboration between the surrogate servers of CDN's can be implemented using Cooperative push-based [6], Non-Cooperative pull based

[7], Cooperative Pull based [8], Request Redirection Mechanism [9].

III. Existing Approaches of CDN

There are various works being carried out in the area of CDN system in existing research arena. According to reputed research publishers IEEE Xplore, there are 4051 research papers that directly or indirectly deal with discussing the problems and solutions in CDN system. However, a narrowed search shows that there are 480 journals published in last 5 years related to improving the performance of CDN. All these research papers are focused on different types of research problems e.g. placement [10], cost, optimization [11], communication strategy development [12], mobility [13], replica management [14] etc. This section discusses the existing research-based approaches towards improving the performance of CDN. Haghighi et al. [15] have presented a stochastic mechanism to carry out efficient optimization in cloud environment of CDN. They have discussed cloud sites, user sites and cluster graph model for system model and map formulation. In the cluster-graph model formulation, they have mentioned the state space, action space, Rewards and transition probabilities along with feedback based quality of experience. The resource optimization formulation has done by object function dynamic programming, approximate sub-optimal algorithm, unlimited bandwidth & bandwidth algorithm, Limited bandwidth and sort & select algorithm. The performance evaluation of the introduced method by calculating normalized accumulated rewards, time-normalized, and a number of user and improvement gain for software-as-a-Service scheme. Papagianini et al. [16] have presented a modeling of CDN over cloud that performs three steps e.g. service area clustering and inter cluster content distribution graph, inter-cluster content distribution graph over networked cloud environment and replica placement in the network cloud. The performance evaluation was assessed by experimentation set up, different comparative results, relative partitioning cost for 5 and 10 cloud providers and by mapping a number of cloud providers vs. computation time.

Dong et al. [17] have introduced a streaming-based method for constructing a data forwarding architecture to enhance the cloud service provider capacity. The presented study has used game theory using Nash equilibrium with an aid of a unique negotiation-based approach for the purpose of cost modeling of CDN system. Existing approaches has also used the concept of the content-based networks considering the mobility concept of cloud. The study states the importance of content-based management system for data placement considering significant case studies of traffic and resource problems over cloud networks. The study outcome proved ts efficiency towards minimizing latency reduction. The problems associated with connectivity of CDN over fog computing was carried out by Mouradian et al. [18]. According to the authors, there are various dependable parameters of fog computing e.g. heterogeneity, QoE management, scalability, mobility, federation, and interoperability that affects the performance o CDN system. Siracusano et al. [19] have presented a re-designing of CDN for dynamic content delivery and effectiveness of the services. The presented architecture was found to support significant level of optimization. The issues and opportunities like end-user mapping and redirection, network performance discovery and proxy offloading is discuses along with state-of-art, opportunity and envisioned a solution. The implementation and evaluation have done by path selection based on runtime, solution quality and a number of proxies, TCP proxies offloading and internet deployment based on transfer and deployment time.

IV. Existing Approaches of CCDN

With the rise of massive and discrete demands of the data from the user, the service providers of CDN are in consistent threats of competition towards catering up such dynamic needs. The only solution towards it is to depend upon third party a service provider which also offers more dependencies towards its availability over specific geographic location [20]. Therefore, such problems are now overcome using cloud-based CDN (CCDN) system that contributes towards smart placement of data over the distributed cloud storage that is fully capable of offering 24/7 data availability for an user for any part of the world. Apart from this, there are various beneficial points of adopting CCDN that is claimed not only for offering cost effective solution but also certain redefined services towards data delivery system (Figure 3). The benefits of CCDN are to offer value of service as all the models of CCDN offer pay-per-service. Upon hosting CDN services over the cloud, the availability of the services exponentially increases owing to service availability. As cloud supports a better form of interoperability, CCDN offers extensive heterogeneous service deployment even in CDN system too. Figure 3 highlights pictorial depiction of benefits offered by CCDN.

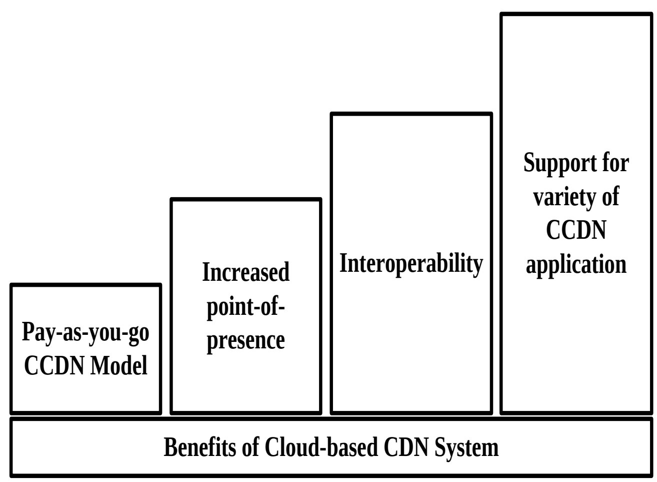

Fig. 3. Benefits of CCDN

Different research approaches towards CCDN can be briefed as following with respect to content placement, fog computing, replica server placement, file management system, mobile edge computing, caching, and content distribution.

A. *Efficient Content Placement*

There have been various studies carried out towards addressing the content placement problem of cloud. The work carried out by Jin et al. [21] has used Topkis-Veinott for addressing the problems associated with inequality in optimization of location. The study outcome has been found to minimize cost of transport and storage of data. Mathematical approach of Lagrangian relaxation has been adopted by Khalaji and Analoui [22] for the sole purpose of minimizing the complexity issues associated with content placement problems to show the outcome with optimal cost effectiveness. Usage of dynamic programming-based approach for solving similar problem was discussed by Chen and Chen [23] with the study outcome to exhibit low complexity. Adoption of mixed integer linear programming was introduced by Xu et al. [24] as a part of optimization model for solving similar problems. The study outcome has been claimed to offer better capacity of storage. Literature has also witnessed the usage of greedy based approach as well as other search optimization approach e.g. Tabu search as seen on the work carried out by Yang and Huang [25] to prove that it offers an efficient performance of content placement. Apart from this, there are also different set of work being carried out by other researchers e.g. [26] towards similar problems. However, it is still an open end problems in CCDN.

B. Fog Computing based Approach

Cloud computing has some inherent capability such as scalability, on-demand resource allocation, a flexible pricing model, reduced management, and easy allocation and service provisioning. However, some of the limitations can arrive such as connectivity between the cloud, and the end user or devices, latency due to the overhead by inter-cloud communication and rule may prescribe processing at the location where the cloud provider has no data center. To overcome these limitation fog computing is utilized to provide quality of application. The research work towards the fog system for end-user applications and application specification architectures were found in recent past. Some of the works like Mouradian et al. [18], Stolfo et al. [27] and Wang et al. [28] have discussed end-user application specific architectures for the platform as a service (PaaS), mobile fog and development of IOT applications in Fog respectively. The [18] presents a PaaS architecture to automate applications within a hybrid cloud or fog environment. The mobile fog is a high-level programming model which can be used for future internet needs. The distributed data flow mechanism of [27] gives IoT application which works better in Fog. The application specific architecture for fog system was presented in Stantchev et al. [29], Kapsalis et al. [30] and Datta et al. [31]. The [31] is helpful in healthcare IT professionals to achieve adequate QoS. The three-level architecture of vehicular fog computing is presented [30] for vehicles as infrastructures and yields smart sensor based healthcare system. The consumer specific fog computing architecture that enables roadside units based on IoT services as shown in the Figure 4. The above-mentioned scheme is found more frequently adopted by various researchers in order to introduce the potential of fog computing over CDN. It consists of three different layers or stratum where the top layer is retained for the cloud to host surrogate server. The middle layer holds the fog processing by managing different distributed and synchronized access points. Finally, the end layer connects to edge users.

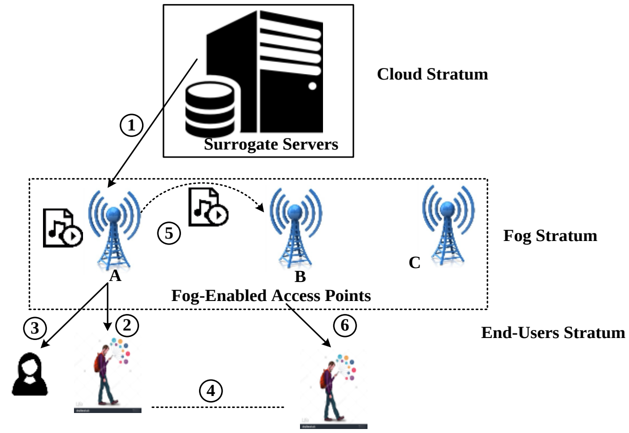

Fig. 4. Schema of Fog Computing using CDN

At present, the approaches of CDN-based research work using fog computing are basically two types, i.e. architecture-based and algorithmic-based. The architecture-based approach has basically focused on developing applications for end-users using agnostic architecture (deals with issues, e.g., Resource management, scheduling application for the end user, etc.) and for exclusive applications (e.g., Applications related to connected vehicular nodes, healthcare, smart appliances, etc.). Similarly, algorithm-based approaches emphasis on storage/ distribution, resource consumption, end-user, etc.

C. Efficient Replica Server Placement

There are issues in the content delivery network while transferring the contents to the end user. To avoid content delivery issues, replica server placement and content placement method in the cloud will achieve the requirements of the user. Hence the replica server placement approach will lead to the fast delivery of content, reduction of data loss and reduce the cost [32]-[35]. Replica server placement algorithms are as shown in below Figure 5.

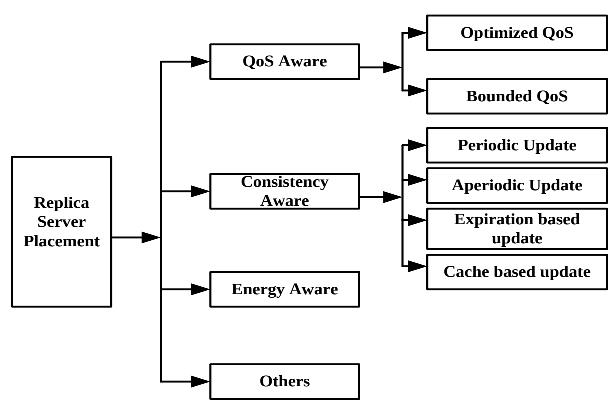

Fig. 5. Replica server placement techniques [32]

D. Qualitative File Management with Resource Saving

A multimedia or real-time data are usually bigger and uses too much resource for its operation. It is because a typical CDN system fails to manage the video provisioning issues owing to different reasons i) the video clip may be accessed at a time by numerous online subscribers rather than separated by a specific user, ii) variability of multiple resource requirements, and iii) the server selection and video placement are directed through online as a visitor or client arrive and departs the network. So, the overhead clip management will limit to provide real-time service. Hence file management with resource-saving or Adaptive Data Placement (ADP) system will improve power efficiency and resource in any CDN [35].

E. Efficient Mobile Edge Computing and Caching

The smart devices with different new application have increased exponentially in day by day. Due to the heavy burden on the backhaul links, latency, and other reasons, the traditional network cannot easily accommodate user demands. Therefore, mobile edge computation and caching at the edge of the cellular network is adapted in existing literatures [36], which bears the limitation and improve the QoS with high throughput [37-39]. Different communication technique with caching and computing as shown in Figure 6 below:

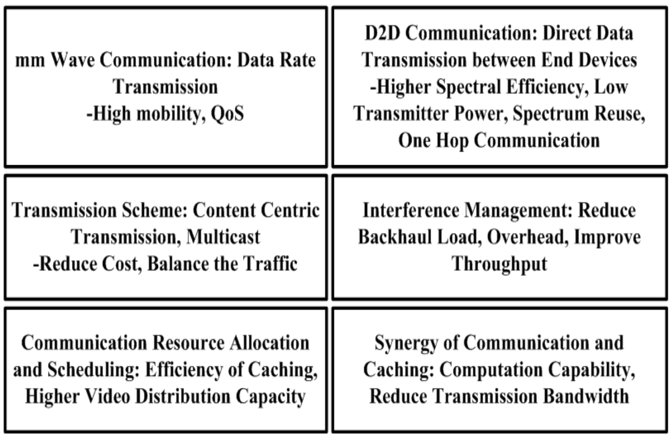

Fig. 6. Communication techniques in edge computing and cashing

F. Content Distribution

The future generation network (5G) offers promising efficient services for dynamic user requirements. However media entertainments, the IoT industrial devices contribute to the video traffic, which causes operation cost in Internet Service Provider and network load problems [40]. Therefore, Named Data Networking (NDN) is a more efficient form to support content distribution in IoT applications and NDN with network coding technique is also claimed to enhance the IoT throughput and efficiency of content transformations for 5G [40]. There are some of the works have done by Li et al.[41] and Kwak [42] presented 5G information-centric networking which shows the flexibility of mobility as a service in the future 5G network. Similarly, NDN based IoT study with different types of the application has been addressed which gives security of data [43]. The content distribution and NDN network using network coding theory proposed in the work of Zhao et al. [44], which benefits in storage efficiency and energy consumption.

G. Caching as a Service

The cellular network cannot efficiently handle the massive delivery of content that is continuously requested by multiple users, as each request is processed as a different End-To-End Connection (E2E) [41]. To exploding traffic demand, CaaS (Cashing-as-a-Service) is utilized based on Cloud related Radio Access Network (RAN) with potential techniques. This process exhibits the capability to cache anything at anytime and anywhere in the cloud-related 5G network system. It leads to improve the user quality of service in different mobile application [41]. Similar kind of work like Hybrid content cashing in the 5G network for Efficient Content Exclusion and Replication in work of Kwak et al. [42] and Bilal and Kang [43]. Table 1 below shows the recent CaaS techniques and its performances.

TABLE I. CAAS APPROACHES AND PERFORMANCES

Authors	Solution Approaches, Algorithms	Performance
Zhao et al. [44]	Cluster content cashing structure	Gain, cost
Aggarwal et al. [45]	The functional caching approach, a heuristic algorithm	Latency
Hu et al. [46]	Caching and Request Balancing (CRB) algorithm, Differential Provisioning and Caching (DPC) algorithm	Efficiency

Therefore, a closer look into the above outcomes shows that there are various literatures emphasizing on improving CDN performance. There is no doubt that cloud-based CDN is claimed to offer more advantages to the content delivery system; however, still, there are some problems that are found missing in any of the existing research approaches of cloud-based CDN system. The present state of cloud eco-system is already shrouded y security problems as well as performance issues at the same time. This primary problem can for sure offer challenges towards the efficient operation and productivity that can seriously affect the enterprise business. Another challenging problem observed in almost all the approaches discussed under this section is that existing scheme of CDN claims to offer supportability of the static data packet from one to another point, but there is no evidence to prove if it supports real-time transmission of data/service of dynamic origin. Apart from this, there is always a contradiction of a federation-based criterion where the cost factor of service is never found to be considered.

Apart from these, there is also the certain dedicated effort of improving the performance of CDN with a target to obtain a better form of scalability, mobility supportability, working with heterogeneous devices, interoperability, and supportability of federation criteria. However, the summary of Table-2 to Table 4 shows that almost all the studies have been associated with problems and there is no significant literature to offer comprehensive and full-fledged supportability of all such factors. Moreover, the methodology of carrying out the research (which is mainly prototyping) is another reason to narrow down the scope of work where the prominence of various network-related attributes on the cloud is found hypothetically considered in existing studies. These causes were reducing the applicability of existing schemes towards the CDN system that is claimed to be using either cloud or fog computing.

TABLE II. SCHEDULING SCHEMES ON CDN SYSTEM

Authors	Techniques	Advantages	Limitation
Giang et al. [47]	Prototyping, directed graph	Supports QoS	Doesn't support federation-based criteria
Hong et al. [48]	Simulation-based study	Offers diversified service handling	Doesn't offer QoS
Yangui et al. [49]	Prototyping, layer-based architecture	Induces better interoperability	Doesn't ensure supportability of diversified service handling

TABLE III. CDN SCHEMES TOWARDS COMMUNICATION PROBLEM

Authors	Techniques	Advantages	Limitation
Aazam et al. [50]	Prototyping, architecture-based	Offers interoperability	Doesn't address mobility issues
Shi et al.[51]	Prototyping, layer-based communication system	Simplified model	Significantly suffers from interoperability, mobility
Krishnan et al. [52]	Prototyping, architecture-based	Conceptual model	Significantly suffers from interoperability, mobility

TABLE IV. CDN SCHEMES FOR RESOURCE MANAGEMENT

Authors	Techniques	Advantages	Limitation
Cardellini et al. [53]	Prototyping, scheduler design	Comprehensive model	No benchmarking
Bittencourt et al. [54]	Analytical, layer-based architecture	Offers better QoS and mobility	Doesn't offer scalability
Kapsalis et al.[55]	Simulation-based, load balancing	Offers better QoS and mobility	Doesn't offer interoperability

V. OPEN RESEARCH ISSUES IN CCDN

The prior set of sections has briefed the existing approaches and methods of improving the performance of CDNs. The existing approaches have beneficial points as well as limitations too. Although certain limitations could be overcome, there was no prominent discussion regarding its solution, which is now termed as research gaps. This section discusses the prominent research gaps as follows:

- *Security Prone:* There are very few research approaches that have been emphasizing on the prominent security breaches over CCDN. As exposures of CCDN towards adversaries are exponentially more, offering robust security is still a far away from successful real-time implementation.

- *Placement Strategies in Nascent Stage:* The placement strategy orients around exploring the suitable position of the server where the content, as well as the proxy server, should be residing on. It is quite a challenging task as it completely depends upon the frequency of accessing the specific resources as well as consumer-based unpredictable behavior. At present, the majority of the placement of data is highly static and very less dynamic, although some advancement has happened in the area of virtualization over the cloud.

  Routing among Surrogate-Server: A surrogate server is also characterized by a certain set of resources and capabilities that are required to be utilized effectively. An efficient surrogate server should be able to identify the direction of routing that should not only save cost but should be highly faster. Unfortunately, existing literature towards CDN has no emphasized on this problem. With the increase of dynamic and complex traffic behavior, there is a good probability that the decision of routing could go inappropriate that will result in unwanted cost levied by the user.

- *Request Redirection Method:* Proximity metric is one of the essential, dependable parameters to perform request redirection problem. Apart from security routing problem, it is yet a challenging task to take a precise decision of performing redirection of request on a specific set of CDN nodes ensuring lower cost.

- *Caching Techniques Localization of Surrogate-Server:* There are different forms of caching technique that is used in CDN; however, there are still certain problems in it. In the existing literature, the effects of diversified traffic behavior of HTTP header on the caching method while localizing the surrogate server are unexplained. The need for a change of default configuration on the existing CCDN in order to suit the traffic demand is not found to be discussed in existing kinds of literature.

VI. CONCLUSION

This paper discusses various aspects of CDN where it could be found that it offers a significant advantage to a reliable and dedicated channel of data/service delivery, but it is also associated with a potential set of problems. Although, by migrating CDN over cloud has offered some tangible benefits but the problems have now doubled as cloud-based CDN exposes the CDN system to a large, dynamic, complex, and unsecure data. Since there is less number of studies carried out in the existing system; we focused on such problems and various research gaps in this study. Our next future work shall be to extend this review work further and make it more exhaustive as well as evolve up with some concrete solution to resist such critical research problems in CDN.

REFERENCES

[1] Q. Jia, R. Xie, T. Huang, J. Liu, and Y. Liu, "The Collaboration for Content Delivery and Network Infrastructures: A Survey," IEEE Access, vol. 5, pp. 18088-18106, 2017.

[2] K. Hosanagar, R. Krishnan, M. Smith and J. Chuang, "Optimal pricing of content delivery network (CDN) services," 37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the, 2004, pp. 10 pp

[3] Pathan M, Buyya R. "A taxonomy of CDNs: In Content delivery networks," 2008 (pp. 33-77), Springer, Berlin, Heidelberg.

[4] Stocker, Volker, Georgios Smaragdakis, William Lehr, and Steven Bauer. "The growing complexity of content delivery networks: Challenges and implications for the Internet ecosystem." Telecommunications Policy 41, no. 10 (2017): 1003-1016.

[5] G. Ma, Z. Chen, J. Cao, Z. Guo, Y. Jiang and X. Guo, "A tentative comparison on CDN and NDN," 2014 IEEE International Conference on Systems, Man, and Cybernetics (SMC), San Diego, CA, 2014, pp. 2893-2898.

[6] Pallis, George, and Athena Vakali. "Insight and perspectives for content delivery networks." Communications of the ACM49, no. 1 (2006): 101-106.

[7] Garmehi, Mehran, Morteza Analoui, Mukaddim Pathan, and Rajkumar Buyya. "An economic replica placement mechanism for streaming content distribution in Hybrid CDN-P2P networks." Computer Communications 52 (2014): 60-70.

[8] Buyya, Rajkumar, Al-Mukaddim Khan Pathan, James Broberg, and Zahir Tari. "A case for peering of content delivery networks." arXiv preprint cs/0609027 (2006).

[9] Wang, Limin, Vivek Pai, and Larry Peterson. "The effectiveness of request redirection on CDN robustness." ACM SIGOPS Operating Systems Review 36, no. SI (2002): 345-360.

[10] Hu, Han, Yonggang Wen, Tat-Seng Chua, Zhi Wang, Jian Huang, Wenwu Zhu, and Di Wu. "Community based effective social video contents placement in cloud centric CDN network." In Multimedia and Expo (ICME), 2014 IEEE International Conference on, pp. 1-6. IEEE, 2014.

[11] Raciborski, Nathan F., and Bradley B. Harvell. "Write-cost optimization of CDN storage architecture." U.S. Patent 8,321,521, issued November 27, 2012.

[12] Kovvali, Surya Kumar, Charles Boyle, Ravi Valmikam, and Krishnan Ramakrishnan. "Hierarchical Device type Recognition, Caching Control & Enhanced CDN communication in a Wireless Mobile Network." U.S. Patent Application 13/183,777, filed July 19, 2012.

[13] Tariq, Muhammad Mukarram Bin, Ravi Jain, and Toshiro Kawahara. "Mobility aware server selection for mobile streaming multimedia content distribution networks." In Web content caching and distribution, pp. 1-18. Springer, Dordrecht, 2004.

[14] Harahap, Erwin, Janaka Wijekoon, Rajitha Tennekoon, Fumito Yamaguchi, Shinichi Ishida, and Hiroaki Nishi. "Distributed algorithm for router-based management of replica server in next-CDN infrastructure." In 2013 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery, pp. 266-272. IEEE, 2013.

[15] A. A. Haghighi, S. Shahbazpanahi and S. Shah Heydari, "Stochastic QoE-Aware Optimization in Cloud-Based Content Delivery Networks," in IEEE Access, vol. 6, pp. 32662-32672, 2018.

[16] Papagianni, A. Leivadeas and S. Papavassiliou, "A Cloud-Oriented Content Delivery Network Paradigm: Modeling and Assessment," IEEE Transactions on Dependable and Secure Computing, vol. 10, no. 5, pp. 287-300, Sept.-Oct. 2013.

[17] C. Dong, Y. Jia, H. Peng, X. Yang and W. Wen, "A Novel Distribution Service Policy for Crowdsourced Live Streaming in Cloud Platform," IEEE Transactions on Network and Service Management, vol. 15, no. 2, pp. 679-692, June 2018.

[18] Mouradian, D. Naboulsi, S. Yangui, R. H. Glitho, M. J. Morrow and P. A. Polakos, "A Comprehensive Survey on Fog Computing: State-of-the-Art and Research Challenges," in IEEE Communications Surveys & Tutorials, vol. 20, no. 1, pp. 416-464, First quarter 2018.

[19] Siracusano, Giuseppe, et al. "Re-designing Dynamic Content Delivery in the Light of a Virtualized Infrastructure." IEEE Journal on Selected Areas in Communications 35.11 (2017): 2574-2585.

[20] M. A. Salahuddin, J. Sahoo, R. Glitho, H. Elbiaze and W. Ajib, "A Survey on Content Placement Algorithms for Cloud-Based Content Delivery Networks," in IEEE Access, vol. 6, pp. 91-114, 2018.

[21] Y. Jin, Y. Wen, K. Guan, D. Kilper and Haiyong Xie, "Toward monetary cost-effective content placement in cloud centric media network," 2013 IEEE International Conference on Multimedia and Expo (ICME), San Jose, CA, 2013, pp. 1-6.

[22] F. K. Khalaji and M. Analoui, "Hybrid CDN-P2P architecture: Replica content Placement Algorithms," The 5th Conference on Information and Knowledge Technology, Shiraz, 2013, pp. 7-12.

[23] J. Chen and C. Chen, "Using Particle Swarm Optimization Algorithm in Multimedia CDN Content Placement," 2012 Fifth International Symposium on Parallel Architectures, Algorithms and Programming, Taipei, 2012, pp. 45-51.

[24] K. Xu, X. Li, S. K. Bose and G. Shen, "Joint Replica Server Placement, Content Caching, and Request Load Assignment in Content Delivery Networks," in IEEE Access, vol. 6, pp. 17968-17981, 2018.

[25] C. Yang, L. Huang, B. Leng, H. Xu and X. Wang, "Replica placement in content delivery networks with stochastic demands and M/M/1 servers," 2014 IEEE 33rd International Performance Computing and Communications Conference (IPCCC), Austin, TX, 2014, pp. 1-8.

[26] Papagianni, Chrysa, Aris Leivadeas, and Symeon Papavassiliou. "A cloud-oriented content delivery network paradigm: Modeling and assessment." IEEE Transactions on Dependable and Secure Computing 10, no. 5 (2013): 287-300.

[27] S. J. Stolfo, M. B. Salem and A. D. Keromytis, "Fog Computing: Mitigating Insider Data Theft Attacks in the Cloud," 2012 IEEE Symposium on Security and Privacy Workshops, San Francisco, CA, 2012, pp. 125-128

[28] Y. Wang, T. Uehara and R. Sasaki, "Fog Computing: Issues and Challenges in Security and Forensics," 2015 IEEE 39th Annual Computer Software and Applications Conference, Taichung, 2015, pp. 53-59.

[29] M. Mukherjee et al., "Security and Privacy in Fog Computing: Challenges," in IEEE Access, vol. 5, pp. 19293-19304, 2017.

[30] A. Kapsalis, P. Kasnesis, I. S. Venieris, D. I. Kaklamani and C. Z. Patrikakis, "A Cooperative Fog Approach for Effective Workload Balancing," in IEEE Cloud Computing, vol. 4, no. 2, pp. 36-45, March-April 2017.

[31] H. Zhang, Y. Qiu, X. Chu, K. Long and V. C. M. Leung, "Fog Radio Access Networks: Mobility Management, Interference Mitigation, and Resource Optimization," in IEEE Wireless Communications, vol. 24, no. 6, pp. 120-127, Dec. 2017.

[32] Sahoo J, Salahuddin MA, Glitho R, Elbiaze H, Ajib W. A survey on replica server placement algorithms for content delivery networks. IEEE Communications Surveys & Tutorials. 2016 Nov;19(2):1002-26.

[33] J. Sahoo and R. Glitho, "Greedy heuristic for replica server placement in Cloud based Content Delivery Networks," 2016 IEEE Symposium on Computers and Communication (ISCC), Messina, 2016, pp. 302-309.

[34] Eslami G, Haghighat AT, Farokhi S. New replica server placement strategies using clustering algorithms and SOM neural network in CDNs. Int. Arab J. Inf. Technol.. 2017 Mar 1;14(2):260-6.

[35] Sun G, Chang V, Yang G, Liao D. The cost-efficient deployment of replica servers in virtual content distribution networks for data fusion. Information Sciences. 2018 Mar 1;432:495-515.

[36] Kuo WH, Lin YH. Resource-Saving File Management Scheme for Online Video Provisioning on Content Delivery Networks. IEEE Transactions on Computers. 2016 Jun 1;65(6):1910-20

[37] Wang S, Zhang X, Zhang Y, Wang L, Yang J, Wang W. A survey on mobile edge networks: Convergence of computing, caching and communications. IEEE Access. 2017;5:6757-79.

[38] G. Ma, Z. Wang, M. Zhang, J. Ye, M. Chen and W. Zhu, "Understanding Performance of Edge Content Caching for Mobile

Video Streaming," in IEEE Journal on Selected Areas in Communications, vol. 35, no. 5, pp. 1076-1089, May 2017.

[39] T. Taleb, S. Dutta, A. Ksentini, M. Iqbal and H. Flinck, "Mobile Edge Computing Potential in Making Cities Smarter," in IEEE Communications Magazine, vol. 55, no. 3, pp. 38-43, March 2017.

[40] E. Baccelli, C. Mehlis and O. Hahm. "Information Centric Networking in the IoT: Experiments with NDN in the Wild," ACM Conference on Information-Centric Networking, pp. 77-86, 2014.

[41] X. Li, X. Wang, K. Li and V. C. M. Leung, "CaaS: Caching as a Service for 5G Networks," in IEEE Access, vol. 5, pp. 5982-5993, 2017.

[42] J. Kwak, Y. Kim, L. B. Le and S. Chong, "Hybrid Content Caching in 5G Wireless Networks: Cloud Versus Edge Caching," in IEEE Transactions on Wireless Communications, vol. 17, no. 5, pp. 3030-3045, May 2018.

[43] M. Bilal and S. Kang, "A Cache Management Scheme for Efficient Content Eviction and Replication in Cache Networks," in IEEE Access, vol. 5, pp. 1692-1701, 2017.

[44] Z. Zhao, M. Peng, Z. Ding, W. Wang and H. V. Poor, "Cluster Content Caching: An Energy-Efficient Approach to Improve Quality of Service in Cloud Radio Access Networks," in IEEE Journal on Selected Areas in Communications, vol. 34, no. 5, pp. 1207-1221, May 2016.

[45] V. Aggarwal, Y. R. Chen, T. Lan and Y. Xiang, "Sprout: A Functional Caching Approach to Minimize Service Latency in Erasure-Coded Storage," in IEEE/ACM Transactions on Networking, vol. 25, no. 6, pp. 3683-3694, Dec. 2017.

[46] M. Hu, J. Luo, Y. Wang and B. Veeravalli, "Practical Resource Provisioning and Caching with Dynamic Resilience for Cloud-Based Content Distribution Networks," in IEEE Transactions on Parallel and Distributed Systems, vol. 25, no. 8, pp. 2169-2179, Aug. 2014.

[47] N. K. Giang, M. Blackstock, R. Lea, and V. C. M. Leung, "Developing IoT applications in the Fog: A Distributed Dataflow approach," in Internet of Things (IOT), 2015 5th International Conference on the, 2015, pp. 155–162.

[48] K. Hong, D. Lillethun, U. Ramachandran, B. Ottenwälder, and B. Koldehofe, "Mobile Fog: A Programming Model for Large-scale Applications on the Internet of Things," in Proceedings of the Second ACM SIGCOMM Workshop on Mobile Cloud Computing, New York, NY, USA, 2013, pp. 15–20.

[49] S. Yangui, P. Ravindran, O. Bibani, R. H. Glitho, N. B. Hadj-Alouane, M. J. Morrow, and P. A. Polakos, "A platform as-a-service for hybrid cloud/fog environments," in 2016 IEEE International Symposium on Local and Metropolitan Area Networks (LANMAN), 2016, pp. 1–7.

[50] M. Aazam and E.-N. Huh, "Fog Computing and Smart Gateway Based Communication for Cloud of Things," in 2014 International Conference on Future Internet of Things and Cloud (FiCloud), 2014, pp. 464–470

[51] H. Shi, N. Chen, and R. Deters, "Combining Mobile and Fog Computing: Using CoAP to Link Mobile Device Clouds with Fog Computing," in 2015 IEEE International Conference on Data Science and Data Intensive Systems, 2015, pp. 564–571.

[52] Y. N. Krishnan, C. N. Bhagwat, and A. P. Utpat, "Fog computing - Network based cloud computing," in 2015 2nd International Conference on Electronics and Communication Systems (ICECS), 2015, pp. 250–251.

[53] V. Cardellini, V. Grassi, F. L. Presti, and M. Nardelli, "On QoS-aware scheduling of data stream applications over fog computing infrastructures," in 2015 IEEE Symposium on Computers and Communication (ISCC), 2015, pp. 271–276.

[54] L. F. Bittencourt, M. M. Lopes, I. Petri, and O. F. Rana, "Towards Virtual Machine Migration in Fog Computing," in 2015 10th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC), 2015, pp. 1–8.

[55] A. Kapsalis, P. Kasnesis, I. S. Venieris, D. I. Kaklamani, and C. Z. Patrikakis, "A Cooperative Fog Approach for Effective Workload Balancing," IEEE Cloud Comput., vol. 4, no. 2, pp. 36–45, Mar. 2017.

Adapted Speed Mechanism for Collision Avoidance in Vehicular Ad hoc Networks Environment

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***Abstract*—The disrespect of the safety distance between vehicles is the cause of several road accidents. This distance cannot certainly be estimated at random because of some physical rules to be calculated. The more speed gets higher, the more stopping distance increases, mainly in danger case. Thus, the difference between two vehicles must be calculated accordingly. In this paper, we present a mechanism called Adapted Speed Mechanism (ASM) allowing the adaptation of speed to keep the necessary safety distance between vehicles. This mechanism is based on VANET network operation and Multi Agent System integration to ensure communication and collaboration between vehicles. So, it is necessary to perform real-time calculations to make adequate and relevant decisions.**

Keywords*—*VANET; multi-agent systems; safety distances; stopping distance; JADE framework

I. Introduction

Keeping enough distance from the vehicle ahead means respecting the balance of traffic. This is the best way to avoid a collision. In many cases, this distance is not respected. For example, on the motorway, where the speed is the fastest, nearly two-thirds of drivers do not always respect the safety distance, which generates several traffic problems.

The use of new communication technologies such as the infrastructure and services offered by the vehicle network (VANET) and the integration of intelligent agents can avoid such problems and improve the quality and safety of driving.

Vehicular Ad hoc Network (VANET) is a particular type of MANET where mobile nodes are smart vehicles equipped with computers (OBU), network cards and sensors [1].

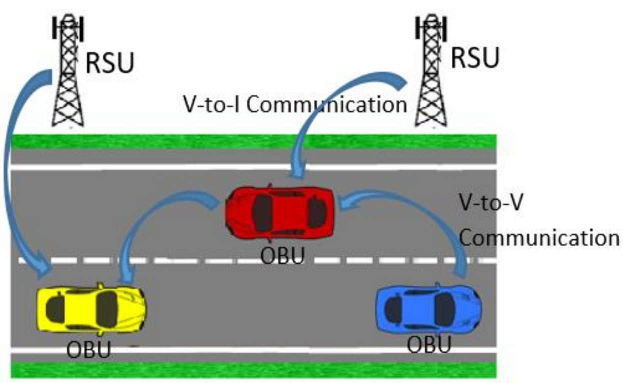

Fig. 1. VANET Network.

Like any other Ad hoc network, vehicles can communicate with each other (for example: exchanging traffic information) or with base stations called roadside unit (RSU) which can be placed all along the roads (seeking information or accessing other networks ...).

VANET networks are based on communication and information exchange between vehicles (V-to-V) [2], and between vehicles and roadside unit (V-to-I) (Examples: signals, intersections lights, etc.) or external network elements (Satellites, WiMAX, LTE…) (Figure 1).

VANETS networks are characterized by great dynamics and mobility nodes, repetitive changes in the network topology and very variable network density. VANETs are expected to implement a variety of wireless technologies such as Dedicated Short Range Communications DSRC, which is a type of Wi-Fi. Other more wireless technologies are Bluetooth, Cellular, Satellite, and WiMAX.

The main applications of VANET networks can be classified in three categories [3][4]:

1) Application in prevention and road safety: VANETs help to prevent collisions and work on the roads, to detect obstacles (fixed or mobile) and to distribute weather information by sending warning messages. It can be used for example to alert a driver to the happening of an accident, and then he can exercise some prudence and forethought when heading to the accident either by changing his direction or doubling his vigilance.

2) Application for traffic optimization and help in driving: Car traffic can be greatly improved through the collection and sharing of data collected by the vehicles, which becomes a technical support for drivers. For example, a car can be notified in case of abnormal slowdown situations [5] (cork, traffic jam, rockslide or works).

3) Applications for driver and passenger comfort: Vehicular networks can also improve the comfort of drivers and passengers. This comfort is illustrated by the internet access, messaging, inter-vehicle chat, etc… [6]. Passengers in the car can play in networks, download MP3 files, send cards to friends and access to other services.

Hence, our ultimate goal is to design a mechanism that could help solve some of the most common road traffic problems, such as the safety distance between vehicles, and improving road safety, then making it smarter.

The remainder of this paper is organized as follows: Section 2 gives an overview of Multi-Agent Systems. Section 3 describes our Adapted Speed Mechanism (ASM). Section 4 provides the simulation results. Finally, in Section 5 we conclude our results with a view on the future trends.

II. Agent and Multi-Agent Systems

An agent is an autonomous physical or abstract entity that is able to act and perceive by itself and about its environment. The agent can communicate with other agents and whose behavior is the result of its observations, its knowledge, and interactions with other agents [7][8]. The agent has its own resources and skills. The agent can both offer services and possibly reproduce some of them.

A multi-agent system (MAS) is a community of autonomous agents evolved in a common environment (Figure 2), according to modes of cooperation, competition or even conflict to achieve a global objective [9][10]. These agents constitute a complex system that includes intelligence which could be described as collective.

The agents in a multi-agent system have several important characteristics: [11]

- Autonomy: agents are partially independent and self-aware;
- Local views: no agent has a full global view;
- Decentralization: no agent is designated for controlling.

Multi-agent systems can manifest self-organization, self-direction and other controlling paradigms. They can also relate complex behaviors even when the individual strategies of all their agents are simple.

MAS tend to find the best solution for their problems without any intervention. There is a high similarity here to physical phenomena, such as energy minimizing, where physical objects tend to reach the lowest energy possible within the physically constrained world [12]. The systems also tend to prevent propagation of faults, self-recover and be fault tolerant, mainly due to the redundancy of components [13].

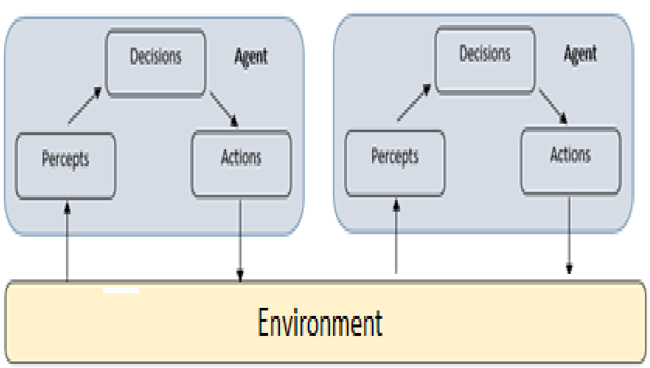

Fig. 2. Multi-Agent System Processes.

MAS are applied in the real world to graphical applications such as computer games. Agent systems have already been used in films. They are used in coordinated defense systems. Other applications include transportation, [14] logistics, [15] graphics and GIS. It is widely advocated for use in networking and mobile technologies, to achieve automatic and dynamic load balancing, high scalability and self-healing networks.

MAS have also applications in the field of artificial intelligence where they reduce the complexity of solving a problem by dividing the necessary knowledge into subsets, by associating an independent intelligent agent with each of these subsets and coordinating the activity of these agents [16]. This is called distributed artificial intelligence.

III. Adapted Speed Mechanism (ASM)

Our mechanism aims to force the driver to drive with adequate speed to keep the safety distance (Figure 3) between two vehicles to avoid a possible collision. This is based on the exchange of information between vehicles via the VANET network infrastructure and by the intelligent agents located in the vehicles that deal with message management and calculation.

Principle: at a time t, the vehicle (B) sends its speed, its position, and its length to the vehicle (A) and vice versa ((A) to (B)) and thanks to the calculations carried out based on the kinematics equations, the vehicle (A) will have results concerning the time and distance of a likely collision, and then adjust its speed to avoid it.

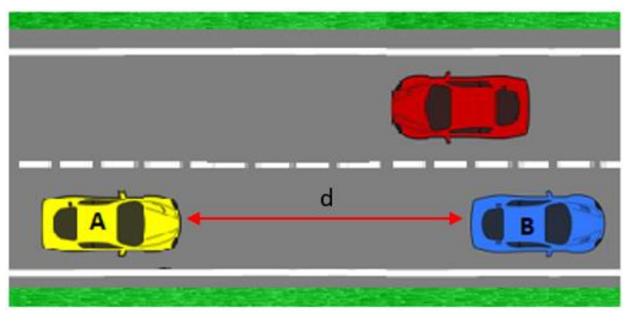

Fig. 3. Safety Distance between Vehicle.

The equations of rectilinear motion uniformly accelerated are given by [17]:

$$X_A\ (t) = X_A\ (t = 0) + V_A\ (t = o) \times t + \frac{1}{2} a_A\ \times t^2 \qquad (1)$$

$$V_A\ (t) = V_A\ (t = o) + a_A\ \times t \qquad (2)$$

$$V_A^2(t) = V_A^2(t = 0) + 2 \times a_A\ \times \Delta x \qquad (3)$$

Where

- t is the elapsed time;
- $X_A\ (t = 0)$ is the initial displacement from the origin;
- $X_A\ (t)$ is the displacement from the origin at time t;
- $V_A\ (t = o)$ is the initial velocity;

- {\displaystyle \mathbf {v} (t)}$V_A\ (t)$ is the velocity at time {\displaystyle t} t;
- {\displaystyle \mathbf {a} }a_A is the uniform rate of acceleration;
- $\Delta x = X_A\ (t) - X_A\ (t = 0)$.

A likely collision will occur when:

$$\boldsymbol{X_A\ (t) = X_B\ (t)} \quad (4)$$

Due to the exchanged positions, the distance separating the two vehicles is given by the following formula:

$$d(t)_{AB} = \sqrt{P(t)_A^2 \ - \ P(t)_B^2} \quad (5)$$

Suppose Vehicle (A) rolls with speed $V_A\,(t)$, the mechanism consists on calculating the suitable slowing down deceleration for having the appropriate speed at of the safety distance to avoid a possible collision.

The mechanism therefore must make sure to calculate the following equation:

$$\boldsymbol{X_A\ (t) + d(t)_{AB} \leq X_B\ (t)} \quad (6)$$

Where $d(t)_{AB}$ is the safe distance.

The table below (Table I) shows the recommended safety distances according to the type of road:

TABLE I. SAFETY DISTANCE ACCORDING TO SPEED LIMIT

Road type	**Speed limit**	**Safety distance**
Urban	50 (km/h)	28 (m)
Extra-Urban	90 (km/h)	50 (m)
Expressway	110 (km/h)	62 (m)
Highway	130 (km/h)	73 (m)

A. Safety Distance

The safety distance is the distance that must be between two vehicles. It depends on the speed at which you ride. But generally, it is admitted that this distance is given by the distance traveled by your car for 2 seconds [18].

In this case:

$$Safety\ distance = V_A\ \times 2seconds \quad (7)$$

B. Stopping Distance

Stopping distance is the distance traveled by your vehicle between the moment you perceive the danger and the moment when your vehicle is finally stopped. The stopping distance is composed of the reaction path and the braking path [19].

- Reaction path

The reaction path is the distance your car travels when you see the danger and the moment you press the brakes. A caring and healthy driver has a reaction time of 1 second.

There is a formula to get the reaction path.

$$Reaction\ path = \frac{3 \times V_A\,(km/h)}{10} \quad (8)$$

- Braking path

The braking path is the distance your vehicle traveled between the moment you pressed the brake and when the car was completely stopped.

We must distinguish two cases. The case of the dry pavement and the case of the wet pavement which considerably lengthens the braking distance.

- Dry pavement:

$$Braking\ path = \frac{V_A\,(km/h)}{10} \times \frac{V_A\,(km/h)}{10} \times \frac{3}{4} \quad (9)$$

- Wet pavement

$$Braking\ path = \frac{V_A\,(km/h)}{10} \times \frac{V_A\,(km/h)}{10} \quad (10)$$

The stopping distance is the addition of the reaction and braking paths. Then:

$$Stopping\ distance = Reaction\ path + Braking\ path$$

IV. Simulation and Results

To simulate our approach we have developed an application with java language using JADE Framework (Java Agent DEvelopment) [20]. The Topology is a simple road composed of two lanes and consists of vehicles deployed in the different tracks.

As mentioned above, we have created two agents: Vehicle (A) Agent and Vehicle (B) Agent. Each agent is contained in a platform (Container) composed of an Agent Management System (AMS) and a Directory Facilitator (DF) as showed in figure 4. JADE agents use messages that conform to FIPA ACL (FIPA Agent Communication Language) specifications [21].

Thus, the integration of the agents in the vehicles aims at the exchange of messages in real time and made the necessary calculations according to the kinematics equations. Based on agents' properties such as cooperation, coordination and negotiation [22], agents form a distributed and cooperative environment that allows drivers to drive with optimal speeds to avoid possible collisions.

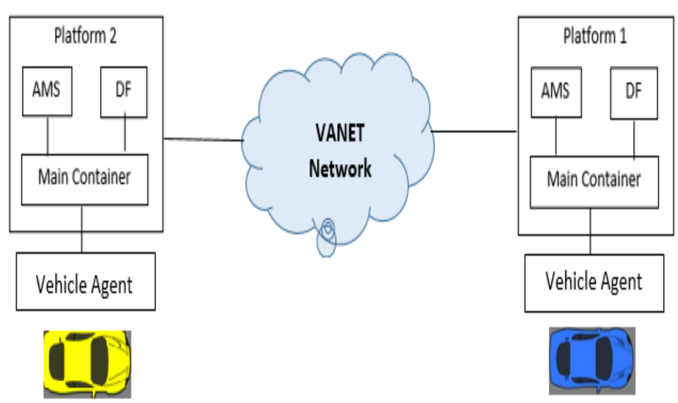

Fig. 4. Architecture of the Proposed Mechanism.

TABLE II. INITIAL PARAMETERS

Parameter	Value
$V_A(t)$	30 m/s
$V_B(t)$	0 m/s, 10 m/s
$d(t=0)_{AB}$	50 (m)

We will analyze two situations: the vehicle B is in a stop state, and the second case, the vehicle B rolls with a speed lower than that of vehicle A. We will seek the minimum deceleration necessary to avoid the collision. The table II below shows the initial parameters:

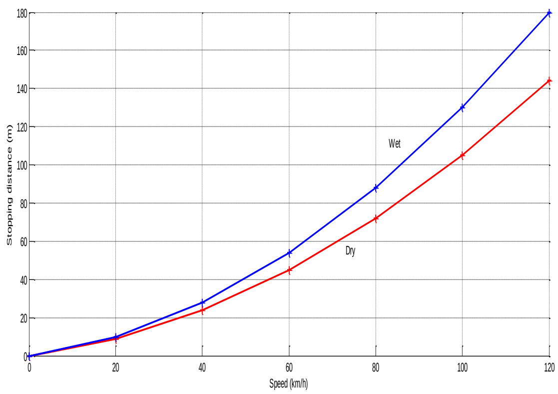

Fig. 5. Stopping Distance According to Speed.

At the moment of collision, the problem is to solve the following system of equations:

$$\begin{cases} X_A\ (t=0) + V_A\,(t=o) \times t + \dfrac{1}{2} a_{A\,(min)} \times t^2 = X_B\ (t) \\ V_A\,(t) = V_B\,(t) \end{cases}$$

Therefore, we will have the following results:

Figure 5 shows the stopping distances according to the speeds in case of Dry and wet road. We note that as the speed increases the stopping distance increases too. In case of wet road, to stop takes more distance than in case of dry road.

Figure 6 illustrates the different variations of traveled distances related to the function of time and according to different decelerations for the case of fixed vehicle (B) ($V_B\,(t) = 0$). We notice that for the case of (a = 0) that is to say the vehicle (A) rolls with a constant speed ($V_A\,(t) = 30m/s$), the collision between the two vehicles will occur after 1.67 seconds. We also notice that we will never have a collision for a deceleration of (a = -12 m/s^2) or less. Thus, the recommended deceleration to avoid a possible collision is: a_{min} <-9 m/s^2. Based on the results shown in figure 7 above, if the vehicle (B) runs with a speed ($V_B\,(t) = 0$) and vehicle (A) still runs with a constant speed ($V_A\,(t) = 30m/s$) (a = 0), a collision with the vehicle (B) will occur in 2.5 seconds. For cases (a = -6, -9, and -12m/s^2), a collision will never occur. The recommended optimal deceleration to avoid a possible collision is: a_{min} <-4m / s^2.

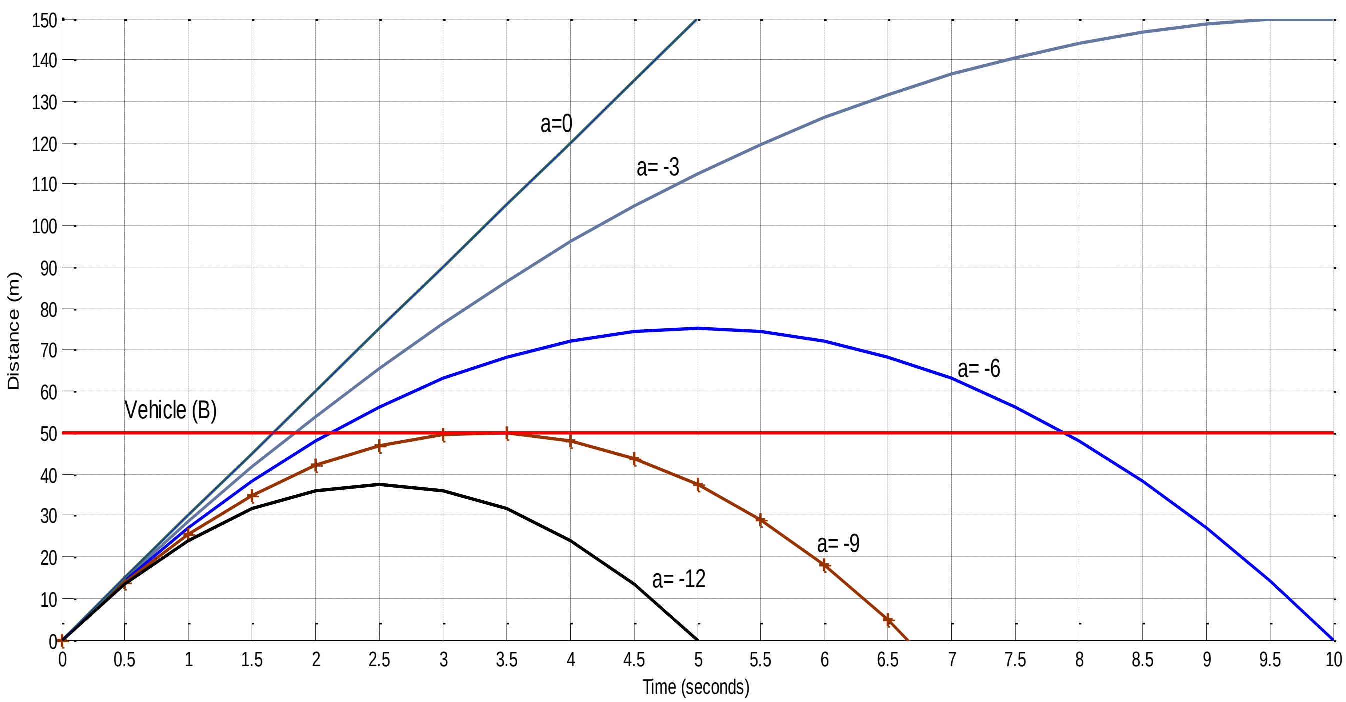

Fig. 6. Stopping Distances According to Different Deceleration and time ($V_B\,(t) = 0$).

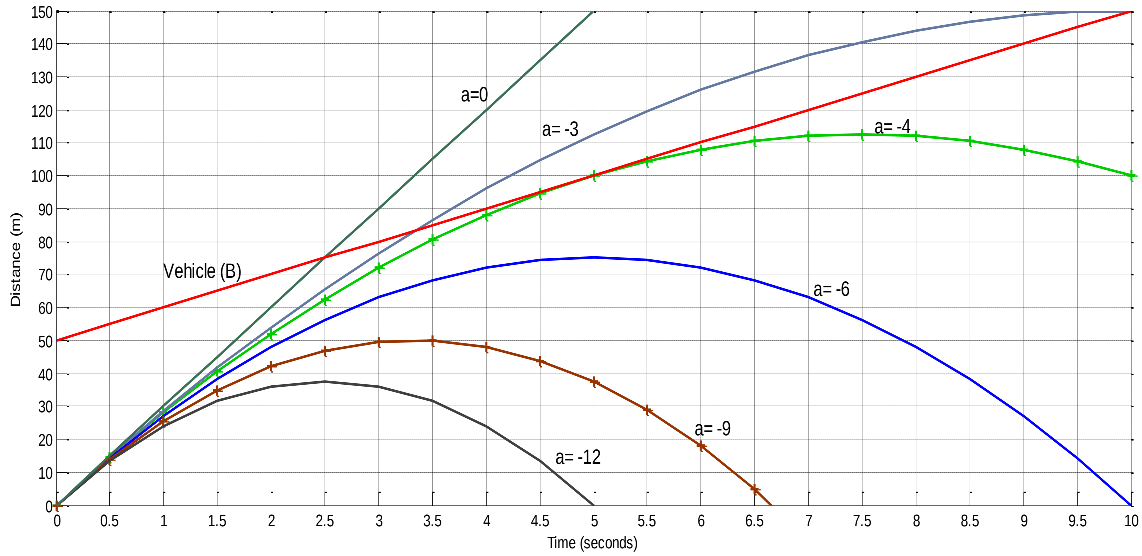

Fig. 7. Stopping Distances According to Different Deceleration and time ($V_B\,(t) = 10m/s$).

V. Conclusion

In this work, we presented a mechanism called Adapted Speed Mechanism (ASM) allowing the adaptation of speed to maintain the recommended safety distance between the vehicles in order to avoid possible accidents. This mechanism is based on VANET network operation and the integration of agents in vehicles. Thus, these agents form an intelligent system for communication and collaboration between vehicles by changing useful and necessary information to ensure driving in good conditions. In future work, we will improve our system to take into account other factors that can influence the calculation of the safety distance such as weather conditions, road conditions as well as vehicles condition.

References

[1] H. Hartenstein and K. Laberteaux, Eds., VANET: Vehicular Applications and Inter-Networking Technologies. Wiley, 2010.

[2] K. C. Dey, A. Rayamajhi, M. Chowdhury, P. Bhavsar, and J. Martin, “Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication in a heterogeneous wireless network - Performance evaluation,” Transportation Research Part C: Emerging Technologies, vol. 68, pp. 168–184, 2016.

[3] Raju Barskar, Meenu Chawla, Vehicular Ad hoc Networks and its Applica-tions in Diversified Fields, International Journal of Computer Applications (0975 8887) Volume 123 No.10, August 2015.

[4] P.Pereira, A. Casaca, J.Rodrigues, V. Soares, J. Triay, C.Cervello-Pastor,” From Delay-Tolerant Networks to Vehicular Delay-Tolerant Networks,” Communications Surveys & Tutorials, IEEE, Vol.14,Issue.4, pp. 1166 -1182,2012.

[5] S.Al-Sultan, M.M. Al-Doori ,A.H. Al-Bayatti , H. Zedan,” A comprehensive survey on vehicular Ad Hoc network,” Journal of Network and Computer Applications, Vol. 37, pp.380–392, 2014.

[6] H.Hartenstein, K.P.Laberteaux, “A tutorial survey on vehicular ad hoc networks,” Communications Magazine, IEEE, Vol.46, Issue. 6, pp. 164 - 171, 2008.

[7] Julie A. Adams. Multiagent Systems: A modern approach to distributed artificial intelligence. AI Magazine, 22(2) :105–108, 2001.

[8] Ferber, J. (1999). Multi-agent systems: An introduction to distributed artificial intelligence. Harlow, UK: Addison-Wesley

[9] Chopra, N., & Spong, M. W. (2006). Passivity-based control of multi-agent systems. In Advances in Robot Control (pp. 107–134). Berlin, Heidelberg: Springer.

[10] Nicholas R.Jennings “On agent-based software engineering” Artificial Intelligence, Volume 117, Issue 2, Pages 277-296, March 2000,

[11] Wooldridge, Michael (2002). An Introduction to MultiAgent Systems. John Wiley & Sons. p. 366. ISBN 0-471-49691 X

[12] Ferdinand P. Beer, E. Russell Johnston, Jr. Lecture Notes: J. Walt Oler Texas Tech University ”VECTOR MECHANICS FOR ENGINEERS: DYNAMICS”, Kinematics of Particles. © 2007 The McGraw-Hill Companies, Inc.

[13] Orcun. Y, Geylani. K 2014 “A multi-agent system for minimizing energy costs in cement production” Computers in Industry, Volume 65, Issue 7, Pages 1076-1084, September.

[14] Oprea, M.: 2004 “Applications of multi-agent systems, in: Reis, R. (ed.): Information Technology, Kluwer Academic Publishers, Boston Dordrecht London 239-270.

[15] Xiao-Feng Xie, S. Smith, G. Barlow. 2012 “Schedule-driven coordination for real-time traffic network control”. International Conference on Automated Planning and Scheduling (ICAPS), São Paulo, Brazil,: 323–331.

[16] Máhr, T. S., Srour, J., De Weerdt, M., Zuidwijk, R. (2010). 2009"Can agents measure up? A comparative study of an agent-based and on-line optimization approach for a drayage problem with uncertainty" Transportation Research Part C: Emerging Technologies. 18: 99. doi:10.1016/j.trc..04.018.

[17] Ponomarev, S., Voronkov, A. (2017) “Multi-agent systems and decentralized artificial superintelligence”. arXiv preprint arXiv:1702.08529.

[18] “BASIC theory of driving The Official Handbook” published by Singapore Traffic Police, on 01.07.2017.

[19] Dr Michael Evans “Maths delivers! Braking distance” Australian Mathematical Sciences Institute (AMSI), 2013.

[20] Bellifemine, F., Poggi, A., & Rimassa, g. (2001). Developing multi-agent systems with a FIPA-compliant agent framework. Software-Practice and Experience, 31, 103–128.

[21] FIPA, Geneva, Switzerland, FIPA ACL Message Structure Specification, 2000/08/01 edition (August 2000).

[22] S. Kraus, “Negotiation and cooperation in multi-agent environments,” *Artificial Intelligence*, vol. 94, no. 1-2, pp. 79–98, 1997.

Software Components' Coupling Detection for Software Reusability

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***Abstract*—Most of the software systems design and modeling techniques concentrates on capturing the functional aspects that comprise a system's architecture. Non-functional aspects are rarely considered on most of the software system modeling and design techniques. One of the most important aspects of software component is reusability. Software reusability may be understood by identifying components' dependence, which can be measured by measuring the coupling between system's components. In this paper an approach to detect the coupling between software system's components is introduced for the purpose of identifying software components' reusability that may help in refining the system design. The proposed approach uses a dynamic notion of sequence diagram to understand the dynamic behavior of a software system. The notion of data and control dependence is used to detect the dependences among software components. The components' dependences are identified in which one component contributes to the output computation of the other component. The results of the experiments show that the proposed algorithm can help the software engineers to understand the dependences among the software components and optimize the software system model by eliminating the unnecessary dependences among software components to enhance their cohesiveness. Such detection provides a better understanding of the software system model in terms of its components' dependences and their influence on reusability, in which their elimination may enhance software reusability.**

Keywords*—Software component coupling; software component dependence; software component reusability; components interdependence; components dependence testing

I. Introduction

Software components interact with each other by maintaining a duct. Such interactions incorporated via software connectors. Software connectors play different roles in providing interaction among set of components, in which a protocol specification defines its properties such as the types of interfaces it is able to mediate, assurances about interaction properties, rules about interaction ordering, and interaction commitments (e.g., performance). Software connectors facilitate the interaction as communication, coordination, conversion, or facilitation [1]. Components interactions may be incorporated using different types of software connectors such as procedure call, data access, event, stream, linkage, distributor, arbitrator, and adaptor. In addition, software component may be interacted using composite connectors i.e., multi-type connector.

One of the software design basic principles when designing software component's is maximizing the component's cohesiveness and minimizing component coupling. Software coupling was first introduced by Stevens at el. [2]. Coupling is a measure of the interdependence degree between software components [3]. The Components interaction may take different forms in terms of the degree of their interdependence. Coupling can occur in various ways, however, the concentration are on dependencies between components that arise from associations and collaborations. Software components may exhibit different levels of interdependence; Myers [4] has identified the levels of coupling as follows; content coupling, common coupling, external coupling, control coupling, stamp coupling, and data coupling. Ideally, the best case for components' reusability is to have no coupling among software components, however, such case may not be achievable in most of the cases, therefore, such coupling's levels can be used as an interdependence measure between software components. These levels of coupling can be ordered based on their effects on components' understandability, maintainability, and reusability from the worst to the best as follows; content coupling, common coupling, external coupling, control coupling, stamp coupling, and data coupling [5], in which the content coupling is the worst because it represents the high and tight components' coupling; and the data coupling is the best because it represents the low and loose components' coupling. Data coupling occurs when a simple data i.e., a simple argument, is passed between the interconnecting components. Stamp coupling occurs when a data portion of data structure is passed between components, control coupling occurs when a control such as flag is passed between components, external coupling occurs when the two components are tied to an environment or medium that is external to the system such as communicating via I/O device or file, common coupling occurs when the interacting components reference a global data. Content coupling occurs when one component uses or changes the data or control information maintained within the boundary of another component [6]. Additional types of coupling have been introduced; such as tramp coupling [5], scalar data coupling, scalar control coupling, non-local coupling, and global coupling [7].

Low coupling is desirable because less interaction between components reduces the possibility of the affects that may be caused by a failure or change in one component to other connecting components [5]. In addition, low coupling enhances components independence which leads to software understandability as well as software reusability. Software dependence is one of the core factors for the software reusability measurement, in which component's dependency should be measured to understand software component's reusability. Such dependency can be measured by measuring the coupling between system's components. The coupling measures the strength of the relationship between two modules. In the case of object-oriented designs, modules are classes. Since the introduction of this measure, a large number of coupling measures have been proposed [8], which correspond to different types of relationships between classes.

In this paper, an approach to detect the coupling between software system components is introduced for the purpose of identifying software components' interdependence which may contribute to understanding the software components' reusability that may help in refining the system design. The proposed approach uses a dynamic notion of sequence diagram to understand the dynamic behavior of a software system. The notion of data and control dependence is used to detect the dependences among software components. The dependences among two software components are identified such that such dependence of one component influences or contributes to the output computation of the other component. This paper is organized as follow; the following section presents the related work, section III provides some basic definition of the terms used throughout this paper. The proposed algorithm is described in section IV, and section V provides the experimental study of this work. The conclusions and the future works are presented in section VI.

II. The Related Work

Most of the software testing research has concentrated on the implementation phase of the software development life cycle. Software testing at early stages of software system development has been recognized in past few years and many software modeling testing researches has been conducted in the literatures. Software components' coupling has been investigated in the literatures as a metric for different purposes such as complexity [9], modularity [10], maintainability [11, 12], dependencies [8, 13], reusability [14, 15, 16], dependability [17],

Software coupling has been used for structured design to identify the modules' dependence. An early attempt to use module coupling based on the measurement of information flow between system components has been proposed in [9] for evaluating the structure of large-scale systems. Among the proposed metrics, in addition to module coupling, are procedure complexity and module complexity.

A framework of coupling measurement in object-oriented systems has been presented in [8] based on a standard terminology, formalism, and a review of the existing frameworks and measures for coupling measurement in object-oriented systems. A unified framework based on this review was developed in which the existing measures were classified. The proposed framework provides a mechanism for comparing measures and their potential use, integrating existing measures as well as defining new ones, and selecting from existing measures for a specific goal of measurement. It has been reported that most of the coupling measurement in object-oriented systems focuses on components' static dependencies and much less has investigated components' dynamic dependencies.

In [15] static measures of indirect coupling have been proposed to assess the reusability of Java components retrieved from the internet by a search engine. The class coupling has been traditionally described as when a class accesses one or more of another class's variables or invokes at least one of its methods. However, such description ignores inheritance based coupling but a variant includes it. The proposed measures intended to overcome the limitation of the existing static measures to handle indirect coupling such as inheritance. An empirical comparison of the proposed measures has been presented to test such metric.

A new design pattern coupling role and component concepts have been proposed in [13] to solve the challenge of building the appropriate coupling of separated code elements of components, and reducing the build-level dependencies. Roles are related to the functional aspects of a target software program (composition and collaboration of functional units) and components correspond to the physical distribution of code elements with limited build-level dependencies. The proposed coupling is enabled to instantiate a software program using a generic main program to retrieves and composes functionalities at run-time according to a description file.

An information theory has been used to propose coupling measures for modular systems [10]. An abstraction of software system, such as graph, has been used to represent system in which inter-module coupling and intra-module coupling have been proposed to assess or predict the quality of software system. Inter-module coupling measures system level coupling based on relationships between modules, and intra-module coupling is similar, but measures a different subgraph, i.e., measures coupling at subsystem level.

An indirect coupling metric that identify the exact relationship between indirect coupling and maintainability has been presented in [12]. A chain that is expressed in terms of graph vocabulary has been used as a central attribute to detect the indirect coupling. The proposed metrics focus on the reflection of "strength" as it is a fundamental component of coupling which is viewed as the relationship between a given pair of classes as well as on the aggregation of coupling relationships with respect to a single class with the intent of seeing how much influence a given class has over the system.

A dynamic coupling metric has been proposed in [14] to measure the direct coupling of object-oriented software at the object level based on the structural relationships, method call types, and the number of method calls between classes. The proposed metric is designed for embedded systems that are based on component-based or object-oriented systems to produce efficient and reusable component.

A module coupling has been used to propose a spatial impact metric to capture the extent of error propagation in a software system by identifying the location of dependability components called detectors and correctors at early stage of software system development [17]. The proposed metric is based on the hypothesis that modules with high coupling values are most likely potential locations for detectors.

A survey of the components dependencies has been done in [16] in which a classification of such dependencies is introduced based on composition, distribution and platform dependencies to promote component reusability. The authors assessed the contemporary component models for networked embedded systems using Loosely-coupled Component Infrastructure (LooCI), which is a platform-independent component model designed for networked embedded systems. LooCI eliminates composition dependencies at compile time with explicit definitions of interfaces and receptacles. The authors have found that most of the component models in such systems eliminate composition dependencies but not distribution and platform dependencies.

A static analysis tool for measuring the coupling between Java classes has been presented in [11] for the purpose of maintainability, based on source code analysis aiming to identify the types of couplings that are not available until after the implementation is completed. It uses interdependencies between objects to define coupling types, in which it defines four types of coupling; parameter coupling, external/file coupling, inheritance coupling, and global coupling.

An empirical study is presented in [18] that analyzed the coupling among number of open source software projects to identify two types of coupling; logical coupling and structural coupling. This study aims at to determine the interplay between the two types of coupling, the coupling strength between classes, and the level of stability between the coupled classes as stable or unstable. In addition, this study aims to understand the impact of the two types of coupling on each other. Statistical tests have been used to compute the correlation between the strengths of logical and structural dependencies. Although the achieved results cannot be generalized, statistical analysis has shown that interplay occurs between structural and logical dependencies in most of the analyzed software projects.

A component ranking method based on non-dominated sorting for the purpose of software components reuse is presented in [19] in which a specification of the relative importance of non-functional properties is used for a partial ordering. In addition, components' coupling has been used as a measure for the external and internal dependencies between classes; however, such measure is restricted to the entry class of candidates determined by test-driven search evaluation. An explorative study has been applied on a set of components obtained from the Maven Central repository.

A study of coupling measures between software components has been presented in [20] to determine the most significant coupling measure among a set of measures. The authors have categorized the coupling measures in two categories; ratio oriented and ratio less. The analysis of the coupling measures has been conducted by defining two types of class interactions; Operation-Operation interaction which is defined as the interaction between two operations of two or more different objects or classes, and Class-Class interaction which is defined as the interaction between two classes if any one of the above two interaction occurs. A case study has been performed on three industrial software systems.

A measure of the level of coupling for components within a software system has been used in [21] to predict the maintenance efforts for the purpose of evaluating the relationship between system design decisions and the costs of maintenance. The aim of this paper was reduce the cost of redesign a software system by predicting the released value of such redesign, or what has been called architectural debt. The authors have measured system coupling for two software systems; one has a hierarchical design, the other has a core-periphery design, and have shown that, the tightly-coupled components cost more to maintain than loosely-coupled components.

In [22] software metrics have been used to classify the software components into cyclic and non-cyclic for the purpose of understanding the relationship between the dependencies of cyclic components and defect profiles of cyclically dependent components. A static analysis has been used to identify the components' coupling, in which some measures have been used such as coupling between classes and response for class. An empirical study of six object-oriented programs along with some statistical tests has been conducted to investigate the components' cyclic dependencies and their impact on detecting defective components. The study has shown that components with cyclic dependencies are the more defective than non-cyclic components which is similar to the results of related studies.

A multiple dependency metric based on network analysis has been proposed in [23] to investigate the relationship between structural features of classes and their functions within a network system. The metric measures the degree of reusability of a component, as well as its direct and indirect coupling. The measurement of coupling (direct and indirect) may indicate the construction cost of new class. The authors have conducted an empirical study on several open source codes, which has shown that, the used metric is useful in analyzing the complexity, stability, and maintainability of classes. In addition, it has shown that, classes with multiple dependencies have more complicated functions that are less cohesive than other less complicated classes.

The coupling between object classes (CBO), as an object-oriented design metric, has been introduced in [24], as a count of the number of other classes to which a class is coupled with, in which methods of one class use methods or instance variables of another.

A dynamic coupling measure is presented in [25] for change proneness of classes in object-oriented software. The data is collected and analyzed through a dynamic analysis of the code at runtime or from the dynamic design models to collect such measures to identify the objects interaction. Such dynamic measures capture more properties that static measures.

Although the aforementioned related work proposed several techniques for testing and detecting different types of software components' dependences and couplings, the main purpose of detecting software components' dependence is to identify the components' coupling that reduces components' reusability. Most of the presented related works identify software components' coupling without investigating whether such coupling is contributing to the components' computation i.e., component's output. Such is based on the premise that each dependency among components within a software system should influence at least one component's output; otherwise, such dependency is unnecessary and may be eliminated without influencing the software semantic.

This paper introduces an approach that detects the software components' coupling based on dependence that influences or contributes to the components' output computation which may help in understanding components' reusability for the purpose of refining the system design.

III. Basic Definitions

Software components collaborations can be dynamically modeled by a sequence diagram model, such dynamic model of the system is represented by a sequence of messages passed between the components showing the message-sends involved in specific collaborations in order to carry out the system functionality. In UML, sequence diagrams are employed to model the runtime of the software system.

The sequence diagram describes the dynamic behavior of system and can be viewed as a set of sequences of events, referred to as traces, where each event represents an occurrence of a message passed between components. For a given sequence diagram *S*, a trace of the sequence diagram is defined and referred to as T_s. For a finite set *R* of roles and a finite set *M* of messages, a message label is defined as a function *g* that maps each message in *M* to a triple (*l*, *s*, *r*) where *l* denotes a label of the occurred message, *s* and *r* denote roles in *R*, called sender and receiver, respectively [26]. Assume that there are an infinite set *O* and a finite set *L* for participating objects and labels of messages, respectively, an event $e_p \in T_s$ as a triple $g(e_p) = (l_{e_p}, s_{e_p}, r_{e_p})$ is defined, where the *p* is the event number within the trace T_s, $l_{e_p} \in L$ for the label, $s_{e_p} \in O$ for the sender, and $r_{e_p} \in O$ for the receiver. Because a code statement within an event may be executed several times during a trace, an execution position for each executed code statement within an event is defined as Y^i in which *Y* is the code statement number and *i* is the position of an executed code statement within the message's code statements. Y^i is referred as executed code statement or execution position interchangeably.

The event *e* can be represented as a directed graph (*V*, *E*), where *V* is a set of nodes, and *E* is a set of arcs. The nodes represent the objects associated with an event (sender and receiver). The arcs represent the dependence among the participating objects within a given event. Such dependence can be identified as data or control dependence. Every graph has an entry node V_0 and an exit node V_x. The program dependence graph has been proposed in [27] for the purpose of program optimization. Program dependence graph is a control flow graph with nodes corresponding to statements and control predicates, and arcs corresponding to data and control dependencies. It has been widely used for program analysis for different purposes such program testing and program optimization.

The data dependence can be defined in terms of defining or using passed data among participating objects via message passing within an event in a trace T_s. The data passed among objects within an event e_p in a trace T_s via label l_{e_p} are stored in a memory address referred to as variable. A passed variable might be simple data type, data structures, or complex objects. Also, a variable may contain data that is used as a control flag. A use of a variable occurs when such variable is referenced, and a definition of a variable occurs when a value is assigned to it. A variable *v* that is passed via a label l_{e_p} is said to be used at r_{e_p} if such variable is referenced. A variable *v* passed via a label l_{e_p} is said to be defined at r_{e_p} if a value has been assigned to that variable. A variable might be defined (assigned another value) several times and may be at different objects (receivers) within an event in a trace T_s. A label is considered as used if at least one of its passed variables has been referenced, and is considered as defined if at least one of its passed variables has been defined. The last definition *LD*(*v*) of a variable *v* at execution position *m* within a receiver object of an event e_p in a trace T_s is defined as the closest execution position Y^i within the sender or receiver object of the event e_p that contains a definition of *v* such that $i < m$. Another type of dependence comes in the form of returned value of the receiver to the sender such that the sender is dependent on the receiver. Therefore, returned value of passed variable *v* via a label l_{e_p} is defined if a value is returned from the receiver r_{e_p} to the sender s_{e_p}. Such returned value may come in the form of passed value, reference value, shared data structures, or common variable.

The data dependence captures a situation where one object (sender) assigns a value to a variable and the other object (receiver) uses that value. In terms of the directed graph, the sender object assigns a value to a variable before the entry node V_0 of a directed graph, and the receiver object uses that value before the exit node V_x. The control dependence captures the situation when the execution of a statement within an object (receiver) depends on the evaluation of a test statement (i.e., a predicate) of a conditional statement within another object (sender). Originally, the control dependence has been defined in [27]. The proposed definition is modified to fit the control dependence among software components. Formally, let *Q* and *Z* be two code statements within participating sender and receivers objects of an event, respectively, and (*Q*, *X*) be a branch of *Q*. Code statement *Z* postdominates code statement *Q iff Z* is on every path from *Q* to the exit node V_x of the event. Code statement *Z* postdominates branch (*Q*, *X*) *iff Z* is on every path from *Q* to the event's exit node V_x through branch (*Q*, *X*). *Z* is control dependent on *Q iff Z* postdominates one of the branches of *Q* and *Z* does not postdominate *Q*. As stated earlier, coupling is a measure of the interdependence degree between software components [3], in which coupling is defined between two components if they exhibit data or control dependences.

Due to various reasons, components may exhibit dependence (data or control) that is not contributing to their output. The output of a component may be a regular output statement or return statement. The dependence that is not contributing to the components' output computation is unnecessary or useless dependence, and may occur due to fault in the system model or poor design. Therefore, the notion of influence between components is identified, such that component c_1 influences component c_2 *iff* the data or control dependence contributes to the output computation of component c_2. As described earlier, coupling is a measure of the interdependence degree and the strength of the relationship between software components. Hence, the coupling that is based on the influence among the components is recognized for the purpose of software reusability. However, the other components' dependences that are not contributing to the component's output are considered as unnecessary coupling that should be minimized to improve the software reusability. The proposed approach aims to provide a new type of information that is based on the premise that the components' dependence is computed based on the influence of a component on another component's output.

IV. Components Coupling Detection Algorithm

The proposed algorithm is based on the notion of data and control dependence defined in the earlier section to identify the component coupling. A trace analysis has been used to determine the defined-used chain; in which different sets are defined to store some collected data for later analysis. Therefore, the sequence diagrams of the system model under analysis should be instrumented and recorded in a trace T_s. As described earlier, the sequence diagram trace T_s consists of a series of events that records the message label l_{e_p} along with its passed parameters, the sender s_{e_p} along with its defined variables, and the receiver r_{e_p} along with its used variables. In the trace T_s, the used and defined variables are stored at each executed code statement. The trace T_s of a given system is instrumented based on test cases that may be generated based on random inputs, certain inputs, or based on system operational profile [28], which is a description of how the system is used. It is usually developed during the system engineering or requirements definition phase.

As described earlier, the aim of the proposed approach is to identify the coupling among systems' components for the purpose of understanding components' reusability which may contribute to system design refinement. For that purpose, the proposed algorithm analyzes the system model under analysis in a backward fashion that requires the sequence diagram trace T_s to be recorded and the data are collected and stored in defined sets, in which the analysis starts from the end of the sequence diagram trace T_s and goes backward. Such approach, i.e., backward analysis, is appropriate for analyzing the dynamic model of the system under test in which the model is executed first, and the data is collected and stored in the trace, so that the model is analyzed dynamically based on its actual execution. However, such approach can be used for static analysis of a model, in which the model is analyzed statically, i.e., without its execution, to collect and store data in the trace based on all possible execution traces.

The proposed algorithm, as presented in the subsequent paragraph, requires the trace of the sequence diagram T_s as an input. The algorithm starts by defining two sets for the data and control dependences and identifying the used variables at s_{e_p} and r_{e_p}. Then it sets all executed output and return code statements in the participating objects within each event (r_{e_p} and s_{e_p}). Then the algorithm iterates from the end of the trace T_s and goes in backward fashion to identify the data and control dependence for every event in the trace T_s.

ALGORITHM
INPUT: T_s
OUTPUT: Coupled components
1 DEFINE *DataDependent*() and *ControlDependent*() as two sets of data and control dependences
2 DEFINE USED(O, Y^i) as the set of used variables at Y^i of a given object $\in O$.
3 SET all output/return executed code statements within s_{e_p} and r_{e_p} as marked for each event.
// start from the end of the T_s in backward fashion
4 WHILE (not the beginning of T_s)
5   FOR (every e_p) DO
6   WHILE (not V_0 of e_p)
7   FOR (every marked executed code statement $Y^i \in r_{e_p}$) DO
8   FOR (every variable v $\in$ USED(r_{e_p}, Y^i)) DO
// returns the executed code statement X^i as the last definition of v
9   X^i= Find_LD(v);
10   SET X^ias marked executed code statement;
11   IF ($X^i \in s_{e_p}$) THEN
12   ADD (s_{e_p}, r_{e_p}) to *DataDependent*();
          END_IF;
        END_FOR;
// returns Z^i that controls Y^i or zero if no control dependence
13   Z^i= Find_CD(n);
14   IF (Z^i> zero) THEN
15   SET Z^ias marked executed code statement;
16   IF ($Z^i \in s_{e_p}$) THEN
17   ADD (s_{e_p}, r_{e_p}) to *ControlDependent*();
          END_IF;
        END_IF;
      END_FOR;
    END_WHILE;
  END_FOR;
END_WHILE;
18 DISPLAY *DataDependent*() & *ControlDependent*() as the coupled components.

As described earlier, the algorithm starts by defining several sets to be used during the analysis and marking all executed output code statements in the trace T_s within each executed component. The algorithm analysis starts from the end of the trace T_s and goes backward and iterates for every event while not reaching its entry V_0. Then for every used variable at every marked executed code statement, the algorithm finds its last definition, and marks it. If the marked executed code statement is within the sender object, it means that the data dependent among the sender and receiver object contributes to the output computation of the receiver object. As a result, the sender and receiver objects are added to the *DataDependent* set as data dependent objects. Next the algorithm checks whether the marked executed code statement is control dependent on any other code statement, if so, such executed code statement is marked. In addition if this marked executed code statement is within the sender object, the sender and receiver objects are added to the *ControlDependent* set as control dependent objects. The algorithm iterates until it reaches the beginning of the trace T_s, and at the end, it displays the coupled components as the dependent components based on the influence on the output computation. In addition, for the purpose of investigating useless dependences, the algorithm can provide all data and control dependences among components regardless of their contributions to the computations of the components' output.

Although, there are many dependencies that might occur among software components, the proposed algorithm minimizes such information by only identifying the dependencies between components that contribute to the computations of the components' output. The software engineers can use such information to identify the coupled components for the purpose of software reusability. In addition, software engineers can consider the rest of dependences among software components as an unnecessary coupling that might occur as a result of poor or inefficient software components' design. The software engineers might use such information to investigate such dependencies for potential design problems. The contribution of the proposed approach is that, it computes the components' dependences based on the premise of components' output computation, such that a component influences another component if it contributes to its output computation.

V. Experimental Study

To illustrate the applicability of the proposed algorithm a small experimental study has been conducted. This study consists of three samples of sequence diagrams for selected operations within software system. In addition, testing is performed on randomly selected operations within four software systems that were modeled by different groups of students as system modeling project of real world systems. According to the proposed algorithm, the success criterion for detecting coupled components is the detection any form of data or control dependences. To demonstrate how the proposed algorithm is applied, consider the events in Figures 1, 3, and 5. The components model presented in the figures are simple examples of events that show sequence diagrams of a portion of lending library system, portion of home surveillance system, and student class enrolment. The presented samples of sequence diagrams and traces have been simplified for the purpose of demonstrating the algorithm. In addition, based on the specification of the given object, a note has been added at the activation bar of the receiver object containing a pseudo code that describes the execution of the sent message.

Figure 1 shows the sequence diagram of a lending library system event, in which a message *LendCopy*(*title*) is being sent to the *Main* object to search for a given *title*, and then *GetNumAvailable*() message is sent to the *aCopy* object to return how many copies are available for a specific *title* that is returned as *num* variable. Figure 2 shows the trace T_s of the lending library system event. The trace starts with the event's entry V_0 which shows the function $g(e_1)$ as the event triple, i.e., message label, sender, and receiver. When inspecting this trace by the proposed algorithm, the code statement at the execution position 4^4 is marked as an output code statement, then the analysis starts from the event's exit V_x in backward fashion. The marked execution position 4^4 is identified and its last definition at position 3^3 is marked. Note that this code statement does not belong to the sender object, so no data dependent is detected. The algorithm iterates until it reaches the event's entry V_0. According to this quick analysis, no data or control dependent is detected among these two objects (Main and aCopy), in which a conclusion can be drawn that no coupling is detected between Main and aCopy, in which either of these two components can be reused within another system or subsystem without the need of attaching the other component.

Another example is presented in Figure 3 which shows a simplified sequence diagram of an event of within a home surveillance system, in which a message *Activate_Deactivate*(*sensor*) is being sent to the *Control_Panel* object to search for an object *Sensor* to activate it or deactivate it. Figure 4 shows the trace T_s of the event of the home surveillance system. As can be seen the message *Activate_Deactivate*() is being sent to the object *Sensor* to examine its state, in which the *Sensor* is activated if its state is inactive and deactivated if its state is active. The code statement at the execution position 5^5 is marked by the algorithm as an output code statement, which returns the *Sensor* state to the control panel. The algorithm detects no used variables at this marked code statement, and as a result no data or control dependences are detected between the *Control_Panel* and *Sensor* objects in which no coupling is identified among those two objects, and they can be reused separately.

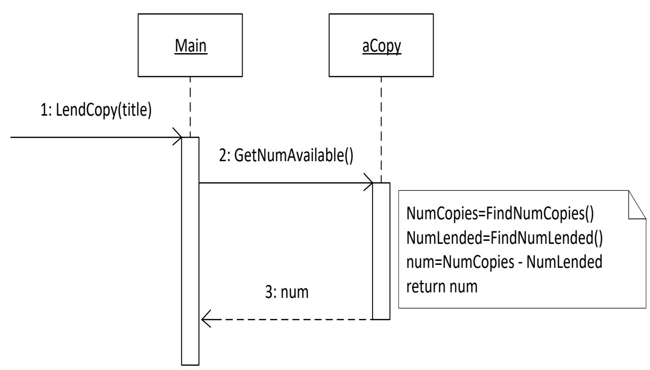

Fig. 1. Sample Sequence Diagram of a Lending Library System.

V_0 g(e_1)=(LendCopy(title), Main, aCopy)
1 Send "LendCopy(title) to Main"
  1^1 FindTitle(title)
2 Send "GetNumAvailable() to aCopy"
  1^1 NumCopies=FindNumCopies()
  2^2 NumLended=FindNumLended()
  3^3 num= NumCopies - NumLended
  4^4 return num
3 Send "num to Main"
4 V_x

Fig. 2. The Trace T_s of the Sequence Diagram of a Lending Library System in Fig 1.

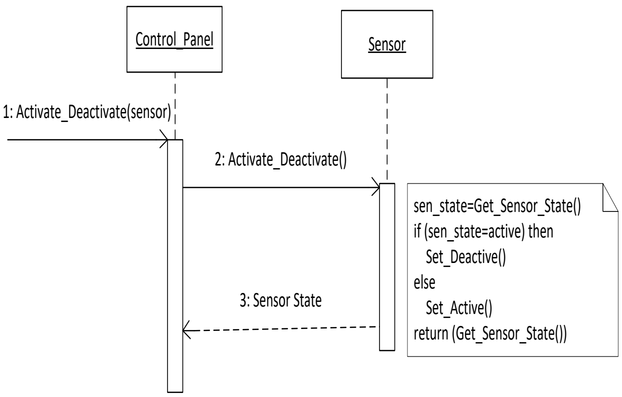

Fig. 3. Sample Sequence Diagram of Home Surveillance System.

V_0 $g(e_1)$=(Activate_Deactivate(sensor), Control_Panel, Sensor)
1 Send "Activate_Deactivate(sensor) to Control_Panel"
2 Send "Activate_Deactivate() to Sensor"
1^1 sen_state=Get_Sensor_State()
2^2 if (sen_state = active) then
3^3 Set_Deactive()
4^4 else Set_Active()
5^5 return Get_Sensor_State()
3 Send "Sensor State to Control_Panel"
4 V_x

Fig. 4. The Trace T_s of the Sequence Diagram of Home Surveillance System in Fig 3.

The last example is the sequence diagram of student class enrolment that is shown in Figure 5. As shown the message *Register*(*std, CourseID*) is sent to the *aStudent* object to search for the course, then the message *Enroll*(*std, IsPrerequisite*) is sent to the *aCourse* object to search for the session number and assign the student to it if the prerequisite course is satisfied, next the session number is returned to the *aStudent* object. Figure 6 shows the trace T_s of the event of the student class enrolment system. When analyzing this trace by the proposed algorithm in backward fashion, with the assumption that the *IsPrerequisite* flag is true, the code statement at the execution position 5^5 is marked, then the last definition of the *SessionNumber* is identified at execution position 3^3 and marked. The algorithm iterates searching for marked code statement and looking for the last definition of all used variables at each marked code statement and marks them. As a result, the code statement at the execution positions 2^2 is marked in which a control dependent is identified between the two objects *aStudent* and *aCourse* because the passed flag *IsPrerequisite* is used at the predicate of the execution position 2^2. Also, data dependent is identified as well between these two objects because the passed variable *std* is used at the marked execution position 3^3. The detected data and control dependent contribute to the output computation of this event; therefore, a coupling can be identified between the two objects *aStudent* and *aCourse*. Therefore, the software engineer should consider the coupling among these two components when reusing either one.

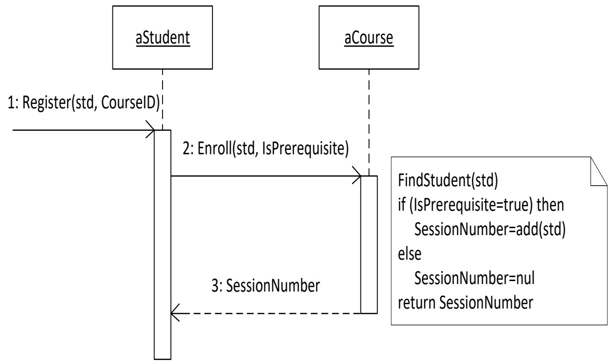

Fig. 5. Sample Sequence Diagram of Student Class Enrolment.

V_0 $g(e_1)$=(Register(std, CourseID), aStudent, aCourse)
1 Send "Register(std, CourseID) to aStudent"
1^1 FindCourse(CourseID)
2^2 CheckPrerequisite(CourseID)
2 Send "Enroll(std, IsPrerequisite) to aCourse"
1^1 FindStudent(std)
2^2 if (IsPrerequisite = true) then
3^3 SessionNumber = add(std)
4^4 else SessionNumber = nul
5^5 return SessionNumber
3 Send "SessionNumber to Student"
4 V_x

Fig. 6. The Trace T_s of the Sequence Diagram of Student Class Enrolment in Fig 5.

The remaining of this section describes some real world software systems which have been used to test the proposed algorithm. Table 1 summarizes the four software systems that have been modeled by different groups of students as a system modeling project of real world systems to demonstrate their skills in software design and architecture course. These four systems have been selected as semi-commercial software systems to test the applicability of the proposed algorithm for the real world systems.

TABLE I. EVENTS OF THE SELECTED SYSTEMS WITH COMPONENTS' DEPENDENCES

System Name	**Components (s_{e_p} & r_{e_p})**	**Message Name**	**Coupling**
NCAAA System	Website & Database	validate(ID)	No
University RFID	Sensor & RFID_Reader	read(signal)	Yes
Studying Abroad Advising System	Registration_System & Authentication_System	Validate_User_Information(info)	No
Truck Car Traffic Tracking System	RTD & DB_Driver	Retrieve_Driver_Data(ID)	Yes

The first system model is the NCAAA Accreditation System which is an automation system aims to automate all the processes that are required for any university applying for accreditation at the Saudi National Commission for Academic Accreditation and Assessment (NCAAA). The purpose of this system is to develop a system model that can be implemented to automate the accreditation process via an online system. The selected message *validate*(*ID*) is a validation event that occurs as a result of sending the message *validate*(*ID*) from the website object to the database object. This message validates the login of a client against the registered clients in the database. After analyzing this event by the proposed algorithm based on the specifications of the participating objects, no data or control dependence was identified among the object website that influences the output computation of the database object. Such result indicates the independence of the two components from each other, and the software engineer may reuse any of the two components without the need to attach the other one.

The second system model is the University RFID that is a part of an access control system that allows the university to control and monitor the access to its buildings and properties. The modeled system manages the access to the buildings, classrooms, labs, and offices within the university via the use of hardware solutions such as RFID cards that are linked to a software solution to manage and monitor the access. The selected message *read*(*signal*) is a reading event that occurs as a result of sending a signal to the sensor component which causes a *read*(*signal*) message to be sent to the *RFID_Reader* object to read the signal. After analyzing this event using the proposed algorithm based on the specifications of the participating objects, it has been identified that, the computation of the returned value of the *RFID_Reader* object is dependent on the passed data of the sensor object. Therefore, such dependence influences the output computation of the *RFID_Reader* object, and as a result, there is a coupling among the two objects sensor and *RFID_Reader* that must be considered when reusing either of these two components within another system.

The third system model is the Studying Abroad Advising System which aims to automate the supervision program at the ministry of higher education in Saudi Arabia. The ministry has established a scholarship program for Saudi students to study their BSc, MSc, and PhD in various specialties. This program is offered for the students to study at local private universities as well as at abroad universities. The ministry would like to manage this program such as facilitating the admission to the program, local/abroad universities subscriptions, monitoring students' performance, and facilitating the communications with the students/guardians. The selected message *Validate_User_Information(info)* is sent from the *Registration_System* object to the *Authentication_System* object. This event has been analyzed by the algorithm based on the specifications of the participating objects and found no data or control dependence of the object *Registration_System* that influences the computation of the output of the *Authentication_System* object, such detection identifies the independence of the two components, in which the two components may be reused separately within other system or subsystem.

The fourth system model is the Truck Car Traffic Tracking System that aims to help the Riyadh Traffic Department (RTD) to manage the trucks movement within the city highways and local roads due to the congestions that caused by these truck cars during the day and rush hours and to monitor the vehicles movements on the roads and highways by linking the RTD system with GPS system. The purpose of the modeled system is to guide the truck vehicles to follow alternative roads during the rush hours or in the case of congestions in the highway. Also, the system aims to provide different services such as monitoring the vehicles movements and issuing violation tickets. A data retrieving event has been selected that occurred as a result of sending the *Retrieve_Driver_Data*(*ID*) message from the RTD object to the *DB_Driver* object. After analyzing this event by the proposed algorithm, based on the specifications of the participating objects, control dependence is discovered by the RTD object that influences the computation of the output of the *DB_Driver* object, which causes a coupling among these two objects that should be considered when reusing either one.

Although the experiments have been investigated on several events within some selected software systems' models, the results of the experiments have shown encouraging results for the applicability of the proposed algorithm in detecting software components' coupling. The proposed algorithm can help the software engineers to better understand the software system model and the relationships among its components. This may help the software engineers to comprehend the software components' dependences in order to optimize the software system model by eliminating the unnecessary dependences among software components. Such minimization definitely, will increase the components' cohesiveness, and as a result, the software components' reusability should be improved. In addition, the algorithm provides the software engineer with information about the influence among components that identifies components' coupling in which a component should be attached with another reused component within other system or subsystem.

VI. Conclusion

In this paper an approach for detecting coupling among software components has been proposed. The proposed approach analyzes the software system model under test in terms of a sequence diagram trace which represents the dynamic behavior of the system under analysis. The notion of data and control dependence is used in the proposed approach to identify the dependence among system components. The notion of influence between components has been introduced in which a data or control dependence of a component is considered if it contributes to the output computation of the other component. The applicability of the proposed algorithm in identifying the software components' coupling has been presented in the paper through an experimental study.

The experimental study has shown encouraging results in detecting the coupling between the software components. The software engineer may use the results to have a better understanding of the software system model under analysis in terms of the dependences among its components and how they may influence their reusability. Software engineers may use the provided information by the algorithm to eliminate the unnecessary components' couplings for the purpose of enhancing software reusability.

The proposed algorithm has been applied manually by inspection and walkthrough of the tested model, in which the trace is inspected manually. The future plan is to implement the proposed algorithm in which the system model under test can be automatically instrumented and the trace is recorded dynamically, in which the model analysis can be performed at the runtime. In addition, an integration of the proposed algorithm within one of the open source environment may be implemented in which the system model can be constructed and examined. Furthermore, an investigation may be conducted to extend the algorithm to identify the different types of coupling among components such as content coupling, common coupling, external coupling, control coupling, stamp coupling, and data coupling.

REFERENCES

[1] R. Taylor, N. Medvidovic, and E. Dashofy, Software Architecture Foundations, Theory, and Practice, 2010, Wiley.

[2] W.P. Stevens, G.J. Myers, and L.L. Constantine, "Structured design". IBM Systems Journal, 1974, 13(2), pp. 115-139.

[3] L.L. Constantine and E. Yourdon, Structured Design, 1979, Prentice-Hall, New Jersey.

[4] G. Myers, Reliable Software through Composite Design, Mason and Lipscomb, New York, 1974.

[5] P.-J. Meilir, Practical Guide to Structured Systems Design, Prentice Hall, 2nd Edition, 1988.

[6] R. Pressman, Software Engineering: a Practitioner's Approach, 1992, McGraw-Hill.

[7] A.J. Offutt, M.J. Harrold, and P. Kolte, "A software metric system for module coupling", The Journal of Systems and Software, March 1993, 20(3), pp. 295-308.

[8] L. Briand, J. Daly, and J. Wust, "A unified framework for coupling measurement in object-oriented systems", IEEE Transactions on Software Engineering, 1999, Vol. 25, No. 1, pp. 91-121.

[9] S. Henry and D. Kafura, "Software structure metrics based on information flow", IEEE Transactions on Software Engineering, 1981, Vol. SE-7, No. 5, pp. 510-518.

[10] E.B. Allen and T.M., Khoshgoftaar "Measuring coupling and cohesion: an information-theory approach", Proceedings of the 6th International Software Metrics Symposium, 1999, pp. 119 – 127.

[11] J. Offutt, A. Abdurazik, and S. Schach, "Quantitatively measuring object-oriented couplings", Software Quality Journal, 2008, Vol. 16, No. 4, pp. 489 – 512.

[12] H.Y. Yang and E. Tempero, "Measuring the strength of indirect coupling", IEEE Proceedings of the Australian Software Engineering Conference (ASWEC'07), 2007.

[13] J.-B. Fasquel and J. Moreau, "A design pattern coupling role and component concepts: Application to medical software", The Journal of Systems and Software, 2011, No. 84, pp. 847–863.

[14] M. Choi and J. Lee, "A dynamic coupling for reusable and efficient software system", IEEE 5th International Conference on Software Engineering Research, Management and Applications, 2007, pp. 720-726.

[15] G. Gui and P.D Scott., "Ranking reusability of software components using coupling metrics", The Journal of Systems and Software, 2007, No. 80, pp. 1450–1459.

[16] W. Horré, D. Hughes, K.L. Man, S. Guan, B. Qian, T. Yu, H. Zhang, Z. Shen, M. Schellekens, and S. Hollands, "Eliminating implicit dependencies in component models", Proceedings of the IEEE 2nd International Conference on Networked Embedded Systems for Enterprise Applications (NESEA) , 2011, pp. 1-6.

[17] A. Jhumka and M., Leeke "The early identification of detector locations in dependable software", Proceedings of the 22nd IEEE International Symposium on Software Reliability Engineering, 2011, pp. 40-49.

[18] N. Ajienka and A. Capiluppi, "Understanding the interplay between the logical and structural coupling of software classes", The Journal of Systems and Software, No. 134, 2017, pp. 120–137.

[19] M. Kessel and C. Atkinson, "Ranking software components for reuse based on non-functional properties", Inf Syst Front, No.18, 2016, pp. 825–853.

[20] K. Hasan and M. Hasan, "Principal Component Analysis of Coupling Measures for Developing High Quality Object Oriented Software", International Conference on Computer and Communication Engineering (ICCCE 2010), 2010.

[21] A. MacCormack and D. Sturtevant, "Technical debt and system architecture: The impact of coupling on defect-related activity", The Journal of Systems and Software, No. 120, 2016, pp. 170–182.

[22] T. Oyetoyan, D. Cruzes, and R. Conradi, "A study of cyclic dependencies on defect profile of software components", The Journal of Systems and Software, No. 86, 2013, pp. 3162– 3182.

[23] M. Yutao, H. Keqing, L. Bing, and Z. Xiaoyan, "How multiple-dependency structure of classes affects their functions a statistical perspective". The 2nd International Conference on Software Technology and Engineering, 2010, pp. V2-60-V62-66.

[24] S. Chidamber and C. Kemerer, "A Metrics Suite for Object Oriented Design", IEEE Transactions on Software Engineering, Vol. 20, No. 6, 1994, pp. 476-493.

[25] E. Arisholm, L. Briand, and A. Føyen, "Dynamic Coupling Measurement for Object-Oriented Software", IEEE Transactions on Software Engineering, Vol. 30, No. 8, 2004, pp. 491-506.

[26] S.M. Cho, H.H. Kim, S.D. Cha, and D.H. Bae, "A semantics of sequence diagrams", Information Processing Letters, 2002, No. 84, pp. 125–130.

[27] J. Ferrante, K. Ottenstein, and J. Warren, "The program dependence graph and its use in optimization", ACM Transactions on Programming Languages and Systems, 1987, Vol. 9, No. 3, pp. 319-349.

[28] J. Musa, "Operational profiles in software reliability engineering", IEEE Software, March 1993, Vol. 10, No. 2, pp. 14-32.

Analysis of Coauthorship Network in Political Science using Centrality Measures

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***Abstract*—In recent era, networks of data are growing massively and forming a shape of complex structure. Data scientists try to analyze different complex networks and utilize these networks to understand the complex structure of a network in a meaningful way. There is a need to detect and identify such a complex network in order to know how these networks provide communication means while using the complex structure. Social network analysis provides methods to explore and analyze such complex networks using graph theories, network properties and community detection algorithms. In this paper, an analysis of co-authorship network of Public Relation and Public Administration subjects of Microsoft Academic Graph (MAG) is presented, using common centrality measures. The authors belong to different research and academic institutes present all over the world. Cohesive groups of authors have been identified and ranked on the basis of centrality measures, such as betweenness, degree, page rank and closeness. Experimental results show the discovery of authors who are good in specific domain, have a strong field knowledge and maintain collaboration among their peers in the field of Public Relations and Public Administration.**

Keywords—Social networks; undirected graph; centrality measures; community detection; data visualization

I. INTRODUCTION

Many problems in computational sciences like neuroscience, neuro-informatics, pattern recognition, signal processing and machine learning generate massive amounts of multidimensional data with multiple aspects and high dimensionality. Data is growing rapidly, day by day, because this is collected by cheap and numerous information sensing. The real world is full of different kinds of complex networks. The complexity of these networks is rapidly increasing day by day, for the enhancement and advancement in the technology. One prominent example of these type of networks is the network of internet users. According to [1], the internet users grew many fold in recent era. During last decade, from 2005 to 2015, internet users increased from 1 billion to 3.17 billion, showing the rapid growth of users. Social network analysis provides methods to explore and analyze such complex networks using graph theories, network properties and community detection algorithms. Combination of edges and nodes make a network or graph [2]. There are various types of graphs based on their characteristics. For example, the edges of facebook are undirected as shown in figure 1(b), while edges of social network of twitter are directed as shown in figure 1 (a) [3]. A graph that has some weight on its edges, is called weighted directed graph or weighted undirected graph as shown in figure 1 (c) [23,24].

The social network analysis has been widely explored to discover relationship patterns or communication patterns among individuals, teams, groups, societies, communication devices and even among organizations. The study discloses patterns of association that help in best decision making and better understanding of various patterns or groups in a graph [4].

One of the kind of social networks is coauthorship network. By applying social network analysis techniques we can discover different patterns of collaboration among authors. We can discover most active researcher, who is prominent in the field by applying different measures of social network [5]. Citation network is established, if one author cites the paper of other author and in result we obtain the network of co-authorship [6]. When author publishes a paper with another author then they form one-to-one relationship. If author has a publication with multiple co-authors then they form one-to-many relationship. And if co-authors have contributed in more than one papers then the relationship is many-to-many.

Centrality is computed by using centrality measures on directed or undirected graph. Some commonly used centrality measures are: degree centrality [5,7,8,9], closeness centrality [5,7,8,9], betweenness centrality [5,8,22] and PageRank [10,11,12,22].

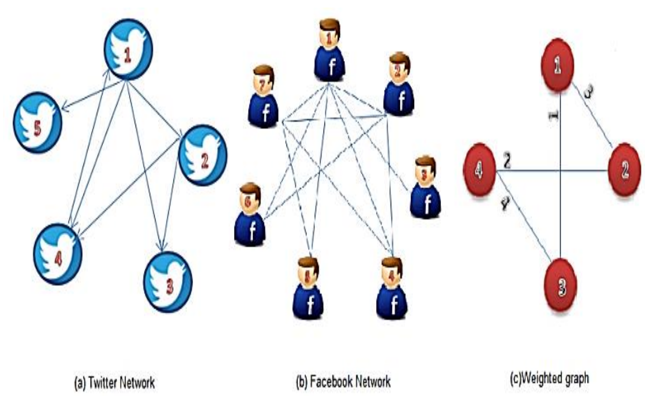

Fig. 1. Directed Twitter Network (b) Undirected facebook Network (c) Weighted Graph.

II. Related Work

Modularity divides a complex network into small groups called modules. If the modularity value of a graph is high then it means that modules are cohesive and are strongly connected with each other. Shang et al. [13] proposed a MIGA-Modularity and Improved Genetic Algorithm to overcome the difficulty for finding optimal solution when handling large scale network problem with hill climbing. MIGA has low computational time and can detect more than half part with prior information using simulated annealing method.

Sutaria et al. proposed a community detection algorithm in which author finds the communities on the basis of modularity class [14].

Newman proposed CNM algorithm, discovering non-overlapping and overlapping communities [15]. Palla et al. described cumulative distribution functions P(scom), P(dcom), P(sov) and P(m) that used four basic quantities. Each node represented as i of network characterize as membership number n_i of the community. Communities are represented as α and β, that share overlapping property depicting the size of the community. Palla et al. used k-clique method for finding communities in a network. The benefit of this method over divisive method and agglomerative method is that it allows construction of unconstrained network of communities [16].

Karsten et al. used a simple approach with common neighboring similarity, topological clustering coefficient similarity and node attribute similarity using directed weighted graph. Proposed approach identified the clustering coefficient of the node, using clustering coefficient similarity. It measures the contribution of the connectedness among the neighboring nodes. Common neighboring similarity captures overall connectedness between immediate neighbors of nodes by substituting the neighbors. Finally, node attribute similarity computed the weight of edges based on node attribute similarity [17].

Yang et al. proposed an approach that utilized the spectral clustering algorithm which compared network communities quantitatively. Thirteen different communities were examined and divided into four classes. This methodology used for comparing networks, based on real data and examining their robustness [18]. Authors found that this method reliably detected ground-truth communities.

Qiu et al. proposed a ranking algorithm called ocdRank for finding overlapping communities in social network. The algorithm combines the features of overlapping community detection and community member ranking in heterogeneous social networks. Results show that ocdRank has low time complexity and detected better community structure as compared to other community detection methods [19].

In [20], Altunbey et al. proposed an algorithm called Parliamentary Optimization Algorithm (PAO) for finding overlapping communities in social networks.

In 2013, Li et al. embedded the six social capital measures, closeness, degree, betweenness, team exploration, profilic co-author count and publishing tenure, for analyzing the research impact. The dataset consists of more than hundred scholars between the time span of 1999 to 2003. Li et al. analyzed the impact of social capitals on citations. Author defined the three social capital dimensions of relational, structural and cognitive capital, for coauthorship network. The results show that the ‘relational capital’ and ‘team exploration’ have no direct impact on citation count but ‘betweenness’ has indirect effect [6].

Newman et al. performed case study on coauthorship network [5]. Author collected data from bibliographic resource, consisting of 1589 researchers as nodes and 2742 links, drawn by edges. The authors are ranked by applying four common centrality measures.

Liu et al. performed analysis on dataset using binary undirected network model [8]. The data is collected from IEEE and ACM conferences. A new network is introduced, named ‘weighted directional network model’. Another dataset is obtained from ACM DL and JCDL and DBLP for IEEE ADL. This dataset contains 1567 authors, 3401 links among authors, and 759 publications. The largest component from network is observed and analysis showed that SIGMOD, NCSTRL and JCDL network have 60%, 57.2%, and 32.7% values of all authors, respectively. The results also show that DLS domains are strongly linked with scientific domain.

Yun et al. performed analysis by using micro-level properties on co-authorship network. The dataset contains information about sixteen journals from time span of 1988 to 2007. Four centrality measures that are closeness centrality, degree centrality, PageRank and betweenness centrality are used to rank top 30 authors and shows the highest collaboration among authors [21].

III. Proposed Methodology

The proposed analysis methodology consists of three steps: First, the data is collected from Microsoft Academic Graph (MAG), then in second step, the data is preprocessed and transformed in required form, thirdly, we applied centrality measures and ranked the authors related to each field. We have chosen two fields of Political Science, Public Relations and Public Administration, and analyzed these fields using most common centrality measures. In the study, the goal is set to find most prominent group of authors in each field and ranked these authors according to work in their respective field. The proposed methodology is applied one by one on each field, which is discussed in subsequent sections.

IV. About Dataset

Table I gives the data statistics related to the sub fields of Political Science that is Public Relations and Public Administration. Microsoft Academic Graph (MAG) is an open dataset of coauthorship network provided by Microsoft. This coauthorship network dataset is downloadable from Microsoft website. The dataset comprises of information of all aspects of the research papers including Journal, Conference and CERN and other projects. In coauthorship network, there is collaboration of co-authorship with an appropriate affiliation. Most of the publications of MAG have 2 to 15 co-authors and in some cases 6,000 co-authors, More than 30 million publications have 2 to 15 co-authors. The most productive research year for the field of Political Science, was 2013.

TABLE I. DATA STATISTICS RELATED TO PUBLIC RELATIONS AND PUBLIC ADMINISTRATION

	Public Relations	Public Administration
Number of authors	83516	238385
Modularity	0.999	0.974
Network diameter	41	34
Connected components	18862	49787
Avg. clustering coefficient	0.915	0.877
Avg. path length	12.834	24.831
Avg. degree	2.683	4

V. RANKING AUTHORS IN PUBLIC ADMINISTRATION ON THE BASIS OF CENTRALITY MEASURES

For the analysis, common centrality measures of social networks have been applied, such as closeness centrality, degree centrality, betweenness centrality and PageRank. These metrics are used to rank authors according to their fields.

A. Ranking Authors based on Degree Centrality

The degree centrality measure is used to find highest degree node. The degree centrality measure highlighted those scientists who have highest collaboration. The average degree distribution of public relations is 2.683. Most of the researchers have low degree and few researchers have high degree as shown in Table II.

The author named as '14674B35-DanckerDLDaamen' of public relation affiliated to Leiden University, has highest influence and frequent collaboration with other 47 researchers as shown in figure 2. '14674B35-DanckerDLDaamen' has worked exclusively in public opinion field which is the sub field of public relations. The second most influence author is '7FF2291D-DarrelMontero' and is affiliated with Arizona State University.

We extracted the graph of top 10 degree researchers and their connected researchers as shown in figure 3. This graph contains 426 researchers and 1146 collaborations. Average degree of top 10 degree graph is 5.38, network diameter is 4, modularity is 0.7 and there are 11 connected components in the network. Modularity value shows that this graph has good community structure. In figure 5, the most productive institute is the Univeristy of Missouri. '7F4328BD-GlenTCameron' is the researcher who has degree 38 and ranked as 4th in top ten degree, with 41 other researchers. The author collaborated with University of Missouri, Missouri School of Journalism and University of Georgia and he has productive research with University of Missouri as he has 19, 6 and 1 publications, respectively. The second most productive institute is University of Minnesota. '7E654E5D-DavidPFan' is the researcher who has 27 degree and ranked as 10 in top ten degree researchers, having collaboration with 28 other researchers. The author is affiliated to University of Minnesota and he has eleven publications.

B. Ranking Authors based on betweenness Centrality

Betweenness centrality ranks the nodes with highest value that are part of most of the shortest path. The network diameter of public relations is 41 and the length of average path is 12.833. Majority of the researchers have zero or near to zero betweenness, some researchers have high betweenness, which shows that they are responsible for flow of knowledge from one community to another community.

TABLE II. AUTHORS RANKING OF PUBLIC RELATIONS ON BASIS OF DEGREE CENTRALITY WITH RESPECT TO OTHERS

Author	Degree	Rank	Betweenness	Rank	Closeness	Rank	PageRank	Rank
14674B35-DanckerDLDaamen	46	1	8.85E-07	381	6.18E-04	1424	5.62E-05	101
7FF2291D-DarrelMontero	44	2	5.46E-07	425	7.17E-04	1409	8.86E-05	19
0B211A8C-PaulSlovic	42	3	1.28E-04	35	3.70E-03	108	1.18E-04	6
7F4328BD-GlenTCameron	38	4	2.21E-04	12	3.80E-03	73	1.51E-04	2
2A8E03FD-SFMccool	36	5	2.99E-06	308	7.23E-04	1408	8.31E-05	27
0106C2B9-RobertJBlendon	35	6	1.13E-04	42	2.98E-03	650	8.80E-05	21
7D5AAC1C-FranciscoHGFerreira	31	7	3.77E-07	462	4.55E-04	1548	4.10E-05	259
290A255A-JillRoessner	29	8	1.90E-07	533	5.09E-04	1485	4.41E-05	208
771B6FCA-DietramAScheufele	28	9	7.29E-04	1	4.43E-03	1	8.26E-05	29
7E654E5D-DavidPFan	27	10	1.75E-04	23	3.70E-03	109	1.07E-04	10

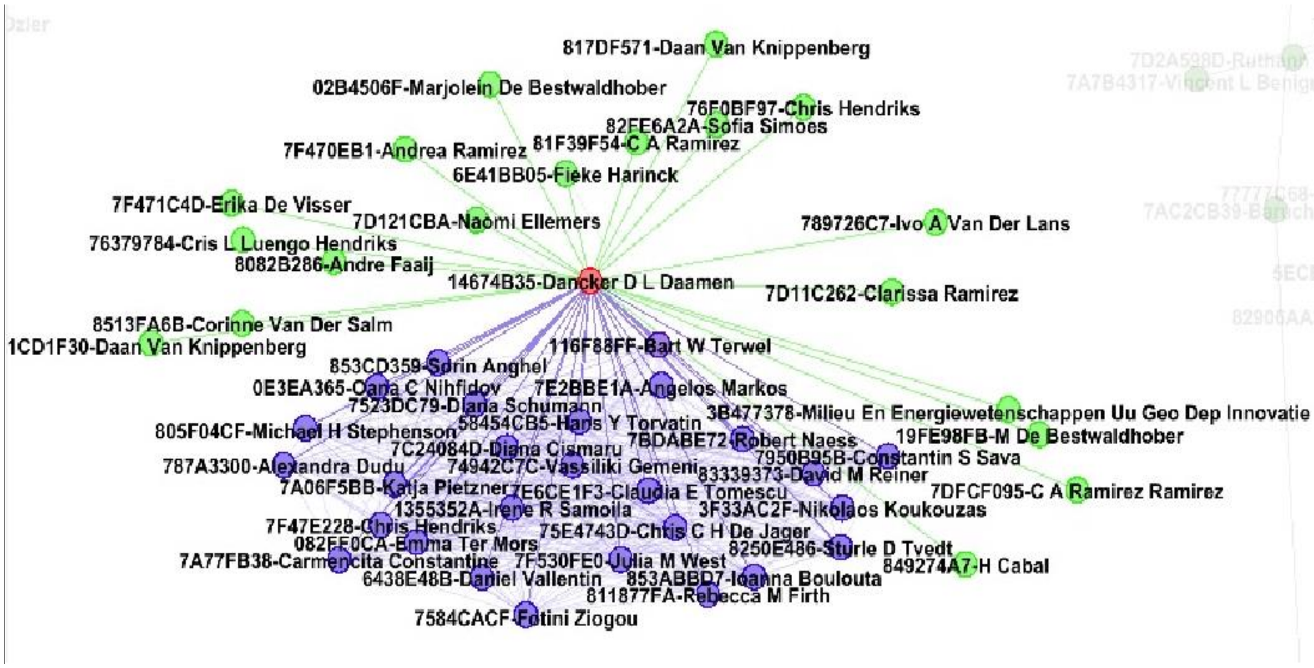

Fig. 2. '7FF2291D-DarrelMontero' with Highest Degree Centrality.

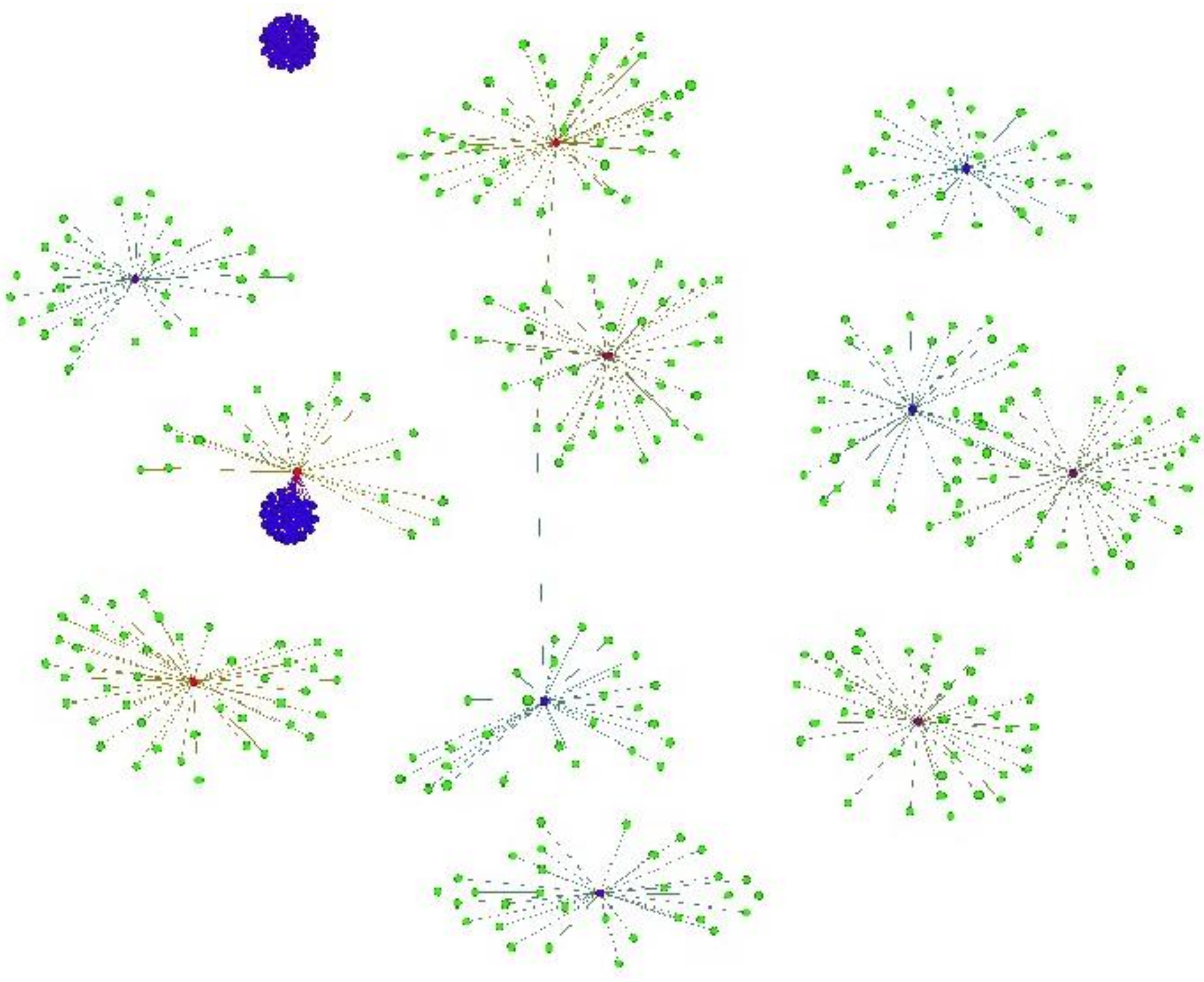

Fig. 3. Top 10 Authors of Public Relations having Highest Degree Centrality.

TABLE III. RANKING AUTHORS ON THE BASIS OF BETWEENNESS CENTRALITY

Author	**Degree**	**Rank**	**Betweenness**	**Rank**	**Closeness**	**Rank**	**PageRank**	**Rank**
771B6FCA-DietramAScheufele	28	9	1412952.09	1	4.43E-03	1	8.26E-05	29
80EE5C66-JeongnamKim	12	25	1146458.61	2	4.41E-03	3	5.26E-05	113
7CF2B524-DoohunChoi	5	32	1139426.84	3	4.42E-03	2	1.98E-05	1851
7E3071EE-BeylingSha	12	25	762604.15	4	4.32E-03	4	4.86E-05	155
7CF3C0D4-ElizabethLToth	20	17	709156.65	5	4.22E-03	6	8.66E-05	23
76015751-BryanHReber	14	23	606510.35	6	4.01E-03	28	5.01E-05	133
805E4884-PatriciaMoy	12	25	530612.87	7	4.18E-03	7	5.20E-05	118
4AF7AF7E-KrishnamurthySriramesh	22	15	479380.97	8	4.18E-03	8	9.75E-05	13
72B6EC1A-DebashishMunshi	5	32	437850	9	3.09E-03	560	2.14E-05	1625
5F07A3FF-VericaRupar	6	31	432422	10	2.89E-03	744	2.91E-05	743

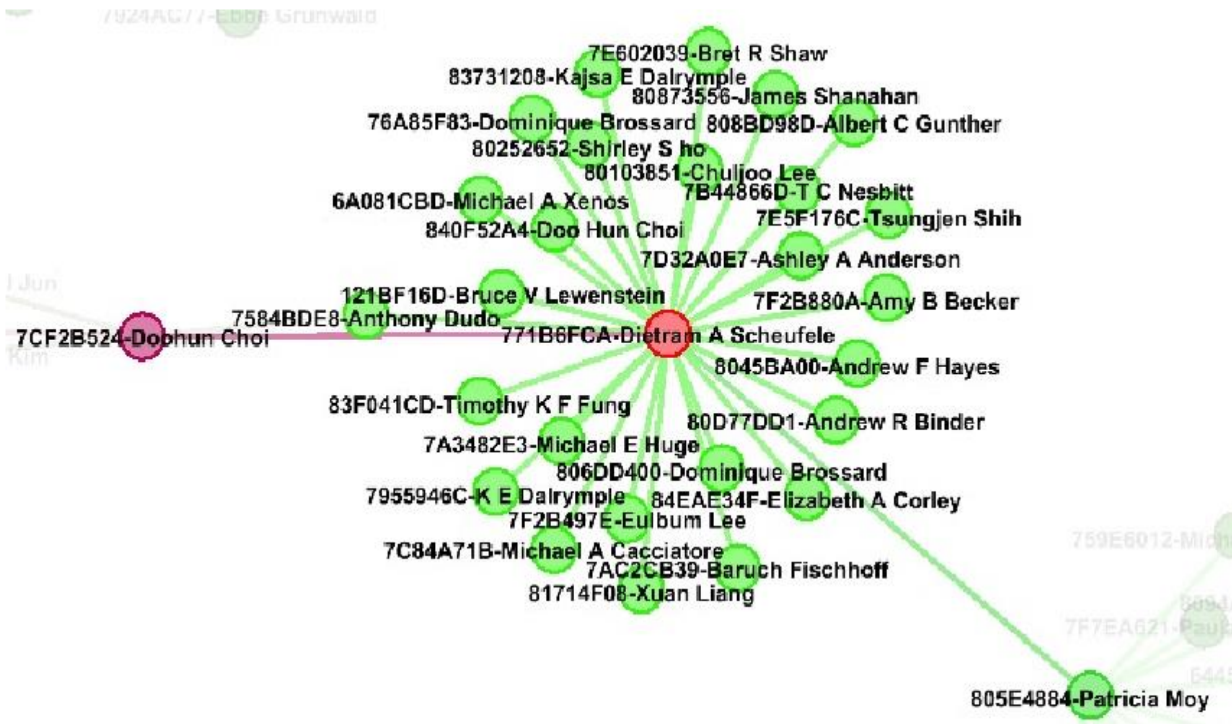

Fig. 4. '771B6FCA-DietramAScheufele', Author of Public Relations having Highest Betweenness Centrality.

TABLE IV. RANKING AUTHORS ON THE BASIS OF CLOSENESS CENTRALITY

Author	**Degree**	**Rank**	**Betweenness**	**Rank**	**Closeness**	**Rank**	**PageRank**	**Rank**
771B6FCA-DietramAScheufele	28	9	7.29E-04	1	4.43E-03	1	8.26E-05	29
7CF2B524-DoohunChoi	5	32	5.88E-04	3	4.42E-03	2	1.98E-05	1851
80EE5C66-JeongnamKim	12	25	5.92E-04	2	4.41E-03	3	5.26E-05	113
7E3071EE-BeylingSha	12	25	3.93E-04	4	4.32E-03	4	4.86E-05	155
0916F08B-JamesEGrunig	15	22	2.06E-04	16	4.30E-03	5	6.28E-05	70
7CF3C0D4-ElizabethLToth	20	17	3.66E-04	5	4.22E-03	6	8.66E-05	23
805E4884-PatriciaMoy	12	25	2.74E-04	7	4.18E-03	7	5.20E-05	118
4AF7AF7E-KrishnamurthySriramesh	22	15	2.47E-04	8	4.18E-03	8	9.75E-05	13
7584BDE8-AnthonyDudo	2	35	0.00E+00	1064	4.18E-03	9	8.19E-06	5052
7F6A3D86-SeihillKim	4	33	1.18E-06	364	4.17E-03	10	1.99E-05	1832

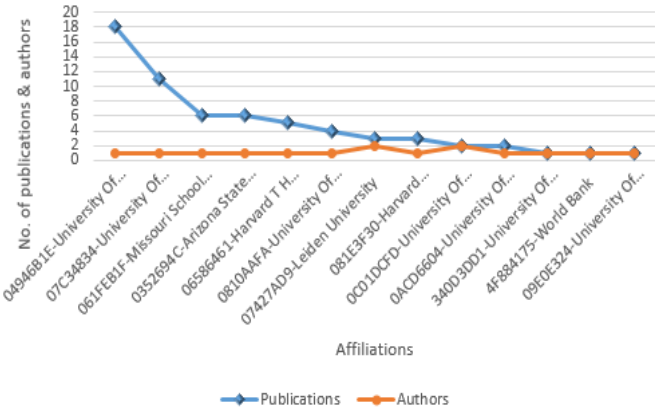

Fig. 5. Institutes and their Publications of Top 10 Researchers W.R.T Degree.

Table III shows the top 10 researchers who have high betweenness in the field of public relations. Figure 4 shows the graph that contains 119 researchers and 129 collaborations. The network diameter of graph is 8, average path length is 4.32, 0.754 modularity and there are 2 connected components. The most influential author is '771B6FCA-DietramAScheufele' who is affiliated to 'University Of Wisconsin Madison', 'Nanyang Technological University', 'Ohio State University', 'Cornell University', 'University of Washington' and 'University of Wisconsin Madison School of Journalism Mass Communication'. The author is the most central researcher and is involved in shortest path from one researcher to other researcher and have frequent collaboration, as he is ranked 9 in degree centrality measures.

Node '80EE5C66-JeongnamKim' is the second most central researcher having frequent collaborations. He has ranked 25th in degree centrality measures, affiliated to 'Purdue University', 'University Of Houston', 'University Of Maryland College Park', 'Hankuk University of Foreign Studies','University Of Siena', 'Hong Kong Baptist University', 'Indiana University', 'Kansas State University' and 'San Diego State University'. He has worked in multiple fields like 'Reputation', 'Soft Power' and 'News Media', sub-fields of public relations. He has collaborated with 13 other researchers.

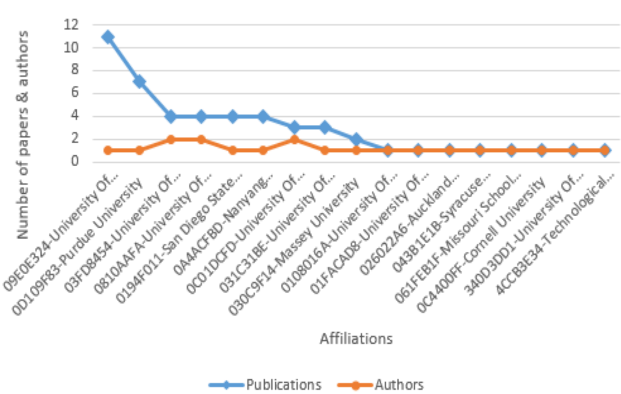

Fig. 6. Institutes and their publications of top 10 researchers w.r.t betweenness

In figure 6, the most productive institute is the Univeristy of Georgia as this institute has highest number of publications. '76015751-BryanHReber' is the researcher who has degree14 and ranked as 6th in top 10 betweenness researchers, having collaboration with 15 other researchers. He has collaboration with University of Georgia, University of Alabama, Missouri School of Journalism, University of Florida and University of Maryland College Park, as he has 11, 8, 4, 2 and 1 publications, respectively. The second most productive institute is Purdue University. '80EE5C66-JeongnamKim' is the researcher who has degree 12 and ranked at second place in top 10 betweennes researchers. having has collaboration with 13 other reasearchers, in collaboration with Purdue University, University of Maryland College Park ,University of Houston, Hankuk University of Foreign Studies, University of Siena, Hong Kong Baptist University, Kansas State University, San Diego State University and Indiana University. He has 7, 3, 2, 1, 1, 1, 1, 1 and 1 publications with these institutions, respectively.

C. Ranking Authors based on Closeness Centrality

The author '771B6FCA-DietramAScheufele' is most central researcher and ranked first in betweenness and closeness centrality, as shown in Table IV. He has worked exclusively in public opinion field which is the sub field of public relations. '7CF2B524-DoohunChoi' is the second most central researcher. Graph of top 10 researchers based on closeness centrality is shown in figure 8. This graph contains 105 researchers and 121 collaborations. The diameter of network is 7, average path length is 4.073, 0.683 is modularity and there is a single component.

Figure 7 shows the most productive institute that is '03FD8454- University Of Maryland College Park'. '0916F08B-James E Grunig', '7CF3C0D4-Elizabeth L Toth' and '7E3071EE-Beyling Sha' researchers are affiliated to ''03FD8454-University Of Maryland College Park'' and they have 4, 3 and 1 publications, respectively. The second most productive institute is '0D109F83-Purdue University'. '80EE5C66-Jeongnam Kim' researcher is affiliated to '0D109F83-Purdue University' and has 7 publications.

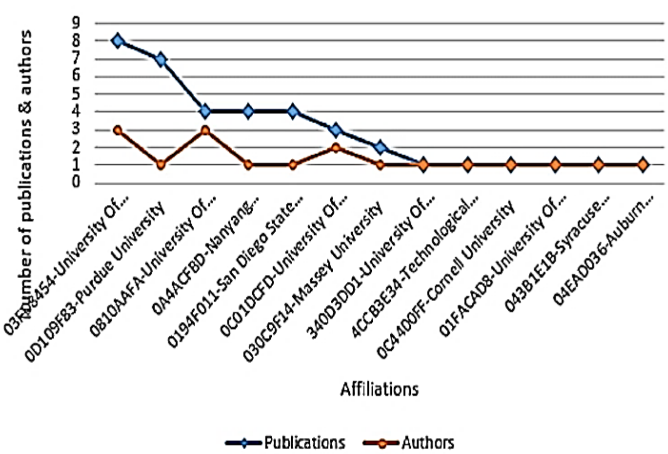

Fig. 7. Institutes and their Publications of Top 10 Researchers W.R.T Closeness.

Fig. 8. Top 10 Researchers of Public Relations based on Closeness Centrality.

TABLE V. RANKING AUTHORS ON THE BASIS OF PAGERANK

Authors/Researchers	**PageRank Value**	**Rank**
7F4328BD-GlenTCameron	1.51E-04	1
4AA5A185-JamesNDruckman	1.32E-04	2
7CF120D6-RichardDWaters	1.31E-04	3
7DE76C34-LeeBBecker	1.18E-04	4
0B211A8C-PaulSlovic	1.18E-04	5
81353F03-MaureenTaylor	1.11E-04	6
2B74CFC5-StantonAGlantz	1.10E-04	7
81A7F237-RobertLHeath	1.09E-04	8
7E654E5D-DavidPFan	1.07E-04	9
811A205F-WilliamLBenoit	9.94E-05	10

D. Ranking Authors based on PageRank

We have discussed top ten researchers having highest PageRank centrality of 'Public Relations-025B78CE', as shown in Table V.

Figure 9 shows the researcher '7F4328BDGlenTCameron', who has the highest PageRank, and has worked in '03FEE94E-Media Relations', '09820AAE-Communication Management', '09BDF000-Corporate Communication' and '071FA02B-Journalism' fields. '7F4328BD-GlenTCameron' is affiliated with three different affiliations i.e. '04946B1EUniversity of Missouri', '061FEB1F-Missouri School of Journalism' and '09E0E324-University of Georgia'. Figure 9 contains 281 nodes and 272 edges. Network diameter is 4, modularity is 0.889, average path length is 2.271 and there are 9 connected components.

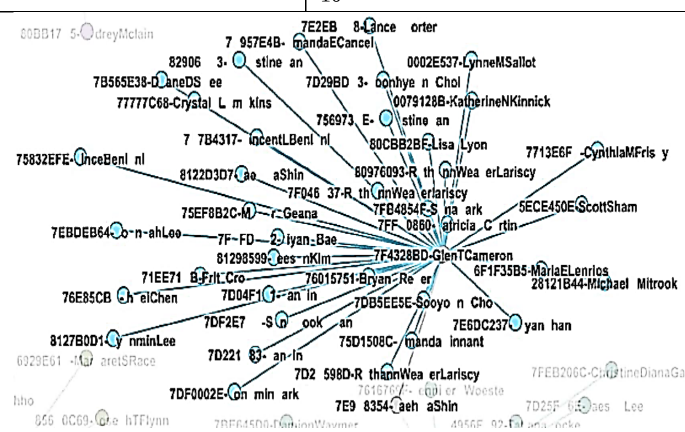

Fig. 9. Author '7F4328BD-GlenTCameron' having Highest PageRank Centrality.

Fig. 10. ‘12F4FDCC-Eds’, Author of Public Admininstration having Highest Degree Centrality.

VI. Ranking Authors in Public Administration on the Basis of Centrality Measures

A. *Ranking Authors based on Degree Centrality*

The average degree distribution of public administration field is 3.924. In public administration field, most of the researchers have low degree and some have high degree.

The author of public administration, named as ‘12F4FDCC-Eds’ is affiliated to ‘Centro Agronomico Tropical De Investigacion Y Ensenanza’, who has highest influence and frequent collaboration with 110 researchers as shown in Table VI and in figure 10. ‘12F4FDCC-Eds’ has prominent worked in 0B2F54F0-Kenya, 0A51FEF5-Refugee, 034E1111-International Law, which are the sub-fields of public administration.

The second most influencing and frequent collaborative author is ‘7EBE0990-RobertEBlack’, affiliated to ‘0A183231-Johns School of Public Health’. He also has worked with other different affiliations i.e ‘05B090CE-University of California Berkeley’, ‘08A948CC-Johns Hopkins University’, ‘4FBCBEC0-United Nations High Commissioner For Refugees’. ‘7EBE0990-RobertEBlack’ has worked in ‘0A51FEF5-Refugee’,‘0AAE1030-Containment’, ‘0B2F54F0-Kenya’ and ‘063ABE50-Displaced Person’ fields which are sub-fields of public administration and he has collaborated with 70 other researchers.

TABLE VI. Ranking Authors on the Basis of Degree Centrality

Author	Degree	Rank	Betweenness	Rank	Closeness	Rank	PageRank	Rank
12F4FDCC-Eds	164	1	1.39E-03	18	3.73E-02	2535	5.36E-05	13
7EBE0990-RobertEBlack	159	2	4.44E-03	1	4.62E-02	1	5.44E-05	11
0CAEADF8-Vu	146	3	3.71E-03	2	3.72E-02	2674	8.72E-05	3
7C467844-FrancoisDabis	130	4	1.07E-03	45	4.29E-02	24	3.33E-05	84
766E0394-ADHarries	109	5	6.03E-04	152	4.16E-02	104	4.04E-05	36
8068F04B-DavidMckenzie	103	7	2.27E-03	6	4.29E-02	23	6.43E-05	5
7B95835A-DavidHPeters	99	8	3.43E-03	3	4.48E-02	2	5.50E-05	10
781D4EE0-ZulfiqarABhutta	93	9	2.27E-03	5	4.40E-02	4	3.15E-05	108
14ABE527-DavidRBangsberg	92	10	2.00E-03	8	4.33E-02	13	2.62E-05	240

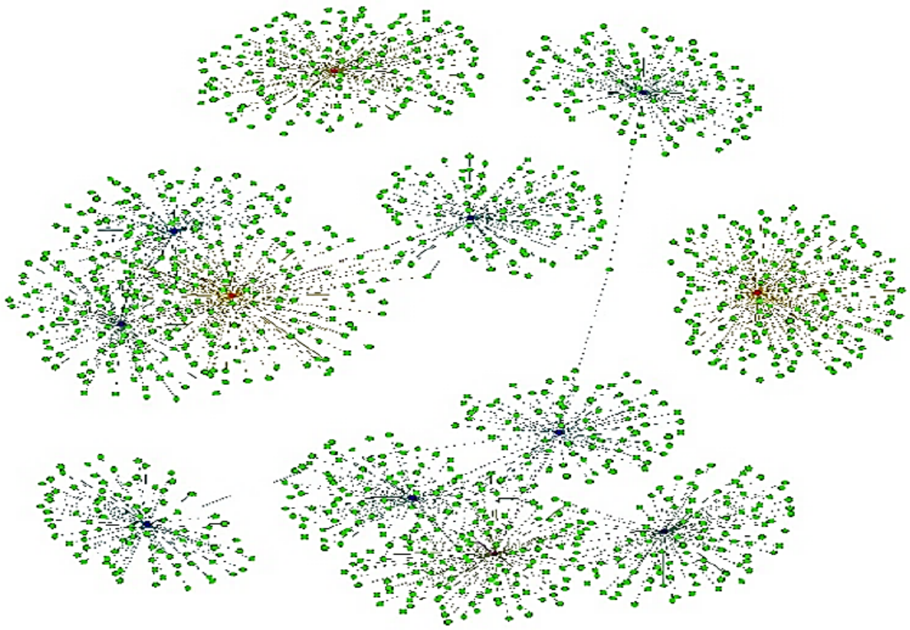

Fig. 11. Top 10 Researchers on the basis of Degree Centrality.

TABLE VII. RANKING AUTHORS ON THE BASIS OF BETWEENESS CENTRALITY

Author	**Degree**	**Rank**	**Betweenness**	**Rank**	**Closeness**	**Rank**	**PageRank**	**Rank**
7EBE0990-RobertEBlack	159	2	4.44E-03	1	4.62E-02	1	5.44E-05	11
0CAEADF8-Vu	146	3	3.71E-03	2	3.72E-02	2674	8.72E-05	3
7B95835A-DavidHPeters	99	8	3.43E-03	3	4.48E-02	2	5.50E-05	10
5F59DCDC-LantPritchett	57	42	2.46E-03	4	4.31E-02	14	1.91E-05	653
781D4EE0-ZulfiqarABhutta	93	9	2.27E-03	5	4.40E-02	4	3.15E-05	108
8068F04B-DavidMckenzie	103	7	2.27E-03	6	4.29E-02	23	6.43E-05	5
7A320C3A-FrankJChaloupka	77	22	2.16E-03	7	4.15E-02	118	5.03E-05	16
14ABE527-DavidRBangsberg	92	10	2.00E-03	8	4.33E-02	13	2.62E-05	240
29EA980D-AgnesSoucat	80	20	1.95E-03	9	4.27E-02	27	3.34E-05	83
75282DF5-GershonFeder	42	57	1.91E-03	10	3.97E-02	579	2.38E-05	325

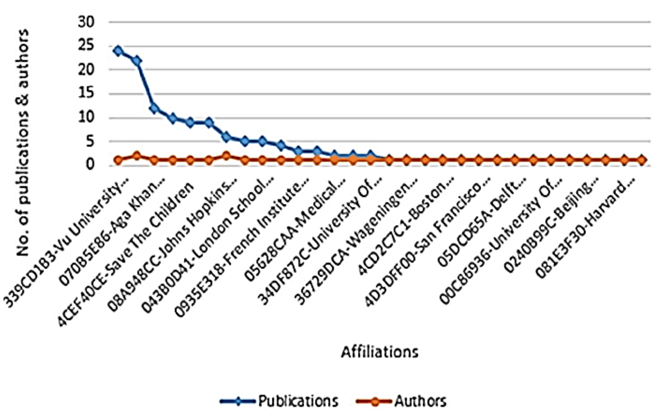

Fig. 12. Institutes and their Publications W.R.T Degree Centralities.

Community of top ten degree researchers and their connected researchers is shown in figure 11. This graph contains 1263 researchers and 1389 collaborations. Average degree of graph is 2.2, network diameter is 6, modularity is 0.829 and there are four connected components. The most productive institute in community of top 10 highest degree researchers of public administrations are the '339CD1B3-Vu University Amsterdam', '0A183231-Johns Hopkins Bloomberg School Of Public Health', '070B5E86-Aga Khan University' and so on as shown in figure 12. '0CAEADF8-Vu' has 146 degree and ranked at 3, '7EBE0990-RobertEBlack' has degree 159 and ranked at 2 and '781D4EE0-ZulfiqarABhutta' has 93 degree ranked at 9, are affiliated to '339CD1B3-Vu University Amsterdam', '0A183231-Johns Hopkins Bloomberg School Of Public Health' and '070B5E86-Aga Khan University', respectively.

B. Ranking Authors based on Betweenness Centrality

The network diameter of public administrations is 34 and the average path length is 24.833. The highest normalized betweenness is 4.44E-03 and least is zero. The author '7EBE0990-RobertEBlack' has collaborated with '0C45A054-Diarrhoeal Disease Research Bangladesh', '0A183231-Johns School Of Public Health', '08A948CC-Johns Hopkins University', '070B5E86-Aga Khan University', '4CED0A71-World Health Organization', '05628CAA-Medical Research Council', '043B0D41-London School Of Hygiene Tropical Medicine', '4CEF40CE-Save The Children' and 21 other affiliations, having highest influence and frequent collaboration with other 148 researchers as shown in Table VII. '0CAEADF8-Vu' is the second most central researcher and have frequent collaboration as he is ranked 3 in degree centrality measures having 146 degree and affiliated to '339CD1B3-Vu University Amsterdam', '3653C029-Vu University Medical Center', '34DF872C-University Of Amsterdam' '00C86936-University Of Cantabria' and 17 other affiliations. Graph for top ten researchers with respect to betweenness centrality is shown in figure 13. This graph contains 900 researchers and 944 collaborations.

The network diameter of top 10 betweenness researchers graph is 10, average path length is 4.83, 0.832 is modularity and there are 2 connected components. The most productive institutes in community of top 10 betweenness researchers of public administrations are the '339CD1B3-Vu University Amsterdam', '0A183231-Johns Hopkins Bloomberg School Of Public Health', '070B5E86-Aga Khan University', '096500C2-University Of Cape Town', and 26 other affiliations. Since they have large number of publications as shown in figure 14. '0CAEADF8-Vu' researcher belongs to '339CD1B3-Vu University Amsterdam' and he has 24 publications.

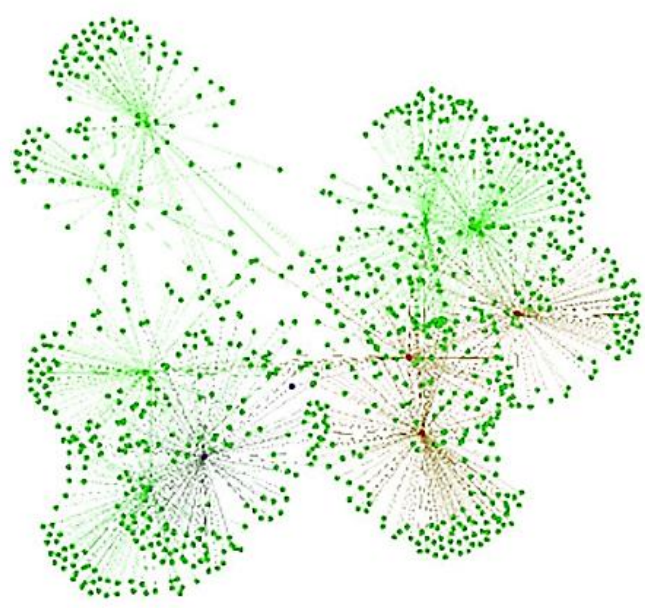

Fig. 13. Top 10 Researchers W.R.T Betweenness.

'7B95835A-David H Peters' and '7EBE0990-Robert E Black' belong to '0A183231-Johns Hopkins Bloomberg School Of Public Health' and they have 10 and 20 publications ,respectively.

C. Ranking Authors based on Closeness Centrality

The author of public administration field, named '7EBE0990-RobertEBlack' is ranked first in closeness, same as in betweenness, as shown in Table VIII. '7B95835A-DavidHPeters' is the second most rated researcher who is responsible for spreading information frequently to other researchers in a network, since he has ranked 8 in degree centrality measures having 99 degree and prominently affiliated to '08A948CC-Johns Hopkins University', '0A183231-Johns School Of Public Health', '0992A59E-Makerere University School Of Public Health', '0AE9B3CC-Indian Institute Of Health Management Research' and 12 other affiliations as shown in figure 16.

The most productive institute in community of top 10 closeness researchers of public administrations are the '0A183231-Johns Hopkins Bloomberg School of Public Health Health', '0A1685A1-Universidade Federal De Pelotas', '070B5E86-Aga Khan University', '08A948CC-Johns Hopkins University', '4CEF40CE-Save The Children' and 13 other affiliations as shown in figure 15.

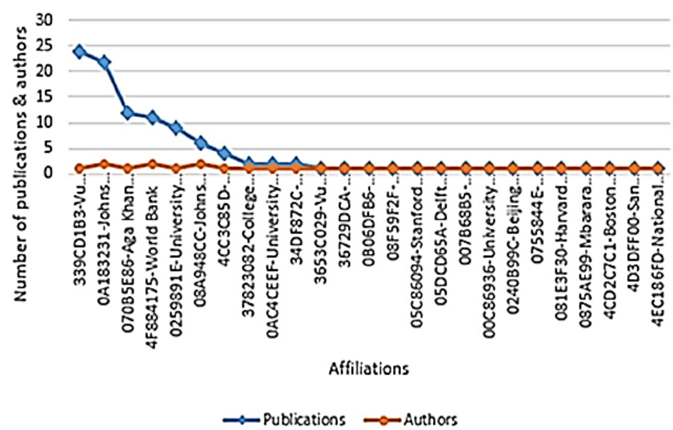

Fig. 14. Institutes and their Publications W.R.T Betweenness Centrality.

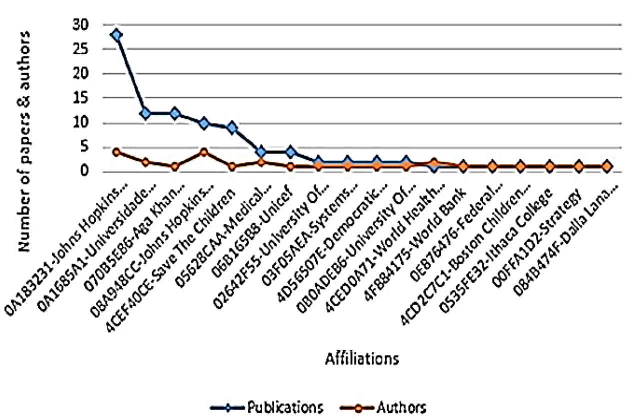

Fig. 15. Institutes with their Publications and Authors of Top 10 Closeness Researchers of Public Administration.

TABLE VIII. TOP 10 AUTHORS RANKING IN PUBLIC ADMINISTRATION ON THE BASIS OF CLOSENESS CENTRALITY

Author	Degree	Rank	Betweenness	Rank	Closeness	Rank	PageRank	Rank
7EBE0990-RobertEBlack	159	2	4.44E-03	1	4.62E-02	1	5.44E-05	11
7B95835A-DavidHPeters	99	8	3.43E-03	3	4.48E-02	2	5.50E-05	10
7FD861D8-MickeyChopra	83	17	1.12E-03	38	4.41E-02	3	3.19E-05	105
781D4EE0-ZulfiqarABhutta	93	9	2.27E-03	5	4.40E-02	4	3.15E-05	108
130B76BC-VirojTangcharoensathien	34	65	7.76E-04	99	4.39E-02	5	1.92E-05	644
80FEB1CC-PrabhatJha	42	57	1.52E-03	15	4.38E-02	6	1.96E-05	601
7DDF7540-RonaldHGray	74	25	8.71E-04	73	4.37E-02	7	2.67E-05	219
77843A2C-GeoffPGarnett	44	55	6.78E-04	119	4.34E-02	8	1.28E-05	1857
7D1B2864-NeffWalker	40	59	3.21E-04	449	4.33E-02	9	1.07E-05	2738
14ABE527-DavidRBangsberg	92	10	2.00E-03	8	4.33E-02	10	2.62E-05	240

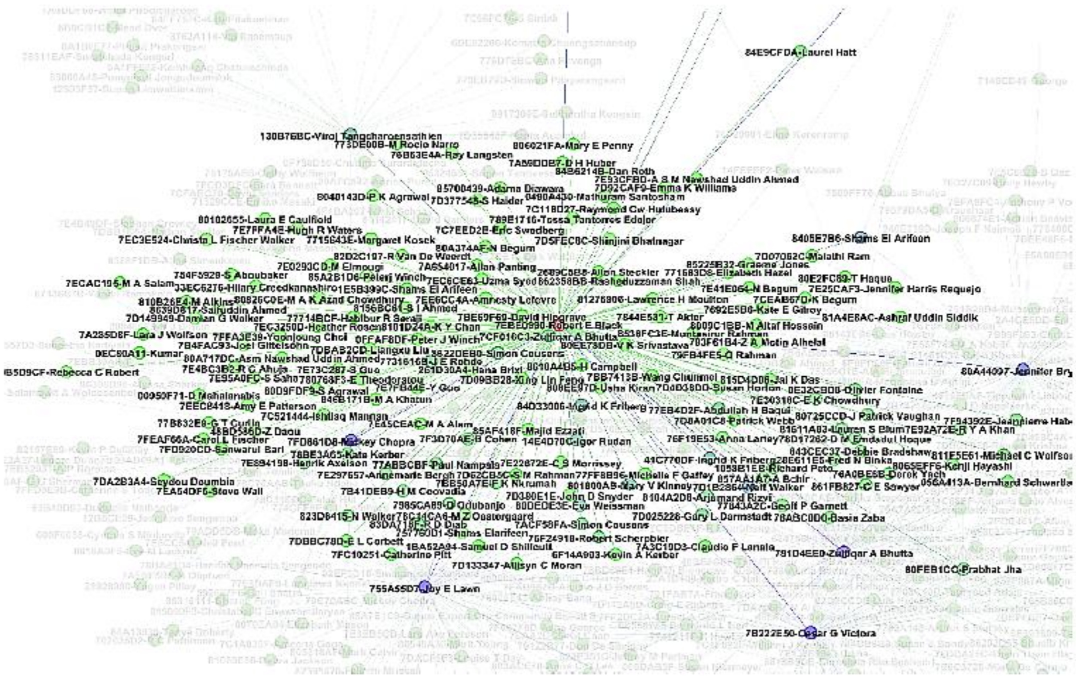

Fig. 16. '7EBE0990-RobertEBlack', Author of Public Admininstrations having Highest Closeness Centrality.

TABLE IX. TOP 10 AUTHORS RANKING IN PUBLIC ADMINISTRATION ON THE BASIS OF PAGERANK

Authors/Researchers	PageRank Value	Rank
7F404D7B-PeterDreier	1.05E-04	1
0CAEADF8-Vu	8.72E-05	2
7E035912-KristinAMoore	6.61E-05	3
8068F04B-DavidMckenzie	6.43E-05	4
7EB811DA-JohnALucas	6.42E-05	5
618527B9-AntonioEstache	6.36E-05	6
7D542665-RobertGottlieb	5.76E-05	7
20CA3DCA-PeterNijkamp	5.63E-05	8
7B95835A-DavidHPeters	5.50E-05	9
7EBE0990-RobertEBlack	5.44E-05	10

'7EBE0990-Robert E Black', '7B95835A-David H Peters', '80A44097-Jennifer Bryce', and '7DDF7540-Ronald H Gray' researchers belong to '0A183231-Johns Hopkins Bloomberg School of Public Health' and he have 12, 10, 05 and 03 publications, respectively. '7B222E50-Cesar G Victora' and '80A44097-Jennifer Bryce' researchers belong to '0A1685A1-Universidade Federal De Pelotas' and they have 12 and 1 publications, respectively. '781D4EE0-Zulfiqar A Bhutta' researcher belong to '070B5E86-Aga Khan University' and this author has 12 publications.

D. Ranking Authors based on PageRank

The top ranked researchers who have highest PageRank are shown in Table IX. The author in 'Public Administration-002F8D8F' field named as '7F404D7B-PeterDreier' is the researcher who has highest PageRank and has published more than 300 publications by collaborating with 63 researchers related to different fields.

In graph of top 10 PageRank researchers, the most productive affiliation is of '339CD1B3-Vu University Amsterdam' with 36 publications as shown in figure 18.

We extracted the graph of top 10 PageRank researchers and their connected researchers as shown in figure 17. This graph contains 645 nodes and 649 edges. Network diameter is 4, average path length is 2.407, modularity is 0.847 and there are seven connected components.

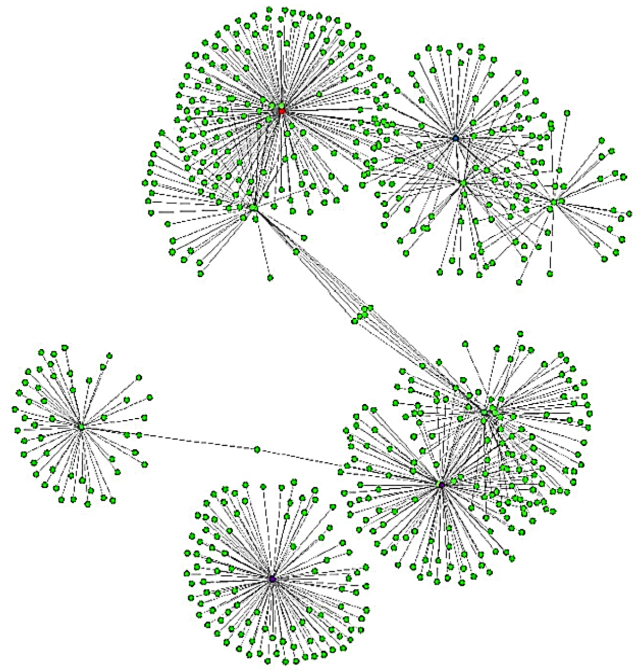

Fig. 17. Graph of Top 10 Authors having Highest PageRank.

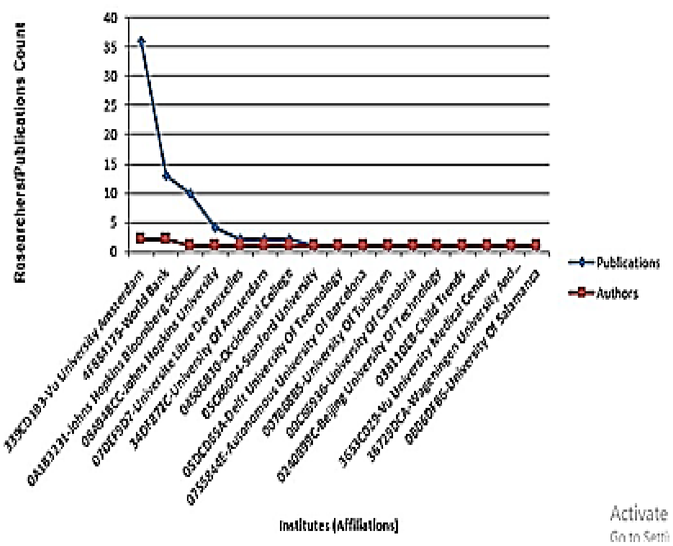

Fig. 18. Institutes and their Publications W.R.T PageRank.

VII. Discussion

The social network analysis has been widely explored to discover relationship patterns among individuals, teams, groups, societies, communication devices and even among organizations. The study discloses patterns of associations that help in best decision making and better understanding of various patterns in a graph. Analysis study in the domain of co-authorship network helps to identify the dynamic collaboration patterns exist in specific field. We applied centrality measures on two sub fields that is Public Administration and Public Relations of Political Science. We have analyzed just two fields because due to the hardware limitation and the availability of too much nodes where our computer is unable to process more than ten billion nodes. Data is collected from Microsoft Academic Graph. We have taken 102975 papers related to the field of Public Relations and 143831 papers related to Public Administration. For coauthorship network analysis, we selected data that covered time span of 16 years i.e. from 2000 to 2016. We represented the graph in the form of adjacency matrix that is created using Python and R. We considered four common centrality measures for coauthorship network analysis and visualized the centralities and author communities using Gephi and R. Different centrality values for different authors reflect collaborative patterns and trends occurring in 16 years of time span. Analysis on this huge database of public administration and public relation authors discovered the top group of authors who collaborated frequently and diversely in both domains. Some authors hold strong position in a network which shows their strong influence in research collaboration and knowledge sharing.

Our analysis is carried out for undirected non-overlapping communities. In future, we will try to carry out an analysis study on directed graph of coauthorship network that will show not only frequent collaboration with co-authors but will also reveal number of publications in relation with other coauthors. There is also a gap to identify the overlapping collaboration among authors because different authors have research contributions in various fields. Other parameters can also be used like impact factor, number of publications and citations count for overlapping community detection to identify and extract the dynamic collaborative patterns in coauthorship network.

REFERENCES

[1] I. Peña-López, "Manual for measuring ICT access and use by households and individuals", 2009.

[2] M. E.J Newman, "The structure and function of complex networks", SIAM review, pp. 167—256, 2003.

[3] N. P. Hummon, P. Dereian, "Connectivity in a citation network: The development of DNA theory", Social networks, pp. 39—63, 1989.

[4] F. Cheong, B. J Corbitt, "A social network analysis of the coauthorship network of the Pacific Asia Conference on Information Systems from 1993 to 2008", PACIS 2009 Proceedings, pp. 23, 2009.

[5] V Umadevi: "Case study—centrality measure analysis on co-authorship network", Journal of Global Research in Computer Science, pp. 67—70, 2013.

[6] E. Y Li, C. H. Liao, H. R. Yen: "Co-authorship networks and research impact: A social capital perspective", Research Policy, pp. 1515—1530, 2013.

[7] J. Sun, J. Tang: "A survey of models and algorithms for social influence analysis", Social network data analytics, pp. 177—214, 2011.

[8] X. Liu, J. Bollen, M. L Nelson, H. Van de Sompel, "Co-authorship networks in the digital library research community", Information processing & management, pp. 1462—1480, 2005.

[9] V. Dequiedt, Y. Zenou, "Local and consistent centrality measures in networks" , 2014.

[10] G. Liu: "Community structure and detection in complex networks", networks, pp. 2658—2663, 2004.

[11] N. K Chitroda, T. Katurbadham: "Improve Page Rank Algorithm using Normalized Technique", International Journal of Datawarehousing and Data Mining, 4 (1):42-47, 2014

[12] A. Sidiropoulos, Y. Manolopoulos, "Generalized comparison of graph-based ranking algorithms for publications and authors", Journal of Systems and Software, pp. 1679—1700, 2006.

[13] R. Shang, J. Bai, L. Jiao, C. Jin: "Community detection based on modularity and an improved genetic algorithm", Physica A: Statistical Mechanics and its Applications, pp. 1215—1231, 2013.

[14] K. Sutaria, D. Joshi, CK Bhensdadia, K. Khalpada: "An Adaptive Approximation Algorithm for Community Detection in Social Network", Computational Intelligence & Communication Technology (CICT), 2015 IEEE International Conference on, pp. 785—788, 2015.

[15] X. Zhang, H. You, W. Zhu, S. Qiao, J. Li, L. A. Gutierrez, Z. Zhang, X. Fan: "Overlapping community identification approach in online social networks", Physica A: Statistical Mechanics and its Applications, pp. 233—248, 2015.

[16] G. Palla, I. Derényi, I. Farkas, T. Vicsek: "Uncovering the overlapping community structure of complex networks in nature and society", arXiv preprint physics/0506133, 2005.

[17] K. Steinhaeuser, N. V Chawla: "Community detection in a large real-world social network", Social computing, behavioral modeling, and prediction, pp. 168—175, 2008.

[18] J. Yang, J. Leskovec, "Defining and evaluating network communities based on ground-truth", Knowledge and Information Systems, pp. 181—213, 2015.

[19] C. Qiu, W. Chen, T. Wang, K. Lei: "Overlapping community detection in directed heterogeneous social network", International Conference on Web-Age Information Management, pp. 490—493, 2015.

[20] F. Altunbey, B. Alatas: "Overlapping community detection in social networks using parliamentary optimization algorithm", International Journal of Computer Networks and Applications, pp. 12—19, 2015.

[21] E. Yan, Y. Ding: "Applying centrality measures to impact analysis: A coauthorship network analysis", Journal of the Association for Information Science and Technology, pp. 2107—2118, 2009.

[22] T. Ahmed T,A. Ahmed , Ali M, M. Kamran, "Analysis of co-authorship in computer networks using centrality measures". In Communication, Computing and Digital Systems (C-CODE), International Conference, pp. 54-57, 2017.

[23] M. E. J. Newman, "Analysis of weighted networks", Physical review E, pp. 056131, 2004.

[24] M. E.J Newman, "Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality", Physical review E, pp. 016132, 2001.

A Study of Retrieval Methods of Multi-Dimensional Images in Different Domains

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***Abstract*—Multiple amount of multi-dimensional images are designed and most of them are available on internet at free of cost. The 3D images include three characteristics namely width, height, and depth. The images which are created as 3D can describe the geometry in terms of 3D co-ordinates. These co-ordinates help to obtain the object from the image much easier and accurate. In this paper, we presented a review about the Multi-dimensional image retrieval. Multi-dimensional image retrieval is a process of extracting the relevant 2D or 3D images from the huge database. To perform image retrieval process on large database, several methods like text based, Content based, Annotation based, semantic based, and sketch based were used. The image retrieval techniques are mostly used in the fields like Digital library, medical, forensic science, and so on. A systematic literature review has been shown for image retrieval methods reported on 2010 to 2017. The aim of this article is to show the various concept and efforts of different authors on image retrieval technique.**

Keywords*—Image retrieval techniques; 3D image retrieval; image retrieval survey

I. Introduction

The digital images are made by small and joined components is said to as pixels. These pixels are organized in horizontal and vertical manner, i.e. rows and columns of matrix. Every pixel includes three attributes X, Y axis and gray value. The intensity of the radiation at the point of receptor exposure is corresponds to the gray value of every pixel. The channels Red, Green, and Blue are combined and forming the colored images and it also called as RGB images [1].

The process of initializing the image as input and getting an output as an attribute or the portion of an image is called Image Processing. The image processing techniques are used in the areas like image sharpening, color processing, pattern recognition, encoding, medical, and so on [2]. The image processing techniques are also used in high data processing and high-performance applications like face detection, face recognition etc. The algorithms used in the field of image processing can process the data of such application in high speed [3].

A technique with simple and global algorithm classes is image processing techniques. These techniques are much challenge and demanding on several systems like, smart devices, driver assistance systems, and medical imaging system. On smart devices like mobiles and tablets, there is need of efficient implantation for optimizing the battery. On the driver assistance systems, the process could be complete in the allocated period of time. The medical system contains huge amount of data, the image processing techniques need to process these data more efficient and faster. These image processing systems are not suitable for real time performance because these systems are mostly designed only to support desktop PCs. These limitations are fixed by inventing the FPGA chips and DSP processor which are based on computational platform [4] [5].

Various image data from different fields are collected and stored in the database, these image data are saved in database in the form of single dimension (1D) or multi-dimensional (2D or 3D). Latterly, these image data are much hard to access and reuse. The image retrieval techniques are enter in this situation and provide a solution for retrieving the stored images. Its main goal is to get an input and retrieve similar images based on the input [6]. On database there are different dimensional images are stored. From that, the single dimensional images only have one dimension called length. The 'line' is a good example for the single dimensional image, the dimension of line is length. The two-dimensional images have two dimensions namely length and width. The 2D images are mostly be in flat. The images which are derived with computer systems are mostly be in 2-dimension, because to build the 3-dimensional image it need to execute some complicated scripts. The 'square', 'triangle', and 'circle' are the good example for 2D images. The 3-dimensional images have three dimensions namely length, width, and depth [7] [8]. The 3-dimensional images take more memory for storing and high bandwidth for the transmission when comparing with 2-dimensional images. The compression techniques are used in this situation for reducing the size of the 3-dimensional images. The 3D images are also said to as stereo image, because it includes two images of same object in a single frame. The compression process of 3D images is carried out based on the relationship between the left eye and right eye image [9]. The reconstruction of 3D image from 2D is also possible and it is already did by several researchers. During the 3D image reconstruction process, the dimensions of 2D image is extracted and then the depth is included with the extracted dimensions on the reconstructed image [10] [11].

These different dimensional images are extracted from the warehouse by using several image retrieval systems. Initially, while coding the image some of the information that is to represent the image are also coded. This information is used for matching the information to obtain the image and it is called retrieval system. The images and the information are coded with the imaging device called digital camera. The 2-dimension and 3-dimension image samples are considered as features which are created by the capturing devices [12]. 3D image retrieval is an important problem in many applications, such as pattern recognition, image search engine, and some other applications [13].

Here in this article, a review about the various image retrieval methods for retrieving different dimensional images is presented. On the image retrieval process, the first step is to extract the features like geometric shapes, spatial and topological relationships, statistical measures, textures, and material colors of the image data. The information of multidimensional image will be created with these features. On the multi-dimensional feature space, the similarity among the input and feature model in the database will be defined. The results of retrieval process are generated by evaluating the similarity degrees [14].

The main goal of the multi-dimensional image retrieving techniques is to show the query or all available model in a useful manner. The retrieval system mainly focuses to describe the characteristics of object models. To achieve higher retrieval quality, the retrieval system should meet some requirements like robustness to linear transformations, invariance to noise, simplification and deformation and finally fast retrieval ability. The shape descriptor will provide better quality in terms of time and accuracy [15].

In market trading, the 3D trademarks are more significant and the registrations of 2D trademarks are also increasing significantly. The 3D trademark includes fixed length, width, height and the images are combined with shapes, text, graphics, symbols and colors. These significant data of 3D trademark are available at every angle [16]. The color attributes of image are one of the most common and basic features and it is used during the process of image retrieval and the spatial relationship among the pixels are defined by using the texture features of the image [17].

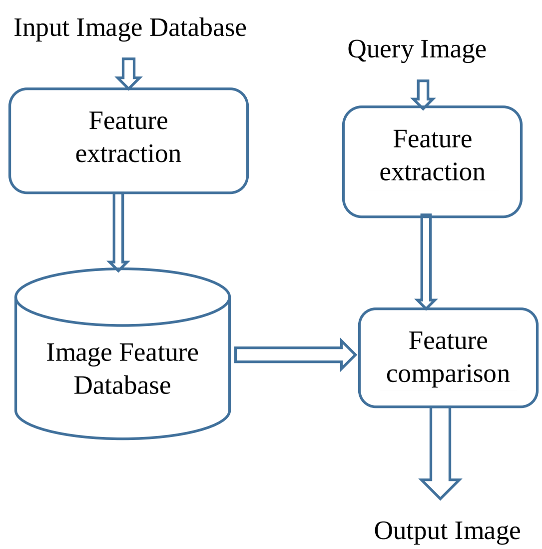

Fig. 1. Basic image retrieval process

In the above fig 1, the basic retrieval process of image is described. Initially on the first step, the text or an image is given as an input. Secondly, the features of the input text or image will be extracted. After extracting the feature from the input, it is matched with the feature of the images that are already stored in the database. At the final step, the feature of the images from the database which are matched with the feature of input is classified as the relevant image. These relevant images are given as the output for the users. Various retrieval methods are available for this retrieval process of image. Some of the most common retrieval techniques are described in this article on the below sessions.

The contribution of this review work is as follows: On section 2, we described some of the related works, section 3 describes the different image retrieval techniques, section 4 describes the some of the techniques used for retrieving the 3D images, and section 5 shows the metrics used for evaluating the performance of retrieval techniques.

II. Related Studies

In this session, some recent works based on image retrieval for retrieving various types of images is presented.

A. *Retrieval of Medical Image*

The amount of medical images are increasing enormously because of the high usage of medical imaging devices, with these devices hospital and other medical related systems producing huge amount of medical image each and every day. It is much hard to manage and analyze after which are stored in the database. These stored medical images can't be retrieve easily from large database, because its search space is much large [18]. For making efficient decision and diagnosis on medical field the authors of [19] presented an article for retrieving such medical images. In this article, the researchers used Fast Fourier Transform (FFT) for compress the convolution features into sequence of bits.

For the query medical image, they obtained the feature maps from the CNN which is already trained. These feature maps are obtained with the help of algorithm called optimal subset selection. With the binarization technique the layer-wise global mean activations of feature maps are transform into binary codes. Here, the hash codes are achieved from feature vector and it is achieved without any training. They presented experiments of their method with two different image datasets (radiology and endoscopy). The result of the experiments shows that the framework proposed in this article performed well on features extraction and on hashing schemes. This hash code extraction framework is also compared with some other existing methods. The disadvantage of this framework is it can't work efficiently on very short codes, because of the use of Fourier spectrum to binary code transformation. On the future work of this article, the researchers planned to develop more feature vectors into hash code for extending the proposed framework and also planned to include some other frequency domain transformation methods.

Another article [20] presented a method to overcome the use of low-level hand-crafted features on medical image retrieval systems. The researchers of this article presented a method for retrieving the medical image large database called histogram of compressed scattering coefficients (HCSCs). The theoretical representation of medical image is obtained by performing the variation of deep convolutional networks and this process is said to as scattering transform. The attained scattering coefficients are compressed by performing the projection process and at last, from these compressed coefficients the bag-of-words (BoW) histogram is developed and it is taken as the features of medical image. The experiments of HSCSs is performed with several CT image datasets (EXACT09-CT, TCIA-CT, and NEMA-CT). The feature obtained using HSCSs performed well on some of the existing features like LBP, LMeP, LWP, and SS-3D-LTP. The future scope of this article is to derive much better projection technique to compress the scattering coefficients, derive better framework for compressed scattering coefficients for obtaining best features and improve the image representation by expanding the scattering transform.

B. Retrieval of Remote Sensing Image

The huge successful technologies like satellite and aerial vehicle producing uncountable quantity of remotely sensed images every day. There on Remote Sensing (RS) community it rises big issue while retrieving the RS image [21]. Some of the researchers focused on retrieving the remote sensing image is described as follows:

In article [22], a method is derived to retrieve the RSIR (Remote Sensing Image Retrieval) called two-stage reranking (TSR). Let assume that, on the initial retrieval we obtained k-nearest neighbors of a query remote sensing (RS), then the obtained neighbors are edited by the TSR using its editing scheme. The active learning algorithm is used to select the representations of RS images and based on the query image the clients will deliver binary labels of RS image. The selected RS images are used to train the binary classifier and its labels are used to classify the remaining neighbors. The neighbors for the exclusion will selected based on the results of classification and result of rank in the initial retrieval process. The next process of TSR is to reranking the remaining RS image (which are not excluded) and it is done by using multi similarity fusion reranking (MSFR). The TSR method uses the experience of users and relationships of images to perform the reranking process. Two kinds of RS images are taken by the researchers for showing the performance of TSR. They earned better performance when compared with other existing reranking approaches.

The scholars of [23] proposed a novel large-scale remote sensing image retrieval approach based on deep hashing neural networks (DHNNs). The DHNNs are derived by using two learning neural network namely feature learning and hashing learning neural network. The DHNNs is optimized in an end-to-end manner. With the supervision of labeled samples the feature extraction process and hashing mapping will be learned automatically instead of making the design of feature with high effort. The application field of DHNNs is extended by calculating it under some remote sensing cases namely scarce and sufficient samples. The DHNNs will be trained through transfer learning for the earlier case to make-up the labeled samples shortage. After this process, again the DHNNs is trained through supervised learning with the huge amount of labeled samples. The experimental process of the method proposed in this article is conducted with two public satellite image dataset. The experimental result shows that the DHNNs based method got better performance than other state-of the-art approaches. On the future work of this article, the researchers planned to discover more ways to train DHNNs by using labeled data with, minimal amount of errors, it makes the generation of data in low cost. Additionally, the authors planned to apply theirs DHNNs based system to more application with the base of remote sensing image by making it to support more applications.

C. Retrieval of Crime Scene Image

The growth of the technology is increasing day by day, at the same time the crime is also increasing. The identification process of criminals is a much complex task. During the investigation of crime, the images that are gathered from the crime spot is stored on huge database and it will be retrieved whenever the need of that images. The crime scene database includes some details like, photographs, images of the criminals or crime scenes collected during investigation by the investigators. The culprits are may find out by matching the current crime scene image with other previous crime scene image. The software with convenient technologically can also help the investigators to make right move on the investigation. The similar image retrieval of crime scene can help to reduce the time of the investigators [24].

The method presented in article [25] for classifying the crime scene images by efficiently describing the texture with DCT-based texture feature. The researchers of this article designed an algorithm based on texture feature for describing the crime scene images by extracting the features of images. Initially, on the description of crime scene images the GIST descriptor is utilized and the color histogram is also included. It helps to describe the crime scene image in various view like color, texture, and structure of scene. For classifying and retrieving the crime scene images, the SVM classifier is used. The combined feature algorithm proposed in this article performed well on retrieving the crime scene image with above 15% of increment on retrieval process while comparing with single-feature-based algorithm. There also obtained 3% of improvement on precision by using SVM classifier.

On this analysis it is that found another notable article [26] for retrieving the shoe print image of crime scene. In this paper, for improving the performance of retrieval process the researchers used hybrid features of region and appearance of image on their manifold ranking based method. The manifold ranking based method proposed by the authors will perform retrieval process on shoe print images with high performance. The authors estimated the matches among the hybrid features and local features of shoeprints present in the crime image. But there have semantic gaps between the low-level and high-level concepts. For improving performance, it needs to focus on sematic gaps between the feature concepts. So, the manifold hypothesis is applied on low level feature and semantic high-level space is applied on the proposed high-level feature method. On the ranking function there some other classification of prior knowledge is included by the researchers. First one is, high score for the images in the database which are much closer to the feature of query image.

Second one is, based on the opinion of the forensic expert the shoeprints are ranked if there are lot of foot prints are present in a single crime scene because it needs to consistent with the expert's opinion. In this article, a score called opinion score is described. It indicates the score that is given for every shoeprint in the crime images by the forensic experts. By ensuing above all constraints, the image which contains related shoeprints can be identified and ranked. At result, it provides the better similar images. They conducted experiments with real crime dataset and their algorithm got better performance of above 93%. On their upcoming work, they planned to minimize the computation cost and maximize the performance by adaptively setting the parameters.

D. Image Retrieval System on Cloud Environment

Many smart devices are built with minimal amount of resources like, RAM, battery life, storage, computing ability, and so on. The smart device users may not have sufficient power to handle huge process like image processing, storing, and searching. So, the smart device users mostly use cloud computing technology for some works like, storing and searching. It performs with high performance on classical computing technologies and provide customization in cloud computing [27]. Here, for retrieving the image from large database cloud, various methods are used. Some of the image retrieval schemes that are recently proposed by various authors are explained below.

In [28] the authors proposed a scheme that supports CBIR over the encrypted images without revealing the sensitive information to the cloud server. In this article, the feature vectors are safeguarded with secure KNN algorithm. It helps to rank the images during the retrieval process without any communication problem by the cloud server. The locality-sensitive hashing is used to build the pre-filter to separate the similar images. The method of this article includes two layers namely upper layer and lower layer. The pre-filter tables are located in the upper layer for enhancing the search efficiency. The lower layer contains one to one map index for ranking the search results. For examine the efficiency, here two typical visual descriptors are defined based on MPEG-7. The authors of this article telling that their method is simplified to the Euclidian distance based CBIR methods. On their future work, they planned to enhance the security level of extracted features from the images and also additionally they planned to make their system to extract features from encrypted images.

The researchers of article [29] construct a novel joint semantic-visual space by leveraging visual descriptors and semantic attributes. It merge the indexing and the attribute as a framework for restricting the semantic gap. This framework tends to improve the flexibility of Coherent Semantic visual Indexing (CSI), it increases the accuracy by boosting the retrieval process with the help of binary codes. Some of the contributions are added in the proposed method of this article. Firstly, joint semantic and visual descriptor space are detected by using the interactive optimization. Secondly, they demonstrate the union of their optimization algorithm by describing the solutions provided by their method for several iterations. Thirdly, they merged two systems namely spectral hashing and joint space system. At last, they build a cloud system for providing the online multimedia services. The best performance of their methodology is shown on their experiments. They conducted experiments with publicly available datasets and they proved proposed method is better than the existing methods. The researchers of this article say that their cloud-based image retrieval system better for using traditional server and efficient for work with high loads on cloud image retrieval.

III. Classification of Image Retrieval Techniques

The image retrieval techniques are designed to search, browse, and retrieve relevant images from large databases. In this session, we shown that some of the popular image retrieval techniques that are used for processing the retrieval task. Some of the techniques which are covered in this review is described below,

- Text based image retrieval
- Annotation based image retrieval
- Semantic based image retrieval
- Sketch based image retrieval
- Content based image retrieval

Every technique has unique procedure to handle the retrieval process. Which will be explained on later sessions, and here on below figure 2, different techniques and its features are described in a diagrammatic form.

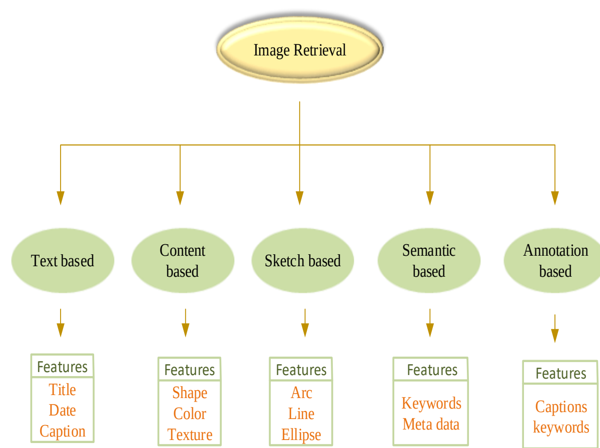

Fig. 2. Different classification of image retrieval techniques and its features

A. Text based Image Retrieval

This text-based image retrieval (TBIR) methods shown in figure 3 are mostly used in the year of 70's, it retrieves the image based on the feature of image like title, creation date, modification, deletion, and caption. This technique is also said to as description-based image retrieval. XML documents with images and having particular multimedia query can also retrieved by using the text-based retrieval method [30] [31]. With the inputted text, the textual and visual content descriptors are made for retrieving the images. These descriptors are transformed to vector format and also computed and changed into vector representation for the images already saved in the database. When users search for the image, they inputted the query and the vector for the query is generated, then it is matched with the already stored vectors in the database. Two different set of images with various weights are obtain as the result on text-based methods. The final image list is obtained by combining the two different set of images in the meaningful way [32]. The text-based methods work by combining the input text query and the descriptions of images. This technique only accepts text-based queries for retrieving the images. Some sample text-based queries are as follows, "search results for animals", "search results for animals added on 2018-05-25".

Main problems of the query by text:

- Unexpressed feelings, emotions
- Many ways of saying the same thing
- Synonyms and homonyms
- Misspellings

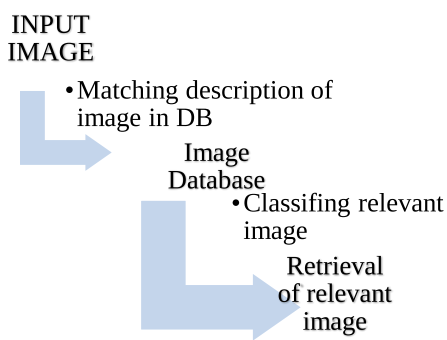

Fig. 3. Basic retrieval process of text-based image retrieval

B. Content based Image Retrieval

The content-based image retrieval systems are different than from text-based retrieval system because content-based system get the image as input and retrieve the similar images based on color, texture or shape shown in figure 4. Input of this type retrieval systems is look like "search for the image which containing animals" (i.e. It will be an animal image). It provides the result as various animal image similar to the input [33]. In this method, the retrieval process is carried out based on the features of the images, it uses the visual contents of the input image as the feature. For extracting the features of the image, feature extraction module is used, it extracts features from the set of images [31].

1) Color

CBIR retrieve the images based on three features of image, among one is color. It is a low-level feature, which is mainly used in the retrieval process because it is invariant to size and orientation. The color histogram of the images will be calculated and color values will be obtained. The similar color values among the input image and images stored in the database are classified. The color proportion of images be also calculated with the region and relationship between several color regions.

2) Texture :

Texture is another common feature of image, it indicated the objects present in the image and the correlation among the nearby environment. The object present in images can easily be identified with the texture. Still there doesn't have any universal definition for texture feature. It includes several basic primitives and it describes the object's structural arrangements and the correlations. The visual patterns of the images will be easily identified with the textures. The texture of the images is defined by text and it is stored in the sets based on the number of textures detected in an image. These sets help to define the texture and locate the texture of images. There also have some methods used on early days for detecting the texture of image, some of them are Co-occurrence matrix, Laws texture energy, and Wavelet transform.

3) Shape :

The shape feature indicates the shape of the objects, it will provide some useful information for retrieving the image, because with the shape of an object the humans can easily identify the objects without any other information. It is much differ from already revised features color and texture, shape additionally describes the semantic information. The shape features are classified into two types, boundary based, and region based. The shape doesn't indicate the shape of an image, it indicates the particular location of objects present in the image. By applying the segmentation or edge detection on an image the shapes will be determined. Other shape-based image retrieval systems identify the shapes by using the shape filters. The obtained shapes must be invariant to translation, rotation, and scaling [34] [35].

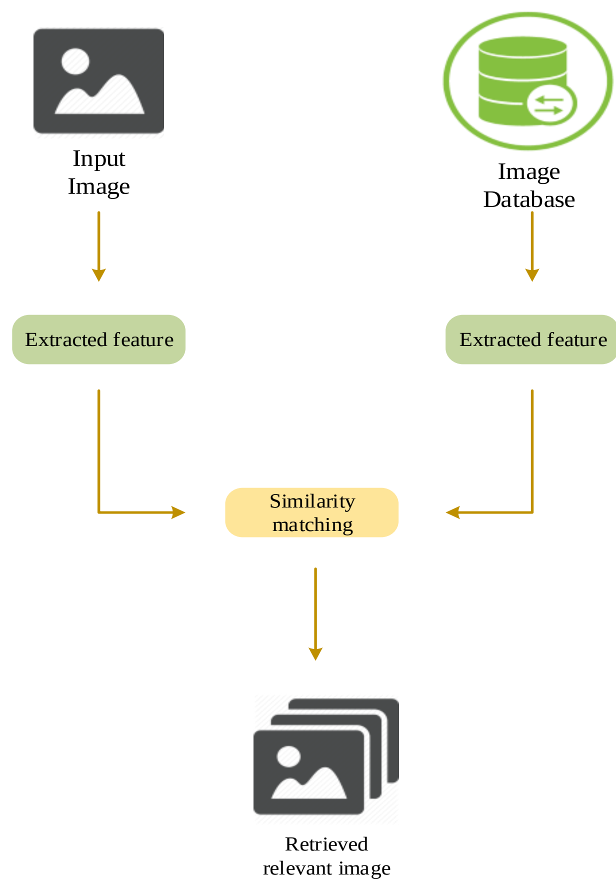

Fig. 4. Basic retrieval process of content-based image retrieval

a) Different Approaches on Content-Based Image Retrieval

Various authors are already focused and designed several content-based techniques, some of them are explained as follows. Munish Kumar *et al* [36] designed a content-based image retrieval system which uses two methods for extracting the features namely, SIFT (Scale Invariant Feature Transform) and ORB (Oriented Fast Rotated and BRIEF). Here, they used SIFT and ORB for detecting and describing the feature of images. The method ORB utilizes two features of image called FAST and BRIEF. They also used clustering algorithm K-means for analyzing the data and to generate several clusters with the help of descriptor vector. For enhancing the performance of their system, they minimized the length of the feature vector by using the LLP (Locality Preserving Projection). For classifying the similar images from the DB, they utilized several classifiers like BayesNet and KNN.

Atif Nazir *et al* [37] presented a new CBIR technique to fuse color and texture features. The authors of this article initially extracted the color information and texture features by using the CH (Color Histogram), transformation technique DWT (Discrete Wavelet Transform), and EDH (Edge Histogram Descriptor). The features which are derived from every image is saved on the DB as the feature vector. This paper exposed a method for retrieving image which works with the base of color and texture of image by using the combined local and global features. By combining the several features like color and text can provide better retrieval results and human visual system. The researchers of this paper, they extracted the local features by using the edge histogram and by using the transformation technique and color histogram the global features are extracted. The authors of this article used feature vector created with proper color and feature and relationships of images are equated by Manhattan distance.

Peizhong Liu *et al* [38] presents a method for CBIR system by integrating high- and low-level features from CNN and DDBTC (Convolutional Neural Network and DotDiffused Block Truncation Coding). The researchers of this article derived the low-level features like texture and color by using VQindexed histogram from DDBTC bitmap and some quantizers. The human perception can efficiently capture by using the features derived using CNN. They created deep learning two-layer codebook features by combining the features of DDBTC and CNN. The dimension of the feature is reduced for enhancing the retrieval rate. The strong feature is formed by GL-FCF and TLCF, with these strong features the overall retrieval rate will be increased. The method presented in this paper, discard some of the irrelevant images at the initial stage by using the hierarchical structure which they build on initial stage. The feature dimension is reduced by using DL-TLCF, it minimizes the comparing period. They initialize the normalized weights for creating the feature DL-TLCF, by creating this feature the performance of their method will improve more significantly.

C. Sketch based Image Retrieval

This retrieval method is much differ from all other methods, it gets query image as sketch shown I figure 5. The sketch image contains the hand drawn objects, based on this sketch-based objects the images will be retrieved. The sketch-based image retrieval (SBIR) system is considered as a young research field, because of the usage and capable in various areas like searching and pattern detection [32].

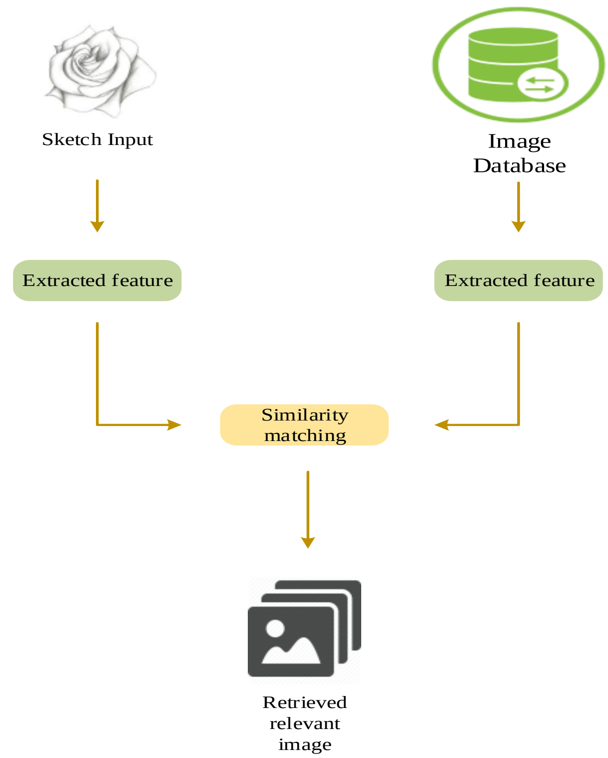

Fig. 5. Basic retrieval process of sketch-based image retrieval

On the previous method (CBIR), it utilizes image as a query. It is not easy for the users to get such picture which satisfies their need or the picture they are looking for. For overcome such issue the SBIR is introduced. It is much easier to draw a sketch based on the image that the user looking for. Most of the applications like CAD and 3D model retrieval methods utilize the sketch as the query for their process [39].

The sketch-based image can easily express and deliver the meaning and the intention of users. So, most of the multimedia contents retrieval systems are derived based on SBIR technique. In digital libraries, there is a huge collection of multimedia contents like image, video, and other data are stored by numerous users through the internet. So, sketch and text-based retrieval systems can perform excellently in digital libraries [40].

a) Different Approaches on Sketch-Based Image Retrieval

SBIR systems are widely used on different types of applications and especially on the situation of querying image not available. Because of the development of touch screen and smart phone technologies it is much simple for creating the sketch. Some of the research made by several authors on SBIR systems are described below.

Yonggang Qi *et al* [41] proposed a method for SBIR system based on the Siamese network. The main goal of this introduced system is to pull the output feature vector to nearby input sketch-image which are characterized as similar and take away from the input sketch if it is unrelated. These processes are carried out by two CNN which is connected with one loss function. The Siamese CNN in the proposed technique of this article can solve domain shift problems. The functions of this method will plot the input patterns into the target space, it helps to estimate the semantic distance in the input space. The main concept of this method is to pull the similar image much closer to input sketch and make away if the image is dissimilar. The researchers of this article telling that their method is introduced for overcome the issues of geometric distortions by absorbing the both positive and negative training pairs.

Jose M. Saavedra *et al* [39] proposed a novel local method based on detecting key shapes. This work focus on the fundamental information in terms of key shapes and local data in terms of local descriptors. The method proposed in this article can maximize the retrieval performance by describing the key shapes of the structures of object present in the image. It identifies some of the shapes that present in the sketch like line, arc, and ellipse.

The author of the previous [39] article Jose M. Saavedra presented another paper [42] for retrieving the image based on sketch. In this article, the authors exposed the improved version of Soft Histogram of Edge Logal Orientations (SHELO) for defining the sketches. They exposed their enhancements through two aspects. I.e. detecting the sketch-based representations with best technique and best normalization strategy of SHELO. To fulfill their first aspect, they introduced an approach called sketch token, it focused on identifying the contours of images in terms of mid-level features. To fulfill their second aspect, they improved the retrieval efficiency by establishing square root normalization.

Xueming Qian *et al* [43] presented a method based on Re-Ranking and Relevance Feedback. This method contains three several methods namely, image grouping, re-ranking via visual feature verification (RVFV), and contour-based relevance feedback (CBRF). The image grouping method aims to identify similar images for creating relevant feedback. The noisy images are eliminating by RVFV and also it makes the high rank images much applicable to the sketch query. The CBRF method identify similar image by using the contours of high ranked images which are already ranked by SBIR system. They are initiating the CBRF phase by eliminating the dissimilar images by applying RVFV. They work out their both system in offline and they are saying that the sketch-based methods will get back much preferred images.

D. Semantic based Image Retrieval

The semantic based image retrieval techniques work based on the keywords of images shown in figure 6. It gets input as image and keyword or only keyword. Most common search engines such as Google and Bing are using keyword-based search techniques for image retrieval process.

This type of image retrieval system works based on the keywords that are already stored by the users while creating the image. It matches the input keyword from the user with the keywords of images stored on the database and retrieve all images with similar keywords. But, this method is also having the possibilities for getting results with irrelevant images.

The [45] performance of semantic based image retrieval systems are better because of some reasons,

- While users searching for the images, if any mistake done on the spell of keyword it affects the retrieval system by retrieving dissimilar images.
- Sometimes it needs to specify the keywords for the images with natural language by the users, it may difficult to the users because the users need some knowledge about the natural language.
- The process of detecting the applicable keywords is much difficult for describing the image.

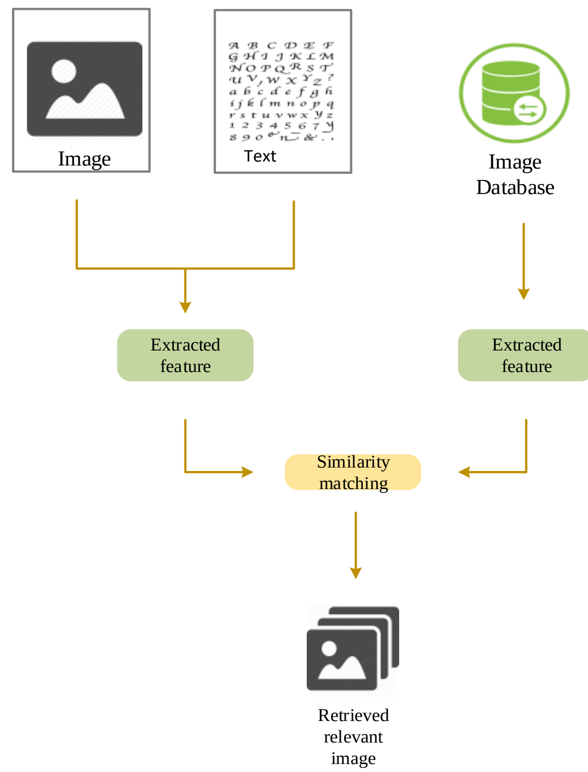

Fig. 6. Basic retrieval process of semantic based image retrieval

a) Different Approaches on Semantic based Image Retrieval

Because of the huge innovations of hand-held technology, inestimable quantity of images is available on web and it can also simply shared and uploaded by the users through the internet. There are several researches are directed on the field of image retrieval, but still efficient technique is not in sight. The [44] main reasons behind this deficiency is unavailability of literal information, nonspecific image data, different format of images, and low-level features of images. For solving such limitation semantic based retrieval techniques are introduced. Some of the research already conducted based on semantic based image retrieval techniques are explained below.

R.I.Minu *et al* [44] presented a semantic method for Ontology Based Image Retrieval System. One of the most investigated research field is image retrieval. In this article, the authors trained their system syntactically and semantically for designing a retrieval system with better accuracy. They focused on the retrieval of image on flower domain. They created the ontology for the flower domain and compared with its feature ontology. The researchers of this article telling that the created ontology can use with any type of retrieval process as a backend process. The method introduced in this article is much suitable for web-based image retrieval and they created the ontology in OWL language.

Umar Manzoor *et al* [45] proposed An Ontology based Approach which uses domain specific ontology for image retrieval relevant to the user query. This method accepts either text or an image as input. This method designed based on hybrid approach and it classify the similar images with the help of shape, color and texture. There is a matching module for matching the keywords/features, it gets the input from the query engine and it uses same process for retrieving the relevant images.

Anshy Singh *et al* [46] introduced a method called image crawling mechanism for retrieving the relevant images from web. The authors of this article focused on two major problems occurs while retrieving images from web, namely, freshness and redundancy. The authors also saying that their method can obtain text information present on the web. So, it can be used as an efficient image search engine. The mechanism of this article works based on the textual information available on nearby images on the web.

Min Wang *et al* [47] proposed a method for retrieving the remotely sensed images through matching the scene semantic information of the image. Initially, the low-level visual features in the image will be obtained with visual feature extraction technique and recorded on multilevel spatial semantics. This process includes some other methods like spatial relationship inference, and SS modeling. This scene semantic based retrieval works based on some features like object area, topology, and orientation of image. The authors saying, they implemented this method by using prototype system, it gives high accuracy rate on retrieval process. The method introduced in this article only supports to retrieve 10-30m remote sensing images. It is mainly because of the matching based spatial resolutions and classification based on the object of image. By using this method for retrieving the remote sensing image will get high accuracy because of the usage of 30m images.

E. Annotation based Image Retrieval

Generally, the users will give text as an input for text-based image retrieval systems for retrieving the images from the local DB or by browsing. This type of systems includes several problems on retrieving the images. Some of the problems are solved by annotation-based image retrieval system, it uses the metadata of images. The metadata includes presentational markup, comment, and explanation, these are attached while creating the image by the designer. The annotations may indicate the small piece of original information of image [48].

Annotation-based image retrieval (ABIR) basically uses text retrieval techniques on textual annotations of images that are included on the images by human [51]. The ABIR technique is new image retrieval method based on the annotation of image. The ABIR techniques includes two steps, automatic image annotation and query processing. The automatic process done by image segmentation and query-based process done by labeling process [52].

The ABIR will retrieve image through three ways,

1) *Free text annotation*
2) *Annotation based on ontologies*
3) *Annotation using key words*

Figure 7 shows the retrieval process in annotation-based method.

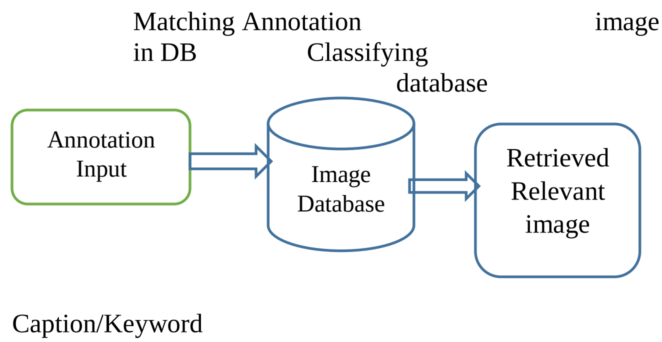

Fig. 7. Basic retrieval process of annotation-based image retrieval

The free text annotation accepts any pattern of text or sentences as input. An ontology is a description of a conceptualization. The ontology includes entities, co-relations, and rules. On the keyword-based annotation, by using the keyword list that included in the image, every image will be annotated, and it is used as a keyword or annotation [32].

a) Different Approaches on Annotation-Based Image Retrieval

ABIR method based different approaches are described here. Hua Chen *et al* [49] presented an ABIR system based on RDF description. The researchers of this articles focused to provide a better concept for describing the semantics of image. On this image retrieval system, they included several levels for obtaining the annotation, i.e. concept, sentence, and instance. The annotation obtained through these levels are used as input/query for retrieving image and that annotations are stored in RDF triples. Some of the improvements that happen while using RDF description-based method are as follows,

- At the initial stage (concept and sentence), the semantic relations among the concepts are obtained, it refers some problems like synonyms and homonyms.
- At the instance stage, it calculates the amount objects like “how many people”, “how many animals”, and so on.

Himali P. Chaudhari *et al* [50] suggested an improved Markovian Model for ABIR using Multiple and Synonymous Keywords. This method is focused to improve the retrieval performance of state-of-art method (MSI). The method introduced in this article, initially identifies the keywords of user input and perform retrieval process and then show the retrieval result. The "recall" performance is reduced with the prevalence of synonyms. Same object can be described in several ways by the users. i.e., some users may have different knowledge, contexts, linguistic habits, and so on. So, such users will describe the things in different manner. This method expands the performance of MSI system by studying or obtaining several keywords from the input of users.

Deniz Kilinc *et al* [51] introduce an expansion and re-ranking approach for annotation-based image retrieval from Web pages. This approach works based on the text available on nearby image on the web and consider it as annotation. Such collected annotation includes useful information like copyright notice, date, and author. The selection approach presented by the researchers will enlarge the documents with WordNet and select the text and use it as annotation. This approach in applied on both document and input of users. By applying it on both sides can improve the retrieval performance than applying it on single side. Additionally, the selection approach provides maximum amount of terms per documents, it makes to look both the quires and documents are much better than the original.

Monica Hidajat [52] presented an ABIR method based on GMM and Spatial Related Object. In this approach, the image feature is clustered by using Gaussian Mixture Model (GMM) and for labelling methods such as, segmentation and multi class support vector machine is used as the classifier. The method introduced in this article includes two stage, 1) training and 2) testing and validation. On the first stage, the model is created for every keyword by using Support Vector Machine. On the second stage, the annotation and retrieval process are carried out.

IV. Various Approaches and Techniques for Retrieving 3D Image

This was already explained in above text about the classification of various image retrieval techniques on previous session. Here, we discussed about some of the approaches and techniques that focused on 3D image retrieval.

The text-based image retrieval techniques are used in olden days and it is not focused by researchers because it has some limited features to retrieve the images. With the text-based retrieval techniques 3D images are can't be retrieve more efficiently. From this study it is found that some articles [53], [54] used content-based retrieval techniques for retrieving 3D images. Most of the researchers are working for retrieving 3D images using contend based method. At the same time, it is facing too much of challenges. The feature extraction process on 3D images are one of the most important challenge for the 3D image retrieval systems. The features extracting from the 3D images will be invariant of viewing angles, i.e. the objects need to visible for viewing from any angle.

Sketch based retrieving methods are also used for retrieving 3D images on [56], [57], [58]. In computer graphics, there is an important application is retrieving the 3D models from 2D. It is also important application on some areas like computer vision and information retrieval. By comparing the several methods, the sketch-based methods are better for the retrieval systems because of the sketch-based idea, sketch-based queries can easily be provided by users. The sketches are best for describing the shapes for retrieving the 3D images.

There are numerous tools are developed for creating 3D models and most of the 3D models are available on the internet at free of cost. Large set of 3D models are also available in market. For retrieving such 3D models is getting huge response and the demands of retrieval systems also increased. M. Elkhal *et al* [55] presented a method for retrieving the 3D images from large database using a method called level cut. This method works based on the binary image which is obtained from the 3D objects. It is achieved by connections in the set of the plans through the 3D object. A set of intermediate parallel plans created by the intersection through the 3D object a set of level cuts that utilized to indexing the 3D model.

Mostly for retrieving the 3D images the content based and sketch-based retrieval techniques are used. Because the 3D images are mostly retrieved based on the color, shape, and texture of the object present in the image. Text or keyword-based retrieval techniques retrieve based on the description or textual expression of images. The keywords of 3D images may not be described that the image is 3D. So, it affects the efficiency of the 3D image retrieval system. I.e., it omits some 3D images during the retrieval process.

V. Various Performance Metrics used by Image Retrieval Techniques

In this session, we illustrate the various performance metrics used by retrieval techniques for evaluating the performance.

True positive (TP): It indicates the state of right results obtained by the system.

True negative (TN): It indicates the state, if there is nothing to display as result and the system displays that no results.

False positive (FP): It indicate the state, if there is nothing to display as result and system displays some dissimilar results.

False negative (FN): It indicate the state, if there something is available, and system shows "there is nothing on result".

Precision: The ratio of obtained right results is described as the precision.

$$\Pr ecision = \frac{TP}{TP + FP}$$

Recall: The ratio of amount correctly obtained result among all right results.

$$\mathrm{Re}call = \frac{TP}{TP + FN}$$

F-measure: It indicates the average of both precision and recall.

$$F - measure = \frac{2 * (recall * precision)}{recall + precision}$$

MAP: Mean average precision is used to find the mean of the average precisions over a set of queries.

VI. Conclusion

Nowadays, the usage of image retrieval techniques is increased because of the high demands of multimedia applications. In this research article, discussion has been done on different types of techniques mostly used in the field of image retrieval namely, text-based, content-based, sketch-based, semantic based, and annotation-based. Every technique has its own advantages and disadvantages. But the basic process of every techniques is same. i.e. these techniques initially extract the features from the input and then match it with the features of images present in the huge database and displays the matched images as result. These techniques can't satisfy the complete requirements of every uses. The requirements of the users will be increase day by day. So, different innovations are highly needed for satisfying the user requirements.

References

[1] de Morais, Camilo de Lelis Medeiros, and Kássio Michell Gomes de Lima. "A colorimetric microwell method using a desktop scanner for biochemical assays." Talanta 126 (2014): 145-150.

[2] Das, Ananya, Abhishek Sahi, and Usha Nandini. "SAR image segmentation for land cover change detection." In Green Engineering and Technologies (IC-GET), 2016 Online International Conference on, pp. 1-6. IEEE, 2016.

[3] Rao, MV Ganeswara, Rajesh K. Panakala, and A. Mallikarjuna Prasad. "Image Processing using FPGAs: A Framework." SCESM-2016, at HIERANK Business School, Noida on (2016): 09-10.

[4] Rao, MV Ganeswara, P. Rajesh Kumar, and A. Mallikarjuna Prasad. "Implementation of real time image processing system with FPGA and DSP." In Microelectronics, Computing and Communications (MicroCom), 2016 International Conference on, pp. 1-4. IEEE, 2016.

[5] Membarth, Richard, Oliver Reiche, Frank Hannig, Jürgen Teich, Mario Körner, and Wieland Eckert. "Hipa cc: A domain-specific language and compiler for image processing." IEEE Transactions on Parallel and Distributed Systems 27, no. 1 (2016): 210-224.

[6] Foncubierta-Rodríguez, Antonio, Henning Müller, and Adrien Depeursinge. "Retrieval of high-dimensional visual data: current state, trends and challenges ahead." Multimedia tools and applications 69, no. 2 (2014): 539-567.

[7] Sefidmazgi, Nima Roohi, and Hussain U. Bahia. "Effect of compaction conditions on aggregate packing using 2-dimensional image analysis and the relation to performance of HMA." Materials and structures 47, no. 8 (2014): 1313-1324.

[8] Egenhofer, Max J. "Qualitative spatial-relation reasoning for design." In studying visual and spatial reasoning for design creativity, pp. 153-175. Springer, Dordrecht, 2015.

[9] Lin, Yu-Hsun, and Ja-Ling Wu. "Quality assessment of stereoscopic 3D image compression by binocular integration behaviors." IEEE transactions on Image Processing 23, no. 4 (2014): 1527-1542.

[10] Willcocks, Chris G., Philip TG Jackson, Carl J. Nelson, and Boguslaw Obara. "Extracting 3D parametric curves from 2D images of helical objects." IEEE transactions on pattern analysis and machine intelligence 39, no. 9 (2017): 1757-1769.

[11] Tulsiani, Shubham, Abhishek Kar, Joao Carreira, and Jitendra Malik. "Learning category-specific deformable 3d models for object reconstruction." IEEE transactions on pattern analysis and machine intelligence 39, no. 4 (2017): 719-731.

[12] Jamkhandikar, Dayanand, Surendra Pal Singh, and V. D. Mytri. "Novel Method for 3D Objects Retrieval." International Journal of Computer Applications 128, no. 14 (2015).

[13] Guo, Kehua, and Guihua Duan. "3D image retrieval based on differential geometry and co-occurrence matrix." Neural Computing and Applications 24, no. 3-4 (2014): 715-721.

[14] Kao, Chi-Chou. "Shape-based 3D model retrieval system." International Journal of Computers and Applications (2016): 1-10.

[15] Alizadeh, Fattah, Alistair Sutherland, and Khaled Moradi. "Patch-Wise Charge Distribution Density for 3D Model Retrieval." International Journal of Modeling and Optimization4, no. 3 (2014): 233.

[16] Lee, Chu-Hui, and Liang-Hsiu Lai. "Retrieval of 3D Trademark Based on Discrete Fourier Transform." In *International Conference on Mobile and Wireless Technology*, pp. 620-627. Springer, Singapore, 2017.

[17] Yang, Jiachen, Bin Jiang, Baihua Li, Kun Tian, and Zhihan Lv. "A fast image retrieval method designed for network big data." *IEEE Transactions on Industrial Informatics* 13, no. 5 (2017): 2350-2359.

[18] Amin Khatami, Morteza Babaie, H. R. Tizhoosh, Abbas Khosravi, Thanh Nguyen, and Saeid Nahavandi. "A sequential search-space shrinking using CNN transfer learning and a Radon projection pool for medical image retrieval." *Expert Systems with Applications* 100 (2018): 224-233.

[19] Jamil Ahmad, Khan Muhammad, and Sung Wook Baik. "Medical Image Retrieval with Compact Binary Codes Generated in Frequency Domain Using Highly Reactive Convolutional Features." *Journal of medical systems* 42, no. 2 (2018): 24.

[20] Rushi Lan, and Yicong Zhou. "Medical image retrieval via histogram of compressed scattering coefficients." *IEEE journal of biomedical and health informatics* 21, no. 5 (2017): 1338-1346.

[21] Peng Li, and Peng Ren. "Partial randomness hashing for large-scale remote sensing image retrieval." *IEEE Geoscience and Remote Sensing Letters* 14, no. 3 (2017): 464-468.

[22] Xu Tang, Licheng Jiao, William J. Emery, Fang Liu, and Dan Zhang. "Two-stage reranking for remote sensing image retrieval." *IEEE Transactions on Geoscience and Remote Sensing* 55, no. 10 (2017): 5798-5817.

[23] Yansheng Li, Yongjun Zhang, Xin Huang, Hu Zhu, and Jiayi Ma. "Large-scale remote sensing image retrieval by deep hashing neural networks." *IEEE Transactions on Geoscience and Remote Sensing* 56, no. 2 (2018): 950-965.

[24] K. V. Shriram, P. L. K. Priyadarsini, and A. Baskar. "An intelligent system of content-based image retrieval for crime investigation." *International Journal of Advanced Intelligence Paradigms* 7, no. 3-4 (2015): 264-279.

[25] Ying Liu, Fuping Wang, Dan Hu, and Jiulun Fan. "Multi-feature fusion with SVM classification for crime scene investigation image retrieval." In *Signal and Image Processing (ICSIP), 2017 IEEE 2nd International Conference on*, pp. 160-165. IEEE, 2017.

[26] Xinnian Wang, Chi Zhang, Yanjun Wu, and Yingying Shu. "A manifold ranking based method using hybrid features for crime scene shoeprint retrieval." *Multimedia Tools and Applications*76, no. 20 (2017): 21629-21649.

[27] Yuan Wang, Meixia Miao, Jian Shen, and Jianfeng Wang. "Towards efficient privacy-preserving encrypted image search in cloud computing." *Soft Computing* (2017): 1-12.

[28] Zhihua Xia, Neal N. Xiong, Athanasios V. Vasilakos, and Xingming Sun. "EPCBIR: An efficient and privacy-preserving content-based image retrieval scheme in cloud computing." *Information Sciences* 387 (2017): 195-204.

[29] Richang Hong, Lei Li, Junjie Cai, Dapeng Tao, Meng Wang, and Qi Tian. "Coherent semantic-visual indexing for large-scale image retrieval in the cloud." *IEEE Transactions on Image Processing* 26, no. 9 (2017): 4128-4138.

[30] Tirilly, Pierre, Kun Lu, Xiangming Mu, Tian Zhao, and Yu Cao. "On modality classification and its use in text-based image retrieval in medical databases." In *Content-Based Multimedia Indexing (CBMI), 2011 9th International Workshop on*, pp. 109-114. IEEE, 2011.

[31] K. Shubhankar Reddy, and K. Sreedhar. "Image Retrieval Techniques: A Survey."

[32] Marshall, A. Malcom, and S. Gunasekaran. "A Survey on Image Retrieval Methods."

[33] da Silva Júnior, João Augusto, Rodiney Elias Marçal, and Marcos Aurélio Batista. "Image Retrieval: Importance and Applications." In *Workshop de Vis~ ao Computacional-WVC*. 2014.

[34] Naidu, M. Ekambaram, and Ravi Kumar Chandu. "A Complementary Review on Various Content Based Image Retrieval System Techniques." (2017).

[35] Wang, Xiang-Yang, Yong-Jian Yu, and Hong-Ying Yang. "An effective image retrieval scheme using color, texture and shape features." *Computer Standards & Interfaces* 33, no. 1 (2011): 59-68.

[36] Kumar, Munish, Payal Chhabra, and Naresh Kumar Garg. "An efficient content based image retrieval system using BayesNet and K-NN." *Multimedia Tools and Applications* (2018): 1-14.

[37] Nazir, Atif, Rehan Ashraf, Talha Hamdani, and Nouman Ali. "Content based image retrieval system by using HSV color histogram, discrete wavelet transform and edge histogram descriptor." In *Computing, Mathematics and Engineering Technologies (iCoMET), 2018 International Conference on*, pp. 1-6. IEEE, 2018.

[38] Liu, Peizhong, Jing-Ming Guo, Chi-Yi Wu, and Danlin Cai. "Fusion of Deep Learning and Compressed Domain Features for Content-Based Image Retrieval." *IEEE Transactions on Image Processing* 26, no. 12 (2017): 5706-5717.

[39] Saavedra, Jose M., and Benjamin Bustos. "Sketch-based image retrieval using keyshapes." *Multimedia Tools and Applications* 73, no. 3 (2014): 2033-2062.

[40] Song, Jinjoo, Hyeyoun Cho, and Sang Min Yoon. "Sketch-Based Shadow Image Retrieval for Digital Library." In *Culture and Computing (Culture and Computing), 2017 International Conference on*, pp. 127-128. IEEE, 2017.

[41] Qi, Yonggang, Yi-Zhe Song, Honggang Zhang, and Jun Liu. "Sketch-based image retrieval via siamese convolutional neural network." In *Image Processing (ICIP), 2016 IEEE International Conference on*, pp. 2460-2464. IEEE, 2016.

[42] Saavedra, Jose M. "RST-SHELO: sketch-based image retrieval using sketch tokens and square root normalization." *Multimedia Tools and Applications* 76, no. 1 (2017): 931-951.

[43] Qian, Xueming, Xianglong Tan, Yuting Zhang, Richang Hong, and Meng Wang. "Enhancing sketch-based image retrieval by re-ranking and relevance feedback." *IEEE Transactions on Image Processing* 25, no. 1 (2016): 195-208.

[44] Minu, R. I., and K. K. Thyagharajan. "Semantic image description for ontology based image retrieval system." *International Journal of Applied Engineering Research* 9, no. 26 (2014): 9332-9335.

[45] Manzoor, Umar, Mohammed A. Balubaid, Bassam Zafar, Hafsa Umar, and M. Shoaib Khan. "Semantic image retrieval: An ontology based approach." *International Journal of Advanced Research in Artificial Intelligence (IJARAI)* 1, no. 4 (2015): 1-8.

[46] Singh, Anshy, Shashi Shekhar, and Anand Singh Jalal. "Semantic based image retrieval using multi-agent model by searching and filtering replicated web images." In *Information and Communication Technologies (WICT), 2012 World Congress on*, pp. 817-821. IEEE, 2012.

[47] Wang, Min, and Tengyi Song. "Remote sensing image retrieval by scene semantic matching." *IEEE Transactions on Geoscience and Remote Sensing* 51, no. 5 (2013): 2874-2886.

[48] Kumar, G. Nandha, and V. Saranya. "IRMA-Improvisation of image retrieval with Markov chain based on annotation." In *Information Communication and Embedded Systems (ICICES), 2014 International Conference on*, pp. 1-7. IEEE, 2014.

[49] Chen, Hua, Antoine Trouve, Kazuaki J. Murakami, and Akira Fukuda. "An intelligent annotation-based image retrieval system based on RDF descriptions." *Computers & Electrical Engineering* 58 (2017): 537-550.

[50] Chaudhari, Himali P., and Dinesh D. Patil. "Improved Markovian Model for Annotation Based Image Retrieval using Multiple and Synonymous Keywords." (2014).

[51] Kılınç, Deniz, and Adil Alpkocak. "An expansion and reranking approach for annotation-based image retrieval from web." *Expert Systems with Applications* 38, no. 10 (2011): 13121-13127.

[52] Hidajat, Monica. "Annotation Based Image Retrieval using GMM and Spatial Related Object Approaches." *International Journal of Control and Automation* 8, no. 8 (2015): 399-408.

[53] Qian, Yu, Xiaohong Gao, Martin Loomes, Richard Comley, Balbir Barn, Rui Hui, and Zenmin Tian. "Content-based retrieval of 3D medical images." In *The Third International Conference on eHealth, Telemedicine, and Social Medicine (eTELEMED 2011)*, pp. 7-12. 2011.

[54] Gao, Xiaohong, Yu Qian, Rui Hui, Martin Loomes, Richard Comley, Balbir Barn, A. Chapman, and J. Rix. "Texture-based 3D image retrieval for medical applications." In *IADIS Int. Conf. e-Health*, pp. 101-108. 2010.

[55] Elkhal, Mustafa, Abdelghni Lakehal, and Khalid Satori. "A New Method For 3d Shape Indexing And Retrieval In Large Database By Using The Level Cut." *Journal of Computer Science* 10, no. 10, 2014.

[56] Wang, Fang, Le Kang, and Yi Li. "Sketch-based 3d shape retrieval using convolutional neural networks." In *Computer Vision and Pattern Recognition (CVPR), 2015 IEEE Conference on*, pp. 1875-1883. IEEE, 2015.

[57] Furuya, Takahiko, and Ryutarou Ohbuchi. "Visual saliency weighting and cross-domain manifold ranking for sketch-based image retrieval." In *International Conference on Multimedia Modeling*, pp. 37-49. Springer, Cham, 2014.

[58] Xu, Peng, Qiyue Yin, Yonggang Qi, Yi-Zhe Song, Zhanyu Ma, Liang Wang, and Jun Guo. "Instance-level coupled subspace learning for fine-grained sketch-based image retrieval." In *European Conference on Computer Vision*, pp. 19-34. Springer, Cham, 2016.

HOG-AdaBoost Implementation for Human Detection Employing FPGA ALTERA DE2-115

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***Abstract*—Human detection system using Histogram of Oriented Gradients (HOG) feature and AdaBoost classifier (HOG-AdaBoost) in FPGA ALTERA DE2-115 are presented in this paper. This work is expanded version from our previous study. This paper discusses 1) the HOG performance in detecting human from a passive images with other point-of-views (30 deg., 40 deg., 50 deg., 60 deg. and up to 70 deg.); 2) FPS test with various image sizes (320 x 240, 640 x 480, 800 x 600, and 1280 x 1024); 3) re-measurement the FPGA's power consumption and 4) simulate the architecture in RTL. We used three databases as a parameter for test purpose, *i.e.* INRIA, MIT, and Daimler.**

Keywords—FPGA; human detection; adaboost classifier; ALTERA DE2-115; Histogram Oriented Gradients (HOG) feature

I. Introduction

The object detection is a critical task for many implementations in computer vision research area, like entertainment and autonomous system/robotics application [1]. The Histogram of Oriented Gradients (HOG) has been widely employed as a feature for object detection [2]. The HOG feature robust to the illumination changes and has a high accuracy in detecting objects with texture variations. So far, there is none proved feature to surpass the HOG existence [3]. That is why HOG-based detectors serve as the fundamental feature for object detection systems. HOG is also commonly implemented for detecting the humans effectively [4-5].

To date, there are many papers on FPGA-based HOG that implemented in Xillix FPGA for high-speed and high-accuracy human detection systems [6-10]. In previous work [11], we have applied the FPGA-based human recognition in an image, we employed ALTERA DE2-115. The results indicate that the humans are succesfully detected from a particular image with 1280 x 1024 resolutions and frame rate with 129 FPS. In that case, we used INRIA database. In [11], we also compared the other related works with our architecture and also investigated its power consumption of FPGA using Altera's Power Analyzer when performing as human detector system.

However, the paper discussion is a lack of the results analysis when the image viewed from different angles using various databases, *e.g.* INRIA, MIT, and Daimler. Hence, we extend its study involving HOG performance for human detection in an image with other angles up to 70^o; FPS test with different image resolutions; review about the power measurement of FPGA; and the simulation result of register-transfer level (RTL). To collect more data, various databases such as INRIA, MIT, and Daimler are used in this research.

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II. Methods

A. System Description

Section II-A describes the HOG algorithm implementation on FPGA ALTERA DE2-115. The illustration of research workflow can be shown in Fig 1. The following is brief description of research methods where the details are presented in Section II-B to Section II-F.

1) Greyscaling and scaling of the image input's are conducted in the first step. Therefore, human on the image can be identified with various distance.

2) Afterwards, the process is continued by every pixel gradient calculation so the dx and dy component can be obtained for every pixel. Both of the components are used to calculate magnitude and angle that used for HOG Feature Extraction every one cell with the size of x*y.

3) HOG Feature Extraction used can minimize system throughput and logic gates utilization because there is not arctan calculation using CORDIC which use a lot of logic gates and add the system throughput.

4) After histogram of 2 x 2 cell is obtained which every cell contained 8 x 8 pixel, the normalization process is performed. In this process, the quadratic and root mathematical operation is approached by the value of the near power of two that segmented into 4 section between two near power of two values so the normalization process can be implemented with shifting operator

5) Because of the FPGA's limited size of memory, histogram binarization is performed so one histogram can be represented using 8 bit. Although the utilization of memory can be reduced to 1/64th, this histogram binarization process can affect the system performance.

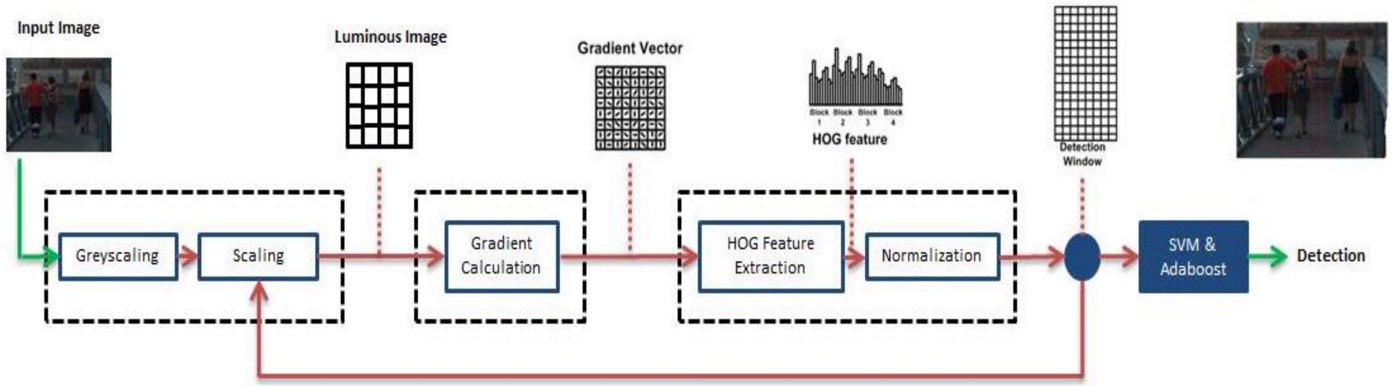


Fig. 1. Workflow of HOG-AdaBoost Implementation in an FPGA ALTERA DE2-115 for Human Detection Purpose.

6) After normalized histogram is obtained, detection process using the neural network is performed. Because this process is needed matrix multiplication, the systolic array is implemented on FPGA so the number of logic gates and system throughput can be minimized. Weight matrix and bias vector are obtained using Support Vector Machine (SVM) and AdaBoost which are done in offline.

B. Grayscaling & Scaling

As discussed before, the Grayscaling process is performed because of the HOG is an object detection method oriented on the shape of an image. The colored image has three matrices consists of R (Red), G (Green), dan B (blue) as visualized in Fig 2. Therefore, the RGB values are not needed and it can be represented by the luminance value. It can be obtained by using Eq (1),

$$Y = 0.298912 \text{ x } R + 0.586611 \times G + 0.114478 \times B \quad (1)$$

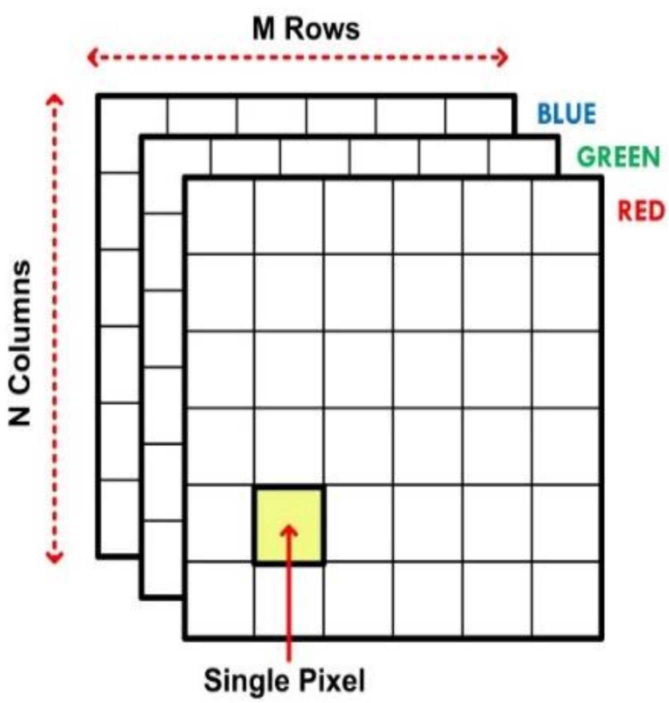


Fig. 2. Matrices of a Color Image, Reproduced from [12].

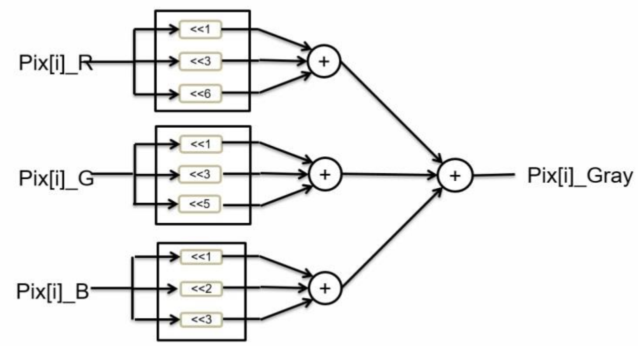


Fig. 3. Preprocessing Architecture.

We can use shifters block to approximate constants as expressed in Eq (1). To simplify the approach, we take two numbers after a comma. The following is the justification:

- 0.29 is approximated by 0.0100101, needing 3 shifters.
- 0.58 is approximated by 0.100101, needing 3 shifters.
- 0.11 is approximated by 0.000111, needing 3 shifters

The scaling process is needed so the system can detect humans from the various different distances. This process used sampling method of some specifics pixel correspond to the scaling rate. The architecture of preprocessing (grayscalling + scalling) can be illustrated in Fig 3.

C. Gradient Calculation

Gradient calculation can be done by calculating the difference of the neighboring pixel horizontally for *dx* and vertically for *dy*. The magnitude and angle value are needed to calculate histogram.

Magnitude calculation is explained on the Eq (2). The magnitude of the gradient *m* is included in histogram based on quantized difference orientation for every luminance value on a certain cell. The process can be illustrated in Fig 4. In this work, the magnitude calculation uses own algorithm to approximate roots and squares. It uses 120 modules in parallel. The architecture is simple subtraction between neighboring pixels. Afterwards, the calculation result is then saved to the SDRAM. The architecture is shown in Fig. 5.

$$m(x,y) = \sqrt{f_x(x,y)^2 + f_y(x,y)^2} \quad (2)$$

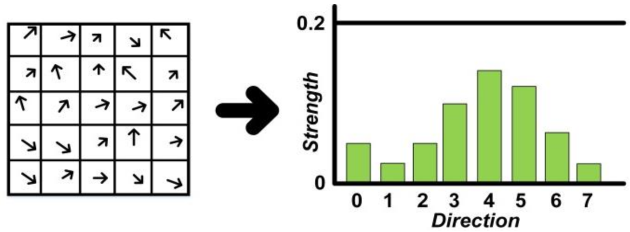


Fig. 4. The Histogram Calculation Methodology Reproduced from [13].

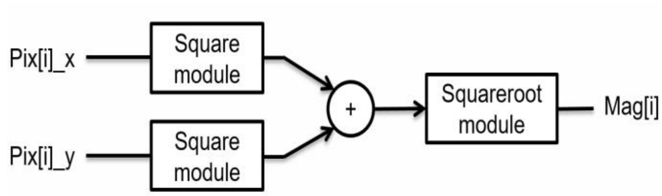


Fig. 5. Architecture for Magnitude Calculation.

D. HOG Feature Extraction

In this method, angle specific value doesn't need to be calculated, however just needed the range of angle values corresponding to the Eq (3). After the range of angle value is known, the magnitude of the pixel is added on the histogram block correspond to the angle value range. In this work, angle calculation is only compute the approximate angle, not the precise numbers so it requires two clock cycles. The architecture is shown in Fig 6.

$$\Delta L_x(x,y)\times \tan Q_{d+1} \le \Delta L_y(x,y) < \Delta L_x(x,y)\times \tan Q_d \quad (3)$$

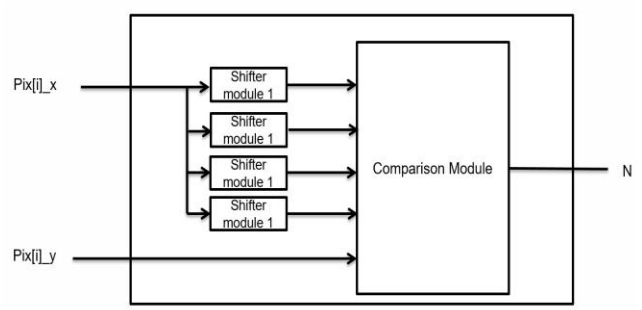


Fig. 6. Architecture for Angle Calculation.

E. The Normalization and Binarization

After histogram is obtained, normalization of the histogram collection is performed correspond with the Eq (4). Afterwards, the approached of the divisor in the Eq (4) is conducted to the power of two value that divided into 4 intervals with every near power of two values.

$$\sqrt{\|V_{i,j}\|^2 + e^2} = \|V_{i,j}\| \quad (4)$$

When normalized histogram is obtained, histogram binarization is performed with classified the histogram value based on a threshold value. When the histogram value is lower than the threshold and it will be represented by "1" binary value and vice versa as illustrated in Fig 7. The normalization block requires a maximum of 19 shifters, 4 clock cycles, and using 61 stage RAM Buffer as shown in Fig 8.

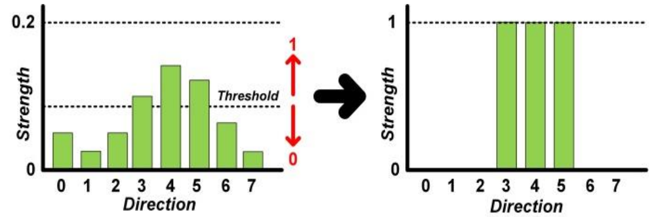


Fig. 7. Normalization Technique, Reproduced from [13].

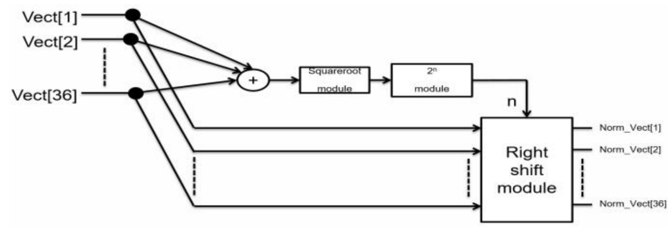


Fig. 8. Architecture for Normalization.

TABLE I. HOG-ADABOOST IMPLEMENTATION IN PSEUDOCODE

```
% Real-time Human Detection with HOG-AdaBoost Pseudocode
%Read an RGB value of each pixel from the image
read_image;
%Greyscaled an image based on the RGB value of each pixel
image_greyscaling;
%Saving the luminance value of each pixel to RAM
save_greyscaled_image;
for every_scaled_image
%Scaled down an image size with the ratio scale 1.25 every iteration
        image_scaling;
        %image window iteration with 8 pixel shifting every iteration
        for every_image_window:8:image_size
                %save image window luminance map into RAM
                temporary_save_image_window;
                for every_cells
                        %calculate gradient using imfilter
                        imfilter_image_window;
                        %converts gradient vector to polar
coordinates for each pixel
                        gradient_vector_to_polar;
                        for every_blocks
                                for every_pixel_inblock

        locate_histogram_angle;
                                        %add magnitude to
histogram based on the angle location

        add_magnitude_to_histogram(angle_location);
                                end
                        end
                        histogram_normalization;
                        saved_temporary_histogram_matrix;
                        %Humn detection using SVM with known
weight 'w' and bias 'b'
                        SVM_classifier(histogram_matrix);
                        if(SVM_score>0)
                                %detection matrix : scale_ratio
and cells information
                                save_detection_matrix;
                end
        end
        %draw a rectangle around human image
draw_rectangle(detection_matrix);
    end
```

F. SVM and AdaBoost

Detection process using HOG used SVM that can classified histogram data into two classifiers, the human is detected or not. Training is done offline using two datasets, *MIT pedestrian database*, and *INRIA database*. Then boosting is performed to increase the accuracy of detection process with combined some classifier with a different algorithm.

G. Implemented Algorithm in Pseudocode

Table I shows the pseudocode for HOG-AdaBoost Implementation in FPGA.

III. Results and Analysis

A. RTL Simulation

FPGA implementation of human detection result is shown in Table II. Every steps of RTL simulation result (as depicted in Fig 1) are shown in Fig 9 to Fig 13. Simulation result in Fig 9 shows the quadratic value process. It can be seen that the quadratic value is obtained in 2 clock cycle.

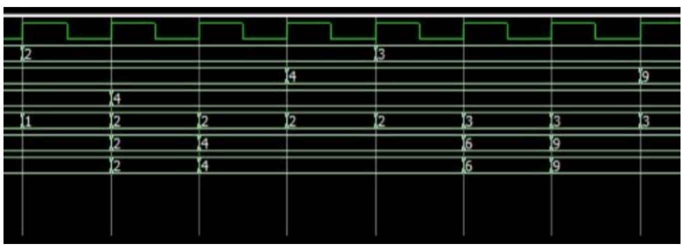


Fig. 9. The Square Root Computation Simulation Result.

TABLE II. The FPGA Implementation Result, obtained from [11]

FPGA Resources	Used	Available	%
Number of Logic Elements	83,497	114,480	72.9
Number of Registers	17,383	28,800	60.4
Number of fully used LUT-FF pairs	2070	23,109	9
Number of Memory bits	2,800,000	3,900,000	71.8
Maximum Frequency	50 MHz		

Therefore, simulation result on Fig 10 shows the magnitude calculation process which adds the two squares value and root process output if given the 16 and 9 as the input is 5.

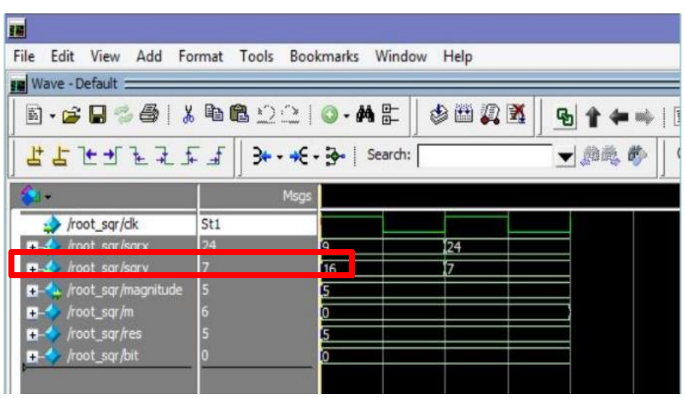


Fig. 10. The Magnitude Computation Simulation Result.

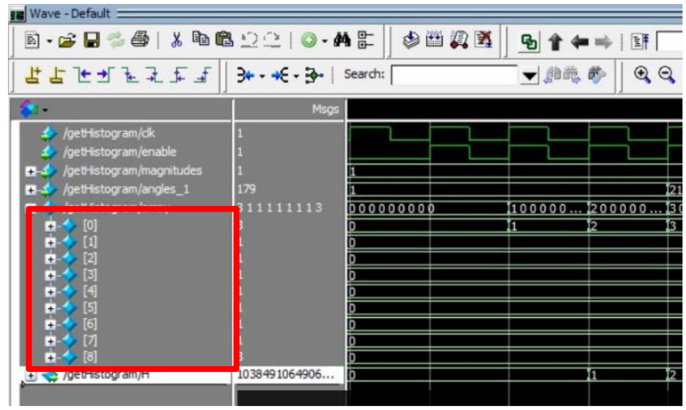


Fig. 11. The Histogram Computation Simulation Result.

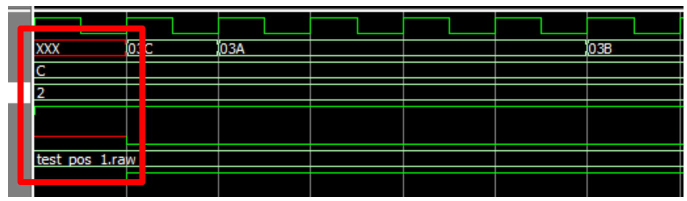


Fig. 12. The Grayscaling Simulation Result.

Fig 11 simulation result shows the histogram calculation added input value to the array with 9 elements for every clock cycle. Fig 12 shows the simulation result of the grayscaling process performed the calculation based on an equation as explained before (Eq 1) and produce output every one clock cycle.

Simulation process of histogram normalization can be seen in Fig 13. The normalization calculation result for every inputs are 300 that approached. Therefore, the divisor value is 256 and the division process can be implemented using shifter.

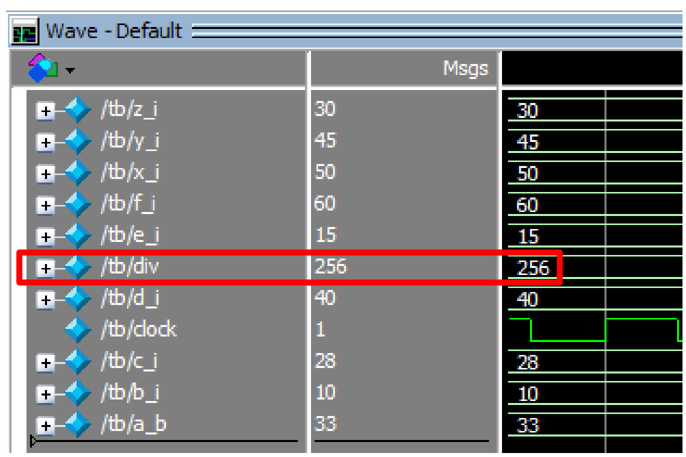


Fig. 13. The Histogram Normalization Simulation Result.

The systolic array implementation module simulation result can be seen in Fig 14. The output can be obtained after 6 clock cycles from the moment data is given, this result is 6 times faster than the usual matrix multiplication in which it is needed 3*3*3 = 27 multiplication iterations in 3 x 3 matrix multiplication.

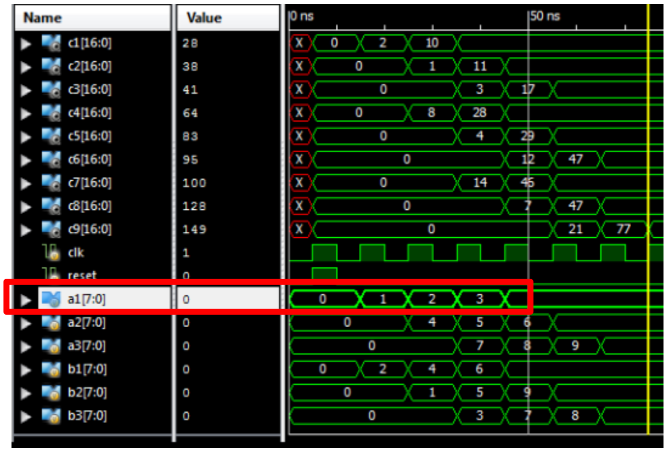


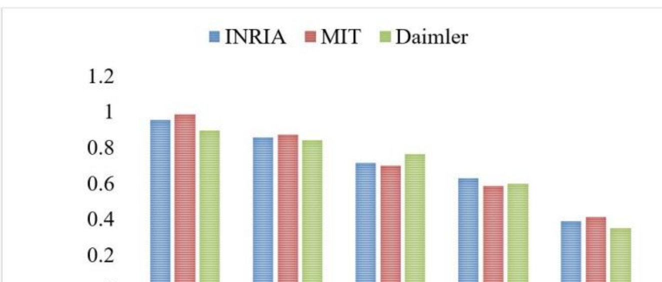
Fig. 14. The Matrix Multiplication Simulation Result.

B. Power Consumption

To measure the power consumption of FPGA DE2-115 implementation, we used The ALTERA's Power Analyzer tool and obtain 3.6 Watt total power.

C. Test with Other Angles

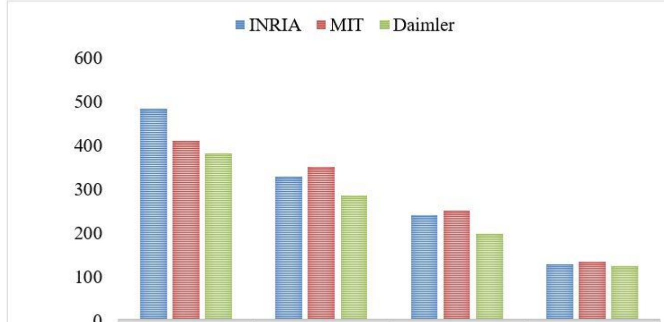
In this testing, human image from three datasets, INRIA, MIT [14], and Daimler with quite a high angle are applied to see the effect of those angle against the detection accuracy. In this testing, 5 angle categories are used as shown in Fig 15. The result is accuracy detection compared to the dataset that used for training. From this data, can be seen for the angle 50^{o} and below, detection process still quite reliable. However, for high angle, the advance adjustment is needed.



	30°	40°	50°	60°	>70°
INRIA	0.954	0.856	0.712	0.627	0.389
MIT	0.985	0.871	0.697	0.584	0.412
Daimler	0.893	0.841	0.765	0.596	0.349

Fig. 15. Test with High Angles (For Interpretation of the Color in this Figure Legend, the Reader is Referred to the Web Version of this Article).

Fig 16 shows table and graph of testing results with three datasets, and the results obtained as detection speed in Frame per Second (FPS). This test is done by inserting test images from the three datasets as fast as possible. Next image will be inserted after the previous image detection process is done. Detection accuracy is maintained still at more than 0.85, if less than 0.85, the pause will be given before the next image is inserted.



	320 x 240	640 x 480	800 x 600	1280 x 1024
INRIA	483	328	241	129
MIT	410	351	251	135
Daimler	381	285	198	125

Fig. 16. The FPS Tests (For Interpretation of the Color in this Figure Legend, the Reader is Referred to the Web Version of this Article).

From that results, can be seen that Daimler consistently has the lowest FPS value. This is because Daimler dataset is designed to have a high level of complexity. However, this result can't be compared with the testing using video, because in video file there is a certain thing, like encoding that not taken into account.

IV. Conclusion

In this paper, we present the human detection system using HOG features and its classifiers using AdaBoost implemented in FPGA ALTERA DE2-115. The RTL simulation shows that the calculation of HOG-AdaBoost implementation in FPGA is approaching the theory. Furthermore, we also perform the power consumption measurement for HOG-AdaBoost in FPGA. Later is the high angle test and FPS test. Based on testing, it can be concluded that for the angle<50 degrees, the detection process still reliable. However, with angle>50, needed further system optimation. One of the methods can be done by using own specific dataset for human images taken from high-angle. With new dataset, the SVM is expected to recognize human with an image taken from a high-angle.

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References

[1] T. Adiono, H. Ega, H. Kasan, R. Marthensa, and S. Fuada, "A high frame-rate cell-based HOG human detector architecture and its FPGA implementation," *Unpublished.*

[2] J. Rettkowski, A. Boutros, D. Göhringer, "HW/SW Co-Design of the HOG algorithm on a Xilinx Zynq SoC," *J. Parallel Distrib. Comput.*, Vol.109, pp. 50–62, May 2017.

[3] K. Takagi, et al., "A Real-time Scalable Object Detection System using Low-power HOG Accelerator VLSI," *J. Sign. Process. Syst.*, January 2014. DOI: 10.1007/s11265-014-0870-7.

[4] A. Suleiman and V. Sze, "An Energy-Efficient Hardware Implementation of HOG-Based Object Detection at 1080 HD 60 fps with Multi-Scale Support" *J. Sign. Process. Syst*., December 2015. DOI: 10.1007/s11265-015-1080-7.

[5] Y. Li, et al., "Adaptive human detection approach using FPGA-based parallel architecture in reconfigurable hardware," *Concurrency Computat.: Pract. Exper.*, June 2016. DOI: 10.1002/CPE.3923.

[6] M.D.T. Kryjak, "FPGA implementation of multi-scale face detection using HOG features and SVM classifier," *Image processing & communications*, Vol. 21(3), pp. 27-44, 2016.

[7] T.S. Saidani and Y.F. Said, "Design of embedded architecture for pedestrian detection in image and video," *IJCSNS*, Vol. 17(12), pp. 120-129, December 2017.

[8] J. Rettkowski, et al., "Real-time pedestrian detection on a xilinx zynq using the HOG algorithm," *Proc. of ReConFig*, pp. 1-8, December 2015.

[9] H. Ameur, A. Helali, and A. Youssef, "Hardwardware implementation of an improved HOG descriptor for pedestrian detection," *Proc. Of ICCAD*, pp. 406-410, January 2017.

[10] M. Hemmati, B-A, Morteza, S. Berber, and S. Niar, "HOG feature extractor accelerator for real-time pedestrian detection," *Proc. of 17th Euromicro conf. On DSD*, pp. 443-550, August 2014.

[11] T. Adiono, K.S. Prakoso, C.D. Putratama, B. Yuwono, and S. Fuada, "Practical Implementation of Real-time Human Detection with HOG-AdaBoost in FPGA," *Proc. of The IEEE Region 10 Conf.* (TENCON), October 2018.

[12] N. Dalal and B. Triggs, "Histograms of oriented gradients for human detection," in *Proc. of the IEEE Conf. Computer Vision Pattern Recognition*, Vol. 1, pp. 886–893, June 2005.

[13] K. Negi, K. Dohi, Y. Shibata and K. Oguri, "Deep pipelined one-chip FPGA implementation of a real-time image-based human detection algorithm," *Proc. of the Int. Conf. on Field-Programmable Technology* (FPT), pp. 1-8, Decembers 2011.

[14] The MIT pedestrian database, [Online], available at http://cbcl.mit.edu/software-datasets/PedestrianData.html, accessed in August 2017.

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Implementation of Intelligent Automated Gate System with QR Code

- An IOT System to Help Gate Management

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***Abstract*—This paper is about QR code-based automated gate system. The aim of the research is to develop and implement a type of medium-level security gate system especially for small companies that cannot afford to install high-tech auto gate system. IAGS is a system that uses valid staffs' QR code pass card to activate the gate without triggering the alarm. It is developed to connect to the internet and provide a real-time email notification if any unauthorized activities detected. Besides that, it is also designed to record all the incoming and outgoing activities for all staff. All QR code pass cards that are generated to staff will be encrypted to provide integrity to the data. The system is based on items such as PIR motion sensor, servo motor, Arduino microcontroller, Piezo buzzer, and camera. The software is implemented using VB.NET and the QR recognition level is about 99% accurate.**

Keywords—Component; internet of things; gate system; VB.NET; QR code

I. Introduction

In this modern society, crime rate is increasing and among the popular victims are the small companies. This is because small companies usually do not have appropriate gating system to prevent unauthorized entries. This is very dangerous and may put the companies at risk.

IAGS uses QR code technology to identify the identity of the staff. This technology not only can be used in the companies' premises, but also in residential areas, paid parking zones, and several other significant areas. This paper proposes the development of a gate system to allow only authorized staff to enter the company premises. The regular web camera will capture the QR codes scanned by the staff and have them verified by the VB.NET software application.

II. Related Work

QR (Quick Response) code refers to a combination of black and white square machine-readable code [1][2]. It is usually used for storing information and is scanned with QR code scanners. QR code scanners can be any kinds of camera, including smartphones camera or webcams. QR code can be easily generated by any online software tools, and it supports any type of data. QR code is possible to be read by the QR code scanner even though the QR code is damaged. Basically, it is still detectable by scanners if the code loss/damage is less than 30%. It also support 360-degree of reading [3].

To increase the security level of the QR code, salted algorithm and hashing algorithm are implemented [4][2]. Hashing algorithm is an algorithm that will take a string or data source and create an encrypted looking string with no meaning value. There are various hashing algorithms such as MD5 for 128 bits, SHA256 for 256 bits, and SHA512 for 512 bits that may be used [5]. Salted algorithm on the other hand, is a randomly generated data used as an additional input to a one-way function that "hashes" a password or passphrase. By implementing both the salted and hashing algorithms, the QR code will not be easily cracked. Based on the criteria stated above, the QR code is most suitable to act as a pass card to implement in the gate system. The example of the salted hashing algorithm is shows in the Figure 1.

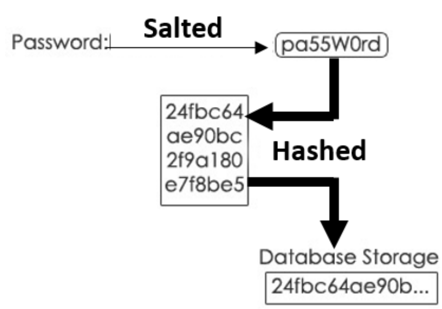

Fig. 1. Example of salted hashing algorithm

The functionality of the current gate systems in the market is not comprehensive [6][7][8][9]. This is because the automated gate systems in the market require expensive installation and maintenance fees which are not affordable by most of the small companies. Small companies rather bear the risks of not installing any gate systems because they could not afford those [7][10]. This is very risky and dangerous as any unauthorized person can freely enter and exit the companies' premises.

Besides that, some of the automated gate system in the market does not provide any monitoring tool or interface to monitor the gate system [11][12]. Some of them are also unable to open the gate manually if there are any problems to the system. Furthermore, some of the gate system do not record the 'check-ins' and 'check-outs' of the staff [13]. This is very inefficient as it could not trace who enters and exits in a specific time range if any suspicious activities happened.

Most of the existing gate systems also do not support online connection [11]. The gate system only trigger the alarm without sending out any notification/email to the relevant department. This is inefficient if the company is not located in urban areas and less people will notice that the alarm has been triggered. The immediate actions cannot be taken and may cost the company huge losses.

III. Methodology

A. Theoritical Framework

Basically, the implementation of nowadays gate system shows the apparent similarities from the theoretical perspective and its implementation. It involves the process of identifying the identity of the person that want to enter the premises, confirming and authorizing the person to enter the premises.

Basically IAGS (Intelligent Automatic Smart System with QR Code) is part of a defense system. It focuses security task including's user authorization, intrusion alarm and uses to protect the organization from the unwanted access. Current implementation for systems such as IAGS are including biometric-based applications, RFID/passcode, vehicle license identification and QR code. IAGS focuses on the implementation of the QR Code for the purposes of user authorization in order to ensure only the right person can enter the premises [10]. The basic theoretical framework of Intelligent Automated Gate System with QR Code is briefly illustrated in Figure 2 below.

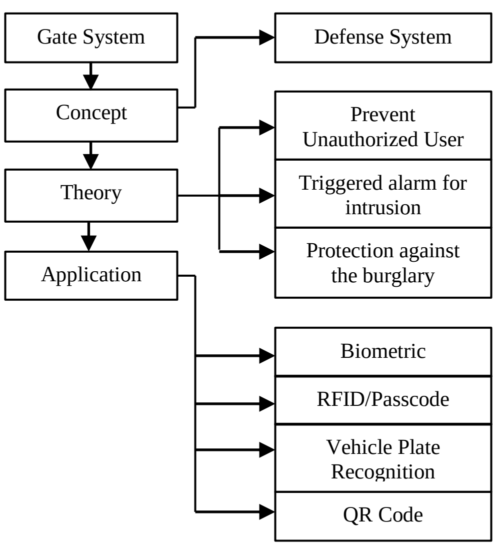

Fig. 2. The theoretical framework

B. The Process

First, in this project, Rapid Application Development (RAD) model will be implemented [14]. This methodology is the most suitable as it designs to produce a high-quality output in the shortest time compared to traditional lifecycle software development. Besides that, the RAD methodology can also provide some output of the product in a very short time and get feedback from the end users regarding their requirements.

RAD is a four-phase software development cycle that combines the element of Standard System Development Life Cycle (traditional SDLC) [14]. The four phases are Requirement Planning, User Design, Construction, and Testing and Cutover. Figure 3 shows the RAD process.

Fig. 3. Process of RAD

C. System Architecture and Design

Figure 4 shows the System Architecture of the Intelligent Automated Gate System. An interface is created using VB.NET to control the Arduino Uno Microcontroller. The Arduino Uno Microcontroller receives the command via a serial port and performs the rotation of the servo motor. If an authorized scanning is detected, the servo motor will rotate 90 degrees as the gate opens, or else it will not rotate and an email will be sent to the relevant department regarding the unauthorized scanning detected. Besides that, there are two cameras that will be used as a scanners to detect the QR code pass card and also perform as security cameras. All information of staffs will be saved into the SQL database including the created QR code and check in/out record.

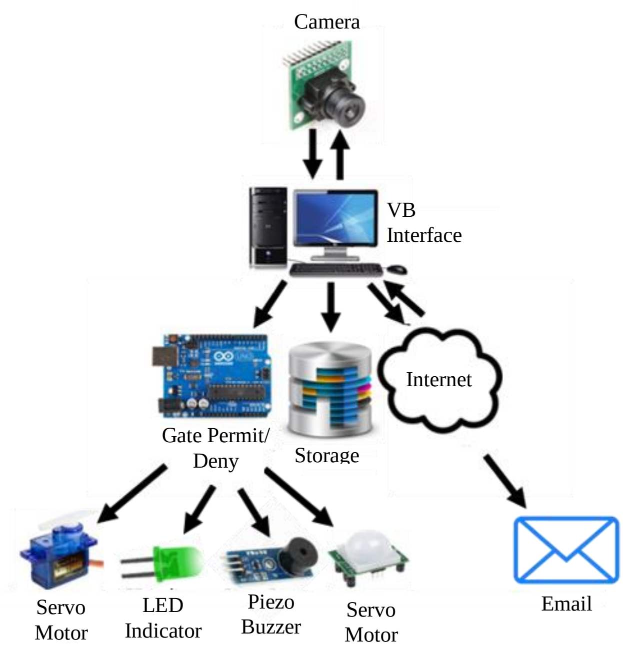

Fig. 4. System Architecture

IV. Results and Discussion

The development of the system is divided into two parts:

i. Hardware development

ii. Software development

A. Hardware Development

The hardware needed in this project includes the Arduino Uno microcontroller, Piezo buzzer, PIR motion sensor, servo motor, LED light, and a web camera. The web camera is connected to the PC via USB cable while the rest of the hardware is connected to the Arduino Uno by using jumper wires. Table 1 shows the connection of the Arduino Uno.

TABLE I. PINS CONNECTION OF ARDUINO UNO

Hardware	Wire	Pins
Led Light (Red)	Power	5V
	Signal	6
Led Light (Green)	Power	5V
	Signal	10
PIR Motion Sensor	VCC	5V
	OUT	12
	GND	Gnd
Piezo Buzzer 5V	VCC	5V
	I/O	9
	GND	Gnd
Servo Motor 1	GND	Gnd
	Power	5V
	Signal	3
Servo Motor 2	GND	Gnd
	Power	5V
	Signal	5

Figure 4 also shows the hardware connections implemented in this project. The servo motor is attached to Arduino Uno microcontroller using the male to male jumper wire. The rotation command will be sent from the VB.NET software application to the Arduino Uno microcontroller via a serial port. PIR sensor is used to detect the motion of the said vehicle. Once the vehicle is detected, it will control the rotation of servo motor to make it rotate 90 degrees to close the gate. The piezo buzzer will be triggered if any unauthorized scanning is detected to alert the security department. Figure 5 below shows the implementation of IGAS in real environment.

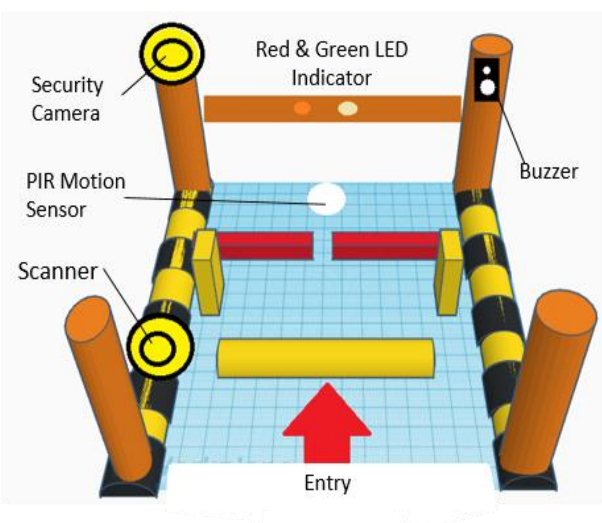

Fig. 5. IGAS in real environment

B. Software Development

A monitoring application created by the VB.NET language is used to monitor and control the IGAS. There are nine (9) main modules in the application as follows:

- Login - This is an authorization process which allows only administrator to log into the software application to perform tasks such as registration for staff, checking check-in/out record, activate/deactivate the security camera, and others.
- Register - This process is to create a new account for new staff. The information of new staff will be saved into the database and the QR passcode will also be generated at the same time.
- Update Info - The staffs' information can be updated from time to time to include information such as telephone number or emails to make sure their information is up to date.
- Delete - Staffs' record can be deleted, if necessary, to avoid congestion in database.
- List of staff - All staffs' information will be shown in a table and can be viewed by the administrator.
- Report – Any check-in/out time activities will be recorded based on the name of the pass card holder.
- Email – An email alert will be send to the relevant department if any unauthorized/suspicious activities found/detected. QR code pass card can also be send to specific staff if there are any losses/updates to the QR code.
- Webcam scanner - A programmed webcam is used as a QR code scanner to detect the QR code for every check-in and check-out processes.

Figure 6 shows the functionality of the Intelligent Automated Gate System in details.

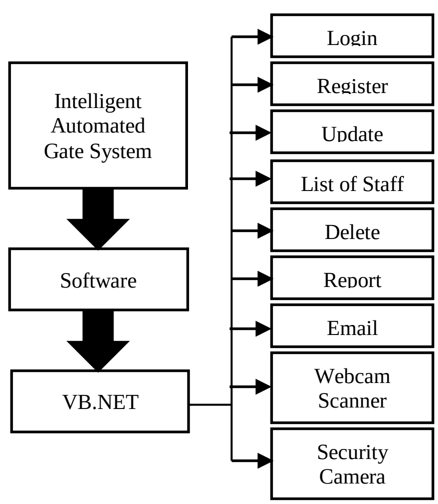

Fig. 6. Functionalities of the monitoring software

The workflow of the hardware system is simplified in the Figure 7 below:

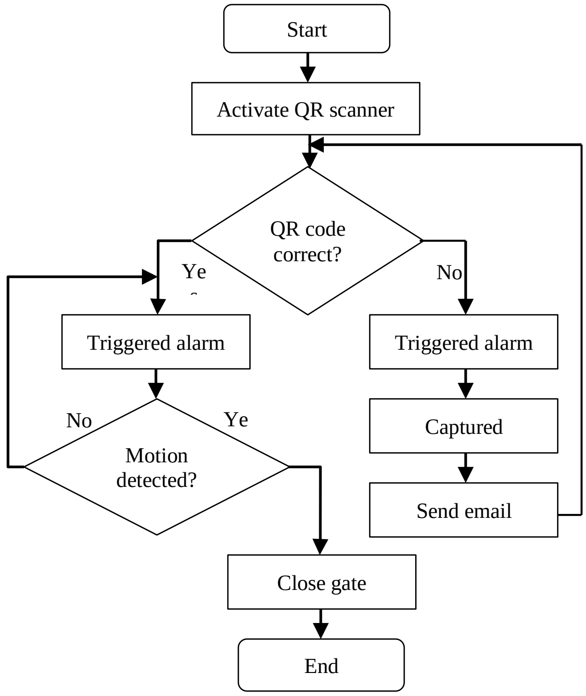

Fig. 7. Work flow of the hardware system

C. Evaluation

The IOT platform is successfully developed and implemented. It is able to open the gate by using a valid QR code which is generated by the monitoring software application. Overall, the system is 99% accurate. Table 2 shows the result of the testing for the IAGS.

TABLE II. QR CODE DETECTION

No of detection	Correct detection	Error detection	Success %
100	99	1	99

The implementation of the system consists of some limitations to be improved in future development. First, the VB.NET software application must be connected to the internet to ensure that the email is sent if any unauthorized activities are detected. The connection strength and speed is important to prevent any delay in the process of sending the email. Second, the light ray is important for the QR code scanner to read the QR code. If the light ray is insufficient, the function of reading the QR code may be affected and it will take longer to decode the QR code.

D. Future Work

We are looking forward to extend this project to make it more functionality and comprehensive. The features that we are looking at are as listed below.

- SMS/ WhatsApp Notification

- IAGS can be improved by adding the SMS/WhatsApp notification instead of email notification. This features will be more efficient [15][16] in order to inform the security department for any immediate action related to intrusion.

- Voice Communication

- Voice communication service will be added at the side of the barrier uses for the security department to communicate with the car driver (if needed). This allows better communication [17][18] if there is any problem in IAGS implementation.

- IP Camera

- An IP camera will be introduced in IAGS instead of USB camera. IP Camera is more economical compared to USB Camera [17][19]. It is also support to rotate the angle of camera and providing a real-time monitoring.

V. CONCLUSION

This paper explains the development of a medium-security level gate system with minimum cost. The system distinguishes the weaknesses of the current gate system in the market by applying a different technology- QR code. Also, the system can be used not only in company premises, but also be implemented in any places and works automatically without the need of human beings. It will definitely increase the performance of a company and prevent office brake-ins effectively.

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REFERENCES

[1] R. M. Bani-Hani, Y. A. Wahsheh, and M. B. Al-Sarhan, “Secure QR code system,” in 2014 10th International Conference on Innovations in Information Technology, IIT 2014, 2014, pp. 1–6.

[2] M. Avinash, R. K. Ku, M. Munusamy, D. Muthuvel, K. N. Ku, and K. Th, “Multi-level Security using QR Code , Biometrics and Password for Security Systems,” vol. 7, no. 4, pp. 6334–6337, 2017.

[3] T. J. Soon, “QR code,” Synth. J. 2008, pp. 59–78, 2008.

[4] A. S. Narayanan, “QR Codes and Security Solutions,” Int. J. Comput. Sci. Telecommun., vol. 3, no. 7, pp. 1–4, 2012.

[5] E. Shi and A. Perrig, “Designing secure sensor networks,” IEEE Wirel. Commun., vol. 11, no. 6, pp. 38–43, 2004.

[6] C. K. Primus, N. S. Yahya, A. Arba, N. A. N.Dandang, and N. O.AFI, “Design and Development of Low Cost Auto Gate System for House , Part 4,” in 2nd Integrated Design Project Conference (IDPC) 2015, 2015, no. January, pp. 0–11.

[7] K. P. Dipali, C. P. Komal, D. R. Roshani, and A. H. Marhaba, “Automatic Gate Opening System for Vehicles With Rfid or Password,” Int. J. Electr. Electron. Res., vol. 2, no. 2, pp. 35–41, 2014.

[8] J. A. Enokela and M. N. Tyowuah, “An electronically controlled automatic security access gate,” Leonardo J. Sci., no. 25, pp. 85–96, 2014.

[9] J. Desai, A. Bhanje, S. Biradar, and D. Fernandez, “IoT based Vehicle Parking Manager,” vol. 61, pp. 222–225, 2017.

[10] S. J. Ganesh, A. Avenash, A. Prakashreddy, C. Baarathi, and S. H. H. Sudhan, “Electronic toll collection system using QR code and RFID registration,” vol. 10, pp. 5–10, 2018.

[11] J. Sanchez del Rio, D. Moctezuma, C. Conde, I. Martin de Diego, and E. Cabello, “Automated border control e-gates and facial recognition systems,” Comput. Secur., vol. 62, pp. 49–72, 2016.

[12] K. Patil, P. Patil, S. Rane, R. Redkar, and P. G. Salunkhe, “Intelligent Car Parking System commanded by Android Application,” Int. Res. J. Eng. Technol., pp. 5–8, 2018.

[13] I. S. Eltoum and Z. Xue, “Automatic Gate Control System Based On Vehicle License Plate Recognition,” Int. J. Eng. Res. Technol., vol. 3, no. 8, pp. 79–83, 2014.

[14] M. A. Hirschberg, “Rapid Application Development (RAD): A Brief Overview,” Softw. Technol. News, vol. 2, no. 1, pp. 1–16, 1998.

[15] A. Awalgaonkar, S. Inamdar, S. Pawar, and A. Sonar, “Mail Notification System for Smart Phones,” Int. Eng. Res. J., vol. 2, no. 12, pp. 4704–4705, 2015.

[16] M. H. Saad, R. A. Shahad, M. Z. Sarnon, and M. F. Mohd, “Smart Pump Operation Monitoring and Notification (PuMa) Via Telegram Social Messaging Application,” vol. 1, no. 3, pp. 57–60, 2017.

[17] Y. Sukegawa and T. Samad, “Improving Effectiveness of Government-Funded R&D Programs—Application of a Stage-Gate System for a Japanese Ministry,” in In 2018 IEEE Technology and Engineering Management Conference (TEMSCON), 2018, pp. 1–6.

[18] B. Binneman and H. Steyn, “Criteria for Selection and Gate Rwviews of Technology Innovation Projects,” South African J. Ind. Eng., vol. 4, no. May 2014, pp. 17–32, 1389.

[19] L. Hang, “Design and Implementation of Intelligent Fire Notification Service Using IP Camera in Smart Home Design and Implementation of Intelligent Fire Notification Service Using IP Camera in Smart Home,” Int. J. Control Autom., vol. 11, no. 1, pp. 131–142, 2018.

Missing Values Imputation using Similarity Matching Method for Brainprint Authentication

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***Abstract*—This paper proposes a similarity matching imputation method to deal with the missing values in electroencephalogram (EEG) signals. EEG signals with rather high amplitude can be considered as noise, normally they will be removed. The occurrence of missing values after this artefact rejection process increases the complexity of computational modelling due to incomplete data input for model training. The fundamental concept of the proposed similarity matching imputation method is founded on the assumption that similar stimulation on a particular subject will acquire comparable EEG signals response over the related EEG channels. Hence, we replaced the missing values using the highest similarity amplitude measure across different trials in this study. Next, wavelet phase stability (WPS) was used to evaluate the performance of the proposed method since WPS portrays better signals information as compared to amplitude measure in this situation. The statistical paired sample t-test was used to validate the performance of the proposed similarity matching imputation method and the preceding mean substitute imputation method. The lower the value of mean difference indicates the better approximation of imputation data towards its original form. The proposed method is able to treat 9.75% more missing value trials, with significantly better imputation value, than the mean substitution method. Continuity of the current study will be focusing on evaluating the robustness of the proposed method in dealing with different rate of missing data.**

Keywords*—Similarity matching; data imputation; wavelet phase stability; missing values; artefact rejection

I. Introduction

Brainprint authentication is catching attention recently because of their high time resolution, portability and relatively low cost [1]. Many decent non-clinical grade Electroencephalogram (EEG) acquisition devices have been introduced to the consumer market. This has greatly helped in promoting the EEG research since the data acquisition process is getting simpler and affordable. The consumer grade EEG devices are capable of providing better portability with reduced calibration time [2]. Brainprint authentication is an authentication method that using EEG signals. EEG is a popular non-invasive method which record the electrical activities of the brain on the scalp. It is normally measure in small voltage fluctuations within the brain. Human brain plays important role in controlling the coordination of nerves and muscles.

The advantage of using EEG signals as biometric modality lies on its uniqueness and confidentiality. Every individual has different brain responses towards different stimuli. Thus, the EEG is expected to have high inter-subject variability and low intra-subject variability. A good biometric modality should also have this property. EEG is outstanding than the current biometric modalities because EEG signals are hidden in our brain and non-observable physically. Other biometric modalities, such as fingerprint or face, are easily obtainable physical sensors from the body surface [3]. Besides, these biometric modalities are lack of the function of liveness detection. Nevertheless, EEG signals can be easily influenced by artefact noises. The large amplitude fluctuations in the EEG signals will be occurred when the subjects having eye blinking, body movements and etc. Therefore, pre-processing steps such as filtration and artefact rejection are necessary to improve the EEG signals quality.

The main purpose of the artefact rejection is to exclude the EEG signals with amplitude greater than 100 µV. Normal amplitude for EEG signals will not exceed 100 µV unless the amplitude come from the artefacts like body movements or eye blinking [4]. Thus, the artefact rejection will lead to missing trials for that particular channel. In order to tackle this issue, a similarity matching imputation method is proposed to deal with the missing values caused by artefact rejection.

The rest of this paper is structured as follows: Section II reviews the related works about the missing values imputation and wavelet phase stability. Section III describes the proposed similarity matching imputation method. Section IV illustrates the experimentation, which includes the data acquisition, experimental setup, data pre-processing, data preparation, wavelet phase stability (WPS) and statistical test. Section V portrays the experimental results and discussion for the proposed similarity matching imputation method and mean substitute imputation method. Section VI draws the conclusion and suggests the direction of future work.

II. Related Works

In the real-life applications, it is not easy to obtain a perfect dataset especially in signal analysis. EEG signals are having the low signal-to-noise ratio. Therefore, pre-processing is compulsory to remove the noise from the signals. Missing values will appear after the pre-processing steps.

One of the easiest ways to deal with the missing values is by ignoring the missing values in the dataset. However, it is very risky if there were large amount of missing values found in the dataset [5]. Another two important issues of large amount of missing values are leading to loss of meaningful information and distorting the result analysis. Consequently, several imputation methods have been used to deal with missing values.

From the past research, mean or mode substitute imputation methods are the most commonly used because there are simple and straightforward methods [6]. Unfortunately, the mean substitute imputation method can severely distort the distribution of the data. In EEG signals analysis, mean or mode substitution might not be appropriate due to the fluctuation of amplitude because it may lead to higher degree of standard deviation. The data structure is hardly maintained due to the high variation in the replacement values [7]. Another alternative way to deal with the missing values for EEG signals was using incremental approach proposed by Kim et al. [8], which is the incremental expectation maximization principal component analysis (iEMPCA). The estimated missing values were close to original data. However, the implementation of the mean substitution method is simpler than the iEMPCA. The EMPCA starts with initializing the mean value. Then, the data is reconstructed by using the number of predefined principal components. The processes will be repeated until convergence. Besides, the incremental approach is applied in the PCA to update the weight vector incrementally for the number of hidden variables. It is to minimize the average reconstruction error. Therefore, the expectation maximization was used to estimate the missing values.

Maximum likelihood estimation method is a famous statistical method, which finds the parameter to maximize the likelihood function. Sieluzycki and Kordowski [9] proposed an maximum likelihood estimation to improve the quality of the imputation method for auditory evoked brain responses. The proposed maximum likelihood estimation method takes into account the trial-to-trial variability on the multichannel level. The proposed algorithm was proven in reconstructing the lateralization of the trial-to-trial variability for the brain evoked responses. Yet, the algorithm needs to further improve when dealing with the nonstationary of the signals that arise from the stochastic noise.

Event-related potentials (ERPs) are commonly used in EEG signals analysis for brainprint authentication [10]–[14]. ERP is the averaging of many trials in order to enhance the signal-to-noise ratio. Averaging across the repeated responses is very useful when we are interested to look at the evoked potentials. However, when we look into the amplitude information of single trial, it tends to be fragile [15]. Other than that, the averaging approach will cause the loss of the information on the response variability across single trials. It is due to the large amplitude fluctuations can be easily produced even though there are slightly changes in measurement setup or body movements. Therefore, we can conclude that the EEG signals having large variance between one trial to another. Thus, phase information is emphasized to illustrate the similarity between the signals. Time domain analysis shows the EEG signals changes over time. On the other hand, frequency domain analysis shows the energy distributed over a range of frequencies and also includes information on the phase shift that applied to each frequency component [16]. Oppenheim and Lim [17] had stressed on the importance of phase in the EEG signals by using the Fourier representation. Other than that, the usefulness of the phase information is also interpreted in signal and image reconstruction [18]. The justification was presented from a statistical viewpoint. Wavelet phase stability (WPS) is proposed in [19] to address the issue of the ERPs. WPS makes use of the wavelet-based measure that gives the phase information. In the view of signal processing, the phase of a signal encompasses more significant information as compared to the amplitude of a signal.

III. The Proposed Similarity Matching Imputation Method

We proposed a similarity matching imputation method to treat the missing values in this case study. Our main idea for the missing values imputation is based on the similarity between two trials. The main concept of the similarity matching imputation method is shown in Fig. 1. The formula of similarity is calculated as follows:

$$similarity = 1 - \frac{|a(x) - a(y)|}{|a_{max} - a_{min}|} \quad (1)$$

Where, $a(x)$ and $a(y)$ are the object x and y which similar to attribute a; a_{max} and a_{min} are the maximal and minimal occurring value of attribute a.

The trials will be excluded if the rate of missing values is greater than 20% of the total values in a trial. In other words, we have used 21 electrodes in total, so the trials with the missing values from 5 electrodes and above will be excluded. It is because large number of missing values can lead to information loss and degraded the meaningful information. Thus, the incomplete trials must be excluded instead of performing missing values imputation. On contrary, the incomplete trials with missing values less than 20% will be treated iteratively.

The proposed similarity matching imputation method will search for the most similar complete trial as the reference point to treat the particular incomplete trial. The similarity measure is calculated by comparing the data without missing value between the complete trial and the treatment trial. Only the EEG signals of the same subject, in the same data acquisition condition (i.e. quiet, low distraction or high distraction), and of the same type of stimulus (i.e. password or non-password) are included in the searching pool. Once the highest similarity measure is found, the similarity matching imputation method will replace the missing values of the particular electrodes from the complete trial.

IV. Experimentation

In this section, we illustrate the EEG data acquisition process, experimental setup, data pre-processing steps, data preparation and implementation. Besides that, we evaluate the performance of the imputation methods based on the amplitude information and the phase information.

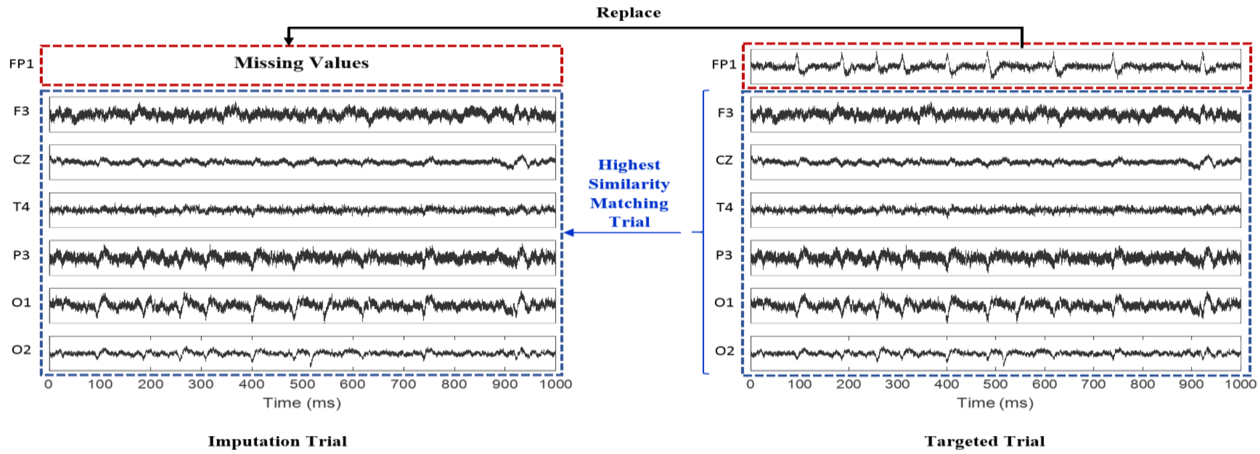

Fig. 1. Concept of Similarity Matching Imputation Method on Targetted Trial with Multiple Electrodes in a Single Subject EEG Data.

A. Data Acquisition and Experimental Setup

A new raw EEG dataset is collected from 4 healthy subjects (with mean age 29.8 years old) in Universiti Teknikal Malaysia Melaka (UTeM). All the subjects had normal vision or corrected normal vision. Beforehand, the investigator clarified the experimental procedures and the subjects were given the informed consent in prior to their participation. An ethical approval had been approved by Medical Research and Ethics Committee (MREC) from Ministry of Health Malaysia. The subject was seated on a back-rested chair to get the maximum comfort during the experiment. The computer display was located 1 meter away from the subject's eyes. EEG data acquisition began by attaching the electrodes onto the subject's scalp. The black and white pictures will display one-by-one and the subjects were asked to recognize the password picture. The subjects were required to click the mouse immediately upon the password picture is displayed. A total of 150 trials were recorded for each session, which are 60 trials of selected password picture and 90 trials with random picture from 260 pictures excluded the password picture. The 150 trials were displayed randomly to the subject. The main purpose for this is to increase the signal-to-noise ratio by averaging the total trials. The Inter-Stimulus Interval (ISI) for each trial was set to 1.5 seconds and the picture was remained on the computer screen for 1 second followed by 1.5 seconds of white blank screen.

EEG signals recording was carried out in three different environment conditions: (a) a quiet condition; (b) a low distraction condition; and (c) a high distraction condition. It is to simulate the real-world environment. For the low distraction condition, an audio clip with consistent office noise effects was played through an audio speaker and the sound level is approximately 55 decibel (dB). On the other hand, for the high distraction condition, an audio clip with inconsistent office noise effects such as noise from phone ringing, printer printing, and etc. was also played through the audio speaker with the sound level approximately 70 dB. The electrodes used to record the EEG signals were 21 electrodes by using Twente Medical Systems International (TMSi) Porti system with sampling frequency 512 Hz. The electrodes are FP1, FPZ, FP2, F7, F3, FZ, F4, F8, T3, C3, CZ, C4, T4, T5, P3, PZ, P4, T6, O1, OZ and O2. All the scalp electrodes were referred to right earlobe and grounded on right hand in the experiment.

B. Data Pre-Processing and Data Preparation

The raw EEG data are noisy, complex and highly uncertain. Thus, the pre-processing steps must be performed in prior to further analysis. The 3 basic steps for stimulus-locked EEG data are filtering, segmentation and artefact rejection. Filtering plays important role in minimizing the background noise and interference and improving the EEG signals quality. The EEG data obtained was bandpass filtered with a Finite-duration Impulse Response (FIR) filter with the cut-off frequencies of 1 – 30 Hz. In addition, the artefact rejection was used to remove the EEG signals responses with excessive body movements or other types of artefacts with amplitude greater than 100 µV. Thus, the trials with amplitude greater than 100 µV were discarded and hence cause the missing values of the particular channels.To evaluate the performance of the proposed similarity matching method, we should know the real values of the missing values. In this experiment, we generated 20% of the missing values in the original observed data to verify the efficiency of missing values imputation.

C. Wavelet Phase Stability (WPS) [19]

Wavelet phase stability (WPS) employs the wavelet-based measure that gives the phase information. It can prove that a reconstructed signal will not suffering from a degradation of the quality. WPS is used to analyze the synchronization process that is locked to the onset of the stimuli. The moving mean of WPS is defined as follows:

$$\Gamma_{s,\tau}^{m}(\mathcal{F}) = \frac{1}{m}\left|\sum_{n=1}^{m} e^{larg\left((\mathcal{W}_{\psi}f_m)(s,\tau)\right)}\right| \quad (2)$$

Where, $m = 1, \dots, M$ and $\Gamma_{s,\tau}^{m}(\mathcal{F})$ measures the mean of the degree of clustering of the angular distribution for certain s and τ for M trials. The value of WPS ranges from 0 to 1; where 1 indicates the perfect phase stability. The smaller the value of WPS, the poorer the phase stability. In this study, we calculated the WPS for the original data, the imputed data using similarity matching method and the imputed data by mean substitution method. Beforehand, there are some parameter setting to be set. We used the 4th derivative of the Gaussian function and the scale parameter was set to 40.

D. Statistical Test

Paired sample t-test is a statistical test which used the comparison of mean from different sources in a dataset. In this study, we used the paired sample t-test to perform the significant test on the amplitude and WPS between the similarity matching method and the mean substitution method respectively. Apart from that, we have also used the paired sample t-test to perform the statistical test on the amplitude between the original data and the imputed data. Paired sample t-test is calculated by comparing the average difference between the samples ($\bar{D}$) to the expected difference between population means (μ_D), and then takes into account the standard error of the differences ($S_D/\sqrt{N}$). The null hypothesis is true if and only if there is no difference between the population mean [20]. The statistical test shows significant different when the *p*-value is less than 0.05.

$$t = \frac{\bar{D}-\mu_D}{S_D/\sqrt{N}} \tag{3}$$

Statistical test is necessary to validate the experimental results. In this study, we compared the amplitude between the original data and the imputed data using similarity matching method; and the amplitude between the original data and the imputed data using mean substitution method. Besides, we also compared the value of WPS between the original data and the imputed data using similarity matching method, and the value of WPS between original data and the imputed data using mean substitution method. It is because the phase information is proven better than the amplitude information.

V. Experimental Results and Discussion

In this section, the experimental results are presented and discussed. The experimental results were validated from four different perspectives, i.e. (1) the comparison of amplitude between the original data and the imputed data using the proposed similarity matching method; (2) the comparison of amplitude between the original data and the imputed data using the mean substitution method; (3) the comparison of WPS between the original data and the imputed data using the similarity matching method; (4) the comparison of WPS between the original data and the imputed data using the mean substitution method. Fig. 2 shows the comparison of grand average amplitude of the original data, the imputed data using the similarity matching method, and the imputed data using mean substitution method. Meanwhile, Fig. 3 shows the statistical test of grand average in amplitude between the original data and the imputed data by using the similarity matching method and the mean substitution method. Both the similarity matching method and the mean substitution method achieved good results. In this study, non-significant different specifies a better approximation of imputation data towards its original form. The imputed data in most of the trials, 23 trials out of a total of 41 trials are significantly close to the original data. However, different methods recorded different sets of non-significantly distinct pairs in the experiment. A total of 16 pairs treated by both of the comparison methods, as shown in bold style, shared the same non-significant validation results to their original data points. On the other hands, an additional of 7 trials treated by similarity matching method, as shown in blue color style, namely trial 1, 12, 31, 33, 35, 37, and 41, are considered close to the original data. A different set of 7 trials treated by mean substitution method, as shown in green color style, namely trial 3, 6, 9, 16, 17, 18, and 30, are also close to the original data. Apart from the evaluation in amplitude, we have also evaluated the quality of the imputed data using wavelet phase stability (WPS). According to [19], the phase of a signal encompasses more significant information as compared to the amplitude. Fig. 4 and Fig. 5 show the comparison of WPS and statistical test between the original data and the imputed data treated by similarity matching method and mean substitution method respectively. We can visually observe that the imputed data by similarity matching imputation method is closer to the original data. The statistical *p*-value threshold at 0.05 is shown as the horizontal dashed line in Fig. 5. There are only 7 trials, out of 41 trials, showed non-significant different between the original data and the imputed data. A total of 6 trials treated by similarity matching method, namely trial 8, 13, 14, 15, 21 and 32, are considered close to the original data. However, only 2 trials out of 41 trials treated by the mean substitution method, namely trial 21 and 23, are considered close to the original data. The proposed similarity matching method is able to treat 9.75% more missing value trials, with significantly better imputation value, than the mean substitution method.

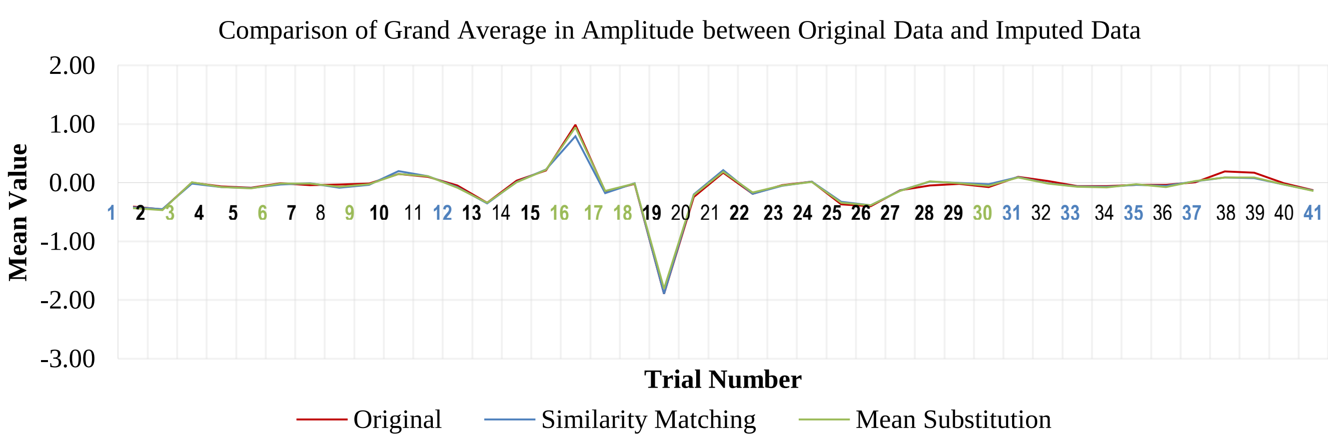

Fig. 2. Comparison of Grand Average in Amplitude between Original Data and Imputed Data.

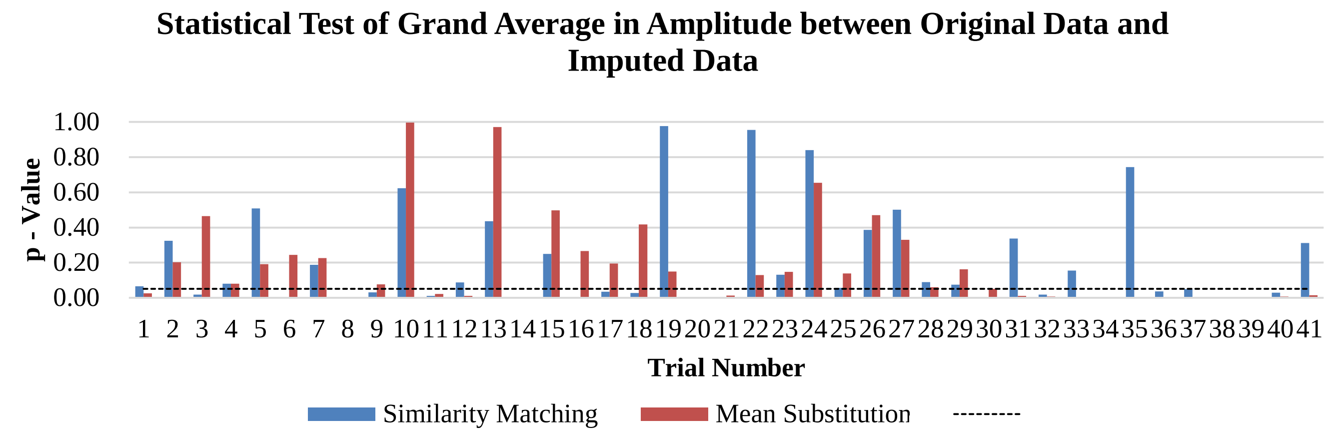

Fig. 3. Statistical Test of Amplitude between Original Data and Imputed Data. Note that the Horizontal Dashed Line in the Figure Indicates the Significant Level p – Value < 0.05.

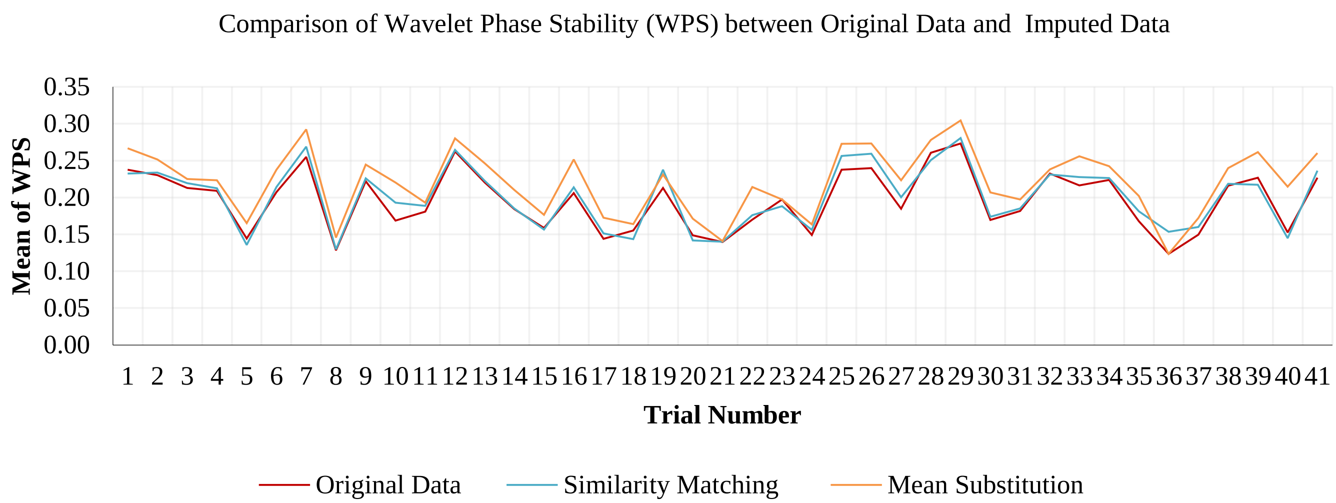

Fig. 4. Comparison of Wavelet Phase Stability (WPS) between Original Data and Imputed Data.

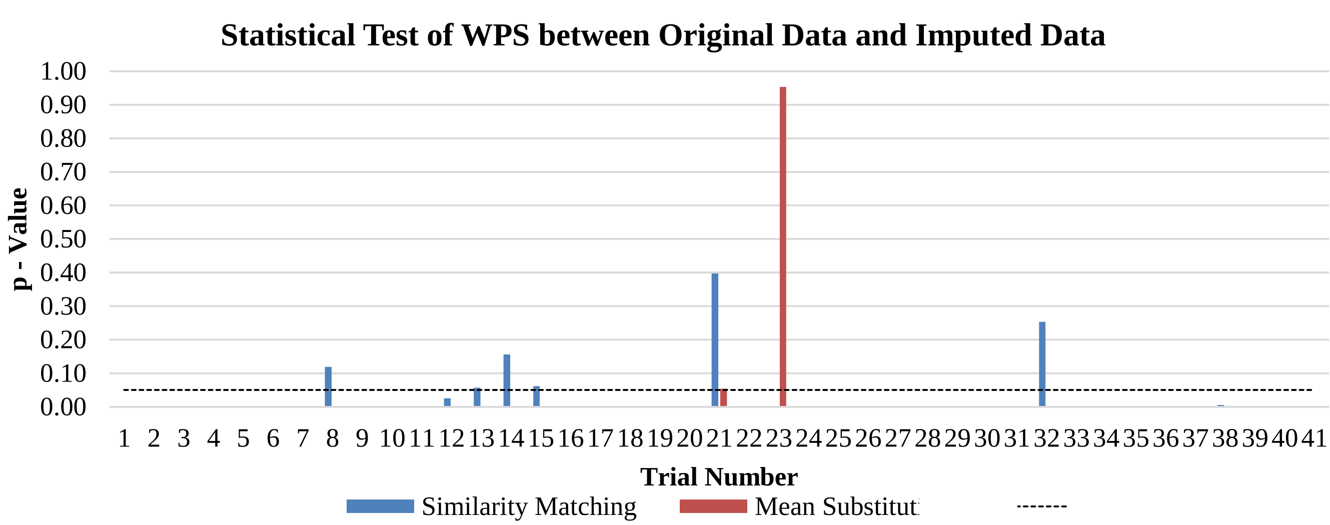

Fig. 5. Statistical Test of WPS between Original Data and Imputed Data. Note that the Horizontal Dashed Line in the Figure Indicates the Significant Level p – Value < 0.05.

TABLE I. MEAN DIFFERENCE OF WPS

Trial	Similarity Matching	Mean Substitution
1	**0.0050**	0.0292
2	**0.0037**	0.0216
3	**0.0063**	0.0120
4	**0.0032**	0.0144
5	**0.0084**	0.0210
6	**0.0068**	0.0302
7	**0.0140**	0.0373
8	**0.0016**	0.0175
9	**0.0041**	0.0224
10	**0.0246**	0.0520
11	**0.0079**	0.0122
12	**0.0023**	0.0178
13	**0.0022**	0.0262
14	**0.0011**	0.0262
15	**0.0022**	0.0176
16	**0.0078**	0.0456
17	**0.0077**	0.0289
18	0.0119	**0.0086**
19	0.0244	**0.0182**
20	**0.0069**	0.0224
21	**0.0005**	0.0010
22	**0.0064**	0.0443
23	0.0091	**0.0000**
24	**0.0068**	0.0141
25	**0.0188**	0.0352
26	**0.0194**	0.0334
27	**0.0157**	0.0387
28	**0.0100**	0.0172
29	**0.0073**	0.0311
30	**0.0043**	0.0373
31	**0.0035**	0.0154
32	**0.0010**	0.0056
33	**0.0116**	0.0396
34	**0.0029**	0.0188
35	**0.0133**	0.0342
36	0.0298	**0.0000**
37	**0.0101**	0.0224
38	**0.0025**	0.0235
39	**0.0099**	0.0346
40	**0.0077**	0.0620
41	**0.0094**	0.0337
Average	**0.0086**	**0.0250**

The mean difference of the WPS between the original data and the imputed data was evaluated to further validate the performance of both the comparison methods. Refer to Table 1. The values in bold style indicate the lower mean difference of WPS as compared to the other imputation method. The lower the mean difference between the original data and the imputed data, the better the performance of the imputation method. The similarity matching method is superior than the mean substitution method from 37 comparisons out of the total of 41 pairs. In opposite, the mean substitution method has outperformed the proposed similarity matching method in merely 4 comparison pairs from the perspective of WPS mean difference. The average of the mean difference of similarity matching method was recorded at 0.0086 only, which is 0.0164 lower than the mean substitution method.

VI. CONCLUSION

This study embarked on the motivation of treating the missing values in EEG dataset. The fundamental concept of the proposed similarity matching imputation method lies on the hypothesis of inducing the best approximated value from other complete trials as replacement. The experimental results have proven that the proposed method is better than its benchmarking mean substitute imputation method in reconstructing the EEG signals to its original form. However, we have fixed the missing data rate to 20% in this study. Hence, it is necessary to further evaluate the robustness of the proposed method in dealing with different rate of missing values in EEG dataset.

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REFERENCES

[1] H. Banville and T. H. Falk, “Recent Advances and Open Challenges in Hybrid Brain-Computer Interfacing: A Technological Review of Non-Invasive Human Research,” Brain Comput. Interfaces, vol. 3, no. 1, pp. 9–46, 2016.

[2] I. Jayarathne, M. Cohen, and S. Amarakeerthi, “Survey of EEG-based biometric authentication,” in 2017 IEEE 8th International Conference on Awareness Science and Technology (iCAST), 2017, pp. 324–329.

[3] I. Nakanishi, K. Ozaki, and S. Li, “Evaluation of the Brain Wave as Biometrics in a Simulated Driving Environment,” in IEEE International Conference Proceedings in Biometrics Special Interest Group (BIOSIG), 2012, pp. 351–361.

[4] M. Teplan, “Fundamentals of EEG Measurement,” Meas. Sci. Rev., vol. 2, no. 2, pp. 1–11, 2002.

[5] R. Little and D. Rublin, Statistical Analysis with Missing Data, Second Edi. A John Wiley & Sons, Inc., 1987.

[6] I. Pratama, A. E. Permanasari, I. Ardiyanto, and R. Indrayani, “A Review of Missing Data Handling Methods on Time-Series Data,” in International Conference on Information Technology Systems and Innovation, 2016, pp. 2349–3968.

[7] M. I. R. Tokle, “Comparison of Missing Data Imputation Methods for Improving Detection of Obstructive Sleep Apnea,” 2017.

[8] S. H. Kim, H. J. Yang, and K. S. Ng, “Incremental expectation maximization principal component analysis for missing value imputation for coevolving EEG data,” J. Zhejiang Univ. Sci. C (Computers Electron., vol. 12, no. 8, pp. 687–697, 2011.

[9] C. SieluZycki and P. Kordowski, “Maximum-likelihood estimation of channel-dependent trial-to-trial variability of auditory evoked brain responses in MEG,” Biomed. Eng. Online, vol. 13, no. 1, pp. 1–19, 2014.

[10] A. Zuquete, B. Quintela, and J. P. Silva Cunha, "Biometric Authentication using Brain Responses to Visual Stimuli," in International Conference on Bio-inspired Systems and Signal Processing, 2010, pp. 103–112.

[11] S. H. Liew, Y. H. Choo, and Y. F. Low, "Fuzzy-Rough Nearest Neighbour Classifier for Person Authentication using EEG Signals," in Proceedings of 2013 International Conference on Fuzzy Theory and Its Application, 2013, pp. 316–321.

[12] I. B. Barbosa, K. Vilhelmsen, A. Van Der Meer, V. Der Weel, and T. Theoharis, "EEG Biometrics : On the Use of Occipital Cortex Based Features from Visual Evoked Potentials," in Norsk Informatikkonferanse (NIK), 2015, pp. 1–11.

[13] B. C. Armstrong, M. V Ruiz-Blondet, N. Khalifian, K. J. Kurtz, Z. Jin, and S. Laszlo, "Brainprint: Assessing the uniqueness, collectability, and permanence of a novel method for ERP biometrics," Neurocomputing, vol. 166, pp. 59–67, 2015.

[14] S. H. Liew, Y. H. Choo, Y. F. Low, and Z. I. Mohd Yusoh, "EEG-based biometric authentication modelling using incremental fuzzy-rough nearest neighbour technique," IET Biometrics, vol. 7, no. 2, pp. 145–152, 2018.

[15] J. Fell, "Cognitive neurophysiology: Beyond averaging," Neuroimage, vol. 37, no. 4, pp. 1069–1072, 2007.

[16] "Practical Introduction to Frequency-Domain Analysis," MathWorks, 2018. [Online]. Available: https://www.mathworks.com/help/signal/examples/practical-introduction-to-frequency-domain-analysis.html. [Accessed: 26-Oct-2018].

[17] A. V. Oppenheim and J. S. Lim, "The Importance of Phase in Signals," Proc. IEEE, vol. 69, no. 5, pp. 529–541, 1981.

[18] X. Ni and X. Huo, "Statistical interpretation of the importance of phase information in signal and image reconstruction," Stat. Probab. Lett., vol. 77, no. 4, pp. 447–454, 2007.

[19] Y. F. Low and D. J. Strauss, "A performance study of the wavelet-phase stability (WPS) in auditory selective attention," Brain Res. Bull., vol. 86, pp. 110–117, 2011.

[20] A. Field, Discovering Statistics using SPSS, 3rd Editio. Sage Publications, 2009.

Topology-Aware Mapping Techniques for Heterogeneous HPC Systems: A Systematic Survey

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***Abstract*—At the present time, the modern platforms of high-performance computing (HPC) consists of heterogeneous computing devices which are connected through complex hierarchical networks. Moreover, it is moving towards the Exascale era and which makes the number of nodes to increase as well as the number of cores within a node to increase. As a consequence, the communication costs and the data movement are increasing. Given that, the efficient topology-aware process mapping has become vital to efficiently optimize the data locality management in order to improve the system performance and energy consumption. It will also decrease the communication cost of the processes by matching the application virtual topology (exploited by the system for assigning the processes to the physical processor) to the target underlying hardware architecture called physical topology. Additionally, improving the locality problem which is one of the most challenging issues faced by the current parallel applications. In this survey paper, we have studied various topology-aware mapping techniques and algorithms.**

Keywords—Virtual topology; physical topology; topology-aware mapping; parallel applications; communication pattern

I. Introduction

Good topology-aware process mapping has an acute role in improving the performance of the parallel applications in high-performance computing (HPC) as well as the energy consumption, considering the increasing hierarchical, heterogeneous and complex nature of the current and future high-performance computing (HPC) platforms. The "Heterogeneous" term refers to non-symmetry in a few or several system aspects. The heterogeneity appears in several parts such as; networks and can emerge from hardware heterogeneity (CPUs, GPUs, FPGAs), software heterogeneity (Compilers, operating system, libraries, etc.) and the network topology complexity [1]. For that matter, the applications of high-performance computing need to adapt the heterogeneity platforms to optimum execution.

As an illustration, the topology-aware process mapping is a way of carrying out a particular task to enhance parallel application execution by decreasing the communication cost of processes by matching the application of virtual topology (exploited by the system for assigning the processes to the physical processor) to the target underlying hardware architecture called physical topology. One of the advantages of topology-aware mapping is the decreased cost of communication, by matching the application data to the processors that are physically close one to the other.

In order to do a topology-aware process mapping, it is necessary to choose the parallel programming models that help in this matter. To put it another way, the parallel programming model has a valuable help in application execution, because some of the parallel programming models have a mechanism that helps the application to exploit the underlying hardware to improve communication and the locality. Moreover, it will be helpful for virtual topology management to reorganize the processes according to the target underlying hardware architecture. Therefore, the most important parallel programming model is the Message Passing Interface (MPI) which is the standard model of the parallel programming models.

As discussed above, we propose the main three steps to make an efficient topology-aware process mapping, as follows:

1) Develop a virtual topology by gathering the application communication pattern.

2) Develop a physical topology by modeling the underlying hardware architecture.

3) Develop a clever algorithm or technique by matching the numbers of computing elements and the process ranks of the application.

The following architecture explains the previous steps "Fig. 1".

The mapping of topologies is of two types: static and dynamic. In the static approach, the mapping can be done prior to the execution. As for the second approach which is dynamic mapping, it happens at runtime (remap the processes to another processor or core during the runtime) [2].

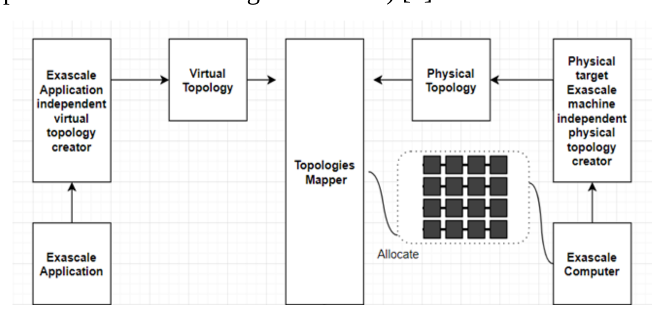

Fig. 1. High-Level Architecture of Topology-Aware Process Mapping.

This paper is organized as follows: section 2 comprises the definitions of the topologies with examples, section 3 includes the previous related work, whilst section 4 discusses the definition of the problem and the section 5 concludes this paper.

II. Topologies Definitions

A. Virtual Topology

The term virtual topology means the dependence among the software processing entitles. These dependencies may be defined as the data that is exchanged between the processes or an access to the memory by the application threads. In other words, the virtual topology refers to the application communication patterns [2]. Furthermore, the virtual topology has several types such as graph topologies and Cartesian topologies. The example of the virtual topology is shown in "Fig. 2"

0 (0,0)	1 (0,1)	2 (0,2)	3 (0,3)
4 (1,0)	5 (1,1)	6 (1,2)	7 (1,3)
8 (2,0)	9 (2,1)	10 (2,2)	11 (2,3)

Fig. 2. Virtual Topology Example, (0.0) is a Coordinate and 0 is a Rank Id.

B. Pysical Topology

Nowadays, the modern machines are increasingly complex, include multiple processors, multi-core processors (socket = package), simultaneous multithreading, NUMA nodes, shared caches, and multiple GPUs, NICs, etc. Similarly, the underlying hardware known as physical topology includes the NUMA memory nodes, cores, simultaneous multithreading, sockets and shared caches [3]. Correspondingly, the application needs to understand the target underlying hardware for optimum execution. The example of the underlying hardware architecture is shown in "Fig. 3".

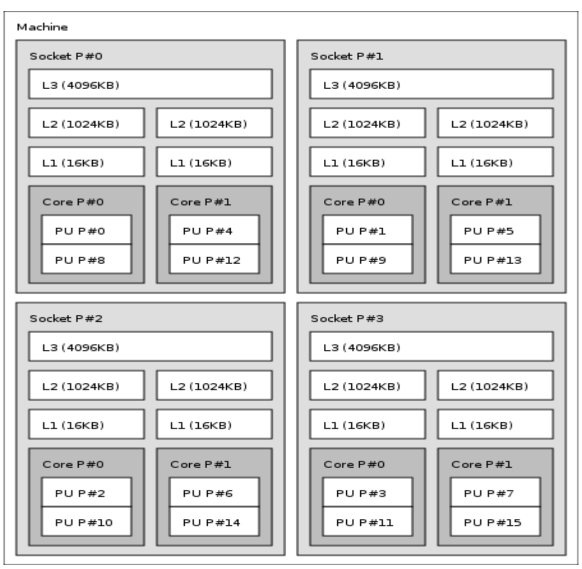

Fig. 3. High-Level Architecture of the Target Machine.

```
Machine:
 NUMANode + Die: Node#0(8GB) Die#0
  L2Cache + Core + L1Cache + SMTproc : L2#0(1MB) Core#0 L1#0(64kB) CPU#0
  L2Cache + Core + L1Cache + SMTproc : L2#4(1MB) Core#1 L1#4(64kB) CPU#4
 NUMANode + Die: Node#1(8GB) Die#1
  L2Cache + Core + L1Cache + SMTproc : L2#1(1MB) Core#0 L1#1(64kB) CPU#1
  L2Cache + Core + L1Cache + SMTproc : L2#5(1MB) Core#1 L1#5(64kB) CPU#5
 NUMANode + Die: Node#2(8GB) Die#2
  L2Cache + Core + L1Cache + SMTproc : L2#2(1MB) Core#0 L1#2(64kB) CPU#2
  L2Cache + Core + L1Cache + SMTproc : L2#6(1MB) Core#1 L1#6(64kB) CPU#6
 NUMANode + Die: Node#3(8GB) Die#3
  L2Cache + Core + L1Cache + SMTproc : L2#3(1MB) Core#0 L1#3(64kB) CPU#3
  L2Cache + Core + L1Cache + SMTproc : L2#7(1MB) Core#1 L1#7(64kB) CPU#7
```

Fig. 4. Hardware Topology Information.

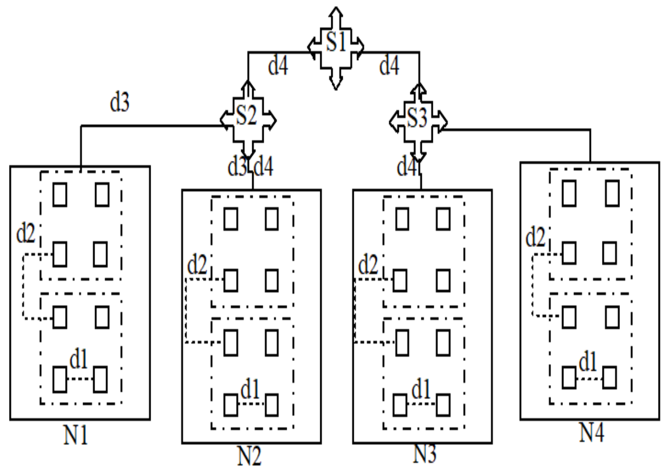

Fig. 5. Physical Topology Distance, d = distince, N = node and s = switch.

Likewise, we can gather the information on the target machine using the topology discovery mechanism as shown in "Fig. 4"

Given that, the physical topology is the hardware affinity known as physical topology distance [4], shown in "Fig. 5".

C. Parallel Programming Model

The main parallel programming models for high-performance computing are OpenMP (which are used for shared memory architecture) and MPI (which are used for distributed memory systems). At the present time, we have several parallel programming models such as OpenCL (Open Computing Language –used for the heterogeneous parallel computing), OpenCV (which has the power to concentrate on the real-time applications) and OpenACC (which is a programming standard and was intended to simplify parallel programming of heterogeneous CPU/GPU systems) [5] [6].

Additionally, in the high-performance computing we can make hybrid parallel programming models to do a specific task that takes the advantages of the shared and distributed memory. "table-1" shows the parallel programming models as well as the systems that implement them [6].

TABLE I. PARALLEL PROGRAMMING MODELS AND THEIR IMPLEMENTED SYSTEMS

Programming Model	**Example Programming Systems**
Shared memory	
Dynamic scheduling, nested bulk synchronous	OpenMP, TBB, Cilk++
Dynamic scheduling, the general synchronization	pthreads, OpenMP, TBB, Cilk++
Distributed memory	
Bulk-synchronous	BSP, MPI with collectives/barriers, X10 with clocks
Static scheduling, two-sided communication	MPI point-to-point
Static scheduling, one-sided communication	MPI RDMA, SHMEM, UPC, Fortran
Hybrid scheduling (static across nodes, dynamic within nodes)	MPI+OpenMP, DPLASMA
The local view of data and control	MPI, Fortran
The local view of control, global view of data	UPC, Global Arrays
Global view of data and control	OpenMP, Chapel
CoProcessor/Accelerator separate memory	OpenCL, OpenACC, CUDA
Domain-specific languages and libraries	PETSc, Liszt, TCE

D. Parallel Computing Systems

The modern engineering and science applications require a massive amount of computing because it deals with very complex problems. In order to address these complex problems, we need powerful computing systems such as parallel computing. As an illustration, parallel computing is one of the most powerful computations that can make numerous calculations and execute the processes, simultaneously. To put it differently, large problems can often be divided into smaller ones, and then solved at the same time [7].

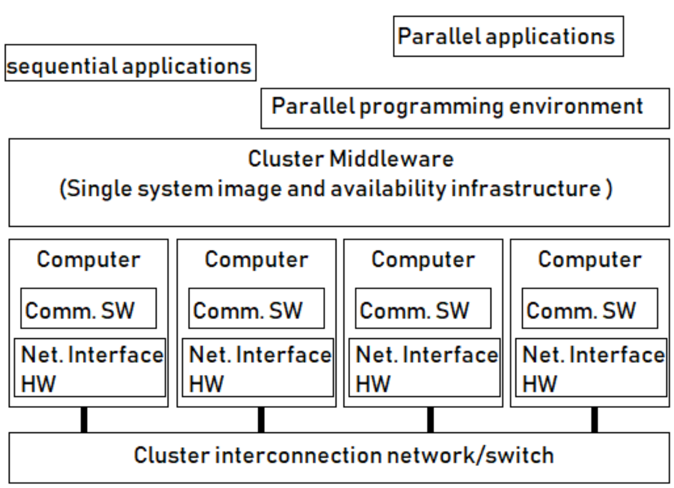

Fig. 6. High-Level Architecture of Parallel Computing.

On the negative side and in our case, the programmers face many challenges with the parallel systems such as the complex hierarchy of the hardware, methods to minimize the memory usage by the applications, less communication, and data locality.

The high-level architecture of parallel computing is shown in “Fig. 6”.

III. BACKGROUND AND RELATED WORK

The modern platforms of high-performance computing (HPC) consists of heterogeneous computing devices which are connected through complex hierarchical networks. In order to efficiently execute the data-parallel Exascale applications on that platforms, we need to balance a load of the processors, as well as minimize the communications cost. To achieve that we need to separate the data among processors whilst considering their speed. The second can be optimized by decreasing the communications volume by mapping the application data to the processors that are physically close to one another. Moreover, the topology information will be used as the guide to improve the communications in the hierarchical-heterogeneous platforms.

Nowadays, as we are moving towards the Exascale, the topology-aware process mapping is becoming an important approach to improve the performance and reduce the power consumption of Exascale applications. Accordingly, most researchers in this area have proposed many techniques and approaches for finding the best and efficient topology-aware process mapping. As can be seen, every researcher focusses on different aspects of how to build the efficient mapping of the process-to-processor. It is also noticed that most researchers come up with their own mapping approach and try to make efficient topology-aware process mapping.

Briefly, we have summarized all the previously done studies on the topology-aware process mapping problem. To begin with, Emmanuel et al. [7] have proposed techniques to deal with NUMA node clusters for reducing the communications costs. The proposed techniques can gather the information of the application communication pattern and the details of the target machine hardware, and then compute the relevant ranks of reordering application process. Eventually, the new ranks are used for reducing the application communication costs. As a matter of fact, those techniques are based on the TreeMatch algorithm. This algorithm deals with resource binding technique such as computing unit numbers and the rank reordering technique as the new MPI ranks. However, the algorithm design is as follows:

```
Input: T // The topology tree
Input: m // The communication matrix
Input: D // The depth of the tree
groups[1..D − 1]=∅ // How nodes are grouped on each level
foreach depth← D − 1..1 do // We start from the leaves
    p ← order of m
    // Extend the communication matrix if necessary
    if p mod arity(T, depth − 1) ≠ 0 then
        m ←ExtendComMatrix(T,m,depth)
    groups[depth]←GroupProcesses(T,m,depth)// Group
    processes by communication affinity
    m ←AggregateComMatrix(m,groups[depth])    // Aggregate
    communication of the group of processes
MapGroups(T,groups) // Process the groups to built the
mapping
```

The work by Guillaume et al. [8] has modified the function of the MPICH2 implementation of the MPI_Dist_graph_create for reordering the process ranks of MPI. The objective is to create a map between the hardware topology and the application communication pattern. Nonetheless, this modification is achieved through two main but different methods, the core binding, and the rank reordering.

Balaji et al. [9] say that the varying mapping of the application on the large-scale systems is an important factor that affects the overall performance. Furthermore, the authors have highlighted the mapping impact on the application performance of "the IBM Blue Gene/Q systems" with the network topology of the 5D torus.

Francois et al. [3] have observed that the number of cores, memory nodes, and shared caches are increasing, thus, making the hardware topology very complex. Moreover, the high-performance computing applications need to be careful while adapting their placement to the target underlying hardware. For that matter, they proposed the hardware locality (HWLOC) tool that gathers the information of the physical topology including caches, processors, and memory nodes which makes it visible to the application as well as the runtime systems. This tool is used by the most important parallel programming models such as OpenMP & MPI.

Joshua et al. [10] have proposed a Locality-Aware Mapping algorithm to distribute the parallel application processes across processing resources in the high-performance computing system. This algorithm is capable of dealing with both, heterogeneous and homogeneous hardware systems. In the final analysis, they implemented it on the OpenMPI.

Bhatele et al. [11] have proposed various heuristics that are based on the hop-bytes metrics for mapping the graphs of irregular communication to the mesh topologies. Their heuristics try to place the communicating processes close to one another.

Mercier et al. [12] built the topology-aware mapping, based on the Scotch library. Generally speaking, they used the virtual topology (The application communication pattern) and the physical topology as a complete weighted graph.

Rashti et al. [13] have extracted the network topologies and intra-node using the InfiniBand tools and HWLOC library respectively. To develop the undirected graph with edges that represent the performance of the communication between cores depending on their distances. Then, this mapping technique is executed by the Scotch library.

Ito et al. [14] have proposed a similar mapping technique but using the existing bandwidth between the nodes measured at the time of execution for assigning the edge weights in the graph of the physical topology. Again, the method of this mapping technique was implemented by the Scotch library.

Chung et al. [15] proposed an efficient technique based on the hierarchical mapping which partitions the physical topology graphs and the process into numerous super nodes. Also, the very first mapping assigns process topology graph supernodes to the equivalent peers in the graph of the physical topology.

Cyril Bordage et al. [16] proposed a Netloc tool for collecting the physical topology that is integrated with a Scotch practitioner for computing the topology-aware MPI process placement. However, their experiments were based on the fat-tree machine.

K. B. Manwade et al. [17] proposed a novel technique known as a “ClustMap” for mapping the application and system topologies.

Abhinav Bhatele et al. [18] constructed an automatic mapping framework that can help the developer to automate the application communication pattern and physical topology of the parallel application. In addition, their framework can analyze the process topology to find regular patterns and then identify the communication graphs dimensions for the application.

Jingjin Wu et al. [19] proposed a strategy for the mapping of the hierarchical task that implements inter and intra node mapping. They considered supercomputers with torus network and fat-tree topologies, additionally providing two mapping algorithms. The first can deal with both inter-node and intra-node mapping. The second can partition the nodes of the computation regarding its affinity.

Torsten Hoefler et al. [2] demonstrate a new heuristic based on the graph similarity and shows its utility with the virtual topology on real physical topologies. In other words, their mapping strategies support the heterogeneous networks and try to reduce the congestion on fat-tree, torus, and the PERCS network topologies for irregular communication patterns.

Subramoni et al. [20] proposed efficient topology mapping on the InfiniBand networks for detecting the InfiniBand network topology and that can be done using the neighbor joining algorithm.

Deveci et al. [21] considered machines with the allocation of the sparse node and then applied a geometric partitioning algorithm to processors and tasks to find the appropriate mapping.

Agarwal et al. [22] proposed a greedy heuristic through the estimation functions that are used to evaluate the mapping decisions effects.

Mohammad et al. [23] used the network/node architecture and graph embedding modules for mapping the application communication topology onto the multi-core clusters physical topology with multi-level networks. As the result, they have got the great improvement in the application communication performance as well as the execution time. In the final analysis, this result is obtained by Micro-benchmark.

IV. Discussions

Aggregated power for computing is recognized as the most recent phenomenon for data-intensive tasks in the 21st century. High-performance computing is able to handle simulation modeling as well as support standard workstations. Through carrying out several computing operations within a reasonable amount of time, high-performance computing is able to counter performance challenges related to limited data sources. This is achieved using high-end specialized hardware that incorporates several units which gather computing power. Additionally, the units use the concept of parallelization to distribute data and operations across the various subsequent levels. This is due to a large amount of data movement and lack of application placement patterns onto the elements of the hardware processing. In short, when we study the process placement, we must focus on the system hierarchy of the high-performance computing (HPC) because the system hierarchy increases more and more, and the nodes become multi-levels of memory (non-volatile memory, faster but smaller MCDRAM for KNL, standard DRAM, etc.) and composed of multicore processors. Moreover, the network that connects these nodes has very complex topology [24]. Thus, it is concluded that the process placement is not an easy task in case of very effective process placement. Additionally, the topology mapping or process placement has a critical role on the parallel application performance and we need to map these processes onto processors carefully. Therefore, the goal of every successful mapping algorithm relies on how to reduce the communication costs by carefully mapping the processes that are closest to each other and require most communication. Algorithmically, the mapping process has two kinds; the first one is how the machine computes the messages communication costs and the second one is how the application can describe the computing elements affinity. Because the affinity of the computing entities is very important in case of mapping the processes on the processors which are close to each other.

Lastly, it was witnessed that the topology-aware process mapping is an active research filed. The both, application communication pattern (virtual topology) and the underlying hardware details (physical topology) are not difficult to extract, the main contribution is the topology process mapping algorithm. In fact, we advise the interested researchers to use HWLOC tool to extract the physical topology (underlying hardware details) [3] and use any graph partitioning or MPI ranks reordering for virtual topology [7].

V. Conclusion and Future Work

At the present time, we observe that the number of nodes are increasing, as well as the number of cores within a node are increasing. As a result, the high-performance computing systems are becoming very complex, which leads to the increase in the heterogeneity levels at the communication channels, such as inter-node and intra-node communications. The diversity in the performance through different communication channels in the high-performance computing systems make it significant to think carefully about information of topology at higher levels. The knowledge of topology facilitates to fulfill the effective exploitation of underlying communication channels which leads to an increase in communication performance at the application level. Therefore, the topology-aware process mapping is a necessary approach for improving the performance of communication in high-performance computing systems. In addition, the topology-aware process mapping helps in reducing the lot of congestion that happens in the system hierarchy on several levels. As we know the congestion has its effect on communication performance. Ultimately, based on the previous description we are aiming and focusing on how to improve the HPC systems performance without adding any extra overhead and/or the power consumption. We will focus on the mapping between the nodes (internode) and the mapping within a node (intra-node) for achieving the efficient performance as much as we can. Given that, we have proposed an efficient new technique based on hybrid parallel programming model as a tri-model for mapping virtual topology onto physical topology to optimize the data locality management for increasing the performance and reducing the power consumption in the HPC systems. This approach can optimize the mapping of inter-node by taking into account the communication pattern of the inter-node and the network topology. Moreover, it will optimize the intra-node mapping whereby the node physical topology and the corresponding communication pattern of intra-node. According to the mapping process, we will consider the load balancing within nodes as the nodes will be heterogeneous.

References

[1] Tania Malik, (2016) Topology-aware Optimization of Communication Cost of Parallel Applications in Heterogeneous HPC Systems, PhD. University College Dublin

[2] Torsten Hoefler, Emmanuel Jeannot, Guillaume Mercier. An Overview of Process Mapping Techniques and Algorithms in High-Performance Computing. Emmanuel Jeannot and Julius Zilinskas. High Performance Computing on Complex Environments, Wiley, pp.75-94, 2014.

[3] F. Broquedis et al., "hwloc: A Generic Framework for Managing Hardware Affinities in HPC Applications," 2010 18th Euromicro Conference on Parallel, Distributed and Network-based Processing, Pisa, 2010, pp. 180-186.

[4] M. J. Rashti, J. Green, P. Balaji, A. Afsahi, and W. Gropp. Multi-core and network aware MPI topology functions. In Proc. European MPI Users' Group Meeting (EuroMPI), pages 50–60, 2011.

[5] M.D. Chougule, P. H. Gutte, "Parallel Programming Models: A Systematic Survey" in an International journal IJCSIT of July issue 2014.

[6] W. Gropp, M. Snir, "Programming for Exascale Computers", Computing in Science & Engineering, 2013, 15(6), P.27-35

[7] Jeannot, E., Mercier, G. and Tessier, F., 2014. Process placement in multicore clusters: Algorithmic issues and practical techniques. Parallel and Distributed Systems, IEEE Transactions on, 25(4), pp.993-1002.

[8] G. Mercier and E. Jeannot, Improving MPI Applications Performance on Multicore Clusters with Rank Reordering, EuroMPI, p.3949, 2011.

[9] P. Balaji, R. Gupta, A. Vishnu, and P. Beckman. "Mapping communication layouts to network hardware characteristics on massive-scale blue gene systems". Computer Science-Research and Development, 26(3-4):247–256, 2011.

[10] Joshua Hursey , Jeffrey M. Squyres , Terry Dontje, Locality-Aware Parallel Process Mapping for Multi-core HPC Systems, Proceedings of the 2011 IEEE International Conference on Cluster Computing, p.527-531, September 26-30, 2011

[11] A. Bhatel´e and L. V. Kal´e. Heuristic-based techniques for mapping irregular communication graphs to mesh topologies. In International Conference on High Performance Computing and Communications (HPCC),pages.765–771,2011.

[12] G. Mercier and J. Clet-Ortega. Towards an efficient process placement policy for MPI applications in multicore environments. In Recent Advances in Parallel Virtual Machine and Message Passing Interface (EuroPVM/MPI), pages 104–115. 2009.

[13] M. J. Rashti, J. Green, P. Balaji, A. Afsahi, and W. Gropp. Multi-core and network aware MPI topology functions. In Proc. European MPI Users' Group Meeting (EuroMPI), pages 50–60, 2011.

[14] S. Ito, K. Goto, and K. Ono. Automatically optimized core mapping to subdomains of domain decomposition method on multicore parallel environments. Computers & Fluids, 80(0):88–93, 2013.

[15] I.-H. Chung, C.-R. Lee, J. Zhou, and Y.-C. Chung, "Hierarchical mapping for HPC applications," in Proc Workshop Large-Scale Parallel Processing, 2011, pp. 1810–1818.

[16] Cyril Bordage, Clément Foyer, Brice Goglin. Netloc: a Tool for Topology-Aware Process Mapping. Euro-Par 2017: Parallel Processing Workshops, Aug 2017, Santiago de Compostela, Spain.

[17] K. B. Manwade and D. B. Kulkarni, "ClustMap: A Topology-Aware MPI Process Placement Algorithm for Multi-core Clusters", in Intelligent Computing and Information and Communication, Jan 2018, pp. 67-76

[18] A. Bhatelé, G. R. Gupta, L. V. Kalé and I. H. Chung, "Automated mapping of regular communication graphs on mesh interconnects," 2010 International Conference on High Performance Computing, Dona Paula, 2010, pp. 1-10.

[19] Wu, Jingjin and Xiong, Xuanxing and Lan, Zhiling "Hierarchical Task Mapping for Parallel Applications on Supercomputers", in J. Supercomput, 2015, pp. 1776-1802

[20] Subramoni H, Potluri S, Kandalla K, Barth B, Vienne J, Keasler J, Tomko K, Schulz K, Moody A, Panda D (2012) Design of a scalable infiniband topology service to enable network-topology-aware placement of processes. In: Proceedings of international conference on high performance computing, networking, storage and analysis, pp 1–12.

[21] M. Deveci, K. Kaya, B. Uc¸ar, and U. V. C¸ ataly ¨ urek, "Fast and high ¨ quality topology-aware task mapping," in 2015 IEEE Intl. Parallel Distrib. Proc. Symp. (IPDPS), 2015, pp. 197–206.

[22] Agarwal T, Sharma A, Laxmikant A, Kale LV (2006) Topology-aware task mapping for reducing communication contention on large parallel machines. In: Proceedings of IEEE international symposium on parallel and distributed processing (IPDPS)

[23] Mehmet D. et al., "Exploiting Geometric Partitioning in Task Mapping for Parallel Computers", Proceedings of the 2014 IEEE 28th International Parallel and Distributed Processing Symposium, p.27-36, May 19-23, 2014

Detecting and Classifying Crimes from Arabic Twitter Posts using Text Mining Techniques

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Abstract—Crime analysis has become a critical area for helping law enforcement agencies to protect civilians. As a result of a rapidly increasing population, crime rates have increased dramatically, and appropriate analysis has become a time-consuming effort. Text mining is an effective tool that may help to solve this problem to classify crimes in effective manner. The proposed system aims to detect and classify crimes in Twitter posts that written in the Arabic language, one of the most widespread languages today. In this paper, classification techniques are used to detect crimes and identify their nature by different classification algorithms. The experiments evaluate different algorithms, such as SVM, DT, CNB, and KNN, in terms of accuracy and speed in the crime domain. Also, different features extraction techniques are evaluated, including root-based stemming, light stemming, n-gram. The experiments revealed the superiority of n-gram over other techniques. Specifically, the results indicate the superiority of SVM with tri-gram over other classifiers, with a 91.55% accuracy.

Keywords—Crimes; text mining; classification; features extraction techniques; arabic posts; twitter

I. Introduction

Ssecurity is a very important element of life. Our most important needs cannot be met unless we are secure. Therefore, security is a necessity in human life that allows us to collectively or individually achieve our goals. Nowadays, with an increasing number of Internet users and the ease of accessibility afforded by the expansion of mobile data technology, there is a corresponding increase in the volume of information related crimes to utilize and analyze. Most of this information is unstructured, in the form of "free text." This trend has led to an increased importance upon devising methods to manage unstructured data.

Particularly in the mobile world, social media has become one of the most popular means of communication for private messages, pictures, and video, and various social networking sites have even become sources of global news, both social and political. Currently, there are many social media sites, such as Facebook, Twitter, and Snapchat Twitter is one of the most common social networking sites for casual chats, sharing photos and ideas, and the transfer of information and news through text, limited to 140 characters,called "tweets". The number of users of Twitter— around 500 million— are tweeting approximately 340 million times per day. Many people in Arabic countries are using Twitter regularly, which makes it suitable for this study. Due in part to its small, readable tweets, Twitter has become an important means of communicating news of criminal activity.

In Saudi Arabia the official spokesman for the Ministry of the Interior stated in a 2015 news conference that the crime rate in Saudi Arabia had reached 270 crimes per day, about 100, 000 crimes annually. The volume of this activity places extreme burdens on the State to adequately analyze crime data [1].This requires the careful study and analysis of crime, its escalation, and its geographic spread, in order to objectively develop strategies to slow the crime rate. A major challenge faced by law enforcement is that there is too much information concerning criminal activity as a result of the increase in the number of crimes, technological advances, and increasing population density. The sheer amount of data requires significant time and effort to analyze and utilize.

Rising crime rates coupled with the spread of this news through social networking sites was a major motivation for the current study. In fact, the public was made aware of many of these events through such platforms. The main objective of this research, therefore, is to extract usable, credible information in order to identify the nature of crimes and to assist law enforcement with future crime prevention, thereby contributing to ensuring the security of humanity. Text classification poses a challenging task for the Arabic language, due to its richness and complexity. In this research, we attempt to address this issue by performing an intensive comparison to assess different machine learning algorithms and the impact of various feature extraction techniques on accuracy. In particular, this research involves four classification algorithms, including SVM, DT(C4.5), CNB, and KNN, in terms of accuracy, speed of training, and execution time. Also, four well-known feature extraction techniques are evaluated, including root-based stemming, light stemming, characters-based n-gram, and words-based n-gram for the Arabic language.

The research seeks answers to the following questions:

- How can we detect and classify crimes from Twitter posts?
- What is the best algorithm for classification, from selected machine learning algorithms for the Arabic language in general and in the crime domain in particular?

- What is the best method for features extraction from selected techniques for the Arabic language in general and the crime domain in particular?

The research is organized as follows: section 2 discusses overview of text mining while section 3 presents background information on Arabic language, section 4 descriptions of crime categories, section 5: presents related work section 6 overview of machine learning algorithms, section 7 illustrates of the methodology and data collection, section 8 presents of the experiments and results, and the conclusion and future work section 9.

II. Text Classification

Text mining aims to take advantage of natural language to find new, previously unknown, relationships between a large volume of ambiguous text documents that contain a large number of words and various grammatical structures [2]. The importance of appropriate document categorization has increased dramatically over the last two decades, due to the explosion of web-based contents. According to Hotho [2] and Vandana [3] 85% of information is stored as text in form reports, news, etc. This clearly demonstrates the utility of text mining to classify document to desired category according to its contents. Before beginning of the text mining, it is necessary to transform each document into a more appropriate form for text classification, this is called pre-processing. The pre-processing generally covers the process of structuring the input text in steps, such as tokenization, eliminating stop words, feature extraction and features weighting. It is a critical step in text classification especially and has a large impact positively or negatively on classification accuracy [3] [4].

Features extraction is important step to mitigate language complexities, especially in Arabic language. Features extraction includes different techniques such as stemming that based on morphological analysis. Stemming takes advantage of the fact that most word variations have similar semantic interpretations and can be handled as one root word [5] [6].

In Arabic, stemming is separated into two types based on morphological analysis: root –based stemming, and light stemming. The basic idea of stemming is to reduce a given word to its root, while light stemming only seeks to remove common affixes in order to produce the stem of a given word, rather than producing a root. For example, in stemming, all of these words— المدرسه (school), مدرس (teacher), and الدروس (lessons) — share a stem, though they have different meanings. On the other hand, light stemming reduces المدرسين, "المدرسون " which means “teachers,” to (مدرس) which means “teacher” [6] [7]. Khoja’s stemmer [8] one of the most widely Arabic root-based stemmer. It is a dictionary-based algorithm that removes affixes and extracts the root word by matching the residual word with patterns. The main drawbacks of this method are its dependence on a dictionary, which must be updated on an ongoing basis, and it replaces the vowel characters with the letter “و” which could lead to mistakes in the extracted root [7]. The Larkey stemmer, light 10, is well-known light stemmer that seeks to remove most frequent suffixes and prefixes [9].

Stemming is useful for extracting features and constructing feature vectors, as well as for enhancing retrieval performance, due to the reduction of variations of a given word to its grammatical root. Stemming also reduces the complexity of the indexing structure, which leads to an improvement in the overall performance [5] [10]. In some cases, however, stemming can reduce the performance of classification, because many conflicting words can have the same root. This reflects the main benefit of light stemming, which focuses on the meaning of the word rather than identifying its root. Therefore, light stemming can improve classification performance, as it maintains word meaning, unlike the stemming approach [6].

Rather than extracting roots, some researchers prefer to utilize statistical methods such as n-gram, which is usually used to classify documents without any stemming. The basic idea is to create a profile for each document by generating all possible continuous n-item slices. This method can be used for a single word, in order to generate all possible continuous n-characters slices, or for a single sentence, in order to generate all possible n-words slices. After generating N-grams for all words in a document, the profile is saved, in order to compare word similarity. The main advantages of this method are that it is language-independent and it works very well with files that contain linguistic errors and noise [11] [12].

After completing pre-processing, text documents transform to vectors by calculating terms weight, which are used in the learning phase for machine learning algorithms. The most common method is term frequency–inverse document frequency (TF–IDF). TF–IDF reflects the importance of a word in a document to collection of documents as in the following equation [13]:

$$w_{dt} = tf_{dt} \times idf_t \tag{1}$$

Where tf_{dt} represents the word occurrences in the document divided by the total number of words, and

$$tf_{dt} = \frac{n_{ij}}{\sum_n n_{kj}} \tag{2}$$

idf_t represents the importance of word in documents

$$idf_t = log\frac{|D|}{\{d:t_i \in d\}} \tag{3}$$

III. Arabic Language

The Arabic language is extremely important, as it is the native language of Arabic countries, and the second language for Islamic countries. Arabic is spoken by more than 310 million people as their native language, and more than 250 million people as a second language, according to the Summer Institute of Linguistics (SIL International) statistics for languages and science professional studies [14] . Unlike Romantic and Germanic languages, Arabic language is an agglutinative language written from right to left. It consists twenty-eight different characters: أ ب ت ث ج ح خ د ذ ر ز س ش

ص ض ط ظ ع غ ف ق ك ل م ن ه و. Arabic contains diacritical marks (ḍammah, fataha and kasra,) that may change the meaning, for example, (مدرَسه) means "school" while (مدرِسه) means "teacher". It has many synonyms that are used frequently, such as "الحزن، الغم، الغمة، الأسى", all of them have the same meaning: "a sense of sadness". Arabic has an extremely complex morphology that relies on more than 11,000 roots and 900 patterns listed in largest Arabic dictionary [15].

A root is the core form of a word, something one cannot further analyze without losing the word's meaning. Simply put, it is the word without any additions at the beginning (prefix), in the middle (infix), or at the end (suffix). Usually these additions, called affixes, are added in order to create new words and meanings [4] [7].

IV. Crimes

Before discussing the types of crimes and their classifications, crime must be defined first. Crime is a breach of the rules of society by committing and act that is detrimental to community [16]. In reality, criminality varies from one country to another, and is determined by weighing the openness of a society against its adherence to religious and cultural traditions.

For the sake of this study, we have investigated what kinds of crimes occur in Arab countries. To do so, we have utilized several sources such as the Statistical Yearbook of crimes issued by the Ministry of the Interior in Saudi Arabia. It divided crimes into ten major categories, such as crimes related person, crimes related mind, crimes related money, etc [17]. The second source is the Uniform Crime Reporting (UCR) that was issued by the Federal Bureau of Investigation (FBI) in the U.S. Department of Justice that examines all types of crime in American society in detail [18]. The study constructing a tree representing three levels of crimes. The first level includes detecting crimes in "tweets." The second level divides crimes according to types of victims—property, individuals, or society. Crimes against persons include all of those crimes whose victims are individuals, with the aim of hurting a particular person, such as murder, sex offense, or kidnapping. Crimes against property include all of those crimes whose purpose is usually to get money or property, such as a robbery, bribery, or burglary. Crimes against society are crimes that are aimed at hurting the community in general and usually do not have a specific victim. The last level classifies crimes according to the offense, such as murder, theft, etc.

This study accounts for the customs and traditions in Arabic countries in its tree construction— for example, sex crimes in America are limited to coercive sexual crimes, while in Arabic countries they include both coercive and consensual outside the frame of marriage. Some types of minor offenses were excluded, because they are not typically tweeted, such as driving infractions. Also excluded were crimes that rarely occur in Arabic society, based on the statistics issued by the Ministry of the Interior, such as technical crimes.

V. Related Work

Extensive English-language research has been conducted on text mining. However, there is little research in the Arabic language on text mining in general and even less research concerning specific crimes. To the best of our knowledge, this is the first study that has focused on crime detection and classification in Arabic social networking sites. This section will address two fields: classification in Arabic language and classification in crime domain in general.

A. Classification in Arabic language

The study [19] is a model by Support Vector Machine (SVM) to categorize Arabic documents. In order to improve the performance, Inverse Document Frequency (IDF) is applied. IDF represents the importance of a given word by calculating the word's occurrence in a document against a collection of documents. To reduce high dimensionality of features in documents, Chi Square x^2 statistics are applied to measure independence between feature words within each category, which eliminates the least important features. The authors conducted an experiment on more than 1,500 documents across nine categories. The experiment used SVM and then compared it with other classifiers, such as Naïve Bayes and KNN. The results showed better performance for SVM than other classifiers, where it reached 88.11% accuracy, while Naïve Bayes and KNN reached 84.54% and 72.72% respectively.

The study [20] conducted experiments on Arabic documents to classify them into predefined categories according to the subject of each document. The authors used root-based stemming that introduced by [2] to extract roots in the pre-processing phase. The Naïve Bayes classifier was used for the categorizing phase on 300 documents and the results showed an average accuracy of 62.23% for the documents tested.

In [21], the authors applied a Neural Network, a simulation of a human brain, to classify "Nine Books," which contains a total of 453 documents across 14 different categories. The network had three layers: a layer for the introduction of the documents, a hidden layer containing an activation function, and an output layer for the classification of the documents. In the learning phase, the initial value of weights for each layer is given randomly. It then updates the weights based on the computing error rate, until the best weight values for accuracy are reached. In the experiment, the input layers contained 739 nodes, which was equal to the number of features, while there were only 10 layers in the hidden layer. The output layer contained 14 layers, equal to the amount of categories in the text. The authors used 20 epochs for training, as this was deemed the best tradeoff between efficiency of the neural network and classification accuracy. The experiment yielded positive results, with 88.33% as the average accuracy.

In [22] a new tool called Arabic Text Classification (ATC) was built, which is used to clean Arabic documents and calculate the importance of each word using a Chi Square. The Chi Square calculates the correlation between the document and each class in order to generate high quality matrices. These matrices are used in weighting features in order to extract the most important features and reduce the volume of documents. The classification was carried out by C5.0 Decision Tree and Support Vector Machine (SVM) on seven Arabic corpora, each of which contained a number of documents and categories. The results showed a better average accuracy for the C5.0 algorithm, which achieved 78.42% accuracy, than the SVM algorithm, which only reached 68.65% accuracy.

The study [23] conducted an experiment on documents containing Facebook comments in Arabic text, then compared the results to English text. The author argues that the classification of short texts, such as Facebook comments, adds another challenge to classification due to the limited number of words. The sample contains a large number of comments that belong to the classes “food” and “weather” in both Arabic and English. The four types of classification algorithms applied were SVM, Naïve Bayes, K-Nearest Neighbor, and Decision Trees. The experiment yielded interesting results, with the accuracy of the Arabic language 11% higher than the English language in both categories. The authors highlighted that this result was because Arabic contains more discriminative words than English does, especially in the “food” and “weather” categories.

In [24], the authors used three classifiers, including DT,NB, and Equational Minimal Optimization (SMO), to construct a classification model to predict a document category. The dataset was collected from multiple websites and Saheeh AL-Bukhari’s book, then divided into four categories: economics, politics, sports, and sayings of the prophet Mohammed. The algorithms were applied to 1,000 documents, and the results reflected a better performance from Naïve Bayes than the other classifiers, as it reached 85.25% accuracy.

The study [11] applied Manhattan distance to measure dissimilarity and Dice’s to measure similarity when classifying Arabic documents. The corpus collected from several online newspapers. Next, a characters-based N-gram was applied to documents to generate all possible slices. The authors conducted an experiment on the generated profile across four categories: sports, the economy, technology and weather. The results showed better performance from Dice’s measurement than the Manhattan distance; the former reached 89% accuracy, while the latter reached 66% accuracy.

In [7] set of experiments were conducted on seven Arabic corpora in order to classify them into predefined categories according to the subject of each document. The corpora were collected from: *BBC* Arabic, *Aljazeera* corpus, and multiple other websites. The classification was carried out according to DT, *KNN*, *SVMs*, and NB variants. Furthermore, the experiments evaluated two features extraction techniques: root-based stemming and light stemming. The author recommended light stemming as a features extraction technique in order to enhance classification accuracy because it preserves word meanings. The results demonstrated the superiority for SVM over other classifiers, especially as it averages 94.11% accuracy. Another study [25] evaluated two approaches of stemming light 10 and Khoja stemming—on Arabic text. The author used the public dataset "Arabic Articles," which consisted of 2,700 documents classified according to nine categories. The experiments conducted by two tools suit Weka and Rapidminer to compare between them. The results showed a better average accuracy for the light 10, which achieved 98.20% accuracy, than the Khoja stemming, which reached 97.80% accuracy. Adding to work of previous study , the study [26] evaluates these approaches by multiple similarity measures while the study [27] used KNN to evaluate these approaches. The results demonstrated the superiority of light 10 over Khoja stemmer, which supported the study’s [25] results.

The study [28] evaluated three preprocessing tasks, including normalization, stop word removal, and light stemming, in terms of accuracy. The author utilized machine learning algorithms NB, KNN, and SVM to categorize Arabic documents. The results showed that light stemming demonstrated the best accuracy among them. It also indicated that, in some cases, removing the stop word can have a negative effect on performance.

Sentiment analysis is special type of text classification that aims to extract subjective information, such as emotions and opinions, in order to classify them into positive or negative categories. The study [29] investigated different representation models, as well as features reduction techniques and their impacts on sentiment analysis.

TABLE I. COMPARISON OF THE REVIEWED STUDIES

Study	Dataset	Study goal	LS	RS	SN	WN	Machine learning algorithms
Mesleh [19]	Newspaper	Text Classification	_	_	_	_	SVM, NB, KNN
Hatem et al.[20]	Arabic Documents	Text Classification	_	✓	_	_	NB
Fouzi et al.[21]	Books	Text Classification	_	_	_	_	Neural Network
Harbi et al.[22]	Online Newspapers	Text Classification	_	_	_	_	SVM, DT
Nawaf et al.[23]	Facebook Comments	Text Classification	✓	_	_	_	SVM, NB, KNN, DT
Khreisat [11]	Online Newspapers	Text Classification	_	_	✓	_	_
Saad et al.[7]	Online Newspapers	Text Classification	✓	✓	_	_	SVM, NB, KNN, DT
Hmeidi et al.[25]	Arabic Articles	Text Classification	✓	✓	_	_	SVM, NB, KNN, DT
Froud et al. [26]	Online Newspapers	Text Classification	✓	✓	_	_	_
Duwairi at al.[27]	Arabic Documents	Text Classification	✓	✓	_	_	KNN
Ayedh et al. [28]	Arabic Documents	Text Classification	✓	_	_	_	SVM, NB, KNN
Duwairi et al.[29]	Online Newspapers	Opinions Classification	✓	✓	✓	✓	SVM, NB, KNN
Brahimi et al.[30]	Twitter Posts	Opinions Classification	✓	✓	✓	_	SVM, NB, KNN
The Proposed Study	Twitter Posts	Text Classification	✓	✓	✓	✓	SVM, NB, KNN, DT

The experiments were performed on two different datasets: the first dataset consisted of 322 reviews of political articles collected manually from the Aljazeera2 website, while the second dataset was public and contained 500 reviews of movies. The results showed that the accuracy of opinion classification was affected directly by dataset type and preprocessing techniques. Also, the study [30] investigated the impact of the preprocessing stage on the opinion classification of two datasets collected from Twitter. The results were comparable to those of the study [29]. Table 1 summarized the reviewed studies where LS: light stemming,

RS: root-based stemming, SN: character-based n-gram and word-based n-gram.

B. Classification in Crime Domain

The authors in [31] applied sentiment analysis to English tweets related to crime in order to identify the users' behavior and attitude regarding crimes. They aimed to identify cities in the USA where the most crimes occur and where the least crimes occur. This has been tested by a geographical analysis of crimes that have occurred in the ten most dangers cities and ten safest cities, as determined by Forbes magazine. These results were similar to those of the study provided by Forbes magazine.

In [32] a web-based system was built for crime analysis and detection in Sri Lanka. The system collected articles from different newspapers by using the Crawler4j web crawler. The study covered the crimes occurred between 2012 and 2014. The articles were classified into two categories: crime and non-crime, using SVM. The results were extremely positive, with an accuracy of 95.71%. The authors in [33] used classification techniques to construct new software called "Z-crime" based on the Decision Tree (ID3) algorithm. The software was used to detect any terrorist attacks that might occur via email analysis.

The study [34] set up a system to efficiently detect the patterns of crimes that have occurred in India. Data concerning the crimes was gathered from several sources, including specialized news sites, blogs, and social sites. The collected data was classified by type of crime using the Naïve Bayes classifier and the results were extremely positive, with an accuracy of 90%.

VI. Machine Learning Algorithms

Recently, there has been a trend toward using machine learning to classify documents by building classifiers through learning instead of the old methods. In general, text classification in machine learning consists three phases. The first phase is data pre-processing to make the text convenient to train a chosen classifier. The second phase uses the classifier to construct a model based on a set of labeled examples, or training set. The last phase is evaluating the constructed model by various performance measures to gauge the model's success [19][35]. In this study different text-classification algorithms are used, such as a Naïve Bayes (*NB*), decision tree (*DT C4.5*), support vector machines (*SVMs*), and *K*-nearest neighbors (*KNN*).

A. The Naïve Bayes (NB)

The Naïve Bayes classifier is one of the simplest classification methods. It is part of the probabilistic family based on Bayes' Theorem[36] [37]. The Naïve Bayes classifier assumes that there is no relationship between features in dataset. It calculates the conditional probability of each new feature belonging to each class, then chooses the class that promises the highest probability. In general, there are two models used in text classification based on the Naïve Bayes conditional assumption: Multivariate Bernoulli Model and the Multinomial Model. In the Multivariate Bernoulli Model, a feature vector is represented as a binary vector that takes two values (1, 0) according to the appearance of a word at least one time in the document. Conversely, the Multinomial Model takes into account the frequency of a word, where feature vectors are represented by an integer indicating the repetition of a word, not just the word's presence [38].

Complement Naive Bayes (CNB), an improved version of the Multinomial Naïve Bayes (MNB) that overcomes its original weaknesses. The MNB is affected by the number of examples in a class, giving a high weight for a class that has more examples. In addition, it assumes there is no relationship between features. The CNB overcomes these problems and works very well with text data and has the highest accuracy among these variations [39].

B. Support Vector Machine (SVM)

SVM is a supervised learning algorithm that represents a data set as points in space separated by lines, constructing a "hyperplane" model for prediction and classification [40]. This hyperplane is used as a boundary to make decisions separately to place each new tuple in its optimal class.

In text classification, SVM is an effective method in the classification of high dimensionality feature space, because the complexity of hypotheses is measured by size of the margin rather than the number of features in the document. SVM needs a large memory capacity to execute properly, and therefore the size of the training set affects the speed of execution, which can be very slow. This is contrary to NB, which is simpler and has a significantly lower memory requirement. Further, larger training sets significantly improve the accuracy of NB, unlike SVM, which already has a high benchmark [41][42].

C. Decision Tree (DT)

Decision Tree is one of the most popular classifiers based on statistics, contains a set of nodes and edges that help in decision-making. Many algorithms are used to construct decision trees such as ID3, C4.5. These algorithms aim to construct the appropriate decision tree for a data set that reduces the error rate. The superiority of C4.5 is clear; in general, it deals with numbers and missing values unlike in ID3. Also, it can deal with over-fitting by a burning procedure to stop the growing of the tree [40].

D. K-Nearest Neighbors (KNN)

KNN is one of the most widely used classifiers based on instance-based learning [40]. The basic idea behind KNN is to assign new objects to the class that receives the majority of votes from its neighbors in an n-dimensional space.

VII. Study Methodology

In general, our system consists of four stages, as presented in Fig. 1.

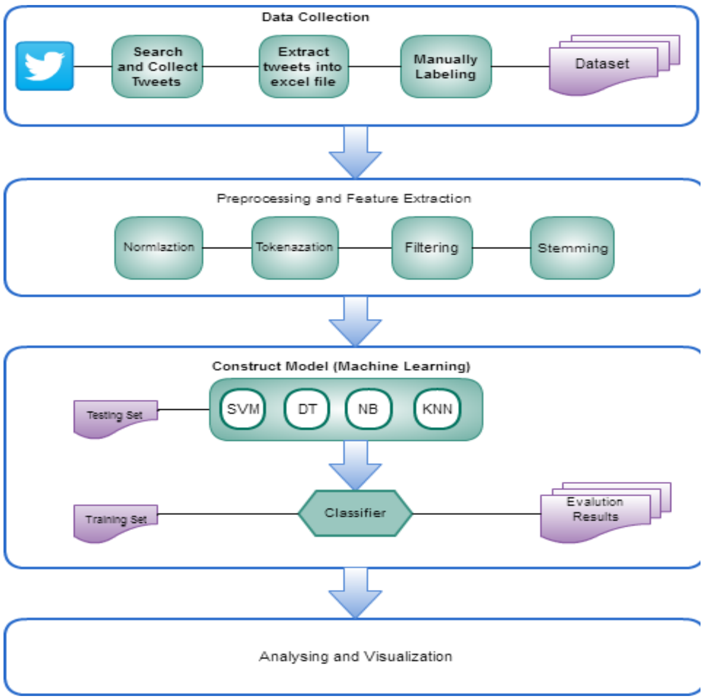


Fig. 1. The Four Stages of The Construct Model

A. Data Collection

In data collection stage, crime-related tweets are collected from Twitter using different tools, such as Twitter API and Topsy, and then extracted to an Excel file with UTF-8 Unicode to support Arabic text. Each tweet is labeled with its corresponding category based on the contents used to create the training set. The collected data set consists of more than 8,000 Arabic tweets from 2013 to 2016. The search targeted specialized news accounts on Twitter. The dataset contains approximately 4,000 different news items about crimes and 4,000 news items about political, health, and new technology issues. The data set contains approximately 187,748 words, with 23,994 distinct words

B. Preprocessing

In our system, preprocessing contains four steps, outlined as follows:

- Normalization is applied to make data more consistent. For example, some of the same words can be written differently in Arabic. For example, "ابتزاز ," which means "extortion," can be written as "إبتزاز." These spelling variations can negatively affect classification accuracy. Thus, normalization is used to overcome this problem. In Arabic, three letters must be normalized:
    - "أ," "آ," and "إ" will be normalized as "ا";
    - "ه" will be normalized as "ة";
    - "ي" will be normalized as "ى."
- Tokenization splits the textual data into a sequence of tokens and removes spaces so that each word is separated by only one white space. This step is very important, especially to text data, which is in an unstructured form that needs to be transformed into a suitable form for processing.
- Filtering reduces the size of the file and improves the efficiency of the text classification process. It is used to remove all non-alphabetic characters, especially signs frequently used in Twitter, such as (#) for hashtags and (@) used for usernames. Moreover, stop word filtering is used to remove all the frequent words that do not affect the meaning of a sentence and carry no value, such as prepositions sentence by comparing them to a list of Arabic built-in stop words. In addition, Length filtering is used to remove any words that exceed a specific length or that are less than specific length. We set the shortest length at 3 because there are many words in our data set with a length of 3 characters, such as "سرق" and "قتل."
- Features extraction, three methods have been used to extract features, including the light stem, root-based stem, N-gram, as well as original features as "bags-of-words" to establish the most suitable approach for our dataset. We have adopted TF–IDF to create vectors, since the initial experiments indicated that its results were significantly better than the binary results.

C. Construct model and Analysis

Machine learning algorithms use training dataset to construct a model that used to classify new tweets while the testing set is used to evaluate the constructed model. In this study four algorithms were used, including *NB, DT C4.5, SVM and KNN.* The classification accuracy is influenced by many of the characteristics of the volume of data in the training phase, diversity, the right selection of features, the type of classifier, and targeted language all have an impact on accuracy [13] [43]. Several measurements are used to evaluate the model for accuracy, recall and precision as in the following equations:

- Accuracy represents the ratio of tuples that are correctly classified by the model. It is calculated using the following equation: $\frac{(TP+TN)}{N}$. (4)
- Recall represents the number of items correctly classified as positive divided by the total number of positive. It is calculated using the following equation: $\frac{TP}{(TP+FN)}$. (5)
- Precision represents the number of items correctly classified as positive divided by the total number of positive predictions. It is calculated using the following equation: $\frac{TP}{(TP+FP)}$ (6)

where True positives (TPs) represent all tuples that were correctly predicted as crimes. False Negatives (FNs) represent all tuples that were incorrectly predicted as non-crimes. False positives (FPs) represent all tuples that were incorrectly predicted as crimes. True negatives (TNs) represent all tuples that were correctly predicted as non-crimes. In this study, we measure the accuracy of the model by applying k-fold cross validation. The dataset is split into K groups, each of which has its own training set and test set. In our experiment, we selected K as 10, and then the original data set was divided into 10 folds, each one containing the same amount of data.

VIII. Results and Evaluation

The experiments were conducted by Rapid Miner. Rapid Miner is a type of open source software developed in 2006 to provide a complete environment for machine learning, text mining, and analytical prediction which make it suitable to our study. The experiments were run on a laptop device with a 64-bit machine and 16 GB memory.

A. *Classifiers' Performance*

The performance of the model, evaluated by different measures, including accuracy, recall, and precision. Accuracy is the most important measure for evaluating the model. Fig. 2 represents the accuracy of different classifiers, including SVM, DT, KNN, and CNB for crimes classification in level three.

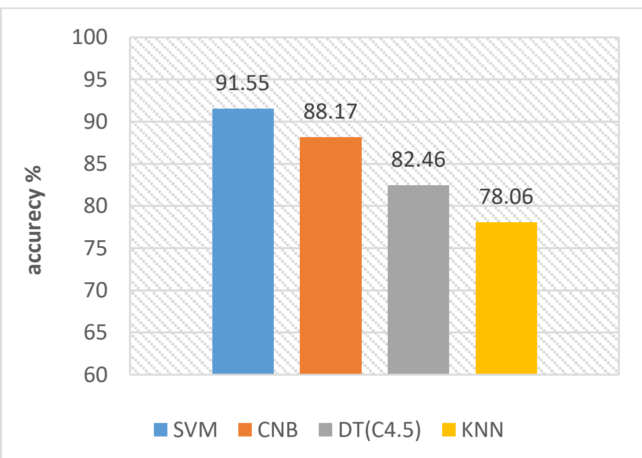


Fig. 2. Classification Accuracy for Classifiers in Classifying Crimes According to Type.

The Naive Bayes usually has a low performance rate with text because of its high dimensionality. Furthermore, the Naive Bayes is usually affected by an unbalanced dataset since it gives a high weight to a class that has more examples. In addition, it assumes that there is no relationship between features. However, we find good results, with 93.29%, 90.88%, and 88.17% in the first, second, and third levels, respectively. These good results are due to our use of a special type of Naive Bayes, which is CNB. CNB works with texts perfectly because it overcomes the weaknesses of Naive Bayes.

KNN got the worst results among the classifiers, with 78.06% in classifying according types. The performance of KNN was affected directly by the feature-extraction techniques because it measures the distance between words. Arabic stemmers have poor performance and return many unrelated words, leading to the poor performance of KNN. Meanwhile, DT results were somewhat low due to the impact of the large number of features in the dataset, which made it more difficult to build the appropriate tree. Fig. 5 illustrates impact of the number of classes on accuracy. The most affected was KNN, which had 89.44% in detection crimes and decreased to 78.06% in classifying crimes, while SVM was the least affected, reflecting its strength and durability. Fig 3 shows the impact of number of classes on classifier accuracy.

Fig. 3. The Impact of Number of Classes on Accuracy.

Accuracy is not enough to ensure the validity of model. Thus, recall and precision are measured for evaluation. Fig. 4 represents the recall and precision of SVM with tri-gram for crime classification.

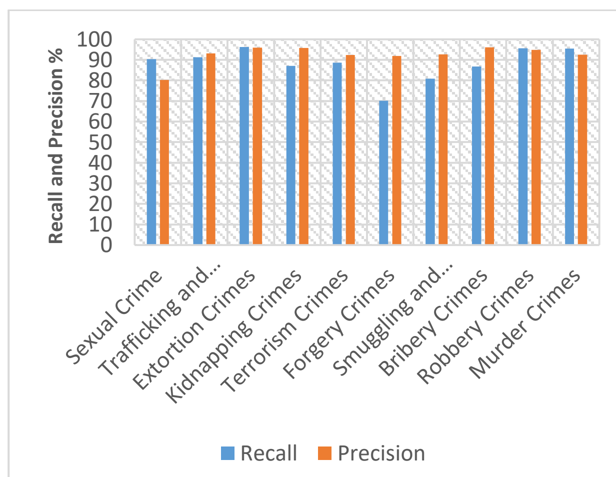


Fig. 4. Recall and Precision for SVM Classifier in Classifying Crimes According to Type.

B. *Feature Extraction Reduction*

The number of features is inversely correlated with classification accuracy. Because the crime dataset contains 187,765 words, we seek to reduce the number of features. Fig .5 reflects the magnitude of reduction according to each of these methods, as well original dataset after tokenizing and filtering.

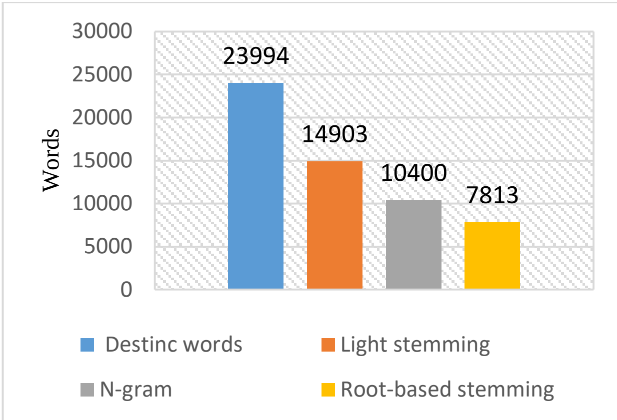


Fig. 5. Impact of Feature-Extraction Techniques on Crime Dataset.

The figure indicates that root-based stemming provides the highest reduction in features with 67.4% due to the fact that a large number of words share the same root. Light stemming results in the smallest reduction, as it removes only prefixes and suffixes. The application of the tri-gram reduction resulted in approximately 56.7% fewer words. The large reduction occurred for two reasons: The nature of the dataset had many similar words; because of that, we specialized in a specific domain, which is the crime domain, as well as took a small n value (three) for the gram that led to generate many similar triple words, which were deleted by RapidMiner.

C. *Feature-Extraction Technique's Impact on Accurecy*

Three methods have been used to extract features, including the light stem, root-based stem N-gram, as well as original dataset. The N-gram has been tested for both character-based and word-based on different values of N to get the best value so as to ensure the highest accuracy. Table 2 represents the accuracy of bilateral, triple, quadruple, and quintet grams with SVM and CNB.

TABLE II. ACCURACY OF THE BILATERAL, TRIPLE, QUADRUPLE, AND QUINTET GRAMS

classifiers		Accuracy	
		Character-based	Word-based
SVM	2-gram	87.82	78.28
	3-gram	91.55	73.74
	4-gram	89.57	70.10
	5-gram	87.15	67.63
CNB	2-gram	79.41	81.14
	3-gram	88.17	80.12
	4-gram	87.08	78.95

The results demonstrate low performance for words-based n-gram in contrast to characters-based n-gram. It takes only 78.28 and 81.84 when N=2 for SVM and CNB, respectively. Also, the table shows the supremacy of the tri-gram with character-based over other values because 85% of the words in Arabic have triple roots. Despite the fact that the tri-gram generates many incomprehensible words, it often leads to the appearance of the root directly for different words that have the same root. For example, "شرعيه" means "legitimacy" and becomes "شرع, رعي, عيه," and "يشرعن" means "legitimizes" and becomes "يشر, شرع, رعن ." The root produced for both words directly is "شرع." Also, "القبض," meaning "the arrest," becomes "الق, لقب, قبض." The root produced directly is "قبض." This fact improves classification accuracy. Fig. 6 represents the impact of different feature-extraction on accuracy.

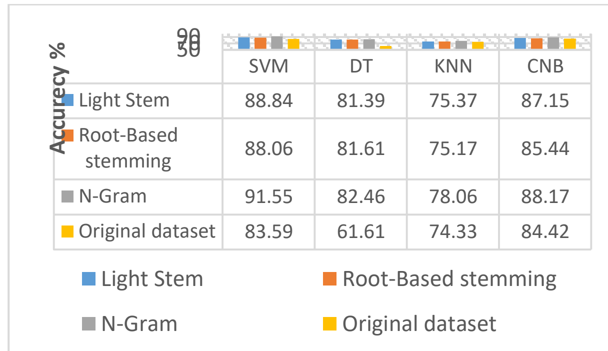


Fig. 6. Impact of Feature-Extraction Techniques in Classifying Crimes According to Type.

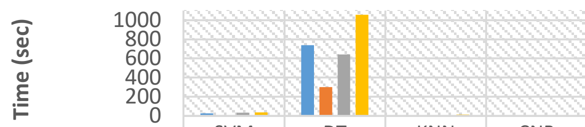
As can be seen in Fig. 6 the tri-gram achieved the greatest accuracy in classifying crimes according types, with 91.55%, 82.46%, 78.06%, and 88.17% for SVM, DT, KNN, and CNB, respectively. The results of root-based and light stemming are approximately similar for DT, SVM and KNN, while light stemming is better for CNB. The lowest result was achieved by DT in classifying crimes for original dataset, at 61.61%.

The overall results reflect the conspicuous superiority of the N-gram to other methods in all classifiers. This is due to reducing the number of features to more than half and also because of our use of the triple-gram. The results of light stemming and root-based stemming are somewhat convergent, although the results of light stemming are better because, as we mentioned earlier, it keeps the word meaning, while root-based stemming produces the same root for many words that have different meanings. The worst results are for raw text due to the large number of variations in words that reflected negatively on the performance of the classifier.

The study [44] and [45] involved completing an experiment to compare light stemming and root-based stemming. The results confirm that light stemming achieves a better level of accuracy than does root-based stemming. Also, the study [7] supports the idea that, despite the fact that convergent results of two types were received. The author reported that the root-based stemming achieves a high level of accuracy because it works perfectly with the triple root and most of Arabic words have triple root, whereas light stemming is better from a linguistic and semantic viewpoint.

D. *Classifiers' Training Time*

Training time is an important factor for building classifiers, especially for the high dimensionality of a text dataset. Fig.7 shows the training time of different classifiers with different feature-extraction techniques, for crime dataset.



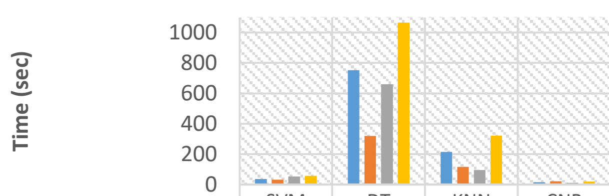
	SVM	DT	KNN	CNB
Light Stem	28	738	6	1.06
Root-Based stemming	9	302	1	0.43
N-Gram	35	642	3	1.32
original dataset	37	1057	15	2.56

Fig. 7. Training Time for Classifiers in Classifying Crimes According to Type.

CNB was the fastest among the algorithms, taking just a few seconds of training time. The high speed of CNB is due to the simplicity of the account conditional probability, which contains just addition and division operations. KNN has few amount of time for training due to its nature, as there is no need to build a model; simply just store features in the memory for later use in classifying. The impact of feature-extraction techniques on DT, CNB, and SVM was similar, where root-based stemming took less time because it reduced the number of distinct words to 67.4% of total words, original set consumed more time to build a model for a large number of distinct words.

E. *Classifiers' Execution Time*

Executing time is another factor used to evaluate the classifiers. Executing time includes the total time for preprocessing, training time, and applying the model time to evaluate the validity of the model. Fig. 8 shows the execution times of different classifiers with different feature-extraction techniques, as well as those for raw text.



	SVM	DT	KNN	CNB
Light Stem	37	753	214	15
Root-Based stemming	31	319	116	22
N-Gram	52	660	95	10
Original dataset	58	1066	321	20

Fig. 8. Execution Time for Classifiers in Classifying Crimes According to Type.

Compared with the training time, we found that the results are somewhat convergent for DT, SVM, and CNB because the application of the model for classifying consumed only a few seconds or a few fractions of a second in some cases. In addition, the preprocessing time consumed only a few seconds. On the contrary, the KNN results differ entirely because, as mentioned earlier, it does not build a model, and the training time is close to zero. This demonstrates the need to spend a lot of time measuring the similarity to the K-nearest neighbors' instances.

CNB was the fastest among the algorithms in all levels even with the execution time, while the slowest was DT. The results of the effect of extracting features of the execution time are dramatically different from the impact on the training time. The impact of feature-extraction techniques on DT, KNN, and SVM depends on the number of words where root-based stemming takes less time and the raw text consumes more time. Meanwhile, CNB is different from the rest due to its high speed of building the model and testing, which take fewer than three seconds. The speed of CNB is linked directly to the speed of the extraction-feature techniques. CNB with root-based stemming was the slowest because root-based stemming usually consumes time to remove the affix and then extract the root, while raw text is the second because a large number of words need to be tokenized.

The study [44] makes a comparison between light stemming and root-based stemming in term of execution time with KNN. The results show that light stemming takes more time, which reinforces the validity of our findings.

Note that the speed of the execution model is affected by three factors: the algorithm used; total number of classes; and the types of feature-extraction techniques. Fig. 9 shows effect of number of classes on classifiers' time. DT was the classifier most affected by the number of classes: 258 seconds in detecting crimes to 660 seconds in classifying crimes according to types. A tree with a great depth had to be built to cover the 11 classes. SVM and CNB rose slightly, while for KNN, there was a disparity between the raising and going down, which mean KNN not affected by the number of classes.

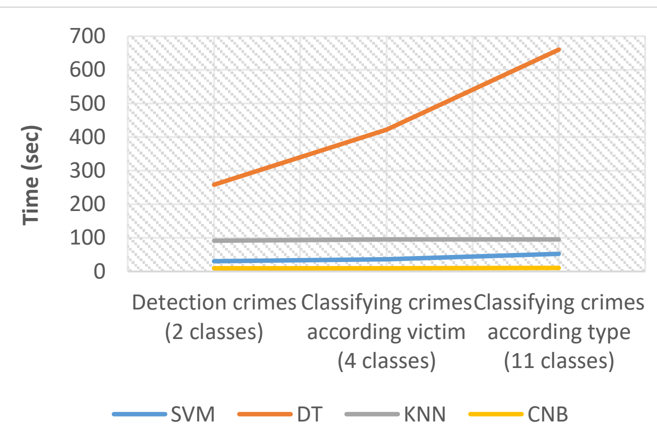


Fig. 9. The Effect of Number of Classes on Classifiers' Execution Time.

IX. Conclusion

In this paper, we put in place, utilizing various machine learning algorithms, a system that is capable of detecting crime-related tweets. Then, we conducted an investigation of different features in the form of light stemming and stemming, together with N-grams. The results indicate that root-based stemming yielded the best results in terms of feature reduction, while the character-based N-gram obtained the best level of accuracy. Based on the findings, we recommend tri-gram to use for the Arabic language, particularly in classification in specific domain due to the nature of the Arabic language, which often relies on the triple roots.

SVM had the best accuracy among the classifiers while the worst accuracy was achieved by KNN. In terms of speed, CNB was the fastest among the classifiers in both training time and execution time, while DT was the slowest, especially in classifying the crimes due to the large number of classes. The most affected of the class numbers in terms of accuracy was KNN. While the most affected of the class numbers on speed was DT.

In future work, we plan to evaluate other machine learning algorithms, such as neural networks, association rules, and others. Also, we intend to expand our analysis to include spatial and temporal analysis to find out when and where crime has spread in the past, and when and where it is most likely to spread in the future.

References

[1] A. Shamany, "Interior: 270 crimes every day. Committed by unemployed and juveniles," 2015.

[2] A. Hotho, A. Nürnberger, and G. Paaß, "A Brief Survey of Text Mining," LDV Forum - Gld. J. Comput. Linguist. Lang. Technol., vol. 20, pp. 19–62, 2005.

[3] V. Gupta and G. S. Lehal, "A survey of text mining techniques and applications," J. Emerg. Technol. Web Intell., vol. 1, no. 1, pp. 60–76, 2009.

[4] A. Farghaly and K. Shaalan, "Arabic natural language processing : Challenges and solutions," ACM Trans. Asian Lang. Inf. Process., vol. 8, no. 4, pp. 1–22, 2009.

[5] H. K. Al Ameed, S. O. Al Ketbi, a. a. Al-Kaabi, K. Al Shebli, N. Al Shamsi, N. H. Al Nuaimi, and S. S. Al Muhairi, "Arabic light stemmer: A new enhanced approach," Second Int. Conf. Innov. Inf. Technol., pp. 1–9, 2005.

[6] F. A. Allah, S. Boulaknadel, a. El Qadi, and D. Aboutajdine, "Arabic Information Retrieval System Based on Noun Phrases," 2006 2nd Int. Conf. Inf. Commun. Technol., vol. 1, no. April, pp. 720–725, 2006.

[7] M. Saad, "The Impact of Text Preprocessing and Term Weighting on Arabic Text Classification," Comput. Eng., no. August, p. 172, 2010.

[8] K. S. and G. R, "Stemming Arabic text," Lancaster, 1999.

[9] L. Larkey, L. Ballesteros, and M. Connell, "Light stemming for Arabic information retrieval," Arab. Comput. Morphol., pp. 221–243, 2007.

[10] N. P. Katariya and M. S. Chaudhari, "Text Preprocessing for Text Mining Using Side Information," vol. 3, pp. 3–7, 2015.

[11] L. Khreisat, "Arabic text classification using N-gram frequency statistics a comparative study," Conf. Data Mining| DMIN'06, pp. 78–82, 2006.

[12] S. H. Mustafa and Q. A. Al-Radaideh, "Using N-grams for Arabic text searching," J. Am. Soc. Inf. Sci. Technol., vol. 55, no. 11, pp. 1002–1007, 2004.

[13] B. Baharudin, L. H. Lee, and K. Khan, "A Review of Machine Learning Algorithms for Text-Documents Classification," J. Adv. Inf. Technol., vol. 1, no. 1, pp. 4–20, 2010.

[14] "Languages of the World (18th ed.).," 2015. [Online]. Available: http://www.ethnologue.com. [Accessed: 16-Sep-2016].

[15] Z. M, "The crown bride of the jewels dictionary." 1965.

[16] A. Shanqity, "The treatment of Holy Qur'an to crime." Madinah.

[17] Ministry of the Interior in Saudi, "Statistical Yearbook of crimes," Riyadh, 2014.

[18] F. B. of I. (FBI), "The Uniform Crime Reporting (UCR)," 2014.

[19] A. M. A. Meshel, "Chi square feature extraction based SVMs Arabic language text categorization system," J. Comput. Sci., vol. 3, no. 6, pp. 430–435, 2007.

[20] H. Noaman and S. Elmougy, "Naive Bayes Classifier based Arabic document categorization," 2010 7th Int. Conf. Informatics Syst., pp. 1–5, 2010.

[21] F. Harrag and E. A.- Qawasmah, "Improving Arabic Text Categorization using Neural Network with SVD," J. Digit. Inf. Manag., vol. 8, no. 4, pp. 233–239, 2010.

[22] S. Al-Harbi, a Almuhareb, and a Al-Thubaity, "Automatic Arabic text classification," 9es Journées Int. Anal. Stat. des Données Textuelles, pp. 77–84, 2008.

[23] M. Faqeeh, N. Abdulla, M. Al-Ayyoub, Y. Jararweh, and M. Quwaider, "Cross-lingual short-text document classification for facebook comments," Proc. - 2014 Int. Conf. Futur. Internet Things Cloud, FiCloud 2014, pp. 573–578, 2014.

[24] A. H. Wahbeh and M. Al-Kabi, "Comparative Assessment of the Performance of Three WEKA Text Classifiers Applied to Arabic Text," Abhath Al-yarmouk "Basic Sci. Eng.," vol. Vol. 21, no. 1, pp. 15– 28, 2012.

[25] I. Hmeidi, M. Al-Ayyoub, N. a. Abdulla, a. a. Almodawar, R. Abooraig, and N. a. Mahyoub, "Automatic Arabic text categorization: A comprehensive comparative study," J. Inf. Sci., vol. 41, no. 1, pp. 114–124, 2014.

[26] H. Froud, A. Lachkar, and S. Ouatik, "A comparative study of root-based and stem-based approaches for measuring the similarity between arabic words for arabic text mining applications," Adv. Comput. An Int. J., vol. 3, no. 6, pp. 55–67, 2012.

[27] N. Khasawneh, R. Duwairi, and M. N. Al-Refa, "Feature ReductionTechniques for Arabic Text Categorization," J. Am. Soc. Inf. Sci. Technol., vol. 14, no. 4, pp. 90–103, 2009.

[28] A. Ayedh, G. TAN, K. Alwesabi, and H. Rajeh, "The Effect of Preprocessing on Arabic Document Categorization," Algorithms, vol. 9, no. 2, p. 27, 2016.

[29] R. Duwairi and M. El-Orfali, "A study of the effects of preprocessing strategies on sentiment analysis for Arabic text.," J. Inf. Sci., vol. 40, no. 4, pp. 501–513, 2014.

[30] B. Brahimi, M. Touahria, and A. Tari, "Data and Text Mining Techniques for Classifying Arabic Tweet Polarity 1," vol. 14, no. 1, pp. 15–25, 2016.

[31] S. Mine, "Crime pattern detection using online social media," 2014.

[32] I. Jayaweera, C. Sajeewa, S. Liyanage, T. Wijewardane, I. Perera, and A. Wijayasiri, "Crime analytics: Analysis of crimes through newspaper articles," 2015 Moratuwa Eng. Res. Conf., no. April, pp. 277–282, 2015.

[33] M. Sharma, "Z - CRIME: A data mining tool for the detection of suspicious criminal activities based on decision tree," 2014 Int. Conf. Data Min. Intell. Comput. ICDMIC 2014, 2014.

[34] S. Sathyadevan, M. S. Devan, and S. Surya Gangadharan, "Crime analysis and prediction using data mining," no. August 2014, pp. 406–412, 2014.

[35] F. Sebastiani, "Machine learning in automated text categorization," ACM Comput. Surv., vol. 34, no. 1, pp. 1–47, 2002.

[36] V. Korde and C. N. Mahender, "Text Classification and Classifiers: A Survey," Int. J. Artif. Intell. Appl., vol. 3, no. 2, pp. 85–99, 2012.

[37] G. Sanguinetti, "Text Classification using Naive Bayes," no. February, 2012.

[38] A. McCallum and K. Nigam, "A Comparison of Event Models for Naive Bayes Text Classification," AAAI/ICML-98 Work. Learn. Text Categ., pp. 41–48, 1998.

[39] and K. D. T. Rennie J, Shih L, Teevan J, "The Poor Assumptions of Naive Bayes Classifiers," no. In Proceedings of the Twentieth International Conference on Machine Learning (ICML)., 2003.

[40] J. Han and M. Kamber, "Data Mining: Concepts and Techniques," Data MiningConcepts Tech., pp. 3–26, 2000.

[41] I. Dilrukshi and K. De Zoysa, "Twitter news classification: Theoretical and practical comparison of SVM against Naive Bayes algorithms," 2013 Int. Conf. Adv. ICT Emerg. Reg., no. December, pp. 278–278, 2013.

[42] A.Sheshasaayee and G. Thailambal," Comparison of Classification Algorithms in Text Mining", International Journal of Pure and Applied Mathematics,pp.425-433,2017.

[43] C. Aggarwal and C. Zhai, "A Survey of Text Classification Algorithms," Min. Text Data, pp. 163–222, 2012.

[44] M. Al-refai, "Stemming Versus Light Stemming as Feature Selection Techniques for Arabic Text Categorization Rehab Duwairil Department of Computer," no. September 2007, pp. 446–450, 2008.

[45] D. A. Said, N. M. Wanas, N. M. Darwish, and N. H. Hegazy, "A Study of Text Preprocessing Tools for Arabic Text Categorization," Proc. Second Int. Conf. Arab. Lang. Resour. Tools, pp. 330–336, 2009.

Pipeline Hazards Resolution for a New Programmable Instruction Set RISC Processor

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***Abstract*—The work presented in this paper is a part of a project that aims to concept and implement a hardwired programmable processor. A 32-bit RISC processor with customizable ALU (Arithmetic and Logic Unit) is designed then the pipeline technique is implemented is order to reach better performances. However the use of this technique can lead to several troubles called hazards that can affect the correct execution of the program. In this context, this paper identifies and analyzes all different hazards that can occur in this processor pipeline stages. Then detailed solutions are proposed, implemented and validated.**

***Keywords*—Processor; RISC; hardware; instruction set; pipeline; hazards; branch predictor; bypass**

I. Introduction

The use of smart digital devices in almost all fields of everyday life increases the embedded systems challenges especially those of microprocessors. In fact, they have to cope with a wide panel of applications and provide at the same time, high performances in terms of operation frequency, energy consumption and area occupation. This complicates extremely the design process and affects the cost and the time to market. On the other hand, these processors are unsuitable for applications with hard real-time constraints. Application Specific Instruction set Processors (ASIP) [1][2] were proposed as an alternative that uses an additional instruction set addressing a defined domain. Thus, compared to the general purpose processors, they provide a significant acceleration but only for a limited class of applications. For better reuse level, designers introduce the configuration concept to make processors customizable and thus fit a large panel of applications. The main proposed solution is to couple a programmable functional unit to the hardwired processor [3][4][5].

In this context, a new configuration technique is introduced. Actually, a hard-wired processor based on a 32-bits RISC architecture is designed then improved to make it able to cope with customizable instruction sets [6]. For better performances, the pipeline technique is implemented to insure better run-time acceleration. However, a processor with pipelined architecture handles many instructions at the some clock cycle which can lead to some execution troubles. Especially when there are dependencies or resources conflicts between these instructions. Such troubles are called hazards since they can randomly happen during the program execution [7][8][9].

In this paper the different hazards related to the architecture of the designed programmable processor are analyzed and classified then the proposed solutions are detailed, implemented and validated. In the second section, an overview of the programmable processor design is presented. In the third section we the data-path is explored in order to find out the different hazards that can happen and classify them. The fourth and fifth sections are respectively dedicated to the implemented solutions for control and data hazards. Then, in the next section the simulation results are illustrated and discussed and finally conclusion and outlooks are presented in the last section.

II. Architecture Overview

The proposed architecture consists of a 32-bits RISC processor based on a programmable ALU that can be customized to handle a large range of instruction sets thanks to the look up table (LUT) technology. In fact, the ALU is composed of a paged LUT where each page contains the truth table of a single operation. Being made of SRAM, these pages can be rewritten if needed to fit any specific application. As for a standard RISC processor we use register/register architecture where the ALU is connected to registers to retrieves its non-immediate operands and store its computing results. This registers are assembled into a register bank. On the other hand, the memory presents two independent interfaces for data and instructions since the processor is designed according to the Harvard architecture.

This processor implements instructions belonging to three different kinds that are namely:

- Arithmetic and logic instructions: They include arithmetic, logic, shift and comparison instructions. The operands are either immediate value or from register bank. The result is stored in the general-purpose registers.
- Instructions for memory access: The address is calculated using a base value and an offset. The address of the register containing the first data and the immediate value representing the offset are both extracted from the instruction word.
- Jump and branching instructions that can be conditional or unconditional.

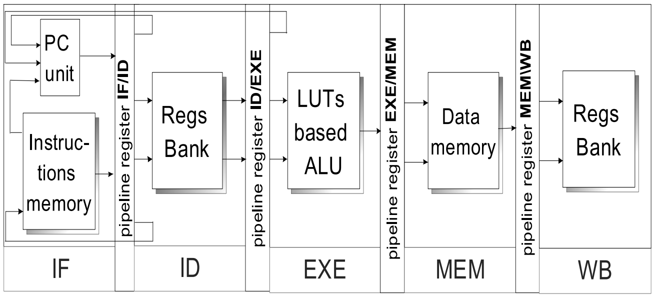

Fig. 1. Pipeline Stages of Our Programmable Processor.

The instruction word is 32-bits length and its structure depends on the data it includes. The R format is composed from the operands and result registers address besides the instruction codes and the shift amount for shift operation. It includes mainly arithmetic and logic instructions with non-immediate operands. Indeed, all instructions using an immediate value, whether for ALU operations, memory access or conditional jump, belong to the I format. Finally the J format is reserved to the unconditional jump instruction.

As shown in Fig.1, all units of the targeted architecture are organized into five balanced pipeline stages representing the five execution phases of an instruction. These stages are:

- Instruction Fetch (IF): Selection and extraction of the instruction from the instruction memory.
- Instruction Decode (ID): Decode of the instruction and extraction of the operands from the register bank in order to be sent to the ALU.
- Execution (EXE): The instruction result is computed.
- Memory access (MEM): The data load and store operations are achieved.
- Write back (WB): The instruction result is stored in the register bank.

III. Pipeline Hazards

The use of pipeline datapath, although it insures a significant computing-power improvement of the processor, generates several execution troubles organized in three hazards categories [10][11][12]:

- Structural hazards: They consist on resources conflicts. In fact, they happen when two different instructions being performed by the processor need to use the some resource at the same clock cycle. For example, if the processor provides only one interface to communicate with memory, it can be requested, at the same time by the instructions in the IF and the MEM stages to access respectively, an instruction and a data. None of these hazards are present in our processor thanks to its design.
- Control hazards: While the branch decision is being calculated, wrong instructions can be introduced into the pipeline which leads to this type of hazards. The branch prediction technique is used to reduce the frequency of wrong instructions fetch.
- Data hazards: They happen when an instruction needs to use a data that is not yet available because it is still being computed by a previous instruction in the pipeline. To solve these hazards, the simplest way is to stall partially the pipeline until the data is ready. However, the frequent use of this technique can lead to an important decrease in terms of pipeline performances. For that, hardwired solutions are implemented to avoid the use of idle cycles as much as possible.

IV. Proposed Branch Prediction Solution

Branch prediction is used to prevent the control hazards. In fact, our programmable processor handles branch instructions that need some clock cycles to decide about the next fetch address. In fact for the conditional branch, the decision is calculated at the EXE stage and even for the unconditional branch the jump address can't be known before the ID stage. Meanwhile, the following instructions are injected into the pipeline. Thus, each time a jump decision is made these wrong instructions must be eliminated. The excessive occurrence of this process considerably decreases the processor run-time performances. Therefore, a branch prediction unit is inserted in the IF stage to speculate the branch decision and to load into the pipeline the most likely true instructions.

A. Static Prediction of the Branch Decision

A first branch prediction approach is the static prediction [13]. Indeed, this method uses a fixed speculation algorithm that is based on the classification of branch instructions in some with a high probability of being taken and others that are often or always not taken. An example of a static prediction consists in classifying the instructions according to their nature: conditional and unconditional. This way, the unconditional branch will form the family of instructions whose prediction is always "taken", while the conditional branch instructions will always be predicted as "not taken". This heuristic based on inaccurate criteria of instructions is not reliable enough because a large number of conditional branches are often taken specially those used for loop management. For this purpose other more precise algorithms are used such as the BTFN (Backward Taken Forward Not taken) which predicts that all the backward jumps are taken. Thus, for the instructions related to the loopback condition, the prediction is always correct as large as the loop is going on and is false only when exiting it. Although the performances enhancement, this algorithm is unsuitable for the instruction sets that rarely use iterations. Generally, the performance of the static prediction is limited because it does not consider the application proprieties and the instructions diversity.

B. Dynamic Prediction of the Branch Decision

An alternative the dynamic branch predictor can be use instead of the static one. The different methods belonging to this category are based on a real-time learning. In fact, decisions history related to each branch instruction are saved then used to better predict future decisions.

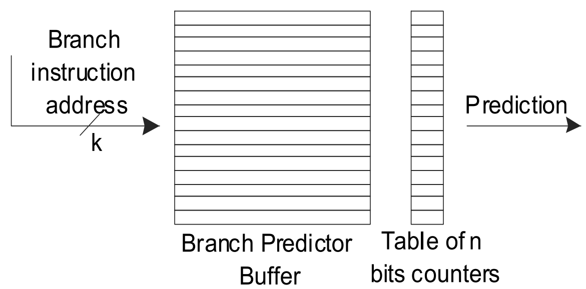

Fig. 2. One-Level Branch Predictor.

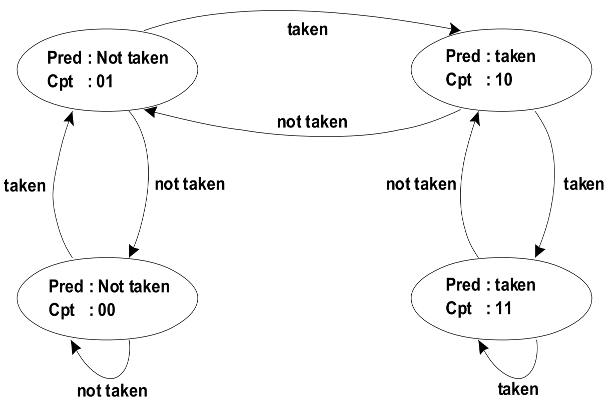

Fig. 3. FSM for the 2-Bits Saturation Counter.

The simplest dynamic predictor is based on the *one-level branch predictor* [11][14]. As shown in Fig.2, this predictor uses a cache memory called *Branch Predictor Buffer* (BPB) or *Branch history table*, which is indexed by the least significant bits of the branch instruction address. This table maps to each address an n-bit *saturation counter* that functions as follows:

- Whenever a branch is taken, the counter increments unless it is already at its maximum value.
- Whenever a branch is not taken, the counter decrements unless it is already equal to zero.

The branch decision is deduced from the value of the *saturation counter*. In fact, if its value is lower than 2^{n-1}, the branch is predicted "not taken" otherwise it is “taken”.

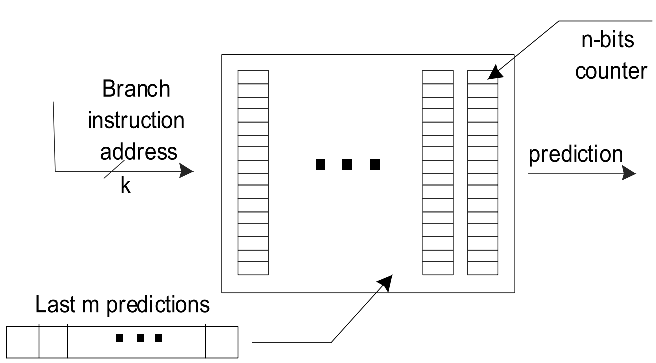

Fig. 4. Correlation-based Branch Predictor.

In the case where a *1-bit saturation counter* is used, the predictor only takes into account the last taken decision (1 if the last time the branch was taken, 0 otherwise). This method is not very reliable because it causes errors even for branch whose decision rarely changes. In fact, if we consider a branch which follows this sequence of decisions: "taken nine successive times, not taken once". In this example, the predictor will commit two errors each time: at the beginning and at the end of the sequence. For better performance, a *2-bit saturation counter* is associated with the *branch address table* [11] [13]. In this case, the predictor operation scheme is managed by the finite state machine illustrated in Fig.3. This way, the prediction changes only if it is false twice consecutively.

In some cases, the program may contain branch instructions whose decision changes frequently and depends on decisions of previous branch instructions. For such situations, it is recommended to use more efficient prediction algorithms that take into account these variations and dependencies. An example is the *two-level branching predictors* [11][14][15]. To this category belongs the *correlation-based branch predictor*. This predictor uses a (m, n) BPB which considers the decisions of the last m stored branches in an offset register to choose a prediction among 2^m . Each one of these predictions is controlled by a saturation counter n bits. Thus, the *two-level branching prediction* consists of a 2^m column table, as shown in Fig.4. For each branch instruction, its address is used for the line selection while the sequence of m bits in the shift register allows the column choice. The value of the counter contained in the selected box allows predict whether the branch will be taken or not. As for the *one-level predictor*, this value will be updated as soon as the decision is calculated. Another *two-level prediction* scheme is the *adaptive algorithm* whose structure is illustrated in Fig.5. This algorithm saves the last m decisions related to each branch instruction and matches each m bit sequence with a *n-bit saturation counter* located in a table named "*Global pattern history*" composed of 2^m lines common to all branching instructions. Thus two branches can be referenced on the same line if they have the same decision history. The *saturation counter* allows, as for all other methods, to predict the branching decision and its value is changed according to the reliability of the prediction.

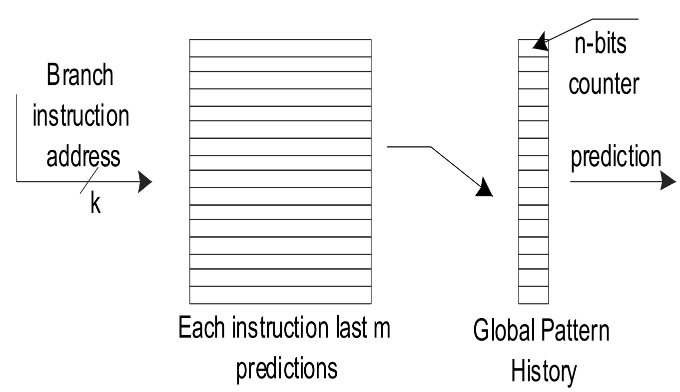

Fig. 5. Two-Level Adaptative Branch Predictor.

The test of a benchmarks range on the various predefined prediction methods shows that they have a variable reliability rate depending on the nature of the different branches [11][13]. Hence the appearance of the hybrid branch prediction which uses two or more independent prediction algorithms operating in parallel [16]. A selection vector, whose value varies according to the history of the branching decisions, allows choose for each branch instruction the most adapted predictor. Other specific predictors characterized by high levels of reliability have been implemented [17][18][19]. Among them there are "*Multiple history length use*"[20], "*de-aliased predictors*"[21], etc.

Among these different branch predictors, the selected solution in order to be implemented is the *one-level predictor* using a *2-bit saturation counter*. This choice is justified by the fact that this predictor is frequently used, it is simple to implement and it presents an acceptable error rate. These factors are sufficient for a first implementation.

C. Branch Direction Prediction

Branch prediction minimizes the impact of late decisions by injecting into the pipeline the instruction corresponding to the decision prediction immediately after the branch instruction. For this, the predictor must know the jump address from the IF stage in the case where a branch is predicted as "taken". However, this address is available only at the level of the ID stage. In order to minimize the latency generated by this address computing delay, a cache memory called "*Branch-Target Buffers*" (BTB) is used[11][14]. Its structure is described in Fig.6. Each line in this memory contains the address of a branch instruction, the jump address, and the corresponding prediction. Whenever a new instruction is present in the IF stage, if its address does not appear in the first column of the BTB, the instruction is not considered as a branch and the execution processes normally. In this case, if the decision corresponds to "taken", a jump to the address of the branch is made. After the execution of a branch instruction, if it is already registered in the BTB, then the prediction is updated according to the decision. Otherwise, the instruction as well as the jump address and the value of the prediction are saved in a line of the BTB. Sometimes the BTB can be saturated. In this case, some branches must be removed to give place to others. As for cache memories, several management algorithms are available. However, a judicious choice must be made to not alter the performance of the predictor.

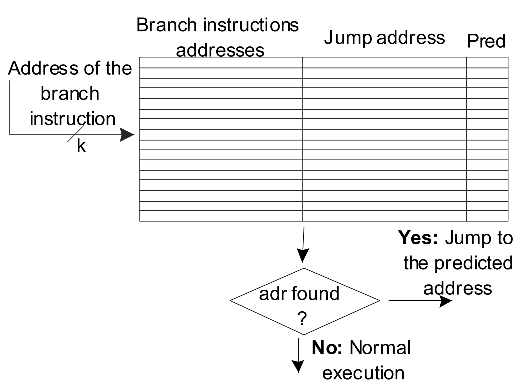

Fig. 6. Branch Target Buffer.

D. Proposed Prediction Algorithm

For the programmable processor, a prediction algorithm that uses the one-level branch predictor and the 2-bit saturation counter was selected for the decision prediction, and the "Branch-Target Buffers" for calculating the branch address. Diagram illustrated in Fig.7 details this algorithm.

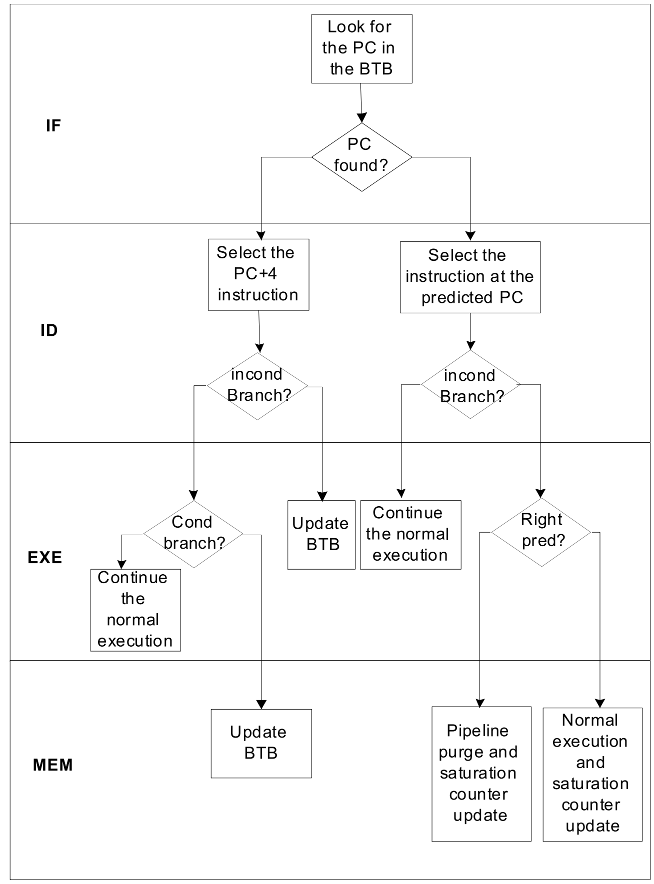

Fig. 7. Prediction Algorithm.

V. Proposed Solutions for Data Hazards

A. Data Hazards Analysis

The resolution of data hazards requires, at first, to study all data-path situations presenting this kind of hazards. For this, first the instructions involved in the happening of these hazards are split into two classes: consumer instructions and producer ones. The first category includes instructions that must use data that is not yet available in the register bank. While the second includes those responsible for calculating the missing results.

It should be noted that an instruction is considered as consumer or producer regarding the pipeline stage in which it needs to use the missing data or produces the required result. For example, for an arithmetic addition instruction, if it needs an operation which is not yet available at the register bank it is "consumer instruction at the EXE stage". However, in the case where a next instruction needs its computation result when it has not yet reached the WB stage, it is considered as "producer instruction at the EXE stage". In the rest of this study, the producer and consumer instructions are respectively named *Res* and *Reg* followed by the name of the stage of the concerned pipeline (ResEXE, RegEXE ...). In order to identify all stages that can host consumer instructions, we ask the question: "*Does this stage use a data retrieved from the register bank* ". While for producer instructions the question is "*Does this stage produce a result to the register bank?*". Thus, the producer instructions are ResEXE and ResMEM whereas the consumer ones are RegID, RegEXE and RegMEM.

Following this classification, all data hazards that may occur in the proposed processor pipeline are identified by studying all possible scenarios from the point of view of producer instructions. In other words, at the output of each pipeline stage that may contain producer instructions this question is asked: *"which of the following instructions may need to use the result of this stage before it reaches the registers?"*

A producer instruction *i* can belong either to ResEXE class or ResMEM one depending on the pipeline stage that computes its result. This produced data can only be used after it has been saved in a register. Meanwhile, three subsequent instructions will have passed the ID stage and have no longer read access to the register bank. Each of these instructions may need to use the result of instruction *i* in one of the pipeline stages ID, EXE, or MEM. Thus, for each instruction category, nine cases of hazards can occur. All these data hazards are summarized in Fig8. The name of each of these hazards will include both consumer and producer instructions names and their relative position where the producer one is always considered as the instruction *i*. For example, if an instruction must use in the ID stage, the result of a previous one computed in the EXE stage, then, it is the hazard named "ResEXE_RegID_i+1" .

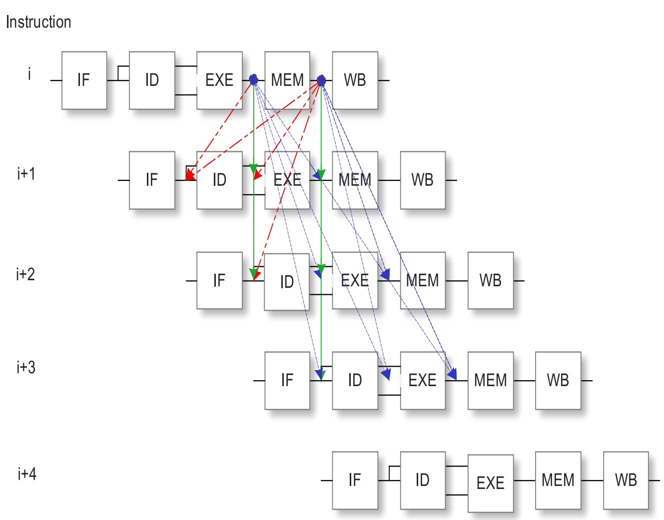

Fig. 8. Data Hazards.

B. Solutions Discussions

In order to solve data hazards, the simplest way is to delay the execution of the consumer instruction until the result of the producer one is available in the register bank. However, the frequent use of this solution degrades considerably the processor performances. Therefore, architectural solutions are proposed to limit as much as possible, pipeline stalling.

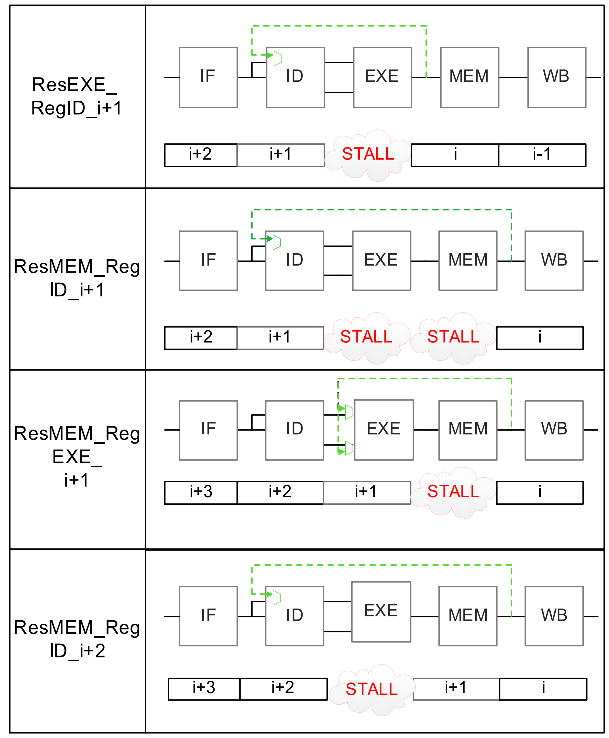

Fig. 9. Proposed Solutions form the First Category of Data Hazards.

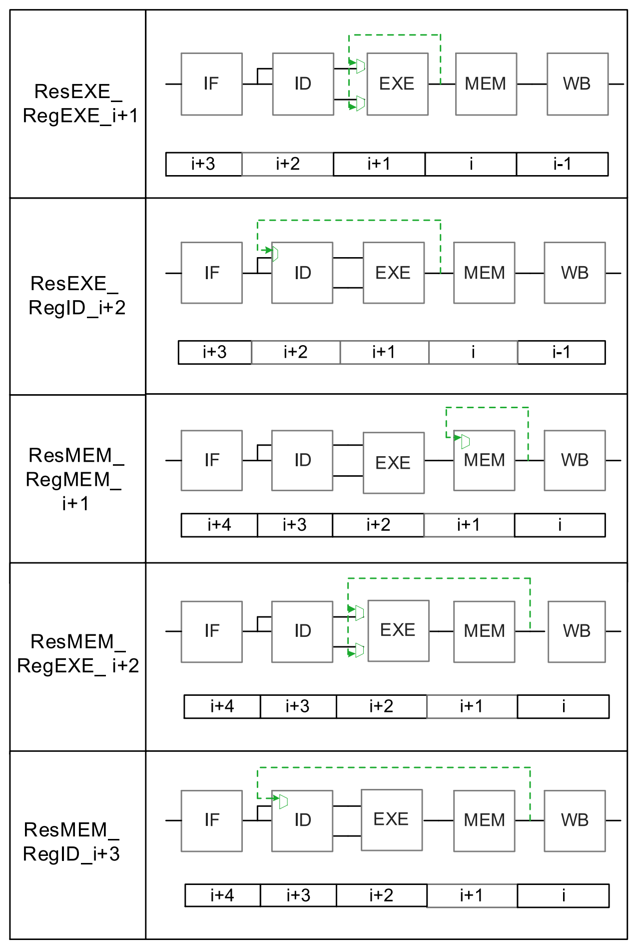

Fig. 10. Proposed Solutions for the Second Category of Data Hazards.

Since there is no common solution to all situations, hazards are classified according to the availability and the position of the result at the clock cycle it is claimed. Three categories are identified:

- The result is not yet calculated.
- The result is ready and has not left the stage where it has been calculated.
- The result is ready and left the stage where it has been calculated but has not yet reached the register bank.

1) First category solutions: The requested data is not yet ready. Therefore, the use of idle cycles is imperative until the result computation ends. Then, a bypass is used to bring back this result to the pipeline stage that requires it. All situations belonging to this category and their proposed solutions are summarized in Fig.9.

2) Second category solutions: In this case, the result is available in the stage where il was calculated. A bypass is simply added to send it back. The different solutions of this hazards category are illustrated in Fig.10.

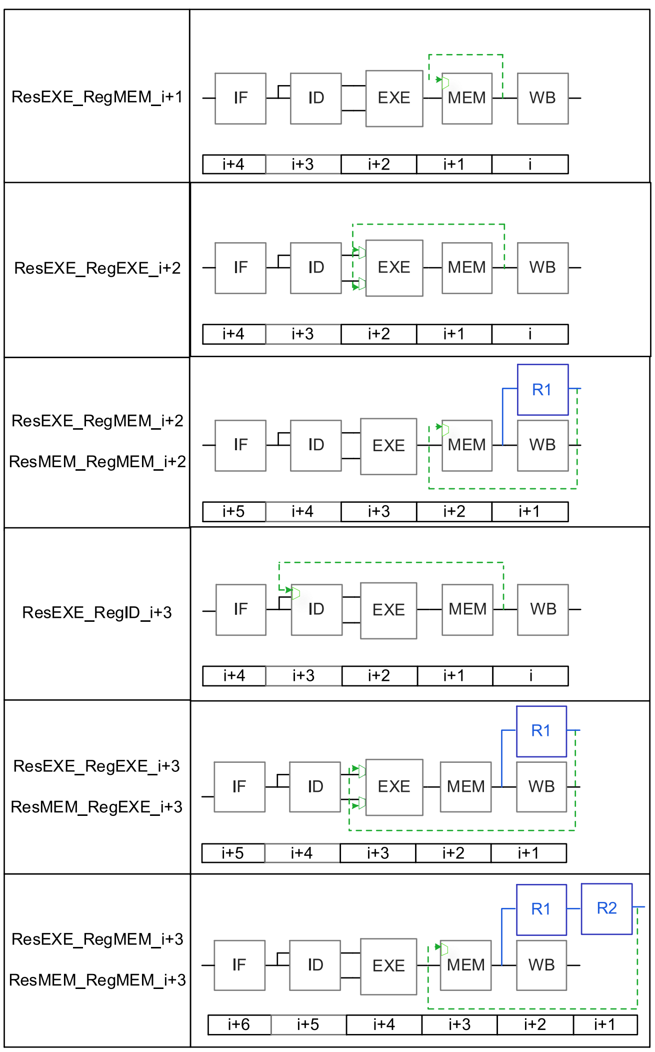

Fig. 11. Proposed Solutions for the Thired Category of Data Hazards.

3) Third category solutions: These hazards occur when the producer instruction result has left its initial pipeline stage but has not yet attained the register bank. Thus, it remains unreachable by the consumer instruction. To solve these hazards, the result must first be located in the pipeline. If the consumer instruction reaches the stage where it need to use the producer instruction result before the latter reaches the WB stages, then, the use of bypass is enough. Otherwise, if the result is already stored in the register bank then it becomes inaccessible because only the instruction in the ID stage has a reading access to the register bank. For such situations, additional registers must be provided to save the result until the consumer instruction requests it. Then, it is brought back via bypass. Fig.11 presents solutions for each instruction belonging to this category.

C. *The Implementation of the Proposed Solution*

A global solution, built from the specific ones proposed for each hazard, is implemented. In fact, bypasses are inserted into the pipeline architecture and multiplexers are used to select the suitable data.

Besides these architectural modifications, the control of stall cycles as well as multiplexers added to the global architecture has to be insured. However, this management of these parameters depends on several factors such as instructions and hazard types. For this, the control of each pipeline stage is analyzed separately. In the absence of hazards, the data is directly extracted from the previous stage. Otherwise, the requested data is either available on one of the bypass paths, or it is still being processed. For this last situation one or more waiting cycles must be inserted. Thus the analysis concerns only stages which can host consumer instructions that are ID, EXE and MEM.

D. *Data Hazards Control*

1) ID stage control: There are six hazards where a consumer instruction is present in the ID stage. Three of them belong to the first category therefore they require one or two waiting cycles before reading the data from one of the bypass. The other three are from the second and the third categories, so the data is read immediately from one of the ID stages inputs. Thus depending on the hazard, one of three following solutions must be selected:

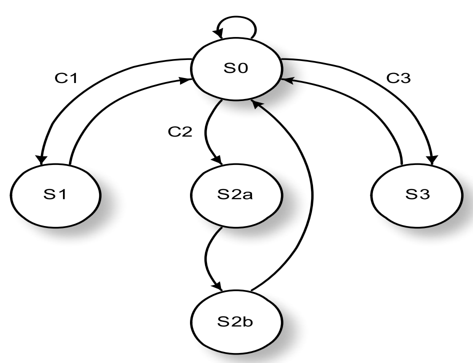

Fig. 12. ID Stage Control.

- Insert 2 stall then read the data.
- Insert 1 stall then read the data.
- Read the date immediately.

These solutions are managed using the FSM presented by the Fig.12. It is composed by five states:

- S_0: Default status, it processes the immediate data reading situations and corresponds to the first waiting cycle if needed.
- S_1: Used by the hazard ResEXE_RegID_i+1 needing only one waiting cycle.
- S_{2a}: It corresponds to the second waiting cycle for the ResMEM_RegID_i+1 hazard needing two stall cycle.
- S_{2b}: Used by the ResMEM_RegID_i+1 hazard.
- S_3: Used by the hazard ResMEM_RegID_i+2 needing only one waiting cycle.

Transitions from S_0 to the other states are controlled by the following conditions:

- **C_1:** stage(i)=ID and TypeInst(i)=RegID and RS(i)=RD(i-1) and TypeInst(i-1)=ResEXE.
- **C_2:** stage(i)=ID and TypeInst(i)=RegID and RS(i)=RD(i-1) and TypeInst(i -1)=ResMEM.
- **C_3:** stage(i)=ID and TypeInst(i)=RegID and RS(i)=RD(i-2) and TypeInst(i -2)=ResMEM.

2) Control of the EXE stage: Among the six hazards including consumer instruction in the EXE stage, only one belongs to the first category and requires a waiting cycle. In the remaining cases, the missing data is available in one of the bypass paths. Thus the control of the EXE stage is done either by immediate reading of the data from the different inputs, or by inserting one stall cycle before. Since there is not a single common solution in all situations, the FSM illustrated in Fig.13 is used. It has only two states:

- S_0: Default status, it processes the immediate data reading situations and corresponds to the first waiting cycle if needed.
- S1: State that processes the ResMEM_RegEX_i+1 hazard requiring only one idle cycle.

The transition condition is:

C : stage(i)=EXE **and** TypeInst(i)=RegEXE **and**

((NbOpInstr(i)= 2 **and** (RS1(i)=RD(i-1) **or** RS2(i)=RD(i-1))

or (NbOpInstr(i)= 1 **and** (RS1(i)=RD(i-1))) **and**

TypeInst(i-1)=ResMEM.

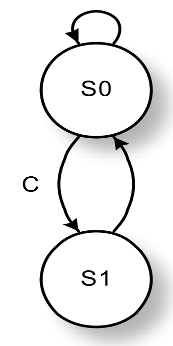

Fig. 13. EXE Stage Control.

3) Control of the MEM stage: The remaining six hazards present consumer instruction at the MEM stage. No waiting cycles are needed for all these cases. Thus the control of this stage consists only on the correct programming of the input multiplexer to choose the suitable data.

VI. Implementation of the Proposed Solutions

The programmable processor as well as the proposed hazards solutions are described in VHDL language. The implementation and validation step were performed using Mentor Graphics Questasim software tool. For this work, we focus only on the validation of techniques we used to solve the different types of pipeline hazards. We choose to study an example of each type.

A. Branch Detection

To validate the branch predictor unit, a code sequence including branch instructions is used. Simulation results are illustrated in Fig.14. *Pred* is the 2-bits saturation counter used by the branch predictor. Its initial value is “01”. Thus, the first branch instruction is predicted as “not taken” and no jump is made. When this instruction reaches the EXE stage, the branch is “taken”. Then, the instruction at the jump address is injected into the pipeline, *Pred* is incremented and the wrong instructions are neutralized. If an branch instruction is fetched again, then, it is predicted as “taken”.

B. Data Hazards Management

This following pseudo-code sequence is used to simulate data hazards:

addi R2, R0, 100

lw R3 0(R2)

addu R4, R2, R3

S_OP1 and *S_OP2* are the controllers of multiplexers at the input of the EXE stage. 0 selects the ID stage data, while 1, 2 and 3 correspond respectively to the MEM and WB stages and the additional register data. Analyzing the simulation of fig.15, it should be noted that the controllers value depend on the required data position. Sometimes, the use of a stall cycle is imperative as for the last instruction.

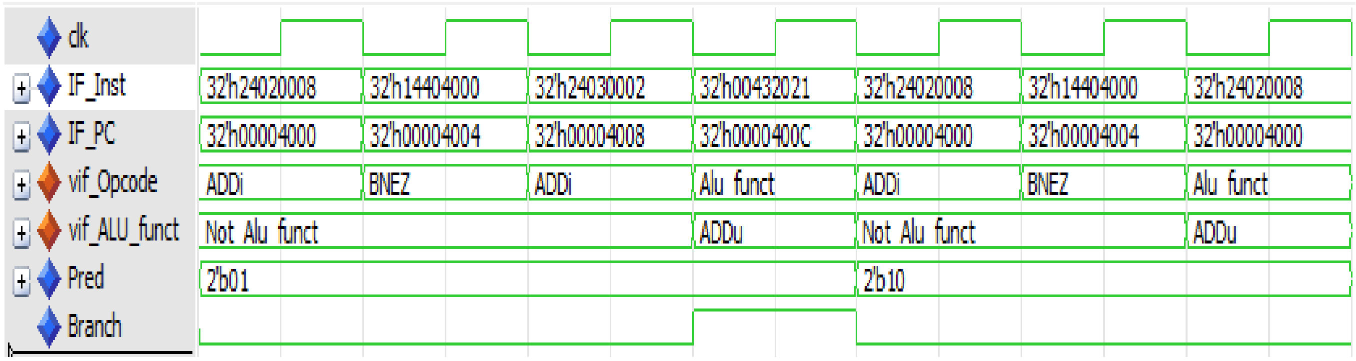

Fig. 14. Branch Detection Simulator.

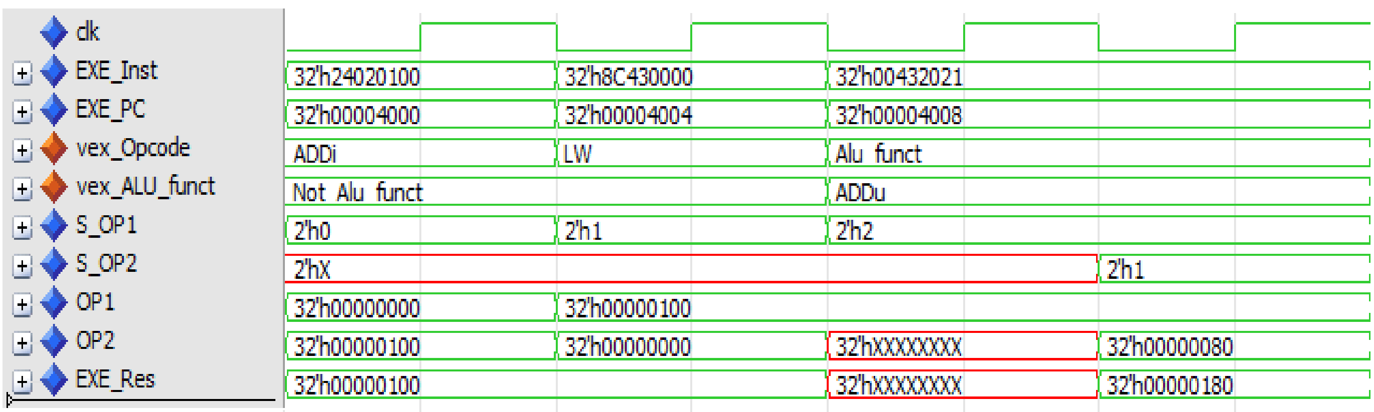

Fig. 15. Data Hazards Control.

VII. Conclusion

The integration of the pipeline technique in the processor architectures is essential to ensure high performances level able to cope with nowadays technology challenges. However, a wrong control of the pipeline stages can disturb instructions execution and alter processor performances. Therefore a precise analysis of hazards related to each pipelined processor architecture, is necessary to be able to implement the suitable control system.

In this paper, a detailed study of the different kinds of hazards that can occur in the pipelined architecture of our programmable processor is presented. Mainly, data and control hazards are identified. Then, solutions for each category are proposed. A prediction algorithm that uses the one-level branch predictor with a 2-bit saturation counter associated to a "Branch-Target Buffers" is used to solve control hazards while for data hazards, bypasses are implemented and controlled using FSMs. These different solutions are implemented and validated using Mentor Graphics Questasim software tool.

In future work, the suitable compiler for this programmable processor will be designed then its silicon implementation will be performed.

References

[1] P. Ienne, R. Leupers, "Automated processor configuration and instruction extension" in Customizable embedded processors, design technologies and applications, 1st ed. Elsevier Science, 2006, ch6, pp.117-142.

[2] M.K. Jain, M. Balakrishnan, A. Kumar, "ASIP design methodologies: survey and issues", inproceedings of Fourteenth International Conference on VLSI Design, Bangalore, India, 2001.

[3] C. Zhang, "Design of Coarse-Grained Reconfigurable Architecture for Digital Signal Processing", PhD thesis, Department of Electrical and Information Technology, Lund University, Sweden, 2009.

[4] N. Vassiliadis, N. Kavvadias, G. Theodoridis, S. Nikolaidis, "A RISC architecture extended by an efficient tightly coupled reconfigurable unit", in International journal of electronics, vol. 93, no. 6, pp. 421-438, 2006.

[5] M.O. Abdulfattah, "Architectural synthesis of a coarse grained run-time-reconfigurable accelerator for DSP applications", PhD thesis, Technische Universität, Darmstadt, Germany, 2006.

[6] H.Najjar, R.Bourguiba, J.Mouine "A new programmable ALU architecture for hard-core processor", International IEEE Multi-Conference on Systems, Signals and Devices, 2016.

[7] D. M. Harris, and S. L. Harris, "Microarchitecture" in Digital Design and Computer architecture, 1st ed. Morgan Kaufmann, 2012, ch. 7, sec. 5, pp. 701-720.

[8] D. A. Patterson, and J. L. Hennessy, "Enhancing performance with pipelining" in Computer Organization and Design, 3ed ed. Morgan Kaufmann, 2007, ch. 6, sec. 2, pp.384-399.

[9] D. A. Patterson, and J. L. Hennessy, "Pipelining" in Computer Architecture and Quantitative Approach, 2nd ed. Morgan Kaufmann, 2012, ch. 3, sec.3, pp. 139-146.

[10] D.A. Patterson and J.L. Hennessy. Computer Organization and Design: The Hardware/Software Interface. The Morgan Kaufmann Series in Computer Architecture and Design. Elsevier Science, 2011.

[11] John L. Hennessy and David A. Patterson. Computer Architecture (2nd Ed.) : A Quantitative Approach. Morgan Kaufmann Publishers Inc., 1996.

[12] D.M. Harris and S.L. Harris. Digital Design and Computer Architecture. Engineering professional collection. Morgan Kaufmann, 2013.

[13] L Gwennap. New algorithm improves branch prediction. MicroDesign Ressources, 9(4), 1995.

[14] B. Lee. Dynamic branch prediction. http ://web.engr.oregonstate.edu/ benl/Projects/branch pred/. Accessed : 2018-01-25.

[15] Tse-Yu Yeh and Yale N. Patt. Two-level adaptive training branch prediction. pages 51-61,1991.

[16] S McFarling. Combining branch predictors. Technical report, 1993.

[17] Andre Seznec and Pierre Michaud. A case for (partially) tagged geometric history length branch prediction. J. Instruction-Level Parallelism, 8, 2006.

[18] Andre Seznec. Analysis of the o-geometric history length branch predictor. SIGARCH Comput. Archit. News, 33(2):394-405, May 2005.

[19] Daniel A. Jimenez and Calvin Lin. Dynamic branch prediction with perceptrons. pages 197,2001.

[20] Andre Seznec, Stephen Felix, Venkata Krishnan, and Yiannakis Sazeides. Design tradeoffs for the alpha ev8 conditional branch predictor. SIGARCH Comput. Archit. News, 30(2) :295-306, May 2002.

[21] Pierre Michaud, Andre Seznec, and Richard Uhlig. Trading conflict and capacity aliasing in conditional branch predictors. SIGARCH Comput. Archit. News, 25(2) :292-303, May 1997.

Automatic Short Answer Scoring based on Paragraph Embeddings

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***Abstract*—Automatic scoring systems for students' short answers can eliminate from instructors the burden of grading large number of test questions and facilitate performing even more assessments during lectures especially when number of students is large. This paper presents a supervised learning approach for short answer automatic scoring based on paragraph embeddings. We review significant deep learning based models for generating paragraph embeddings and present a detailed empirical study of how the choice of paragraph embedding model influences accuracy in the task of automatic scoring.**

Keywords*—*Automatic scoring; short answer; Pearson correlation coefficient; RMSE; deep learning

I. Introduction

Improving the quality of education is always a desired goal in educational institutions. In higher education institutions, many courses are given in large classrooms where number of attending students is large. Such large learning environments present special challenges on instructors and one of these challenges is students' assessments. One technology solution for this problem is automatic scoring of students' answers. Automatic short answer scoring is the task of "assessing short natural language responses to objective questions using computational methods" [1]. This eliminates from instructors the burden of grading large number of test questions and facilitates performing even more assessments during lectures. Different types of questions are used in assessments such as multiple choice questions, true/false questions, numeric answer questions, short answers questions, and essay questions. Short answer and essay answer questions require more complicated work related to text processing and analysis; while automatic scoring of other types can be easy and direct task. This paper is concerned with automatic scoring of short answers. An answer is considered short answer if its length approximately ranges from one phrase to one paragraph [1].

The proposed model employs deep learning method named paragraph embedding on students' answers and reference answers to generate vector representation of answers. Cosine similarity measure between vectors of students' answers and reference answer is used as a feature vector to train regression classifier for predicting students' scores.

Paragraph embedding - also referred to as Paragraph vectors [2], sentence encoders [3] - is the method of generating numeric fixed-length vector representations for variable length pieces of texts [2].

There are two general types for paragraph embedding models. The first one is based on applying mathematical operations (e.g. sum, average) on retrieved word vectors for all words in a given paragraph in order to generate the paragraph vector. The second approach is training a model to infer the paragraph vector for a given sentence. We compared different state-of-the-art techniques from the two types by employing them to solve automatic short answer scoring problem. The objective of this study is to apply a comprehensive evaluation of multiple state-of-the-art paragraph embedding models by applying them to the task of short answer automatic scoring. And consequently, fill the present gap in the literature for this regard.

This paper is organized as follows:

- Section II presents related work of automatic short answer scoring algorithms.
- Section III briefly explains the proposed methods used for text modeling and text similarity.
- Section IV presents the used Dataset.
- Section V describes the models used in this research.
- Section VI shows experiments results and discussion.
- Section VII presents conclusion and future work.

II. Related Work

Different approaches are used to solve automatic short answering problem. The first approach is based on using unsupervised techniques that combine text-text similarity measures to compare student answer and reference answer and predict score based on similarity value.

Survey [4] presents 3 types of text-text similarity measures. The first type is string based similarity measures which work on string sequences (term-based similarity) or character composition (character-based similarity). The second type is corpus based similarity measures which are semantic measures that find similarity between words according to information gained from large corpora. The third type is knowledge based similarity measures which are also semantic similarity measures that are based on semantic networks.

Reference [5] compared number of knowledge-based and corpus-based measures of semantic similarity. These measures were applied on different domain specific corpuses with different sizes to examine the effect of domain and corpus size.

The researchers also introduced a method to feedback model with students' answers to solve the problem of correct student answers that are not similar to the reference answer. The best achieved correlation coefficient value was obtained using LSA corpus based similarity applied on domain-specific corpus built on Wikipedia along with feedback from students answers. Correlation coefficient value is 0.5099 measured by comparing grade assigned to every student answer with actual grade; and 0.6735 measured by comparing total student scores with actual totals of grades per student.

Reference [6] tested different text-text similarity measures and combined measures that gave best results to get overall similarity. The different measures were tested on student answers dataset provided at [7], the highest correlation coefficient achieved when comparing students' answers with reference answers was 0.504. This result was achieved by combining N-gram character based similarity with DISCO [8] first order corpus based similarity applied using Wikipedia data packets.

A second approach is training machine learning algorithms to predict scores given set of calculated features.

Reference [9] presents two supervised learning models. The first model is a regression model trained to predict students' scores. The second model is a multi-class classifier trained to predict the labels of student' answers (e.g. correct, incorrect, or contradictory). The models were trained on eight calculated features. The first three features are based on text similarity between student answer and reference answer calculated in three different methods. The second three features are the same three text similarity measures but calculated after removing question text words from both reference answer and student answer. The seventh feature is calculated after applying term weighting based on variant of tf-idf. The final feature is the ratio of number of words in student answer to that in reference answer. The first model is trained on student answers dataset provided at [7] and the second model is trained on SemEval-2013 task [10]. The regression model achieved correlation coefficient of 0.592 and RMSE of 0.887 when tested on out-of-domain data. The model achieved 0.63 correlation coefficient value and .85 RMSE when tested on in-domain data. The classification model achieved F1 score of 0.550.

A third approach is employing deep learning architectures that enable multi-level automatic feature representation learning. These architectures are increasingly used in the past years as they showed superior results in various NLP tasks [11].

Several paragraph embedding models are built based on deep learning architectures and now became the state-of-the-art methods for NLP problems. Reference [11] provides a review of different significant deep learning models applied in NLP tasks. For the task of paragraph embedding, multiple models were presented. Convolution Neural Networks (CNN) which proved their effectiveness in many computer vision tasks had become the natural choice in NLP tasks with the need for models that can extract high level features form sequences of words. Recurrent Neural Networks (RNN) is another type of deep learning models that become widely used in NLP tasks. Its advantage comes from its nature of memorizing previous computations and using them in current processing. In the context of word sequences, this allows it to capture the inherent sequential nature present in language. A third type of deep learning models is Recursive Neural Networks that is based on the argument that language exhibits a natural recursive structure. I.e. words and sub-phrases are combined into phrases in a tree structure manner. A forth type is Deep Reinforcement Learning models which are applied in NLP problems related to language generation. A fifth type that gained some interest recently is based on merging neural networks with a form of memory that the model can interact with. This type is called Memory Augmented Networks. Word Embeddings trained on large unlabeled corpora provide distributional vector representation of words. These representations have the advantage that they capture semantic meanings of words. The semantic similarities between words can then be measured with simple methods such as cosine similarity. Word embeddings are often used as the input layer for deep learning models. [11]. In this paper, some state-of-the-art deep learning based models trained for NLP tasks are presented and evaluated in the context automatic short answer scoring problem.

III. Vector Representation and Text Similarity Measures

In this paper, the focus is on two approaches that can be used to generate vector representations of short answers, i.e. paragraph embeddings. The first approach is generating the paragraph vector of an answer by calculating the sum of word vectors for words in the answer. The second approach is training a deep learning model to directly infer the paragraph vector of a given answer.

A. *Words Embeddings*

Word embeddings are techniques for learning vector representations for words. Word embedding models are usually trained on large unlabeled corpora in order to exploit their benefits [12]. Multiple models for word embeddings trained on large corpus of data are publically available. These pre-trained models have the advantage of storing semantic relationship between words. In this paper, we tested 4 different pre-trained word vector models for generating paragraph vectors and applied results in task of automatic short answering.

The method is: given a short answer (student answer or reference answer); the objective is to generate the paragraph vector of the answer. First, the answer is tokenized to get a list of its words and any necessary text processing is applied (e.g. removing punctuation marks). Second, given word vector model, the corresponding word vector for each word is retrieved. Finally, to get the paragraph vector, sum operation (which is commonly used in all reviewed literature) is applied on all word vectors to get a single vector representing the paragraph vector. Fig.1 demonstrates this method.

Below we introduce word embedding methods chosen for this study.

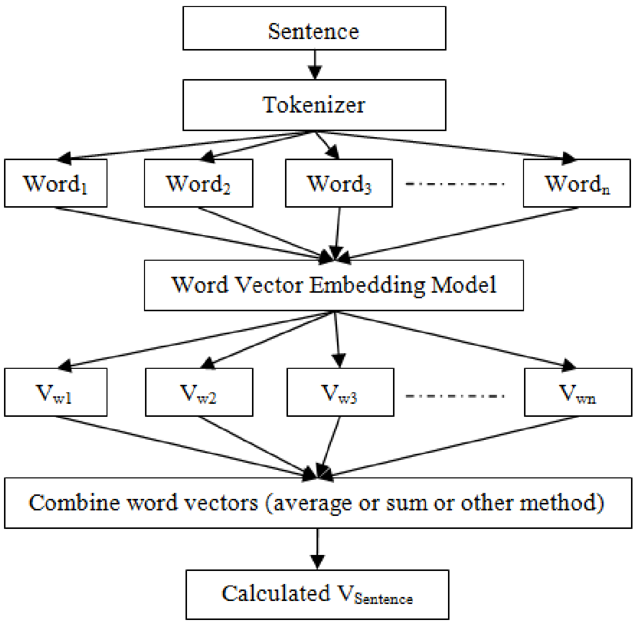

Fig. 1. Generating Paragraph Vectors from Pre-Trained Word Vector Models.

1) Word2Vec: The word2vec model [2] is based on neural network trained to predict a word given the context of surrounding words. One of the features of this model is that after training, words with similar meanings are mapped to similar positions in vector space. Also, some semantic relationships between words can be inferred by applying simple mathematical calculations. For example: "King" - "man" +"woman" = "Queen". Google [1] provides 300-dimensional pre-trained word2vec model. The model was trained on part of Google News dataset (approximately 100 billion words). The model provides word vectors for 3 million words and phrases.

2) GloVe [2]: GloVe (Global Vectors) [13] is a word embedding model that combines features from two major models for generating word vectors: global matrix factorization and local context window (word2vec is an example of local context window model). This combination of features from the two models' types allows taking advantages from both models as well as overcoming some of their drawbacks. We used 300-dimensional pre-trained word vectors trained on a combination of Gigaword5 and 2014 dump of English Wikipedia. The model provides word vectors for 400,000 tokens.

3) Fasttext [3]: Fasttext model [12] is based on skip-gram model where each word is represented as a bag of its character n-grams. A vector representation is associated to each character n-gram; and word vector is computed as the sum of the n-gram vector representations. We used 300-dimensional pre-trained word vectors model that provides 2 million word vectors trained on Common Crawl.

4) Elmo [4]: Elmo (Embeddings from Language Models) [14] is a deep contextualized word representation that models (1) word syntax and semantics and (2) word uses across different linguistic contexts (polysemy). The learned word vectors are function of the internal state of deep bidirectional language model (biLM) rather than just using that top LSTM layer. We used 1024-dimensional word vectors pre-trained on 1 billion word benchmark5.

B. *Paragraph Embeddings*

In paragraph embedding models, deep learning model is trained on sequences of text to directly learn and infer vector representation of variable-size sequence. Fig.2 demonstrates this method.

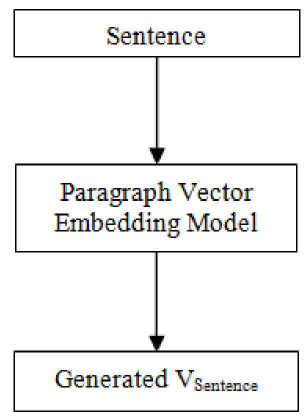

Fig. 2. Generating Paragraph Vectors from Paragraph Embedding Models.

Below we introduce paragraph embedding methods chosen for this study.

1) Doc2vec: With this model, a neural network classifier with stochastic gradient descent algorithm is trained on a fixed-width sliding window over words of paragraphs. Paragraph vectors are learned along with word vectors so the trained model can be used to infer paragraph vectors or word vectors [2] [15].

Gensim Doc2vec [16] is a python library that provides an implementation of paragraph vectors model. It is designed to model word sequences ranging from n-gram sentence, paragraph, or document. We trained 300-dimensional doc2vec model on our benchmark dataset used for addressing automatic short answering problem.

2) InferSent [6]: InferSent [3]is a sentence encoder model for learning universal representation of sentences. The encoder model is based on bidirectional LSTM architecture with max pooling trained on the supervised data of the Stanford Natural Language Inference datasets (SNLI). We used two 4096-dimensional pre-trained models, one uses fasttext pre-trained word vectors for representing words in sentences and the second uses GloVe pre-trained word vectors.

[1] https://code.google.com/archive/p/word2vec/
[2] https://nlp.stanford.edu/projects/glove/
[3] https://github.com/facebookresearch/fastText

[4] https://allennlp.org/elmo
[5] http://www.statmt.org/lm-benchmark/
[6] https://github.com/facebookresearch/InferSent

3) Skip-Thoughts [7] : Skip-thoughts model is an unsupervised learning model for sentence encoding, i.e. mapping a sentence composed of words to sentence vector. The model is trained to generate sentence vectors using an approach similar to skip-gram model [17] but works on sentence level instead of word level. So given a training corpus of contiguous text, the model is trained to predict surrounding context sentences of a given sentence. The model also provides a vocabulary expansion method to encode new words that were not seen in the training phase [18]. We used 2400-dimensional pre-trained skip-thought model where sentence vectors were trained on BookCorpus dataset [19].

C. Text Similarity Measure

For similarity between paragraph vectors, cosine similarity method is used. Cosine similarity of vectors is the cosine of the angle between vectors in inner-product space [20]. This value has the property of being 1.0 for identical vectors and 0.0 for orthogonal vectors. Cosine similarity can also be calculated by applying the inner-product between vectors of unit length.

IV. The Dataset

The benchmark dataset used is short answer grading dataset V2.0[8]. This dataset consists of ten assignments between four to seven questions each and two exams with ten questions each. Total number of questions is 87; six of them are not short answer questions so they were excluded from the authors' published work. The experiments in this paper also were applied only on the 81 short answer questions. The number of students' answers per question ranges from 24 to 31 with average of 28 answers and the total number of short answers is 2273.

These assignments/exams were provided at an introductory computer science class at the University of North Texas. Elements of the dataset are questions' texts, the reference answer for each question, and students' answers. The answers were graded by two different graders; both grades of grader1 and grader 2 along with the average grade of the two graders are provided for each answer. All three types of grades are in range 0 to 5 [7]. This research works on average of grades following other researchers [7, 9, 6].

TABLE I. SAMPLE QUESTION, REFERENCE ANSWER AND STUDENTS' ANSWERS

Question	What is typically included in a class definition?	
Reference Answer	Data members (attributes) and member functions	
Students Answers And Average Grades		
Student 1 Answer	Data members and member functions	5
Student 2 Answer	the keyword class followed by they class name, on the inside you declare public and private declarations of your class	3.5
Student 2 Answer	Class name, two curly prenthesis, public and private	2

[7] https://github.com/ryankiros/skip-thoughts
[8] http://lit.csci.unt.edu/index.php/Downloads

Table I shows sample question with its reference answer and 3 samples of students' answers with their average grades. Prior to feeding students answers and reference answers for the different paragraph embedding models explained in section III, primitive sentence pre-processing techniques were applied to extract tokens after removing punctuation marks and stop words.

V. Methods

In order to compare the accuracy of the various models listed in section III; these models are tested for the task of automatic short answer scoring. Steps are as follow (applied separately for each paragraph embedding model):

A. Generate Paragraph Vector

For each answer (student answer and reference answer), the paragraph vector is retrieved using each of the models listed in section III. In the case of using sum of pre-trained word embeddings, the first step is to load a pre-trained file containing dictionary of words with their word vectors into memory. Then, words of the answer are matched with words in dictionary to get list of word vectors for found words. This is the case with GloVe, Google word2vec, and fasttext embeddings. For Elmo embeddings, a tensorflow hub[9] is used to load online trained model.

For the case of using direct training of paragraph embedding model, settings vary based on the model. We trained doc2vec directly on tokenized students answers and reference answers on order to learn vector representation of them. InferSent provides a pre-trained sentence encoder model that can be used directly to infer paragraph vector of a given sentence. As the training phase requires word vectors to be used as input layer of the deep learning model, the pre-trained model comes with two versions, one trained with Glove word vectors and the second trained with fasttext word vectors. Skip thoughts also provides pre-trained model sentence encoder. The pre-trained model comes with multiple files that can be loaded and used directly to encode sentences to paragraph vectors.

Tables II and III shows the different file sizes of pre-trained embedding models used from the two types.

TABLE II. DISK CONSUMPTION OF PRE-TRAINED WORD VECTOR MODELS

Word Embedding Model	Pre-trained Word Vectors File size
GloVe	989 MB
Google word2vec	3.39 GB
Fasttext	4.20 GB

TABLE III. DISK CONSUMPTION OF PRE-TRAINED PARAGRAPH EMBEDDING MODELS

Paragraph Embedding Model	Pre-trained Model File size
Doc2vec	Didn't use saved models
InferSent	146 MB
Skip thoughts	Multiple files with total size of 5.25 GB

[9] https://tfhub.dev/google/elmo/2

B. Calculate Cosine Similarity

For each student answer-reference answer pair, we calculate cosine similarity of their corresponding paragraph vectors.

C. Train Regression Classifier

We used cosine similarity measure as a feature vector to train Ridge regression classifier model for predicting students' scores. A train/test split of 85% for training data and 25% for testing data is used.

D. Measure Accuracy

Calculate Pearson Correlation Coefficient and RMSE for predicted scores and actual grades.

VI. Experiments and Discussion

Table IV shows the results of applied methods explained in section V. The table shows that the best correlation coefficient result is 0.569 and the best RMSE value is 0.797. Both values were achieved by training doc2vec model only on sentences from the dataset to generate their paragraph vector. But this raises the question: will this model produce same results when tested on new unseen data from same domain of questions? Out of the other models, fasttext achieved best correlation coefficient value (0.519) and Google word2vec achieved best RMSE (0.821) value which requires further investigation as trained paragraph embedding models claim to achieve best state-of-the-art results. From memory consumption perspective, GloVe based paragraph embedding model, InfeSent model, and Doc2vec model provided best results with least amount of memory needed to load pre-trained models. Elmo model consumed the largest amount of memory and time for running the model and yet didn't achieve the best results.

TABLE IV. Results of Regression Classifier Trained on Similarity Between Paragraph Vector of Student Answers And Reference Answers

Paragraph Embedding Method	Model	Dim	Pearson Correlation Coefficient	RMSE
Sum of pre-trained word vector model	GloVe	300	0.507	0.838
	Google word2vec	300	0.532	0.821
	FastText	300	0.519	0.831
	Elmo	1024	0.390	0.896
Training of paragraph vectors model	doc2vec	300	0.569	0.797
	InferSent with Glove word vectors	4096	0.506	0.843
	InferSent with fasttext word vectors	4096	0.4597	0.862
	Skip thoughts	2400	0.468	0.861

Researches [6] and [9] tested their models on same dataset and provided the same accuracy measures as ours. Research [6] which apply direct text-text similarity between student answer and reference answer to predict score achieved correlation coefficient value of 0.504 compared to 0.569 reported in table IV. We couldn't compare with the RMSE value because it was not included in the mentioned paper.

Research [9] presented result of 0.63 correlation coefficient value and 0.85 RMSE by training a regression classification model. All models tested in this paper shows comparable results for RMSE but fewer results in the correlation coefficient. We emphasize on that classification model in reference [9] uses multiple feature vectors for classification task including cosine similarity of off-the-shelf word embeddings. Authors didn't provide test measurements for the effect of each feature vector separately .The classification task in our model uses only one feature vector which is cosine similarity of paragraph vectors.

VII. Conclusion and Future Work

In this study, seven different models for embedding short answer text were evaluated. 4 are based on sum of pre-trained word vectors and 3 are based on trained deep learning model for inferring paragraph vectors. The models were evaluated in the context of the automatic short answer scoring task and the study reveals that using pre-rained models achieved comparable results for the task of automatic short answer scoring.

A Forthcoming paper aims to apply the same methods to other short answer scoring datasets to see if similar results will be achieved. Also, to investigate the impact of word vectors combination new operators (such as weighted sum) and considering the additional use of non-embedding features on the correlation and RMSE values.

References

[1] S. Burrows, I. Gurevych and B. Stein, "The eras and trends of automatic short answer grading," International Journal of Artificial Intelligence in Education, vol. 15, no. 1, pp. 60-117, 2015.

[2] Q. Le and T. Mikolov, "Distributed representations of sentences and documents," in *In Proceedings of the 31st International Conference on Machine Learning (ICML 2014)*, Beijing, China, 2014.

[3] D. K. H. S. B. B. Alexis Conneau, "Supervised learning of universal sentence representations from natural language inference data," *arXiv preprint arXiv*, vol. 1705, no. 02364, 2017.

[4] A. A. F. Wael H Gomaa, "A Survey of text similarity approaches," *International Journal of Computer Applications68*, pp. 13-18, 2013.

[5] M. Mohlerl and R. Mihalcea, "Text-to-text semantic similarity for automatic short answer grading," in *Proceedings of the 12th Conference of the European Chapter of the Association for Computational Linguistics*, Athens, Greece, 2009.

[6] W. H. Gomaa and A. A. Fahmy, "Short Answer Grading Using String Similarity And Corpus-Based Similarity," *International Journal of Advanced Computer Science and Applications(IJACSA)*, pp. 115-121, 2012.

[7] M. Mohler, R. Bunescu and R. Mihalcea, "Learning to Grade Short Answer Questions using Semantic Similarity Measures and Dependency Graph Alignments," in *Proceedings of the 49th Annual Meeting of the Association of Computational Linguistics - Human Language Technologies (ACL HLT 2011)*, Portland, Oregon, 2011.

[8] P. Kolb, "DISCO: A Multilingual Database of Distributionally Similar Words," *In Proceedings of KONVENS-2008*, 2008.

[9] S. M. Arafat, C. Salazar and T. Sumner, "Fast and easy short answer grading with high accuracy.," in Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies., San Diego, California, 2016.

[10] Dzikovska, M. O., R. D. Nielsen and C. Leacock, "The joint student response analysis and recognizing textual entailment challenge: making sense of student responses in educational applications.," *Language Resources and Evaluation*, vol. 50, no. 1, pp. 67-93, 2016.

[11] D. H. S. P. E. C. Tom Youngy, "Recent trends in deep learning based natural language processing," *arXiv preprint arXiv:,* vol. 1708, no. 02709, 2017.

[12] P. Bojanowski, E. Grave, A. Joulin and T. Mikolov, "Enriching word vectors with subword information," *arXiv preprint arXiv,* vol. 1607, no. 04606 , 2016.

[13] Pennington, Jeffrey, R. Socher and C. Manning, "Glove: Global vectors for word representation.," 2014.

[14] M. N. M. I. M. G. Matthew E. Petersy, "Deep contextualized word representations," *arXiv preprint arXiv,* vol. 1802, no. 05365, 2018.

[15] J. H. Lau and T. Baldwin, "An empirical evaluation of doc2vec with practical insights into document embedding generation," arXiv preprint arXiv:1607.05368, 2016.

[16] R. Rehurek and P. Sojka, "Software Framework for Topic Modelling with Large Corpora," in *Proceedings of the LREC 2010 Workshop on New Challenges for NLP Frameworks*, Valletta, Malta, 2010.

[17] T. Mikolov, K. Chen, G. Corrado and J. Dean, "Efficient estimation of word representations in vector space," *arXiv preprint arXiv,* vol. 1301, no. 3781, 2013.

[18] K. Ryan, Y. Zhu, R. R. Salakhutdinov, R. Zemel, R. Urtasun, A. Torralba and S. Fidler, "Skip-thought vectors," *Advances in neural information processing systems,* pp. 3294-3302, 2015.

[19] R. K. R. Z. R. S. R. U. A. T. S. F. Yukun Zhu, "Aligning Books and Movies: Towards Story-like Visual Explanations by Watching Movies and Reading Books.," *arXiv preprint arXiv,* vol. 1506, no. 06724, 2015.

[20] A. Singhal, "Modern information retrieval: A brief overview.," *IEEE Data Eng. Bull.,* vol. 24(4), pp. 35-43, 2001.

Improving Recommendation Techniques by Deep Learning and Large Scale Graph Partitioning

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***Abstract*—Recommendation is very crucial technique for social networking sites and business organizations. It provides suggestions based on users' personalized interest and provide users with movies, books and topics links that would be most suitable for them. It can improve user effectiveness and business revenue by approximately 30%, if analyzed in intelligent manner. Social recommendation systems for traditional datasets are already analyzed by researchers and practitioners in detail. Several researchers have improved recommendation accuracy and throughput by using various innovative approaches. Deep learning has been proven to provide significant improvements in image processing and object recognition. It is machine learning technique where hidden layers are used to improve outcome. In traditional recommendation techniques, sparsity and cold start are limitations which are due to less user-item interactions. This can be removed by using deep learning models which can improve user-item matrix entries by using feature learning. In this paper, various models are explained with their applications. Readers can identify best suitable model from these deep learning models for recommendation based on their needs and incorporate in their techniques. When these recommendation systems are deployed on large scale of data, accuracy degrades significantly. Social big graph is most suitable for large scale social data. Further improvements for recommendations are explained with the use of large scale graph partitioning. MAE (Mean Absolute Error) and RMSE (Root Mean Squared Error) are used as evaluation parameters which are used to prove better recommendation accuracy. Epinions, MovieLens and FilmTrust datasets are also shown as most commonly used datasets for recommendation purpose.**

Keywords—Social big data; social recommendation; deep learning; graph partitioning; social trust

I. Introduction

Social networking sites are used due to a lot of important information available. Large numbers of users interact with each other; share their views on these sites. Business organizations have diverted their business models towards these sites. Researchers, data scientists and innovators are working actively in this area to extract patterns of user behavior. It is assumption that sites which have large numbers of connected users can become source of benefit for other business organizations as well. Analysts have proved that users' personalization is major factor for retaining users on sites. If users are provided with better suggestions for books, friends, topics or products which are of users' interest, it is high probability that effectiveness would be improved significantly. Recommender systems are capable of providing better suggestions to users based on their past history, likings, ratings and trust amongst users. It is dependent on user behavior data and historical data [1]. It is analyzed that 80 percent of movies on Netflix are due to recommendations [2]. 60 percent of YouTube videos from main page are due to recommendation [3]. It reflects significance of recommender systems for users.

Content based and collaborative filtering are categories of recommender systems. In content based systems, users likings is the main factor for recommendation. Ratings based recommendations are provided in collaborative filtering technique. Memory-based and model-based are different methods in collaborative filtering [4]. In memory-based CF, ratings of users are considered for recommendation. In model-based CF, data mining and machine learning techniques are used for recommendation. Models based on clustering [5] and latent semantic [6] are most commonly CF approaches. The drawback of content based approach is users' privacy. Many users do not reveal their like or views for any topic or product. The drawback of collaborative filtering is sparsity and cold start. There exist very few users who provide ratings to products hence user-items ratings matrix values are very less. It is not easy to analyze users similarity based on these few entries. When any user is new to recommender system, there is no ratings information so no similarity with other users can be predicted.

Matrix factorization, large scale graph partitioning, clustering, dimensionality reduction and deep learning are techniques which are provided by recent researches to improve recommendation. There are very few research works which covers all these novel techniques. In this paper, comprehensive analysis of recommendation improvement approaches are available for readers.

Deep learning has been very effective in speech recognition and image processing [7]. Users' likes and similarity with other users are easily concluded from deep learning. AlexNet which is convolutional network model improved classifying images significantly [8]. Feedforward, Recurrent Neural Network, Convolutional Neural Network, Restricted Boltzmann Machine and Deep Belief Network are various models of deep learning. There are models which are beneficial in content based recommendation and others are applicable in collaborative filtering techniques.

The limitation of traditional recommender systems is scalability. When these systems are deployed on large scale data, performance degrades significantly. Some systems are capable enough for recommendation for big social graph, but timings for response are so high that it becomes troublesome for users. There is requirement of novel approach that can handle big social graph. In this paper, solution of scalability issue is also mentioned. Large scale graph partitioning is explained in detail. Random based and trust based partitioning is described in this paper. There are very few research works which covers and integrates sparsity, cold start and scalability solution.

There are numerous datasets available for recommendation which makes readers confused and they are not able to select most suitable dataset as per their requirements. In this paper, Epinions, FilmTrust and MovieLens statistics are described in detail and their usage for particular approaches. MAE (Mean Absolute Error), RMSE(Root Mean Squared Error), Precision , Recall, Diversity, Serendipity and Novelty are used by several researchers as evaluation metrics. The most significant and informative metrics MAE and RMSE are explained in detail in this paper.

The outline of rest of the paper is as follows. Section 2 describes various recommendation techniques and improvements. In Section 3, deep learning application in recommender systems is explained. Section 4 describes standard datasets, metrics used for recommendation performance evaluation Section 5 explains latest tools and systems used for deep learning, recommendation. Section 6 concludes this paper.

II. Recommendation Techniques

Various recommendation techniques are proposed by researchers. Content based, collaborative filtering based and hybrid based are traditional recommendation techniques. When user likes any topic or product, their preferences can be used as important factor to recommend any new topic or product. This type of content based recommendation technique constraint is many users do not provide their preferences. Collaborative filtering is based on users' similarity. When any user A likes any topic or product, rating is provided by user in scale 1-5. In similar manner, other user B also provides rating to same topic or product in the same scale. If these pair of users has provided similar ratings, these users can be considered as similar users. If any new topic or product is liked by user A with some ratings, it is very high probability that other user B will also like this new topic or product with same ratings. The limitation of collaborative filtering is sparsity and cold start. There are very few entries in user- item matrix, so it is difficult to predict recommendation. New users do not provide any ratings hence cold start users cannot be provided with better recommendations. Hybrid approach combines content based and collaborative filtering based approaches.

Fig. 1 clearly demonstrates ratings of products provided by users. User 1 and user 3 have rated Product 1 with same ratings 2 i.e. it can be concluded that these users are similar users. User 4 has provided rating 5 to product 1 hence this user is not similar to user 1 and user3.

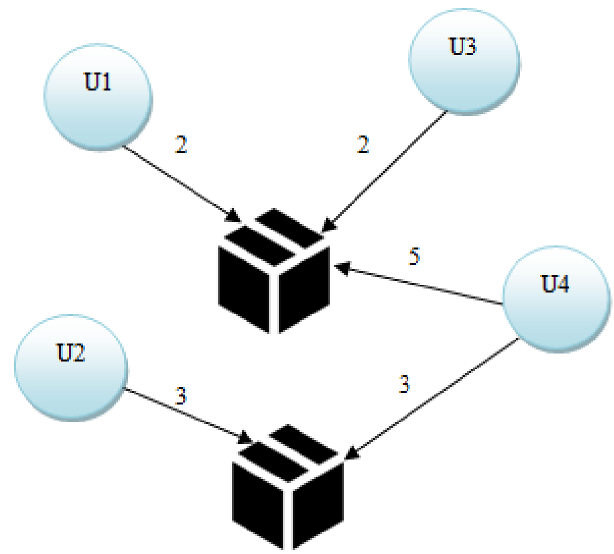


Fig. 1. User – Item Ratings.

TABLE I. USER- ITEM RATINGS MATRIX SPARSE VALUES

Users	***Product 1***	***Product2***
User 1	1	0
User 2	0	1
User 3	1	0
User 4	1	1

TABLE II. USER- ITEM RATINGS COLD START VALUES

Users	***Product 1***	***Product2***
User 1	1	0
User 2	0	1
User 3	1	0
User 4	1	1
User 5	0	0

Table I shows that entries not filled by users in user-item matrix results in sparsity. When numbers of users and items are in large scale, sparsity degrades recommendation accuracy.

When this demo recommender system includes new user 5, there is no entry for this user. Table II shows the cold start issue due to inclusion of new user in recommendation system.

A. Bi-Clustering Approach

Clustering is used to remove the sparsity in user-item matrix. When large scale of data is used in social datasets, there exist a lot of users who have not rated even single item. Processing of large social graph is not an efficient technique. Sparse matrix is optimized to maximum entries filled matrix by using clustering of similar users and items. In uni-clustering approach, only similar users or items are combined. Bi-clustering approach is used to combine users as well as items [9]. Users are combined in one cluster Uc who have similar likings and Items are combined in one cluster Ic which are of similar characteristics. Users and items combinations are not dependent [9]. In bi-clustering technique, many items for which there is no ratings and many users who have not rated any item, are not removed from matrix. These entries are shifted to right side of matrix. Users who are frequent raters and items which are rated frequently are aggregated to one side of area which becomes dense popular. In this approach, empty profiles are removed to provide better recommendation even for large scale datasets.

B. Social Trust Clustering

Social trust is used by several researchers as tool for recommendation. When users are connected on social networking sites, they share their opinion for any topic or product. If any connected user finds this opinion relevant, trust amongst these users increases. These trusted users are strongly connected if represented in social graph. When large numbers of users are connected, large scale graph is not in capability of traditional recommender systems. Trust can be used to cluster strongly connected users. The advantage of clusters is more focus can be given to more trusted users. When recommendation is provided to users, there are very high chances that trusted users are in same cluster.

Clustering has been applied for collaborative filtering, but there are very few clustering techniques based on trust [10]. Similarity measures are used to find similar users in social graph, but several researches prove that it only increases MAE (Mean Absolute Error) i.e. recommendation accuracy degrades. Bayesian model is also used to cluster similar users [11] [5]. Clustering resulted from this approach is not good enough to be applied in recommendation. Graph theoretic methods are also used to cluster users based on their preferences, but is has not been used for recommendation [12].

Trust inference is used to cluster strongly connected users. If users are strongly connected then some extra weight is provided to users for better recommendation. If user A assumes the probability of trusting user B as $p_{a,b}$ and user B assumes the probability of trusting user C as $p_{b,c}$, it is inferred that user A trust on user C should be $p_{a,c}$. Probability of path is large if users are strongly connected. Distance between nodes for clusters is inversely proportional to probability of path amongst them. Several researchers proved that using trust based clustering improves recommendation accuracy by using datasets like Epinions, FilmTrust etc.

In addition to sparsity and cold start, large scale data recommendation is also issue due to which recommendation accuracy is degraded. Scalability issue is resolved by many researchers by using large scale graph partitioning.

C. Large Scale Graph Partitioning

Social networking sites data can be better represented by using graph. Users are represented by nodes and connections amongst users are represented by edges. Social network analyst process and manipulate social graph to extract important information. Social trust, highest influence node, connection of specific node etc are required for better analysis. Large scale social graph cannot be processed by traditional big data technologies. Centralized systems cannot analyze big social graph. There is need of novel approaches for efficiently dealing with large numbers of nodes and edges. Researchers have proved that big social graph can be easily analyzed by distributing it on different nodes using graph partitioning.

Social graph G is partitioned in k partitions - G1, G2, _ _ _ _ _, Gk. These partitions are distributed on nodes so that it can be run in parallel. Random partitioning is used by several researchers to prove the effectiveness of social graph partitioning. It works on different nodes by selecting subgraphs such that every node is part of at least one subgraph and every subgraphs have approximately same numbers of nodes. Balanced partitioning is the main motive of researchers. Social recommendation for large scale graph is not efficient by random partitioning.

Trust is built amongst connected users based on same liking or same ratings for any movie or product. If any user B likes the same product or topic also liked by user A with same ratings, trust values are increased. Trust is asymmetric i.e. if user A trusts user B, it cannot be concluded that user B also have trust on user A. Social graph partitioning with trust assures that most trusted nodes are in same subgraph. It is not assured that partitioning is balanced by using this approach, but recommendation accuracy is improved significantly. Locality is the ratio of number of nodes which are in same subgraph as was in original subgraph and total numbers of nodes. Locality is improved by using trust based partitioning technique. In Fig. 2(a), trusts amongst users are shown as directed edges. In Fig. 2(b) and Fig. 2(c), subgraphs are created after partitioning original subgraph based on trust values.

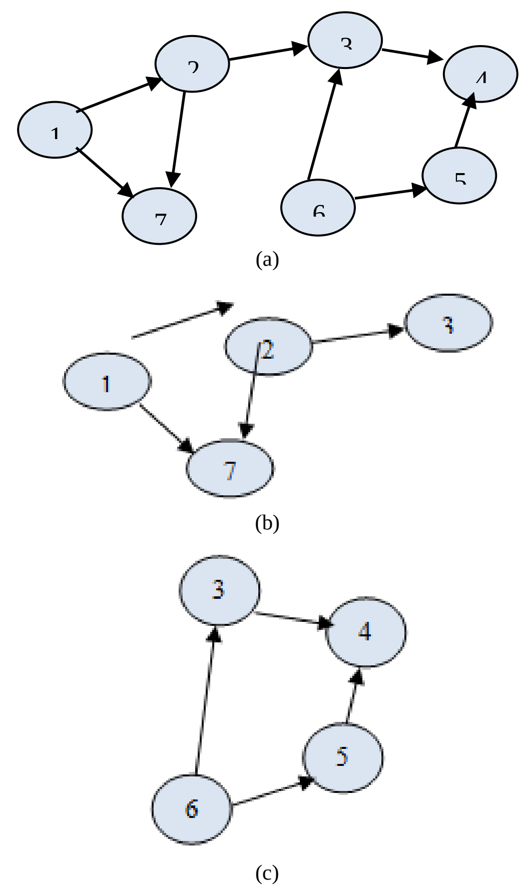


Fig. 2. (a).User – User Social Trust Graph (b). subgraph1 (c). subgraph2.

Pregel is framework based on Bulk Synchronous Parallel Model. Subgraphs are processed by using vertex centric approach. Supersteps are like iterations, nodes process task in parallel in one superstep and assign its processed task to next superstep. Giraph is open source implementation of Pregel like system. There are many abstract classes and methods available in Giraph. Trust based partitioning can be easily configured using Giraph library. Vertex based and edge based partitioning techniques are used for large scale graph. In vertex based partitioning, subgraphs are created by dividing vertices. Edges are the criteria for dividing large scale graphs in subgraphs.

III. Deep Learning based Recommendation

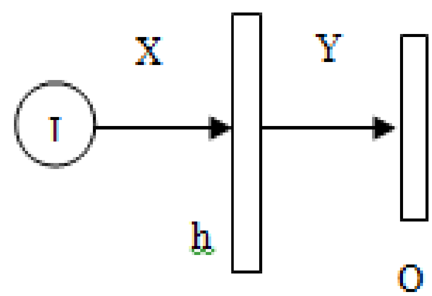
Deep learning is machine learning approach which is applied in many research areas such as Natural Language Processing and computer vision etc [13]. It has provided significant and state-of-the-art improvements in many fields and able to solve complex tasks. It can be used as supervised as well as unsupervised learning. Recommender system is also hot topic for last decade. Several researchers are finding the way to improvise recommender systems. Deep learning is applied by several researchers in recommendation to improve accuracy, precision and recall. Deep learning is applied on recommender systems so that it can improve the performance as it has improved other research areas [13]. Deep learning for recommender systems becomes popular research topic in 2016 during ACM RecSys . The reasons for integrating deep learning with recommender systems are the ability of deep learning to build complex non linear relationship in input and output data, better scalability for large scale of data and better analysing incorrect label data [15]. Researchers have observed that integrating these techniques improves recommendation in tremendous manner. [16] proposed YouTube video recommendation based on deep neural network. In [23], Yahoo news recommender system is implemented using RNN. Traditional recommendation systems are studied extensively and improved, but still sparsity, cold-start and scalability are the issues which degrade recommendation accuracy. Input and output are analysed for verifying improvement in recommendation accuracy. Input in recommendation systems is ratings, clicks or any explicit feedback provided by user and output is ratings prediction for user. Deep learning enhances the improvement in input and output systems. Deep learning can be implemented for content based or collaborative filtering based or combination of different architectures. Deep learning can be used to improve probabilistic matrix factorization. Scalable recommendation is improved by using deep learning as suggested by several researchers.

Several deep learning models are used – Multilayer Perceptron, AutoEncoder, Convolutional Neural Network, Recurrent Neural Network, Deep Semantic Similarity Model and Restricted Boltzmann Machine. Some models use only single deep learning techniques while some models use composite deep learning techniques [7]. It is proved that Restricted Boltzmann Machine performs better that traditional matrix factorization. Several research works have been proposed for applying deep learning in recommendation systems, but very few are able to succeed in improving recommendation accuracy. Moreover, scalability is the main concern for researchers using deep learning for social recommendation. In [4], It is clearly mentioned that neural network can not work properly due to very few entries in user-item matrix. It is necessary to normalize the values so that neural networks are trained effectively.

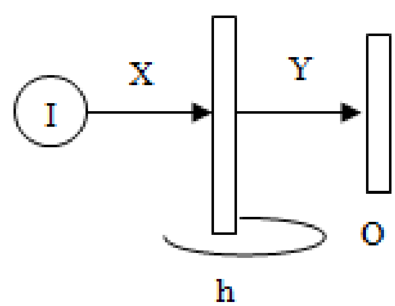
Several models in deep learning are proposed but feedforward neural network is the most commonly used model [13]. In this model, input layer submits data to hidden layer and after some processing functions, it is submitted to output layer. Constraint is that model can only use numerical data, but natural languages are used for recommendation. Recurrent model is applied for using different data and after processing submitted to output layer.

It is clear from Fig. 3(a) that input is submitted to hidden layers and after rectifier function, it is submitted to output function. In Fig. 3(b), recurrent model is demonstrated which used recurring hidden layers for sending information and finally it is submitted to output layer. Natural language processing can be easily applied using recurrent model.

Multilayer perceptron can be applied on user-item ratings to improve recommender systems. It is the simplest model [14] .It can approximate any function [15]. The advantage of using this model is that data need not be input separately as it is directly be used in multilayer neural network model. Multiple layers are present in this model. This model can be used for any degree of accuracy based on measurable function. Neural collaborative filtering uses matrix factorization linear approach and MultiLayer perceptron to improve recommendation accuracy. MLP is applied for improving YouTube video recommendation [16]. Multi-layer neural networks work on its function and perform better than state-of-the-art algorithms for traditional recommender systems. Complex linear and non-linear links can be better predicted by deep neural networks. It can also learn on large scale of data.



(a)



(b)

Fig. 3. (a). Feedforward Model (b) Recurrent Model.

Deep neural network works on at least one input layer and one output layer. Many hidden layers can be present in input and output layers depending upon the complexity of data. There is no standard to define that how many hidden layers can be concluded as deep [17]. Neural network with two hidden layers can be considered as deep neural network [18] [19]. In deep neural network, activation function decides the communication of data amongst different layers. Rectifier function is example of activation function.

$$f(z) = \max(0, z) \tag{1}$$

It is observed in experiment evaluation of several research works that using deep learning, MAE and RMSE improves significantly hence improves recommendation accuracy. It is also analysed that DNN model performs better with two hidden layers as compared to model where more numbers of layers are added.

Artificial neural networks work on at least one input and one output. Rectifier function enhances the ratings prediction hence improves recommendation accuracy. It is observed in research works that simplest rectifier function can improve ratings predictions significantly. Hidden layers numbers selection is tedious task in deep neural network. Researchers have provided the solution that when MAE stops improving, no more hidden layers should be included. User-item and user-user matrix values are combined to be deployed on hidden layers in deep neural network. For Example, music recommendation is very popular amongst users. It provides users choice amongst large numbers of songs. Existing music recommendation techniques are based on content of songs but it is very difficult to recommend songs to user just based on their emotions or solely content of songs. Deep learning is used by several researchers to improve recommendation accuracy.

In [20], novel approach is proposed which combines deep belief network with content to improve recommendation. In this approach, feature learning is based on songs content directly and automatically. In deep belief network, many hidden layers and one observation layer exist. It is combination of Restricted Boltzmann Machines and feed-forward model [14].

The summary of deep learning models used for recommendations are as follows:

- Multilayer perceptron model is type of feedforward model. In this model, there are various hidden layers that functions exactly like feed forward technique.
- Deep Belief Network is combination of Restricted Boltzmann machines and feed forward model. Restricted Boltzmann machines are used in collaborative filtering as user-item matrix can be improved by using this model.
- Convolution Neural Network model is based on signals. It is proven to be efficient in image recognition. Content based recommendation is improved by this model.
- Recurrent Neural Network is used in applications where hidden layers are to be processed many times. In content based recommendation, this model is widely used as it can provide better user's preferences for any topic or product.

Sparsity, cold start and scalability of user-item matrix can be reduced by using deep model and large scale graph partitioning. User-item interaction is improved significantly by using deep learning. For example, in Restricted Boltzmann Machines item features and implicit feedback is considered in addition to collaborative filtering ratings, hence improves sparsity and cold start. In this paper, solution for this concern is provided by following steps:

- Improving trust and rating matrix using indirect trust by hyperedge and transitive closure.
- Improving recommendation accuracy by using deep learning.
- Improving scalability by partitioning large scale social graph.

IV. Recommendation Dataset and Evaluation Metrics

A. Datasets

Several datasets are used by researchers for proving their approach better as compared to previous approaches. It is confusing for readers to select best suitable datasets. In this section, most commonly used datasets are explained with their usage so that readers can use proper dataset in their experiment evaluation based on approach.

1) Epinions: Epinions is site that maintains ratings by users in numerical scale. It also stores trust and distrust amongst users. Several research works use trust as an important factor for proving better recommendation accuracy. This is the reason Epinions is used in a lot of research works. It maintains who trust who and assumed as recommendation standard dataset. Trust data and ratings data are collected in this dataset. Trust data format is source_user_id, target_user_id, trust_binary_value. For example, if user 1000 trusts user 2000, format for storage is 1000,2000,1, where 1 denotes true value of trust amongst these users. In this dataset, only true trust value is stored and no distrust value is stored. Rating data format is user,item,ratings where ratings in scale 1-5. For example user 10 provides rating 3 to item 20, format for storage is 10,20,3. Table III clearly shows the statistics of user-item ratings and user-user trust values. These values are large enough to train the data and test remaining data for social recommendation. The motive of researchers is to improve trusters in this dataset.

TABLE III. Epnions Dataset Statistics

Dataset statistics	
Users	49290
Items	139738
Ratings	664824
Social Trust statistics	
Trusts	487181

2) FilmTrust: FilmTrust is small dataset used for recommendation. In this dataset, co-purchased products record is also maintained. The advantage of this dataset is combination of user-item ratings as well as user trust values. Detailed statistics is mentioned in Table IV.

TABLE IV. FILMTRUST DATASET STATISTICS

Dataset statistics	
Users	1508
Items	2071
Ratings	35497
Social Trust statistics	
Trusts	1853

3) MovieLens: MovieLens is data collected by GroupLens research. It is specifically used for movie recommendation. This dataset is most suitable for large scale recommendation experiment evaluation as shown in Table V.

TABLE V. MOVIELENS DATASET STATISTICS

Dataset statistics	
Users	138493
Movies	27278
Ratings	20000263

B. Evaluation Metrics

Several metrics are used to evaluate recommendation approaches performances. The most commonly used metrics are introduced here so that readers can apply these in their techniques and evaluate performance comparing it with existing techniques. It is verified by several researchers that small improvement in these metrics concluded significant improvements in recommendation accuracy. Precision, Recall, MAE and RMSE are most commonly used evaluation metrics.

1) Mean Absolute Error (MAE): It is sum of difference in predicted ratings by proposed approach and ratings that exist in original and divided by number of observations.

$$MAE = \sum_{i=0}^{n} \big(P1(u,i) - P2(u,i)\big)/n \tag{2}$$

Where P1(u,i) is predicted rating for user u of product i and P2(u,i) is original ratings for user u of product i. Researchers prove their better approaches by reducing this error as much as possible. In **[21]**, it is mentioned that approaches which achieve even small improvement in MAE, is significant contribution.

2) Root Mean Squared Error (RMSE): This metrics is calculated as square root of sum of difference of predicted rating and original rating square and divided by number of observations. Researchers observed that RMSE is more accurate evaluation metric.

$$RMSE = \sqrt{\sum_{i=0}^{n} \big(P1(u,i) - P2(u,i)\big)^2/n} \tag{3}$$

Where P1(u,i) is predicted rating for user u of product i and P2(u,i) is original ratings for user u of product i. RMSE and MAE more difference signifies degraded recommendation performance.

V. RECOMMENDATION TECHNOLOGIES

Several technologies are invented by researchers and practitioners to provide recommendation to users. Standard packages can be applied to applications like statistical analysis as there are fixed and formulated concepts. There is no standard package for recommendation due to its dynamic behaviour. Different types of technologies are available for content based, collaborative filtering based, hybrid based, social recommendation and trust based recommendation. Traditional Big data technologies cannot be used to implement data which is in social graph. Hadoop and MapReduce are not easily deployed for large scale graph processing. Large scale graph where users are represented as nodes and connections amongst them are represented as edges, can be manipulated by graph processing technologies like Pregel, Giraph, GraphLib etc. These libraries are designed specifically for graph algorithms like clustering, partitioning, shortest path or finding maximum weight etc. In this section, most commonly used technologies are described with application examples.

A. Pregel

Pregel uses Bulk Synchronous parallel model. It is based on vertex message passing approach. Supersteps are defined for each iteration and every vertex is running job in parallel in one superstep. When this superstep completes, vertices states is passed to next superstep. This can be most suitable for large scale social recommendation. When recommendation is to be applied for Big data, centralized systems can not process large scale user-item and user-user trust matrix. There is need of novel technique which can distribute large scale data and run jobs in synchronous. Pregel is most suitable model for this issue. Large scale graph algorithms are predefined and also many processing techniques can be customized on Pregel.

B. Giraph

Apache Giraph is API library which is open source implementation of Pregel. Vertex class is already available to form graph of vertices. When any vertex needs to communicate with other vertex, there are methods for accomplish it. VoteToHalt can be used by vertex after completion of superstep. Many graph processing algorithms are defined in Giraph API. Social graph algorithms such as shortest path and global popularity techniques are also available in Giraph API.

C. SNAP

Stanford Network Analysis Platform (SNAP)library is written in C++ and social recommendation can be configured using this library functions. Large network and graph can be easily processed by using this library. During computing on nodes, values can be changed dynamically which is most significant advantage. It was released in 2009 as general purpose STL(Standard Template Library).

D. TensorFlow

TensorFlow **[22]** is library which is open source and deep learning, machine learning algorithms are implemented. It can run on multiple CPUs and GPUs and machine learning, neural networks are used in this library. It can be deployed for large scale of data easily. This library is implemented in C++. TensorFlow is very much efficient for object recognition in image. In TensorFlow, dataflow graph permits user to compute independent tasks in parallel. Data is represented in the form of tensors (n-dimensional arrays) and mathematical computations can be easily modelled using n-d arrays. Large scale of data can be trained using this library efficiently. This library is not only suitable for large scale machine learning implementation but also for small scale. It is very simple to build computational graph and running sessions on graphs. API for C++, MATLAB and Python are defined in TensorFlow. Linear regression model which is used to predict dependent variable from the known set of independent variables, can be implemented using TensorFlow.

VI. Conclusion

Recommendation is very crucial tool for social networking sites and business organization. Large scale of unstructured data results in information overload issue which is very confusing for users to select best suitable topic, news, product, movies or music. Recommendation assists users to provide suggestions based on their likings. In this paper content based, collaborative filtering based and hybrid based techniques for recommendations are explained in detail. It was also mentioned that sparsity, cold start and scalability are the issues in recommendation techniques. Several research works have been carried out to improve recommendation accuracy. In this paper, bi-clustering, social trust clustering, deep learning and large scale graph partitioning are elaborated so that reader can understand different methodologies to improve recommendation. Deep learning based recommender systems is core theme of this paper. Convolutional neural network, deep feedforward model, recurrent neural network model and deep belief model are described with their relevance. Large scale graph partitioning is also categorized as random based or trust based partitioning. Very few research works cover comprehensive analysis of sparsity, cold start and scalability issues in single research work. In this paper, these issues are shown to be resolved by deep learning and large scale graph partitioning. Recommendation experiment evaluation is very much necessary to prove accuracy. Standard datasets such as MovieLens, Epinions and FilmTrust is described in detail. Also, MAE (Mean Absolute Error) and RMSE (Root Mean Squared Error) are mentioned as most commonly used metrics for proving recommendation accuracy. Latest technologies such as Pregel, Giraph and SNAP are also elaborated in this paper.

References

[1] P. Gopalan, J.M. Hofman, and D.M. Blei. "Scalable recommendation with poisson factorization." arXiv preprint arXiv:1311.1704, 2013.

[2] C.Gomez-Uribe and N.Hunt, "The Netflix recommender system: Algorithms, business value, and innovation", ACM Transactions on Management Information Systems (TMIS) 6, 4 , 13, 2016.

[3] J. Davidson, B. Liebald, J. Liu, P. Nandy, T. Vleet, U. Gargi, S. Gupta, Y. He, M. Lambert, B. Livingston, and D. Sampath, "The YouTube Video Recommendation System", In Proceedings of the Fourth ACM Conference on Recommender Systems (RecSys '10). ACM, New York, NY, USA, 293–296, 2010.

[4] H. Lee and J. Lee, "Scalable deep learning-based recommendation systems", ICT Express,2018.

[5] L.H. Ungar and D.P. Foster, "Clustering methods for collaborative filtering" , In AAAI Workshop on Recommendation Systems, pp.112–125, 1998.

[6] T. Hofmann, "Latent semantic models for collaborative filtering", ACM Trans. Inf. Syst. 22 (1), pp. 89–115, 2014.

[7] S. Zhang, L. Yao and A. Sun, "Deep learning based recommender system: A survey and new perspectives", arXiv preprint arXiv:1707.07435, 2017.

[8] A. Krizhevsky, I. Sutskever and G. Hinton, "Imagenet classification with deep convolutional neural networks", Adv. Neural Inf. Process. Syst., 2012.

[9] D. Zhang, C.H. Hsu, M. Chen, Q. Che, N. Xiong, and J. Lloret , "Cold-start recommendation using bi-clustering and fusion for large-scale social recommender systems", IEEE Transactions on Emerging Topics in Computing, 2(2), 239-250, 2014.

[10] T. DuBois, J. Golbeck, J. Kleint, and A. Srinivasan , "Improving recommendation accuracy by clustering social networks with trust", Recommender Systems & the Social Web, 532, pp. 1-8,2009.

[11] J.S. Breese, D. Heckerman, and C. Kadie , "Empirical analysis of predictive algorithms for collaborative filtering", pp. 43–52, 1998.

[12] B.J. Mirza, B.J. Keller, and N. Ramakrishnan, "Studying recommendation algorithms by graph Analysis",Journal of Intelligent Information Systems,20(2), pp. 131–160, 2003.

[13] J. Liu and C. Wu, "Deep Learning Based Recommendation: A Survey", pp. 451-458. 10.1007/978-981-10-4154-9_52, 2017.

[14] R. Fakhfakh , A.B. Ammar and C.B. Amar , "Deep Learning-Based Recommendation: Current Issues and Challenges", International Journal of Advanced Computer Science and Applications (IJACSA), 8, 12,2017.

[15] Q. Dang and C. Ignat, "dTrust: a simple deep learning approach for social recommendation", The 3rd IEEE International Conference on Collaboration and Internet Computing (CIC-17), 2017.

[16] P. Covington, J. Adams, and E. Sargin, "Deep neural networks for youtube recommendations", In Proceedings of the 10th ACM Conference on Recommender Systems, ACM, 191–198, 2016.

[17] J. Schmidhuber, "Deep learning in neural networks: An overview,", Neural Networks, vol. 61, pp. 85–117, 2015.

[18] Y. LeCun, Y. Bengio, and G. Hinton, "Deep learning," Nature, vol. 521, no. 7553, pp. 436–444, 2015.

[19] T. N. Kipf and M. Welling, "Semi-supervised classification with graph convolutional networks," ICLR, 2017.

[20] X. Wang and Y. Wang, "Improving content-based and hybrid music recommendation using deep learning", In Proceedings of the 22nd ACM international conference on Multimedia , pp. 627-636, ACM, 2014.

[21] R. Bell, Y. Koren and C. Volinsky, " Modeling relationships at multiple scales to improveaccuracy of large recommender systems" in Proceedings of International SIGKDD Conference onKnowledge Discovery and Data Mining pp. 95–104,2007.

[22] M. Abadi, P. Barham, J. Chen, Z. Chen, A. Davis , J. Dean, M. Devin, S. Ghemawat, G. Irving, M. Isard and M. Kudlur, "Tensorflow: a system for large-scale machine learning", In OSDI ,Vol. 16, pp. 265-283,2016.

[23] S. Okura, Y. Tagami, S. Ono and A. Tajima, "Embedding-based news recommendation for millions of users", In Proceedings of the 23rd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining , pp. 1933-1942,2017.

Parameters Affecting Underwater Channel Communication Performance

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***Abstract*—Underwater or Acoustic propagation is characterized by three major factors: attenuation that increases with signal frequency, time-varying multipath propagation, and low speed of sound. The background noise, often characterized as Gaussian, is not white, but has a decaying power spectral density. Channel capacity depends on the distance, and may be extremely limited. As acoustic propagation is best supported at low frequencies, an acoustic communication system is inherently wideband and bandwidth is not negligible with respect to its center frequency. The channel has a sparse impulse response, where each physical path acts as a time-varying low-pass filter, and motion introduces Doppler spreading and shifting. Surface waves, internal turbulence and fluctuations in sound speed, contribute to random signal variations. Till date, there are no standardized models for acoustic channel fading. Experimental measurements are often made to assess the statistical properties of the underwater channel.**

Keywords*—*UWSN; doppler effect; attenuation; noise; salinity

I. Introduction

Electromagnetic signals that move from source to destination generally come across with various hindrances. The various models that governs the transmission of signals; focus on how all these factors affect transmission. Figure 1 depicts the basic structure of transmission system. It consists of three components that are ‘Sender’, ‘Channel’ or ‘Medium’ and ‘Receiver’.

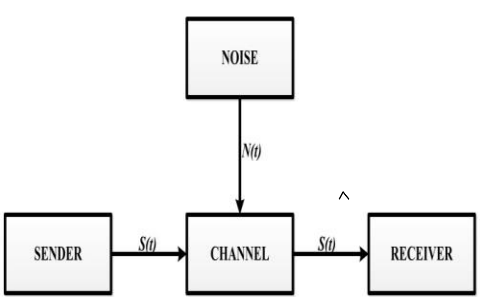

Fig. 1. Basic Communication Model.

Where $s(t)$ is the signal that is transmitted to channel, $\hat{s}(t)$ is the signal that is been received and $N(t)$ are the noises that are affecting the channel. For underwater, acoustic waves are used for communication channels. The acoustic channels are among the critical and challenging medium in recent research [1]. Its features include long propagation and attenuation which is frequency dependent that are extremely affected by the link orientation and by nodes distance [2].

The acoustic links are mostly affected by multi path, Doppler spread, path loss, variable propagation delay and different noises [3].

At low frequencies the propagation of acoustic signals is outstanding however, for the transmission channel its capacity is very least [1]. The range of frequency for acoustic wave is from 10 to 15 kilo Hertz while channel capacity is just 5kilo Hertz and its speed is nearly 1500 meter per second. The propagation is over several channels. High Doppler Effect arises due to mobility of nodes [2]. In fact multi-path propagation, low speed of sound and frequency-dependent attenuation results in Doppler Effect that makes the acoustic channel a challenging medium.

Instead of acoustic waves for underwater the radio signals are not properly propagated apart from low frequencies for very small distances [4]. Similarly the optical waves that are well applied in blue-green area about 500 nm suffer too by attenuation and do not propagate greater than 100m even it have channel capacity in MHz order [5]. Hence, the acoustic signals are considered best for this communication however, it covers a small range. These waves can propagate over kilo-meters or hundreds of kilo-meters, but for the coverage of longer distance, lower frequency is required [6].

Underwater (UW) acoustic transmission over very larger scales that is in thousands km can be possible in one hop but the channel capacity must be in order of 10 Hertz [7]. The horizontal channel is extremely difficult for the multi-path propagation. However, the vertical transmission shows minimum distortion [8].

Concept of UWSN of distributed autonomous motes [9] is presented by improvements and establishments in sensor technology, vehicle and acoustic modems technology. Currently research is ongoing for standardizing UWSN schemes to approve interoperability of various modems. An international NATO led is operational on formation Janus which is an international standard to specify structure of packet as well as rate of bit mechanisms of acknowledgement, etc. for applying in a given frequency distance configurations [10].

Due to lack of "typical applications," two kinds of networks are possible. The first is that have static motes and deployment of these are for lengthy time and these networks are designed for the monitoring of environment. The other one is the one that have not fixed nodes and they are not deployed for longer time. These types of networks are planned for fleets of cooperating AUVs, where vehicles can make decisions by responding to each other but the most significant aspect is energy efficiency for bottom mounted networks.

This article is organized into four sections. Section II provides some existing work. Section III that is further divided in to different parameters of propagation channel that are attenuation, noise, Signal-to-Noise Ratio (SNR), bandwidth, multipath propagation, Delay spread, Doppler distortion, Fading and Scattering are discussed. Finally the article is settled in section IV to consider the effect on upcoming UWSN schemes.

II. Literature Review

At the end of World War II United States developed initial acoustic communication system for underwater. In that system the 8 to 11 kHz band with analog modulation used [11]. But with the passage of time the technology is improved and digital modulation mechanisms came in use. In the era of 80's researchers of Massachusetts Institute of Technology proposed a new system; Frequency Shift Keying (FSK) [12]. It becomes the foundation of commercial base digital acoustic modems of 1st generation [13]. After FSK different acoustic modems developed that based on coded FSK such as WHOI micro modem [14]. As FSK depends on non-coherent detection hence it provides strength to channel losses but its utilization of bandwidth not so well. The research of 90s emphasis on quadrature amplitude modulation and phase shift keying for underwater acoustic channels which provides additional bits per second per hertz of employed channel capacity. Northeastern University and WHOI work for improvements and enhancements which come out with a channel equalization or synchronization method [15]. These efforts become the base of high speed acoustic modem 2nd generation.

The authors of [16] examined acoustic channel features such as noise, speed of sound (propagation speed) with variations in frequency, attenuation, salinity, depth and temperature through some models and mathematical expressions for the area of UWSNs. According to Cooperative Energy-Efficient Protocol for UWSN (Co-UWSN) [17] the researchers used cooperation approach to maximize lifetime of the UWSN, increase the Packet Delivery Ratio (PDR) using SNR and declined consumptions of energy that is mainly advantageous for time-critical as well as delay-sensitive applications. It alleviates possessions of multipath fading and noise using cooperative base transmissions of data. The number of qualified neighbors rises by changing in depth threshold; hence in delay-sensitive applications the acute data loss is minimized. The cooperation character and the optimal weight calculation deliver complementary of load for UWSN with stability of UWSN is heightened too.

The scheme Stochastic Performance Analysis with Reliability and Cooperation (SPARCO) [18] take the features of cooperation approach for increasing and improving the performance of UWSN. Cooperation is utilized for developing a routing technique that is efficient in terms of consumption of energy. The sensors of UWSN are assumed to be entailing of a uni-directional antenna. To reduce the energy usage, multi nodes send their data packets cooperation based by taking the benefits of spatial diversity. Techniques that comprise single hop or greater than one both exploits to declining path losing exist in links connecting sensor nodes and then forwards the data packet.

III. Propagation Channel Parameters

This article is an overview of the acoustic channel features whose purpose is to expose those aspects of propagation that are significant for the design of acoustic communications. Following are the parameters of UW propagation channel.

A. Attenuation

A unique characteristic of an acoustic link is the path loss based on frequency of the signal. The signal dispersion loss and absorption loss are maximized by maximizing distance. Following expression is for the net path loss [19]

$$A(d,f) = \left({}^{d}/_{d_{ref}}\right)^{k} a(f)^{d-d_{ref}} \quad (1)$$

In equation 1 f is the signal frequency while l is distance of transmission which taken in reference to d_{ref}. The exponent k models loss of spreading. Its typical values lie between 1 and 2 for cylindrical and spherical spreading respectively. The coefficient of absorption modeled empirically by Thorp's formula which gives $\boldsymbol{a(f)}$ in dB/km for $\boldsymbol{f}$ in kHz as [18].

$$10 log a(f) = 0.11\frac{f^2}{1+f^2} + 44\frac{f^2}{4100+f^2} + 2.75\times 10^{-4} f^2 + 0.003 \quad (2)$$

(for $f > 0.4$) [dB/km]

$$10 log a(f) = 0.002 + \frac{0.11\,f}{1+f} + 0.011f \quad (3)$$

(for $f < 0.4$) [dB/km]

This function is accurate for frequencies that are exceeding a few hundred Hz. It neglects the effect of frequencies caused by boric acid and magnesium sulfate, salinity and acidity levels of the water in sea or ocean, so they may not leads to very accurate result [16].

B. Noise

In acoustic channel site specific and ambient noises exists. The first one presents specific sites while in second one noise always exists in background of underwater. It arises by distant shipping, turbulence, breaking waves and thermal noise. The turbulence noise is represented by (N_t), shipping noise by (N_s), waves noise by (N_ω), and thermal noise by (N_{th}). The Power Spectral Density (PSD) of N_t , N_s , N_ω , N_{th} are modeled in $dB\ re\ \mu\ Pa$ / Hz as frequency function in kilo Hz.

1) Turbulence noise: Turbulence associated with surface disturbance or tidal flow around an obstruction generates continuous noise. Turbulence is also caused by storms or during the rain events. It may be produced by marine life. The turbulence noise is formulated as

$$10 \log N_t (f) = 17 - 30 \log f \quad (4)$$

2) Shipping noise: Another type of noise is the one caused by ship traffic. The effect of ship traffic is concerned with the number of ships and the distance of shipping from the area of study. The shipping noise is formulated as

$$10 \log N_s (f) = 40 + 20(s - 0.5) + 26 \log f - 60\ log(f + 0.03) \quad (5)$$

with s as the shipping factor which lies between 0 and 1 for low and high activities respectively.

3) Wave noise: Wave noise is caused due to the movement of waves in the sea or ocean. The wave noise formulated as

$$10 \log N_\omega (f) = 50 + 7.5\ \omega^{1/2} + 20 \log f - 40\ log(f + 0.4) \quad (6)$$

with ω as the wind speed in m/s. The movement of water results from tides, winds, currents and storms.

4) Thermal noise: It is taken as additive white Gaussian noise. Additive white Gaussian noise is the noise model used to mimic the effect of many random processes that occur in nature. Thermal noise is created by molecular agitation at the receiver side and it is always present in communication system. The Thermal noise formulated as

$$10 \log N_{th} (f) = -15 + 20 \log f \quad (7)$$

5) Total noise: The overall noise power spectral density for a given frequency f can be computed by adding all types of noise as [16]

$$N(f) = N_t(f) + N_s(f) + N_\omega(f) + N_{th}(f) \quad (8)$$

These noise effects are modeled by Gaussian statistics [18].

C. Signal-to-Noise Ratio

The SNR is attenuation that arises by the noise and frequency. Its power spectral density declines by frequency and SNR which differs over bandwidth of signal. If there are frequencies with narrow band having width as Δf and f as frequency then SNR is modeled by

$$SNR(l, f) = \frac{S_l (f) \triangle f}{A(l, f)\ N(f) \triangle f} \quad (9)$$

where PSD of transferred signal is $S_l (f)$. Thus the narrowband SNR is a frequency function for a specific distance. To attain a pre specified SNR, required power is expressed as $P(l) = p\ \text{x}\ l^{\psi}$ and bandwidth $(l) = b\ \text{x}\ l^{-\beta}$.

where the exponents $\beta \in (0, 1), \psi \geq 1$, and b, p coefficients based on target SNR, ambient noise and acoustic path-loss parameters [20].

D. Bandwidth

Bandwidth *B* is the acoustic channel capacity that is on the order of center frequency expressed as f_c. It impacts on design of signal processing procedures, as it prevents one from making the narrowband assumption, $B \ll f_c$. Since multi-hopping confirms lesser energy consumption, its outcomes doubled for acoustic channel in perspective of energy-per-bit consumption [20]. The interference and collision increased as hops raises hence more retransmissions are required while shorter hops provide greater bit rates and the collision is mostly minimized. The channel capacity is sternly restricted at longer distances: at 100 kilo meter, just a kHz approximately is present. For the smaller range, the capacity rises, but it will eventually be restricted by the transducer. The fact that this channel capacity is restricted denotes the requisite for bandwidth efficient modulation methods in case greater than bps/Hz is to be attained over these links.

E. Multi Path Propagation

Multi path establishment in water is directed by two major effects: first one is sound reflection at surface, bottom and any objects, and sound refraction in water. The later one is a significance of speed of sound variation with the depth that is typically evident in deep water links.

The sound speed depends on temperature and pressure that differ by the water depth. According to the Snell's law, sound wave must movess towards lower propagation speed area. The pressure and temperature are fixed in shallow water. The temperature decline as the depth rises. The mass of water above is insignificant change the pressure. The speed of sound reduces in the area known as main thermocline. The temperature reaches at 4℃ after a little depth, and from there on, speed of sound rises with pressure. When the sound rays initiates, every ray follows a little diverse route and the receiver receives these multiple signals. For putting a mathematical modeling of channel in a view let nominal length represent using $\bar{l}_p$ of the p^{th} propagation path, where p = 0.

The path delays acquired is $\bar{\tau}_p = \bar{l}_p / c$ where *c*, speed of sound taken constant in the shallow water.

Under an ideal situation the coefficient of surface reflection is (-1). Depending on the hard or soft bottom and grazing angle the coefficient of bottom reflection is different. [21].

If the cumulative reflection coefficient we represent by Γ_p with propagation path p^{th} and the propagation loss by $A(\bar{l}_p,\ f)$ associated with this path, then

$$\bar{H}_p(f) = \frac{\Gamma_p}{\sqrt{A(\bar{l}_p, f)}} \quad (10)$$

It denotes p-th path nominal frequency response and all paths perform as low pass filter. The coefficient of absorption do not vary with its value at referenced center frequency and distance hence for interested frequencies and the distances to the mainstream acoustic transmission systems, impact of the path filtering is about similar for entire channel. Signifying this value using a_0, function of transfer of p[th] link is expressed as

$$\bar{H}_p(f,t) = \bar{h}_p \text{ x } \bar{H}_0(f) \quad (11)$$

$$\bar{h}_p = \frac{\Gamma_p}{\sqrt{(\bar{l}_p/\bar{l}_0)^k \, a_0^{\bar{l}_p - \bar{l}_0}}} \quad (12)$$

F. Delay Spread

The T_{mp}` represents the channel's overall delay spread. It is a vital characteristic to model a system of acoustic transmission. The small multi-path spreads revealed by perpendicular channels and large spreads which is possible up to 100's of mille seconds, by horizontal links.

In broadband systems that are single carrier having short data symbols by comparison with multipath spread, amount of symbols is of significant quality that specifies the Inter Symbol Interference (ISI) degree. It edicts filters size that requires to balance the link. The coherence of frequency which is an expressive quality for broadband systems represent by $\triangle f_{coh}$ which is equal to the $1/T_{mp}$. According to multicarrier systems, less than this value parting of carrier is well preserved. It is also important to keep in mind that the channels of acoustic wave are sparse a lot.

$L \sim T_{mp} B$ is the total multipath spread with intervals $T_s = 1/B$ which is less than the L coefficients that suit for signifying retort of channel [22, 23].

G. Doppler Distortion

Time variability of the channel is due to the two reasons, First one is the inherent variations in the propagation channel that results to fading of signal. And second one arises due to the sender and receiver mobility that results in frequency shifting. The difference between these two is that the former occurs randomly and second one is expressed in a deterministic way. Motion of sender and receiver or point of reflection with path of signal reasons the distances of path to change with time. The Doppler Effect magnitude is directly proportional to ratio $a = \upsilon/c$ of relative sender and receiver velocity to the sound speed.

As the speed of electro-magnetic waves is greater than the sound speed hence acoustic signal's, motion induced Doppler distortion is very high.

For the modeling of the Doppler distortion, let we take only propagation path and assumes the relative sender and receiver velocity υ_p that remains constant with this path for some interval of time then path delay expressed as

$$\bar{\tau}_p(t) = \bar{\tau}_p - a_p \text{ x } t \quad ..(13)$$

where the Doppler factor for the p[th] path is $a_p = \upsilon_p/c$.

These factors about equal for entire paths $a_p = a,\ \forall\, p,$ if we have only one dominant component of velocity[23].

To measure time variation delay effect for a signal, suppose we just emphasis at a specific component of the signal. It is in narrowband centered around frequency f_k such that $\triangle f \ll f_k$. Following is relation of signal that is $s_k(t)$ with corresponding baseband $u_k(t)$ are given

$$s_k(t) = Re\{u_k(t) e^{j\,2\,\pi f_k t}\} \quad (14)$$

As signal occupies frequencies narrow band, its copy is received over propagation path p[th] that is given as

$$s_{k,p}(t) = \bar{h}_p Q(f_k) s_k\left(t - \bar{\tau}_p(t)\right) \quad .....(15)$$

The equivalent baseband component of the received signal through

$$s_{k,p}(t) = Re\left\{\upsilon_{k,p}(t) e^{j\,2\,\pi f_k t}\right\} \quad ......(16)$$

The association of baseband

$$\upsilon_{k,p}(t) = \bar{c}_{k,p}\, e^{j\,2\,\pi\, a_p f_k\, t} u_k\left(t + a_p t - \bar{\tau}_p\right) \quad (17)$$

where $\bar{c}_{k,p}$ is constant.

$$\bar{c}_{k,p} = \bar{h}_p \bar{H}_0(f_k) e^{-j2\pi f_k \tau_p} \quad (18)$$

and the Doppler effect are apparent in two factors. First is frequency shifting by the $a_p f_k$ while the other is time scaling by the factor $\left(1 + \mathrm{a_p}\right)$.

H. Fading

The inherent channel varies from very large scale, the slow changes which happens on season base such as the variation in speed of sound profile from summer to winter or everyday such as by the water currents depth variations, to minor scale, the rapid changes which produced by the quick mobility of the water surface.

The large scale occurrences affect ordinary signal power, producing it to change over lengthier time. The small scale occurrences upset rapidly the level of signal, producing change for smaller time.

1) Large-scale effects: Length of the path diverge from the nominal values for measuring arbitrary channel variations, hence.

$$l_p = \bar{l}_p + \triangle\, l_p \quad (19)$$

In equation (19) random displacement is denoted by $\triangle\, l_p$, that designs variations of large scale. The link transfer function that is now random is expressed by

$$H(f) = \bar{H}_0(f) \sum_p h_p\, e^{-j2\pi f \tau_p} \quad (20)$$

where h_p is the path coefficients which is computed same as the nominal equation (12), by l_p instead of $\bar{l}_p$ while delays can be computed as $\tau_p = l_p/c - t_0$ in reference to some time, such as. $t_0 = \bar{l}_0/c$. The corresponding arbitrary path gains also estimated as [24]

$$h_p = \bar{h}_p e^{-\xi \triangle l_p /2} \quad (21)$$

$$\xi_p = a_c - 1 + k/\bar{l}_p \quad (22)$$

$\bar{h}_p$ is calculated by equation (12).

2) Small-scale effects: Previous model does not comprises impacts of scattering that produces dispersion of micro path with every propagation-path. It is shown by a factor which attends path gain $h_p(t)$. A complete model of channel is acquired as

$$H(f,t) = \bar{H}_0(f) \sum_p \gamma_p(f,t)\ h_p(t) e^{-j2\pi f \tau_{p(t)}} \quad (23)$$

In this model, the factor $h_p(t)$ represents slower changing process. The factor $\gamma_p(f,t)$ denotes faster changing scattering process. These factors are often expressed as circularly symmetric complex valued Gaussian processes which are normalized so as not to modify total signal power that is received, i.e.

$$E\left\{\left|\gamma_p(f,t)\right|^2\right\} = 1$$

IV. Conclusion and Future Work

The channel modeling becomes significant aspect of signal processing and analyzing has been examined for decision feedback equalization [22, 23], turbo equalization [24, 25] and multi carrier revealing [26, 27, 28]. Though a larger channel capacity indicates more ISI and frequency discrimination, it infers an enhanced resolution in delay. Hence, the associated signal distortion is apparent as more simple, channel estimation is additionally effective in case when an appropriate sparse model is used, and that leads to better processing of signal. Moreover the signal at a greater rate allows more recurrent channel interpretations thus channel tracking will be easier [29]. Particularly, outstanding efforts are proceeding for merging the small range with greater bit rate UW acoustic transmission systems along leisurelier and lengthier range UW communications [30].

References

[1] Stojanovic, Milica, and James Preisig. "Underwater acoustic communication channels: Propagation models and statistical characterization." IEEE Communications Magazine 47, no. 1 (2009): 84-89.

[2] Harris III, Albert F., and Michele Zorzi. "Modeling the underwater acoustic channel in ns2." In Proceedings of the 2nd international conference on Performance evaluation methodologies and tools, p. 18. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2007.

[3] Akyildiz, Ian F., Dario Pompili, and Tommaso Melodia. "Underwater acoustic sensor networks: research challenges." Ad hoc networks 3, no. 3 (2005): 257-279.

[4] X. Che, I. Wells, G. Dickers, P. Kear, and X. Gong, “Re-evaluation of rf electromagnetic communication in underwater sensor networks,” Communications Magazine, IEEE, vol. 48, no. 12, pp. 143 –151, Dec 2010.

[5] N. Farr, A. Bowen, J. Ware, C. Pontbriand, and M. Tivey, “An integrated, underwater optical /acoustic communications system,” in OCEANS 2010 IEEE - Sydney, may 2010, pp. 1 –6.

[6] L. Freitag and S. Singh, “Performance of micro-modem psk signaling under variable conditions during the 2008 race and space experiments,” in OCEANS 2009, MTS/IEEE Biloxi - Marine Technology for Our Future: Global and Local Challenges, october 2009, pp. 1 –8.

[7] L. Freitag and M. Stojanovic, “Basin-scale acoustic communication: a feasibility study using tomography m-sequences,” in OCEANS, 2001. MTS/IEEE Conference and Exhibition, vol. 4, 2001, pp. 2256 –2261 vol.4.

[8] L. Freitag, M. Johnson, and D. Frye, “High-rate acoustic communications for ocean observatories-performance testing over a 3000 m vertical path,” in OCEANS 2000 IEEE Conference and Exhibition, vol. 2, 2000.

[9] T. Curtin, J. Bellingham, J. Catipovic, and D. Webb, “Autonomous oceanographic sampling networks,” Oceanography, vol. 6, no. 3, pp. 86 –94, 1993.

[10] J. Potter, A. Berni, J. Alves, D. Merani, G. Zappa, and R. Been, “Underwater communications protocols and architecture developments at nurc,” in OCEANS, 2011 IEEE - Spain, june 2011, pp. 1 –6.

[11] A. Quazi and W. Konrad, “Underwater acoustic communications,” Communications Magazine, IEEE, vol. 20, no. 2, pp. 24 –30, march 1982.

[12] A. Baggeroer, D. Koelsch, K. von der Heydt, and J. Catipovic, “Dats - a digital acoustic telemetry system for underwater communications,” in OCEANS 81, sep 1981.

[13] J. Catipovic, D. Brady, and S. Etchemendy, “Development of underwater acoustic modems and networks,” Oceanography, vol. 6, no. 3, 1993.

[14] M. Green and J. Rice, “Channel-tolerant fh-mfsk acoustic signaling for undersea communications and networks,” Oceanic Engineering, IEEE Journal of, vol. 25, no. 1, pp. 28 –39, january 2000.

[15] M. Stojanovic, J. Catipovic, and J. Proakis, “Phase-coherent digital communications for underwater acoustic channels,” Oceanic Engineering, IEEE Journal of, vol. 19, no. 1, pp. 100–111, Jan 1994.

[16] Kularia, Yamini, Sheena Kohli, and Partha Pratim Bhattacharya. "Analysis Of Acoustic Channel Characteristics For Underwater Wireless Sensor Networks." International Journal of Computational Science, Information Technology and Control Engineering Vol.3, No.1/2, April 2016.

[17] Ahmed, S., N. Javaid, F. A. Khan, M. Y. Durrani, A. Ali, A. Shaukat, M. M. Sandhu, Z. A. Khan, and U. Qasim. "Co-UWSN: cooperative energy-efficient protocol for underwater WSNs." International Journal of Distributed Sensor Networks 2015 (2015): 75.

[18] Ahmed, Sheeraz, Nadeem Javaid, Ashfaq Ahmad, Imran Ahmed, Mehr Yahya Durrani, Armughan Ali, Syed Bilal Haider, and Manzoor Ilahi. "SPARCO: Stochastic Performance Analysis with Reliability and Cooperation for Underwater Wireless Sensor Networks." Journal of Sensors2016 (2016).

[19] M. Stojanovic, “On the relationship between capacity and distance in an underwater acoustic communication channel,” in ACM SIGMOBILE Mobile Computing and Communications Review (MC2R). New York, NY, USA: ACM, 2007, pp. 34–43.

[20] “Capacity of a relay acoustic channel,” Oceans 2007, pp. 1–7, Oct. 2007.

[21] M. Stojanovic, “Efficient processing of acoustic signals for high rate information transmission over sparse underwater channels,” Elsevier Journal on Physical Communication, pp. 146–161, june 2008.

[22] W. Li and J. Preisig, “Estimation of rapidly time-varying sparse channels,” Oceanic Engineering, IEEE Journal of, vol. 32, no. 4, pp. 927 –939, october 2007.

[23] S. Roy, T. Duman, and V. McDonald, “Error rate improvement in underwater mimo communications using sparse partial response equalization,” Oceanic Engineering, IEEE Journal of, vol. 34, no. 2, pp. 181 –201, april 2009.

[24] W. Yang and T. Yang, “High-frequency channel characterization for m-ary frequency-shift-keying underwater acoustic communications,” Journal of the Acoustical Society of America, vol. 120, no. 5, pp. 2615–2626, november 2006.

[25] B. Tomasi, G. Zappa, K. McCoy, P. Casari, and M. Zorzi, “Experimental study of the space-time properties of acoustic channels for underwater communications,” in OCEANS 2010 IEEE - Sydney, may 2010, pp. 1 –9.

[26] A. Radosevic, D. Fertonani, T. Duman, J. Proakis, and M. Stojanovic, “Capacity of mimo systems in shallow water acoustic channels,” in Signals, Systems and Computers (ASILOMAR), 2010 Conference Record of the Forty Fourth Asilomar Conference on, nov. 2010.

[27] F. Socheleau, C. Laot, and J. Passerieux, “Stochastic replay of non-wssus underwater acoustic communication channels recorded at sea,” Signal Processing, IEEE Transactions on, vol. 59, no. 10, oct. 2011.

[28] M. Chitre, “A high-frequency warm shallow water acoustic communications channel model and measurements,” Journal of the Acoustical Society of America, vol. 122, no. 5, pp. 2580–2586, november 2007.

[29] J. Zhang, J. Cross, and Y. Zheng, “Statistical channel modeling of wireless shallow water acoustic communications from experiment data,” in Military Communications Conference, 2010 - MILCOM 2010, 31 2010-nov. 3 2010, pp. 2412 –2416.

[30] J. W. Choi, T. Riedl, K. Kim, A. Singer, and J. Preisig, “Adaptive linear turbo equalization over doubly selective channels,” Oceanic Engineering, IEEE Journal of, vol. 36, no. 4, pp. 473 –489, october 2011.

Resource Management in Cloud Data Centers

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***Abstract*—Vast sums of big data is a consequence of the data from different diversity. Conventional data computational frameworks and platforms are incapable to compute complex big data sets and process it at a fast pace. Cloud data centers having massive virtual and physical resources and computing platforms can provide support to big data processing. In addition, most well-known framework, MapReduce in conjunction with cloud data centers provide a fundamental support to scale up and speed up the big data classification, investigation and processing of the huge volumes, massive and complex big data sets. Inappropriate handling of cloud data center resources will not yield significant results which will eventually leads to the overall system's poor utilization. This research aims at analyzing and optimizing the number of compute nodes following MapReduce framework at computational resources in cloud data center by focusing upon the key issue of computational overhead due to inappropriate parameters selection and reducing overall execution time. The evaluation has been carried out experimentally by varying the number of compute nodes that is, map and reduce units. The results shows evidently that appropriate handling of compute nodes have a significant effect on the overall performance of the cloud data center in terms of total execution time.**

Keywords*—*Big data; cloud data center; MapReduce; resource utilization

I. INTRODUCTION

Data sets that are so huge or complex that conventional data processing techniques are incapable to deal with them are called big data. The key sources of big data production are digital applications, social media, transactions, emails, sensors data and migration of almost every manual entity towards automation. The increasing number of challenges of big data are due to its diverse nature which is categorized by its V's [1]. As Big data is growing enormously so is its processing requirements. Consequently, it calls for requirements of huge computational infrastructure, in order to successfully analyze and process large amount of data. This is a two pronged challenge, on one hand the amount of data is constantly increasing and its allocation on suitable set of available resources and on the other hand need to yield the output in less time with minimum cost. To deal with ever growing data sets, the giants like Google, IBM, Microsoft and Amazon have ventured their concentration in cloud computing. They have offered various services based on cloud computing [2]. Cloud computing is a solution to perform large scale complex computing. It abolished the need for expensive hardware, software and devoted space. Cloud computing offers its users a platform which grants resources, services and applications. Mainly the cloud computing offers three different services; platform as a service (PaaS), software as a service (SaaS) and infrastructure as a service (IaaS). For the users, these services are easily accessible on pay per-Use-Demand [3].

Several frameworks have been proposed for processing big data. Some of widely used frameworks are Hadoop MapReduce, Dryad, Spark, Dremel and Pregel [4]. The most well-known framework is MapReduce. MapReduce is proposed by Google to simplify massively distributed parallel processing so that very large and complex datasets can be processed and analyzed efficiently. It is designed on the principle of exploiting the parallelism among the processing units. Popular implementation of the MapReduce framework is Hadoop and is used typically in conjunction with cloud computing, for executing various Big Data applications, including web analytics applications, scientific applications, data mining applications and enterprise data-processing applications [5].

The cloud data centers comprise of several compute nodes servers and storage nodes. Inappropriate handling of cloud data center resources will result in underutilization of the resources, high latency and computational costs. Thus, it would yeild the overall degradation of the system 'performance [6]. Existing researches are revolving around the improvement of resource management of cloud data centers by focusing more on scheduling of tasks on the relevant processers [7-9]. Some researchers tried to alleviate the communication cost of the data movement within the cloud data center [10-11]. While some researchers aiming at energy conservation for resources of the cloud data center [12-13]. Minimal attention has been given towards the optimization factor and some factors of framework used on servers has been explored [14].

However, there is lack of significant research upon the optimization of the resources of the of the cloud data center. In addition, the proper selection and distribution of compute nodes are not considered by research community. The important challenge is effective utilization of resources, with trifling computational cost, while skillfully allocating various assets of the data center to diverse tasks. This research focuses on the appropriate handling of the compute nodes of the cloud data center.

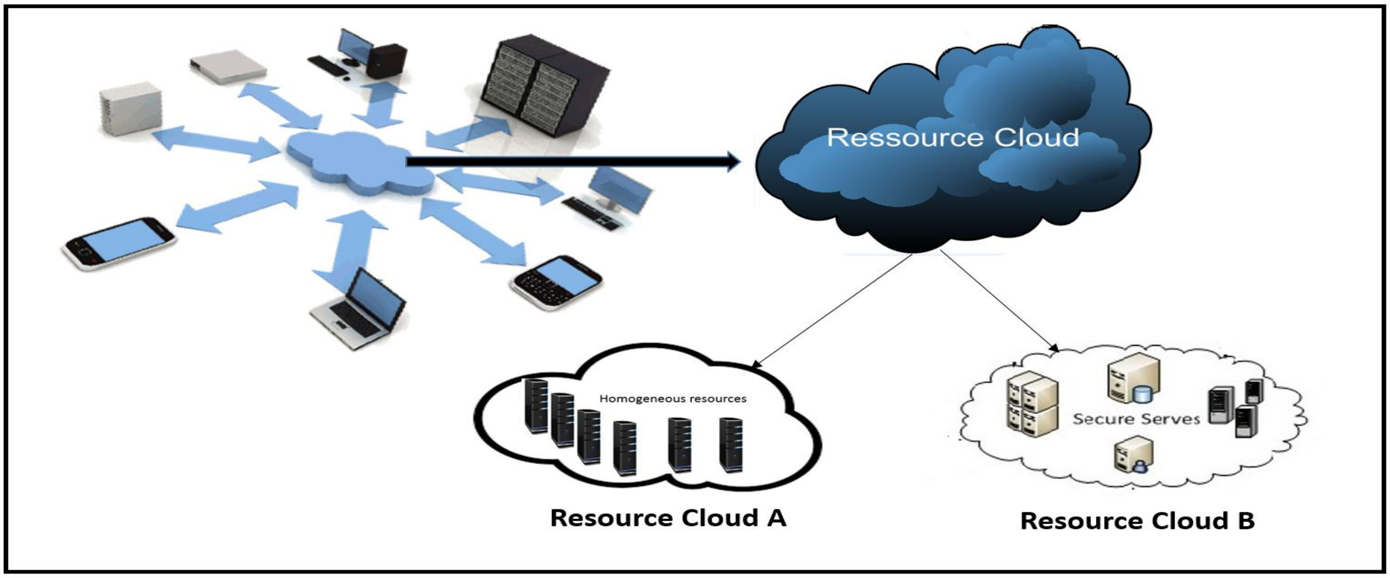

Fig. 1. Overview of Framework.

For illustration of the problem focused in this research study, a general framework is shown in Fig.1. When client submit their requests and the whole data size for processing from all requests is huge. Then, on the submission of this data, it will be divided further for efficient processing among the physical and virtual resources of the Cloud data center. As shown in Fig.1 the data is splitted among different resource clouds and for its data execution on the processing nodes, it will be further chunked and assigned to suitable processing machines according to the submitted task requirement. Thus, splitting the data among the compute nodes and proper parameter handling of the compute resources is necessary.

The organization of the paper is as follows: Section II describes the Preliminaries that is giving the overview of Big Data and its characteristics, enlightens the MapReduce Framework and Cloud Computing details. Section III comprises the Problem formulation. In Section IV, presents the Experimental Setup with the configuration details. Section V is about the Results and discussions. Last section that is, Section VI is of Conclusion and future work and following then are the acknowledgements and references of this study.

II. Preliminaries

A. Big Data

This vast sum of big data is a consequence of the data from different diversity that is, digital applications, scientific data, business transactions, social networking, emails and sensors data. The challenges of big data have been risen because of the 5V's characteristics of big data i.e. how to store, process, merge, manage and govern the different formats of data [15]. The brief detail of the V's are as follows.

- Volume shows the size of big data i.e. gigabyte, terabyte or zettabyte.
- Velocity presents the speed of data movement i.e. batch processing, stream processing or the real time processing.
- Variety represents the formats of the big data i.e. structured, unstructured and semi-structured.
- Veracity shows the quality of the big data, originality and authencity of the big data.
- Value presents the information extraction of big data, statics and hypothetical forms.

B. MapReduce Framework

MapReduce is proposed by Google to simplify massively distributed parallel processing so that very large and complex datasets can be processed and analyzed efficiently. Popular implementation of the MapReduce programming framework is Hadoop and is used typically in conjunction with cloud computing for executing various Big Data applications, including web analytics applications, scientific applications, data mining applications, and enterprise data-processing applications [16-17]. MapReduce is considered the most prominent and effective framework for the big data problems that allow the processing of gigantic data over many underlying distributed nodes. The MapReduce is composed of two basic components i.e., mappers and reducers. The basic concept is to design the map function to generate a set of the intermediate key-value pairs. The reducer is then used to merge all intermedia values associated with the intermediate key. The key feature of the MapReduce framework is that it invokes the parallelism among the computing nodes. The workflow of the MapReduce is shown in Fig.2. MapReduce computes a job in a way that it takes the big data sets for processing and chunked the huge data sets into small chunks and process it over the Map units. The output of the mappers is in the form of key-value pairs. This output has been forwarded to the reducers for further processing and the final out has been collected after the Reduce phase.

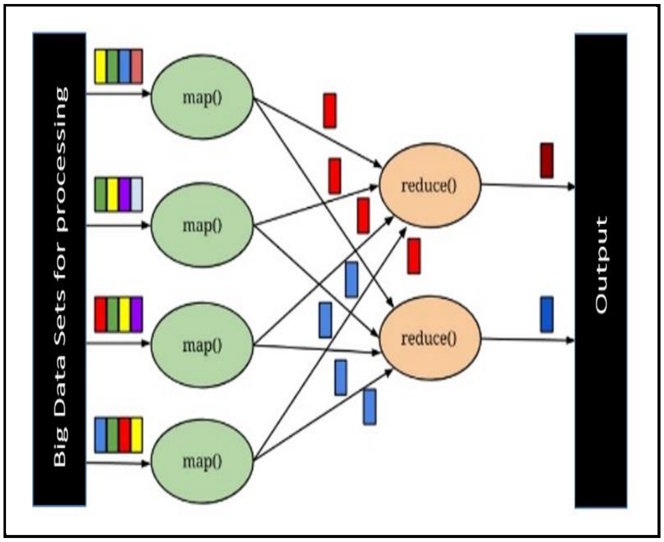

Fig. 2. MapReduce Workflow.

C. Cloud Computing

A newly emerged technology which allows the computations by providing such a platform which allows flexibility in efficient deployment, operation, and management environments. The core model of cloud computing is based on the distributed computing on massive scale, it provide services to the users in computing, networking and storage and the users can use them at their ease. For the organizations, cloud computing offers reliability, availability and scalability. The businesses can benefit from the cloud computing by reducing their cost of investing in business information systems and it can help them in increasing the resource utilization. With the passage of time, the Cloud services from providers like Google, Amazon and Microsoft have been better developed thus resulted in more and more companies diverting towards cloud computing platform. The main purpose of cloud computing model is provision of services, applications and sharing of resources to its users [18].

Big data and Cloud data centers mingled, as big data tasks needs cloud data centers' support for their processing [19]. Cloud data centers provides platforms with physical servers, applications, operating systems and virtual servers either virtually or physically. Cloud server provider can have highest level of resources as well. Traditionally the data centers have the applications which are overworked to deal with the heavy workload [20]. Modern cloud computing infrastructure has the ability to process user's requests at a much faster pace and this ability of analyzing and efficiently processing variety of data has attracted many large enterprises. Low latency results in online services leads to improved user satisfaction and revenue. If a single cloud data center has to process different tasks from different clients or users, then providing the efficient service to all tasks in minimum time with less hardware and computational cost is necessary.

III. Problem Formulation

The main aim of this study is to analyze and optimize the available resources of the cloud data center for the processing of big data sets. Let us consider a cloud data center with its compute resources as shown in Fig. 1. When tasks are submitted from different users to the computational platform for processing. The whole size of the input data tasks could be of certain value. It will be then forwarded to the further sub computational units as shown in Fig.1. Existing studies focused on the improvement of resource management of cloud data centers by encountering assignment of tasks to suitable processing units. However there is deficiency of critical research for the optimization of the resources of the cloud data center. In addition, the proper selection and distribution of compute nodes are underexplored. This research aims at exploring the potential of parameters optimization and suitable distribution of compute nodes for cloud data centers for big data sets processing.

As discussed earlier, MapReduce is becoming one of the most suitable and efficient framework adopted by many large enterprises. It works on principle of parallelism in order to reduce overall execution time and thus improving the performance of the computational platform. MapReduce computes a job mainly into two phases as by the name map and reduce. During the map phase, it splits the input and process it on the given set of nodes. The output of the map phase is in the form of key-value pairs. These key-value sets are stored on nearby machine and then forwarded to the reduce units. The workflow of MapReduce with its default component selection is shown in Fig. 3.

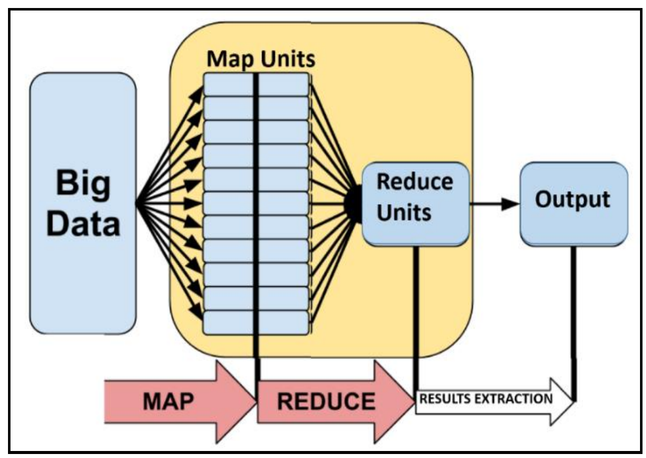

Fig. 3. MapReduce with its Default Number of Reducers.

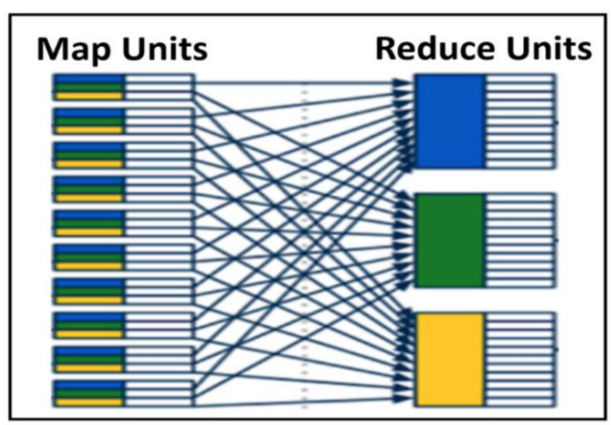

Fig. 4. Proposed Idea for Reduce Units.

In this progression, if the mappers output are divided and forwarded to reducers more than the default value, the overall traffic could be reduced. The overview of division of the mappers output among multiple reducers is presented in Fig. 4.

IV. Experiment Setup

For the implementation of this research study the following described simulation setup has been established. For its installation, first of all, the oracle virtual box was installed in order to take the advantage of creation of multiple machines. The machines are arranged for the master slave architecture. Next to it, is the installation of the Ubuntu setup over the virtual machines. It could be achieved either by installing the Ubuntu on one of the virtual machine and by using cloning feature of oracle virtual box to make the clones of that particular machine or by installing Ubuntu one by one on each of the virtual machines. After this, the Hadoop installation has been carried out. But there are some pre-requisites for the Hadoop installation i.e. the installation of the java either the java development kit jdk or java runtime environment i.e. jre.

The simulations has been done in Hadoop. Comparison analysis has been done in Microsoft Excel. The Hadoop version 1.x allows maximum of the 64 MB block size. The user is able to select the split size for the given data. The Hadoop version 2.x allows maximum of the 128 MB block size. This size can be varied by the user between 64 to 128 MB for Hadoop version 2.x. For the Hdoop 2.x case, the data split size of 128MB was selected for different inputs. The details of the input data size and the split size used are given in the following Table I.

TABLE I. Input Data and Split sizes

Input data size (MB)	Split size1 (MB)	Split size2 (MB)
100	64	128
250	64	128
510	64	128
1180	64	128
2020	64	128
5100	64	128
10480	64	128
15730	64	128

A. *Configuration Details*

For effective utilization of resources, assignment of the tasks to suitable resources is necessary. In addition, proper tuning of the parameters are equally important because inappropriate tuning of the parameters of the resources lead to degradation of the system overall performance. The parameters can be tuned by accessing the configuration files of the computational platform. For Hadoop MapReduce there are many configuration files, when user come across the configuration setting. The interactive files which need to be updated for proposed work setting are the following.

1) hadoop-env.sh
2) core-site.xml
3) hdfs-site.xml
4) mapred-site.xml

V. Results and Discussion

The input data size has been varied from Megabytes (MB) to Gigabytes (GB). The split size was taken as 64 MB and 128 MB. It has been observed that the variation of the split size with the input data size has effect on the number of mappers required for processing as shown in Fig.5. The variation of number of nodes from Fig.5 depicts that choosing the maximum split size will result in the less number of nodes for the input data i.e. split size with value 128 MB gives less than the case of 64 MB split size with same data size. Consequently the variation of mappers will affect the number of the reducers required for efficient processing.

Fig. 6 is depicting that the changing the number of reducers affect the overall execution time also. As observed by Fig. 6 that by elevation in the number of mappers that is with the increase in input data size results in lower execution time if the number of reducers are less. However, the same number of mappers with increasing the number of reducers to a certain value shows significant improvement in the total execution time.

It has been seen that changing the number of reducers along with variation of the number of mappers show a behavior of reducing the execution time at certain value However, the number of reducers providing the best execution time across the given number of mappers is different for different number of mappers. Fig.6 clearly shows that there is no fixed number of reducers for providing the best execution time but varies in number with variation among the number of mapper units. The default number of reducers are one for Hadoop MapReduce. However, for effective utilization of available resources, the number of mappers can be optimized by choosing the maximum split size available.

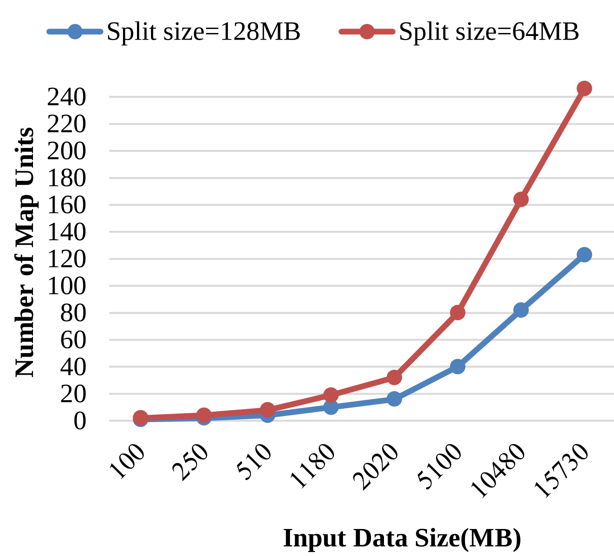

Fig. 5. Number of Mappers vs Different Input Data Size.

VI. Conclusion and Future Work

This research focused on the analysis and optimization of the number of compute nodes for cloud data centers by focusing upon the key issue of computational overhead due to inappropriate parameters selection and reducing overall execution time. For the computational platforms which are following the MapReduce framework, it provides a bases to handle larger type of data sets. As illustrated by the name of MapReduce, it computes a certain job into two phases map and reduce. In the map phase, the input data tasks are assigned to the processing units i.e. mappers. Next to it, in the reduce stage, the intermediate data generated by mapper are sorted and reduced to get the final output. Between the map and reduce phase, there is a migration of data from mappers to reducers. The default value for reducer is one for MapReduce framework. The default selection may lead to higher execution time with large network overhead. For increasing the number of reducers could possibly reduce some traffic and thus improves total execution time. However, for some special cases, number of reducers that is, the reduce phase can be skipped. In that case, mapper's output will be considered as final output. Otherwise, for the follow-up for the reduce phase the mapper's output has been stored to local disk or local storage and then passed to the reducers. The careful consideration is needed before assigning the tasks because the latency will increase if extra storing and fetching of input and output data blocks are manipulated unnecessary.

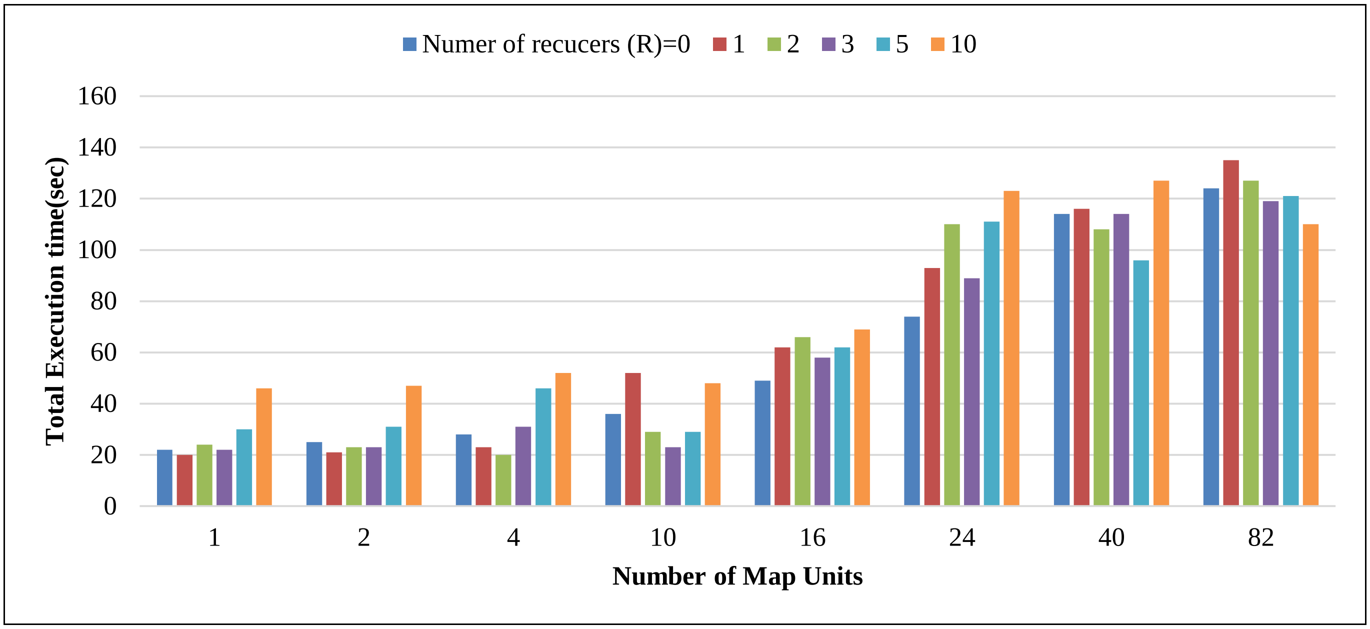

Fig. 6. Total Execution Time vs Number of Mappers with Different Number of Reducers.

Job ID	Name	User	Queue	State	Maps Total	Maps Completed	Reduces Total	Reduces Completed
job_1537633705227_0008	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	10	10	2	2
job_1537633705227_0007	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	123	123	0	0
job_1537633705227_0006	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	123	123	10	10
job_1537633705227_0005	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	123	123	5	5
job_1537633705227_0004	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	123	123	3	3
job_1537633705227_0003	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	123	123	2	2
job_1537633705227_0002	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	123	123	1	1
job_1537616406108_0029	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	82	82	0	0
job_1537616406108_0028	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	82	82	1	1
job_1537616406108_0027	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	82	82	2	2
job_1537616406108_0026	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	82	82	3	3
job_1537616406108_0025	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	82	82	5	5
job_1537616406108_0024	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	82	82	10	10
job_1537616406108_0023	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	10	10	1	1
job_1537616406108_0022	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	4	4	1	1
job_1537616406108_0021	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	4	4	0	0
job_1537616406108_0020	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	4	4	2	2
job_1537616406108_0019	ValueAggregatorJob:	SYSTEM	default	SUCCEEDED	4	4	3	3

Fig. 7. Job Completion with Various Numbers of Mappers and Reducers.

The input data size is varied from Megabytes (MB) to Gigabytes (GB). The split size was varied as 64 MB and 128 MB. The variation of number of nodes from Fig.5 depicts that choosing the maximum split size will result in the less number of nodes for the input data i.e. split size with value 128 MB gives less than the case of 64 MB split size with same data size. Fig. 7 shows that the simulations results with different number mapper and reduce units. In addition, the retrieving, storing and again sending the data to the Data nodes during the intermediate phase of MapReduce itself requires time, computation cost and may produce extra traffic. Moreover, the number of reducers providing the best execution time across the given number of mappers is different for different number of mappers. Fig. 6 shows that there is no fixed number of reducers for providing the best execution time but varies in number with variation among the number of mapper units. Thus, for the future work of this research will follows the modeling of the calculation of compute nodes according to the Cloud data center's capacity.

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References

[1] Géczy, P. (2014). Big data characteristics. The Macrotheme Review, 3(6), 94-104.

[2] Chris Nolter, "IBM Rides the Cloud to New Heights," IBM Ratings Report. July 19, 2018.

[3] Bansal, N., Maurya, A., Kumar, T., Singh, M., & Bansal, S. (2015). Cost performance of QoS Driven task scheduling in cloud computing. Procedia Computer Science, 57, 126-130.

[4] Agneeswaran, V. S. (2014). Big data analytics beyond hadoop: real-time applications with storm, spark, and more hadoop alternatives: FT Press.

[5] Bechini, A., Marcelloni, F., and Segatori, A. (2016). A MapReduce solution for associative classification of big data. Information Sciences, 332, 33-55.

[6] Benifa, J. B. (2017). Performance Improvement of MapReduce for Heterogeneous Clusters Based on Efficient Locality and Replica Aware Scheduling Strategy. Wireless Personal Communications,1-25.

[7] Chen, Q., Zhang, D., Guo, M., Deng, Q., and Guo, S. (2010). Samr: A self-adaptive mapreduce scheduling algorithm in heterogeneous environment. Paper presented at the Computer and Information Technology, 2010 IEEE 10th International Conference on, 2736-2743.

[8] Tang, Z., Liu, M., Ammar, A., Li, K., and Li, K. (2016). An optimized MapReduce workflow scheduling algorithm for heterogeneous computing. The Journal of Supercomputing, 72(6), 2059-2079.

[9] Tiwari, N., Sarkar, S., Bellur, U., and Indrawan, M. (2015). Classification framework of MapReduce scheduling algorithms. ACM Computing Surveys (CSUR), 47(3), 49.

[10] Sowmya, T. S. R. (2016). Cost minimization for big data processing in geo-distributed data centers. Asia-Pacific Journal of Convergent Research Interchange, 2(4), 33-41.

[11] Cavallo, M., Cusmà, L., Di Modica, G., Polito, C., & Tomarchio, O. (2016). A Hadoop based Framework to Process Geo-distributed Big Data. Paper presented at the CLOSER (1).

[12] Beloglazov, A., & Buyya, R. (2012). Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing. Future generation computer systems, 28(5),755-768.

[13] Beloglazov, A., & Buyya, R. (2010). Energy efficient resource management in virtualized cloud data centers. Paper presented at the Proceedings of the 2010 10th IEEE/ACM international conference on cluster, cloud and grid computing.

[14] Aisha Shabbir, Kamalrulnizam Abu Bakar and Raja Zahilah Raja Mohd. Radzi. Replication Effect over Hadoop MapReduce Performance using Regression Analysis. International Journal of Computer Applications 181(24):33-38, October 2018.

[15] Koutroumpis, P., Leiponen, A., and Thomas, L. D. (2017). The (Unfulfilled) Potential of Data Marketplaces: The Research Institute of the Finnish Economyo. Document Number)

[16] Bechini, A., Marcelloni and Segatori, (2016). A MapReduce solution for associative classification of big data. Information Sciences, 332, 33-55.

[17] Aisha Shabbir, Kamalrulnizam Abu Bakar, "Big Data Processing Techniques and Platforms: A Comprehensive Survey", 7th International Graduate Conference on Engineering, Science and Humanities, IGCESH-Proceedings (2018) 698.

[18] Thaman, J., & Singh, M. (2016). Current perspective in task scheduling techniques in cloud computing: A review. International Journal in Foundations of Computer Science & Technology, 6(1), 65-85.

[19] Uta, A., & Obaseki, H. (2018). A Performance Study of Big Data Workloads in Cloud Datacenters with Network Variability. Paper presented at the Companion of the 2018 ACM/SPEC International Conference on Performance Engineering.

[20] Dong, Z., Liu, N., & Rojas-Cessa, R. (2015). Greedy scheduling of tasks with time constraints for energy-efficient cloud-computing data centers. Journal of Cloud Computing, 4(1), 5.

A Multi-Energetic Modeling Approach based on Bond Graph Applied to In-Wheel-Motor Drive System

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***Abstract*—This paper proposes a multi-energetic modeling approach based on Bond Graph tool to modeling a mechatronic system. The use of this approach allows to better understand the real behavior of such system as well as to express the interaction between the elements and their environments. Firstly, the dynamic model of the In-Motor-Wheel Drive System is built using the Bond Graph tool, which is well suited for a multi-energetic modeling system, where several types of energies are included. Secondly, the control system is established and is based on the Pulse Width Modulation (PWM) technique. Finally, the dynamic model is coupled to the control system. They are then successfully implemented and simulated under 20-Sim environment. The simulation results present the performance and the efficiency of the adapted tool not only for dynamic modeling of the synergetic systems, but also to elaborate its control system.**

Keywords—Multi-energetic approach; bond graph tool; PWM; 20-Sim environment; in-wheel motor drive system; mechatronic system

I. INTRODUCTION

The mechatronic system is the synergistic and systemic combination of various components [1] such as actuators, sensors, input/output signal conditioning and interfacing unit, digital control architecture and displays. These components belong to various energy domains such as electronic, mechanic, pneumatic, hydraulic, automatic and computing [2].

The signal flows among these components is shown in Fig. 1.

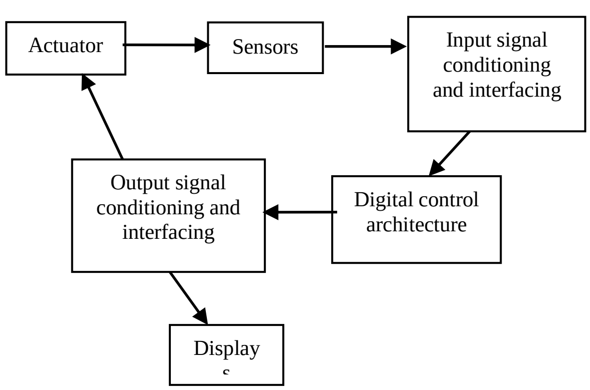

Fig. 1. Various Components of a Mechatronic System [1].

Currently, mechatronics is used in many industrial fields such as the automotive field, due to the development of more powerful, economical, reliable and versatile (flexible) systems and to meet the requirements requested by the user.

The In-Two-Wheels Motors System Drive of an Electric Vehicle is one of the mechatronic application developed in the automotive field. Its advantage includes high efficiency, good repartition of drive power, high performance, safety, stability of the vehicle and optimal size of the system. But, this system has a complicated assembly. This complexity is linked to the [3]:

- multiplicity of subsystems into strong interactions with each other and with its environments;
- superposition of different physical behaviors such as mechanics, electrics, hydraulics and aerodynamics;
- multi-functionality of the system;
- nonlinearity of the dynamic behavior of the elements;

Consequently, the dynamic modeling and development of the control system of such a system have become difficult tasks. This involves the use of an appropriate modeling approach in order to better understand the real behaviors of this system [4].

In this context, this paper aims to a development of a multi-energy approach based on the Bond Graph tool (BG). The need for such an approach consists of a need to bring a methodological aspect to answer the difficulties of modeling, analysis and structuring of the control. The benefit of this approach consists to represent interdisciplinary system systematically.

The particularity of the proposed approach is the determination of the energetic model of a system from its physical representation using a unified energy description language [5], regardless of physics domain and taking into account the interaction of their elements with each other and with the environment in where they operate. Unlike the analytical modeling approach is based mathematical functions. As well as it treats elements of the system in an isolated way by field of discipline.

In addition, this approach gives a structural readability of the system and a visibility on the transfer of energy between the elements [6]. These reasons facilitate the development of the control system based on the BG model.

In this article, the BG-based energy modeling approach is applied to the modeling of the In-Wheel-Motor drive system and to the development of its control system which is based on the sinusoidal PWM technique to control the vehicle speed.

The 20-Sim software is selected to implement and simulate the BG dynamic model system.

This paper is composed of five parts. Firstly, a multi-energetic modeling approach based on Bond Graph tool is presented. Secondly, a brief description of the studied system is presented. Thirdly, the BG model is built. Fourthly, a closed control loop related to vehicle speed is elaborated and it is applied to the dynamic modeling system. Finally, simulation results are presented and discussed.

II. Multi-Energetic Modeling Approach based on BG

In this section, a multi-energetic modeling approach based on BG tool is presented.

A. Concept of a Multi-Energetic Modeling Approach

A multi-energetic modeling approach based on the BG tool rests a unified graphical language and systemic method to model and analyze dynamic systems. The BG tool is based on energy transfer modeling contained in the physical systems. This exchange of energy is represented in graphical form [7].

B. Steps of a Multi-Energetic Modeling Approach

The BG presents the modeling process step by step in a hierarchical and structural way. The different steps of the tool BG are shown in Fig. 2.

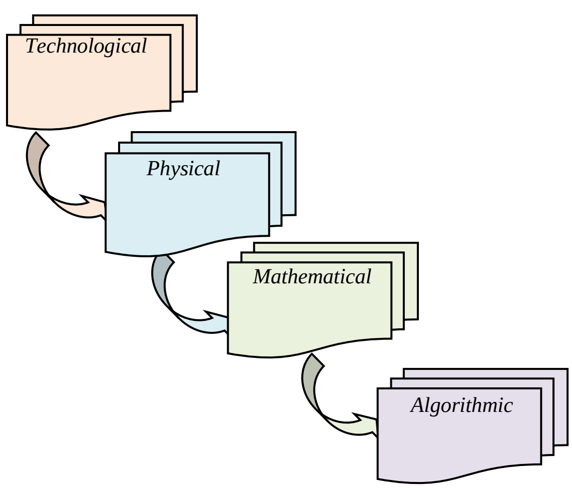

Fig. 2. Various Steps of BG.

BG methodology is composed of four levels [8], [9]:

1) The technological level: consists of a functional analysis of the system called “Word BG”. It decomposes the system into interconnected subsystems. The inputs and the outputs of each subsystem are power variables ("effort" and "flow").

2) The physical level: consists of a phenomenological analysis. The various physical phenomena of each subsystem (dissipation of energy, transformation, accumulation, sources) are represented by the basic elements of Bond Graph which are presented by Fig.3.

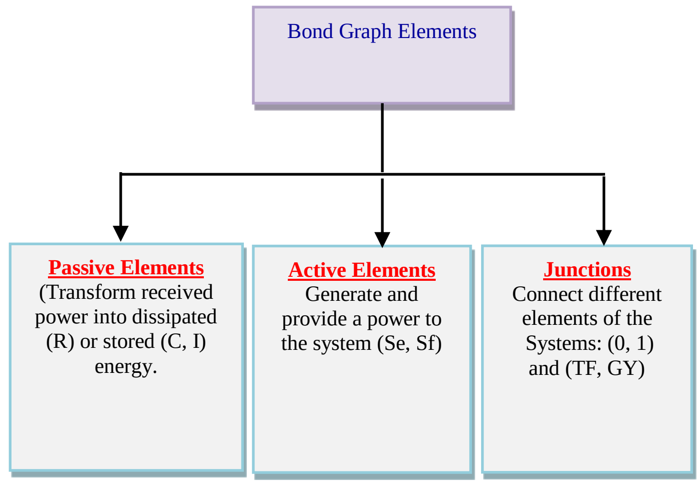

Fig. 3. Basic Elements of Bond Graph [10], [11].

3) The mathematical level: the dynamic equation (algebraic or differential) is deducted directly from the graphical model using the causality notion. From the transfer functions the control system is elaborated.

4) The algorithmic level: consists of the simulation of the diffusion parameters found.

III. Studied System

A. Physical Description

The Electric vehicle equipped with In-Wheel Motors System is proposed. In this paper, only the rear drive system is considered. This system is composed of three parts.

The first part is vehicle dynamic which presents the mechanical aspect of the vehicle. This part is equipped with a chassis, wheels, suspension systems and environment forces.

Second part is the traction which provides the traction force. This force assures movement of the vehicle. This force assures movement of the vehicle. It is equipped with a three-phase inverter, a common battery and an electric actuator such as a PM Synchronous Motor (PMSM) that is widely used in automotive applications especially with in wheel motors. Its advantages include high torque, large power to weight ratio and high efficiency and robustness compared with DC motor and IM [12].

Third is the central part. It generates the information and the control law.

Fig. 4 shows a simplified diagram of the rear traction system of the electric vehicle. It shows the various elements making up the system.

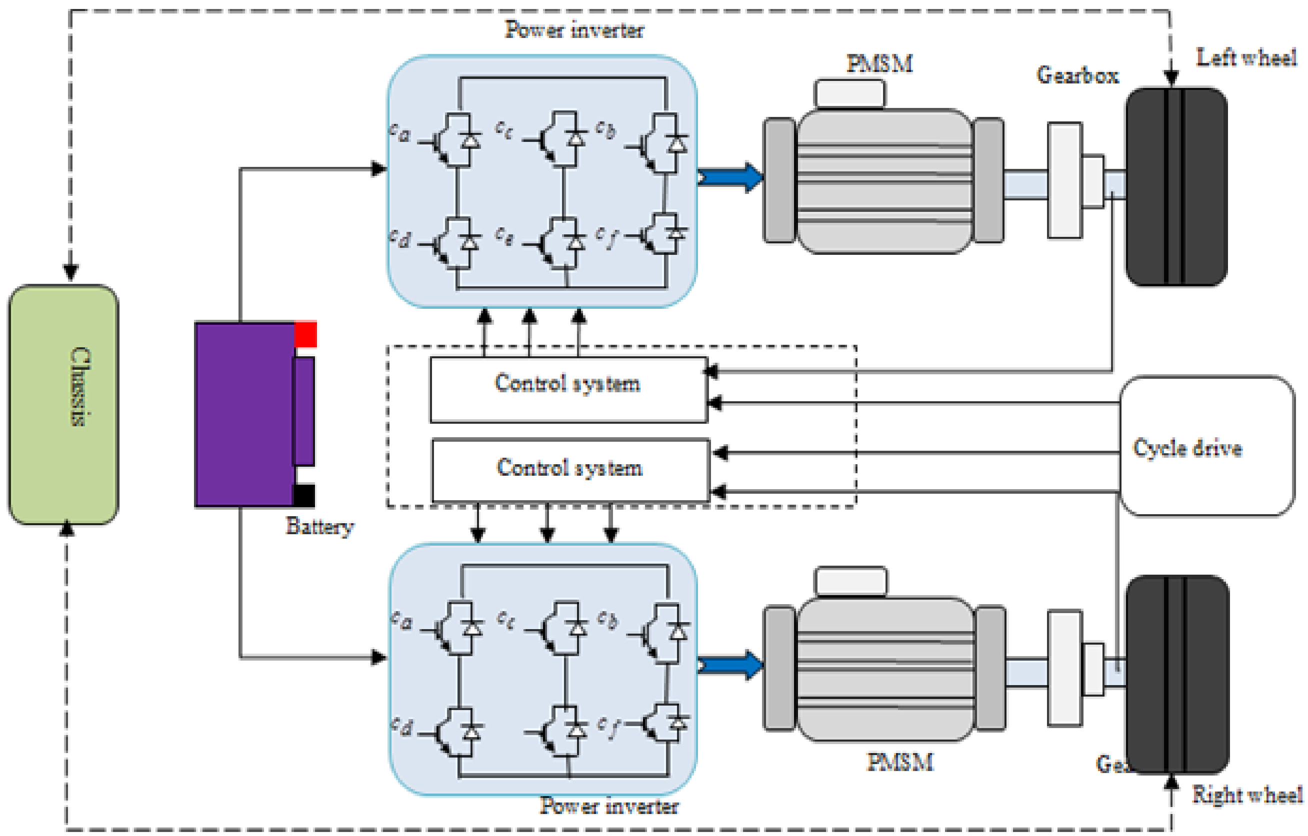

Fig. 4. Schematic Diagram of the Studied System.

B. Dynamic Equation

The equations corresponding to the various subsystems ranging from the battery to the chassis are defined in this section.

1) Dynamic modeling of the PMSM: It is presented as a coupling of electrical, magnetic and mechanical subsystems. The dynamic equations of PMSM are described in the rotating (d-q) reference frame as follows [13]:

$$\begin{cases} V_d = R_s\, i_d + L_d \dfrac{di_d}{dt} - p\,\Omega_m\, L_q\, i_q \\ V_q = R_s\, i_q + L_q \dfrac{di_q}{dt} + p\,\Omega_m \left(L_d\, i_d + \psi_f\right) \end{cases} \tag{1}$$

$$\Gamma_{em} = p\left[\psi_f + \left(L_d - L_q\right) i_d\right] i_q \tag{2}$$

$$J_m \frac{d\Omega_m}{dt} = \Gamma_m - \Gamma_w - B_m\,\Omega_m \tag{3}$$

$$\Omega_{w_i} = k_{red}\,\Omega_{m_i} \tag{4}$$

The second conversion concerns the wheel and is written by:

$$\Gamma_{w_i} = R_w\, F_{w_i} \tag{5}$$

$$\Omega_{w_i} = \frac{V_{veh}}{R_w} \tag{6}$$

2) Dynamic Modeling of the Chassis: This dynamic is given by equation (7) which presents the relation between the acceleration of the vehicle and traction force [5]:

$$M \frac{dV_{veh}}{dt} = F_{tot} - F_{res} \tag{7}$$

F_{tot} is the tractive force generated by the PMSM.

F_{res} is the resistance force presents the environment force and is expressed as:

$$F_{res} = F_{roll} + F_{areo} + F_{slope} \tag{8}$$

The expression of each force is given respectively by the equations below:

$$F_{areo} = \frac{1}{2}\rho C_d\, A_F\, V_{veh}^2 \tag{9}$$

$$F_{slope} = M\, g \sin(\alpha) \tag{10}$$

$$F_{roll} = f_r M g \quad (11)$$

IV. Application Multi-Energetic Approach Modeling Based On BG

This section presents the dynamic modeling of the studied system, including the word BG associated with the system and the BG model of the global system.

A. Word BG

From the description of the studied system presented above, a functional analysis is performed the word BG is obtained and is illustrated by Fig.5.

The nomenclature Table presents the different symbols and variables.

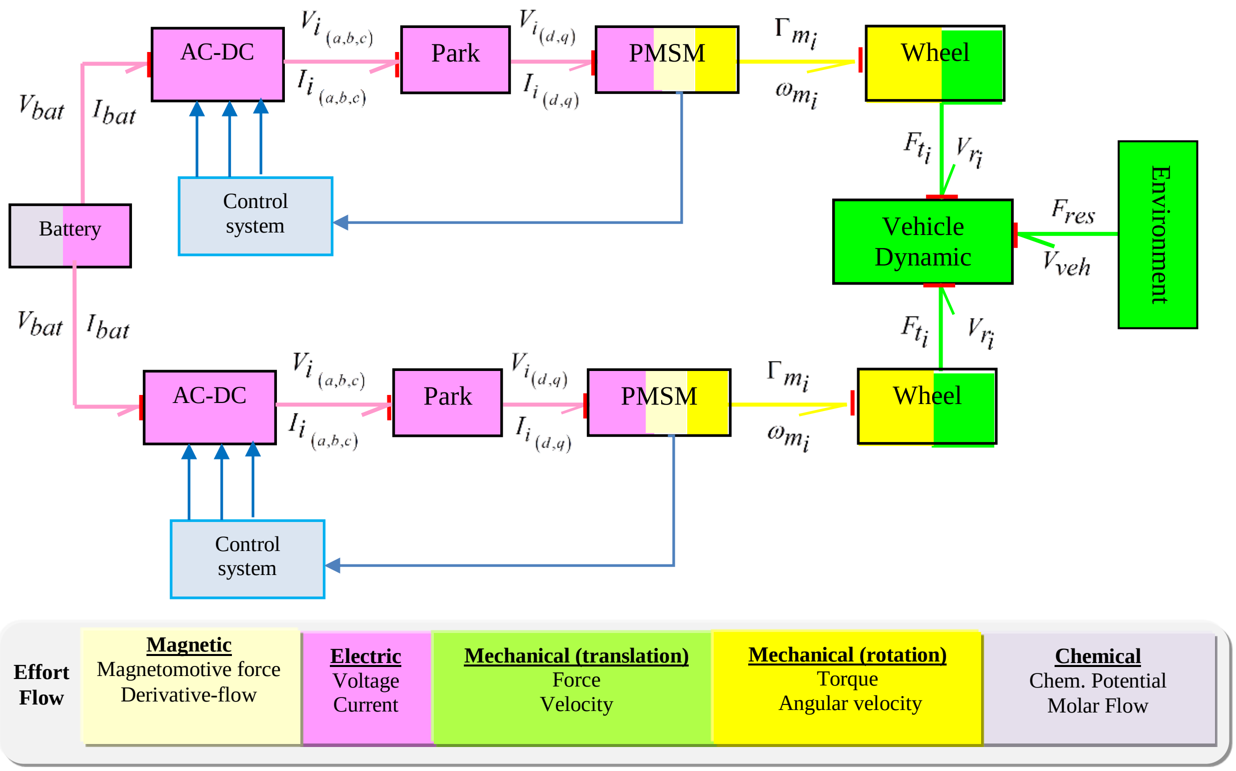

Fig. 5. Word BG of the Studied System.

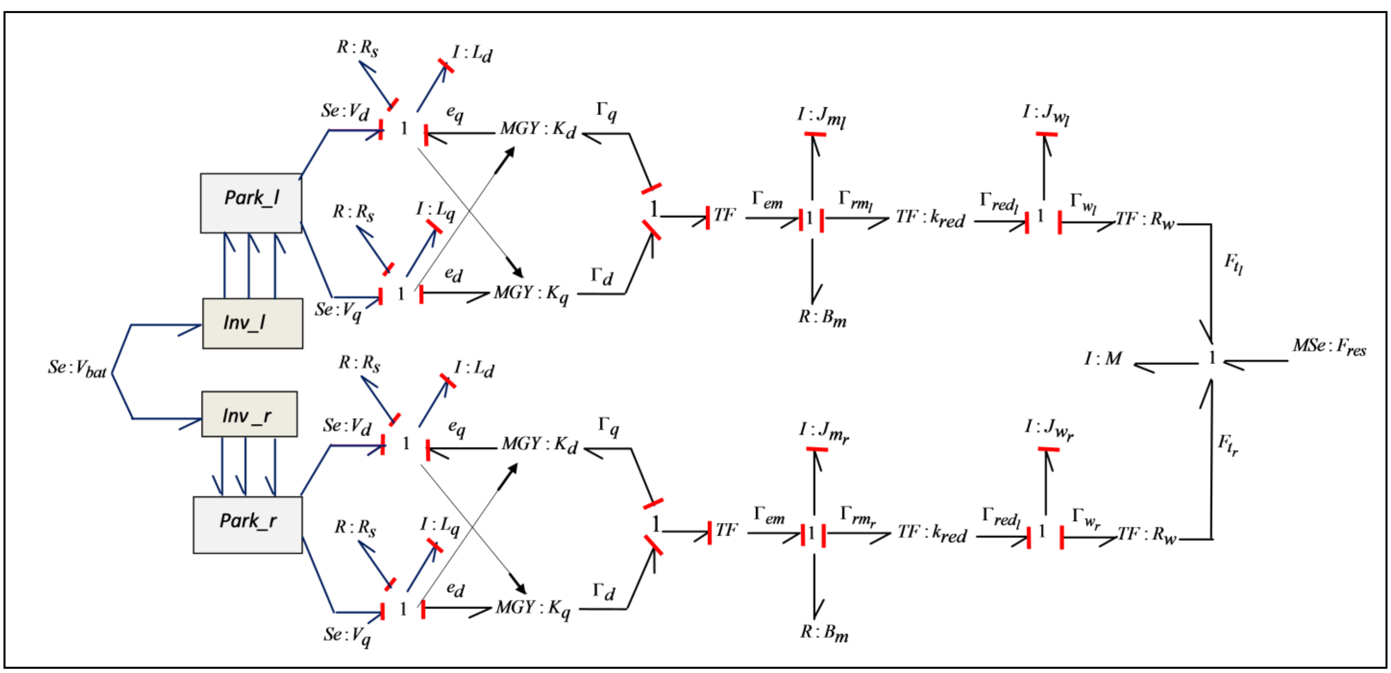

Fig. 6. BG Model of the Studied System.

In the Word BG, the subsystems are composed with technological components which are designated by Words. The inputs and outputs are the energetic interactions that are represented by the power variables. There are two types of power sources: the engine and the environment. The motor provides a torque then it applies to the wheel via a speed reducer. When the vehicle is in motion, the environment generates forces that are applied to the wheel and the vehicle chassis. The Word BG allows a macroscopic representation of the system under consideration.

The next step is to detail each block of the BG to word to in order to obtain the detailed BG of the proposed system.

B. BG Model Construction

The BG model of the studied system is described by Fig.6. This model presents the phenomenological analysis of the studied system. The construction of the complete BG model is deduced directly from the physical modeling system and the Word BG.

In this study, the PMSM is powered by the DC voltage produced by the battery via the Voltage Source Inverter (VSI). In the BG model, the battery is modeled by the effort source (Se).

The VSI is represented by three transformers modulated (MTF) and have the gains η_1, η_2 et η_3.

In Fig. 6, the electrical model of PMSM is represented by I and R, that are present respectively the inductance and resistor of the PMSM.

I: J_{mi} and R: B_{mi} are respectively represented inertia and coefficient of friction of the mechanical model of the PMSM.

MGY: k_i represents the energy transfer between the two sub-models: electrical and mechanical, whose represents the electromotive force.

The dynamic model of the PMSM is composed with an electrical, a magnetic and a mechanical model.

The effort provided by PMSM is transmitted to wheel through the gearbox. That is represented by the transformer element (TF) and has a constant gain. The wheel transforms the torque to a force. This transformation is represented by a transformer element (TF) and it has a constant gain.

The dynamic model of the vehicle is modeled by an energy element (I).

The environment forces are represented by modulated effort sources (MSe).

The advantage BG model is that can be used to resolve many problems such as control, diagnosis, Fault Tolerant Control, etc.

V. Development of the Control Laws

In our application, the desired output to be controlled is the speed of the vehicle.

The design of the control laws of this system is based on a mathematical model (state representation) obtained from the BG model using the mathematical step of Bond Graph tool.

Obtaining the mathematical equations is by applying the basic rules of the BG to the various junctions of the model. These rules are implemented by the constitutive laws of the BG elements concerned.

The control system coupled to the physical vehicle model is presented in Fig. 7.

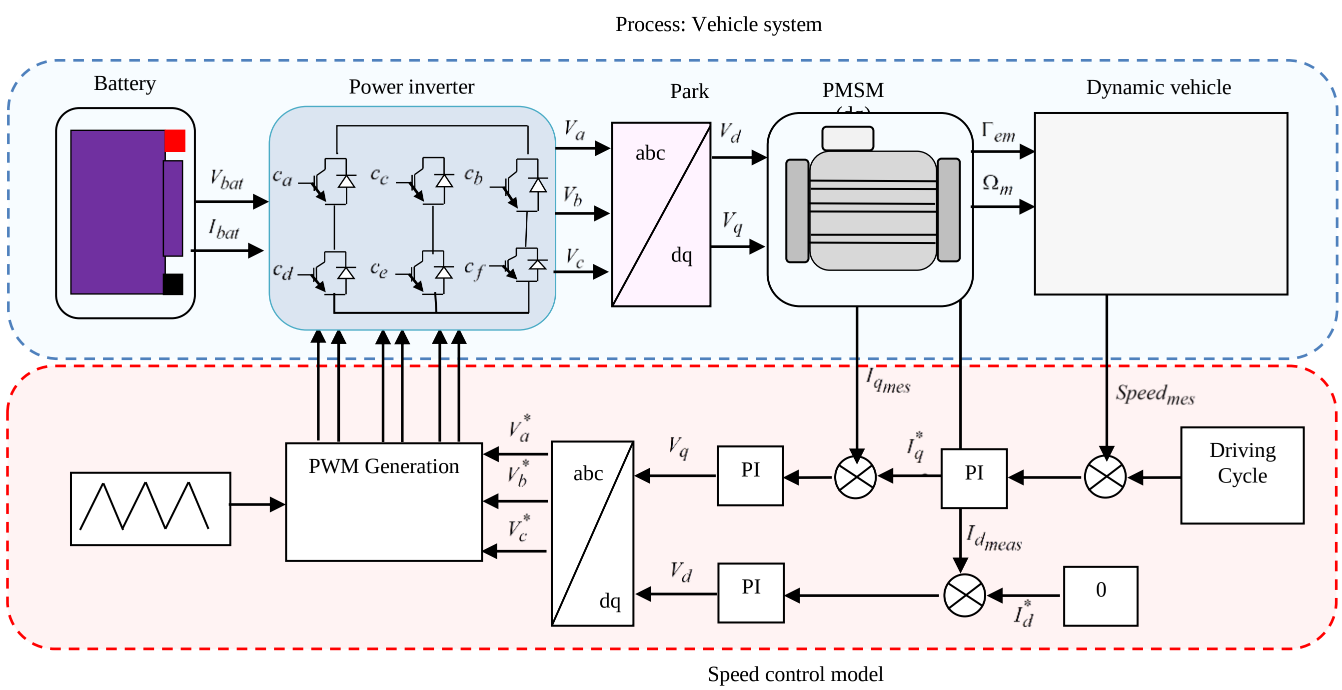

Fig. 7. Control System.

The closed loop control includes two control loops. The inner loop regulates the motor stator currents using two PI current controllers in Park reference frame and compensations of EMFs.

The role of this loop is to obtain the voltage reference in the (d-q) frame.

The equation (13) presents the current control strategy:

$$
\begin{aligned}
V_{d\,ref} &= \left[K_p + \frac{K_I}{p}\right]\left(I_{dref} - I_{dmeas}\right) + e_{dmeas} \\
V_{qref} &= \left[K_p + \frac{K_I}{p}\right]\left(I_{qref} - I_{qmeas}\right) + e_{qmeas}
\end{aligned}
\tag{12}
$$

The outer loop controls the motor's speed. It's used PI controller to provide the total force reference for the velocity measurement and reference using a compensation of the resistive force (if it can be measured or estimated). It is expressed by following equation:

$$
F_{totref} = \left[K_p + \frac{K_I}{p}\right]\left(V_{vehref} - V_{vehmeas}\right) + F_{resmeas} \tag{13}
$$

A. Sinusoidal PWM control Strategy

The PWM model generates the control signals of the inverter. The basic concept of the PWM technique is the comparison of a triangular wave with the fundamental sinusoidal modulation wave as presented in Fig. 8.

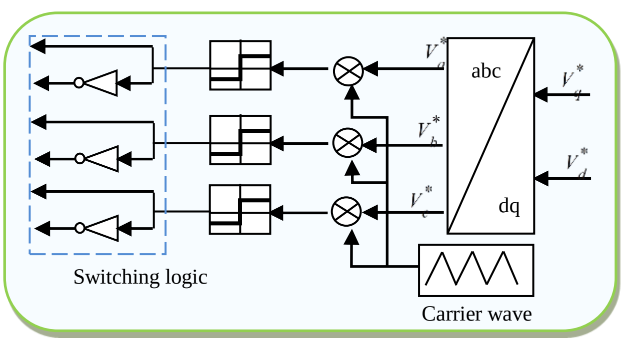

Fig. 8. PWM Model.

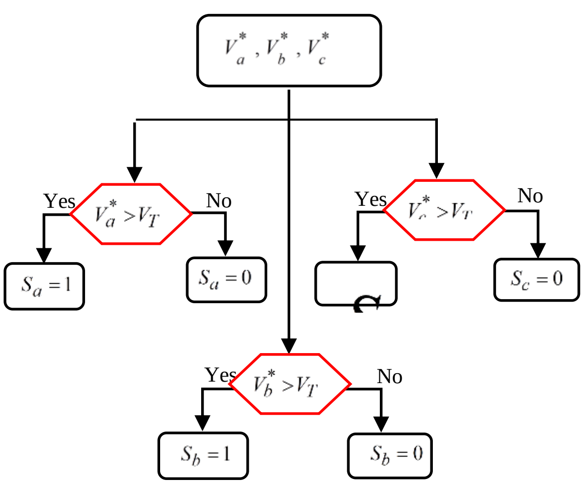

Fig. 9. Algorithm of the PWM Model.

The outputs of PWM go through Controlled Voltage Source blocks before being applied to the PMSM stator windings.

The algorithm of PWM is shown in Fig. 9

VI. Simulation Results And Analysis

A. Simulation Results

In this section, the BG model and its control system are implemented and simulated under 20-Sim software environment [14]. 20-sim is a valuable simulation tool used to model, investigate and simulation of the dynamic behavior of mechatronic system. It is dedicated to the bond graph application. The choice of 20-Sim is justified by the following advantages [15]:

- Ability to simulate and analyze the behavior of multi-domain dynamic systems and create its control systems;
- Ability to present a model graphically, similar to drawing an engineering scheme;
- Ability to even generate C-code and run this code on hardware for rapid prototyping and HIL-simulation;
- Creation of models very quickly and intuitively;
- Ability to create models using equations, block diagrams, physical components and bond graphs.

In order to characterize the system behavior and the performances of the proposed approach, simulations were carried using the model of Fig. 7. The specifications of the PMSM are shown in Table I and in Table II, the specifications of the dynamic vehicle.

The simulations are carried out in three cases:

1) Case A: Flat road with constant speed.
2) Case B: Flat road with 10% slope and constant speed.
3) Case C: Flat road with variable speed.

1) Case A: Flat road with constant speed 80km\h: In this case, we applied a constant speed reference at 80km\h with the flat road condition. Fig.10 shows the vehicle's speed characteristics. At constant reference speed, the vehicle achieves a speed of 80km\h. once the speed reaches a steady value with a small overshoot due to environment force variations.

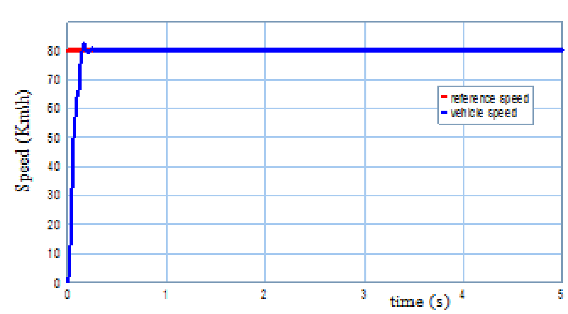

Fig. 10. Vehicle Speed Characteristics for Case A.

2) Case B: Flat road with 10% slope at constant speed: In this case, we applied a constant speed at 80Km\h with the road inclined with slope 10% at 2.5s. The speed stays always the same and the road slope does not affect the control of the vehicle speed, as shown in Fig. 11.

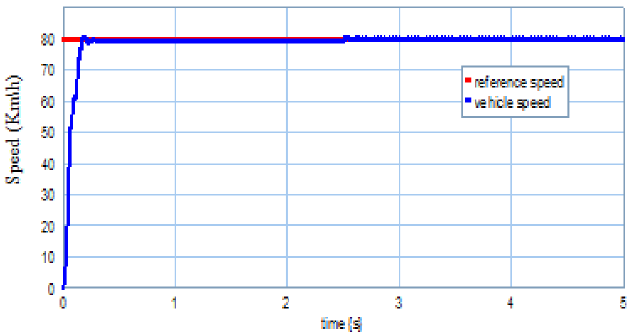

Fig. 11. Vehicle Speed Characteristics for Case B.

3) Case C: Flat road with variable speed: In this case, we applied a variable speed reference between 20km\h and 55km\h, with flat road condition. Fig. 12 shows the speed characteristics of the vehicle with various ranges of speed. We conclude that the speed reference is variable and the motor reaches the desired values very quickly with PI control.

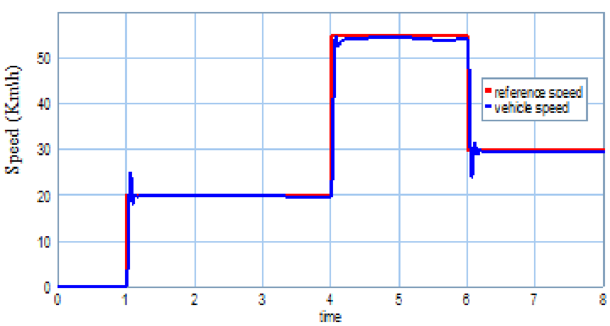

Fig. 12. Vehicle Speed Characteristics for Case C.

B. Analysis of Simulation Results

The simulation results show efficiency and high performances of an energetic modeling approach based on Bond Graph tool for modeling and elaborate a control system for complex and synergistic system. As well as shows, the potential of bond graph to couple two different graphical descriptions: structural (BG) and functional (informational graph) the same model and simulate together under 20-Sim software. The simulation of the speed control system obtained from the BG model for different speed variations and states of the road shows the effectiveness of the simulated control system.

VII. CONCLUSION

In this paper, a multi-energy and multi-physical modeling approach based on a bond graph tool is applied to model and to control a mechatronic system with multi-energy character. Firstly, In-Wheel Motor System Drive model is built. Secondly, its control system is elaborated. Finally, the BG model and control system are implemented under 20-Sim software.

The Bond Graph model of the proposed system is obtained and its control system is validated by simulations.

The study and the simulations show that an energy modeling approach based on BG tool has once again demonstrated its great potential, not only for constructing compact models where different fields of physics and energy but also to elaborate the control system from BG model.

In future work, the BG will be applied for analysis of controllability and observability, diagnosis, supervision of the studied system.

TABLE I. SPECIFICATIONS OF THE PMSM

Symbol	***Description***	***Value***
J_m	Wheel inertia	0. 8e^{-3}Kg/m^2
V_{bat}	Battery voltage	400V
L_d, L_q	*d*, *q* axis inductance	0.2 mH
R_S	stator resistance	0.34 Ohm
Ψ_d, Ψ_q	*d*, *q* axis flux	*0.08 Wb*
P	Pole pairs	4

TABLE II. SPECIFICATIONS OF DYNAMIC VEHICLE

Symbol	***Description***	***Value***
C_d	aerodynamic coefficient	0.55
ρ	Air density	1.25
A_F	Front area of vehicle	1.8m²
M	chassis mass	800Kg
R_w	Wheel Radius	0.296 m

NOMENCLATURES

Symbol	***Description***
J_W	Wheel inertia (motor included)
M	vehicle mass
λ	Slip ratio
μ	Friction coefficient
Γ_W	Wheel torque
α	Angle of the slope
f_r	Friction coefficient
g	Acceleration of gravity
ρ	Air density
C_d	Aerodynamic coefficient
V_{veh}	Linear speed of vehicle
A_F	front area of vehicle
i_d, i_q	d and *q* axis current
R_W	Wheel raduis
Γ_m	Motor torque
Ω_m	Angular speed
V_d, V_q	*d* and *q* axis voltage
R_S	stator resistance
L_d, L_q	*d* and *q* axis inductance
ψ_f	Permanent magnet flux
ψ_d, ψ_q	d and q axis flux
J_m	Rotor inertia
P	Pole pairs

REFERENCES

[1] M.Rochdi, M.P.Pushparaj, O.B.Belkacem "Intelligent Mechatronic System: Modeling, Control, Diagnois," Springer-Verlag, pp.3-50, 2013.

[2] N. Zanzouri , K. Mabrouki, "Robust Diagnosis based on BG Modeling Online Implementatiion in the rear Suspension Motorcycle," 3rd Conference on Control and Fault-Tolerant Systems (SysTol), Barcelona, Spain, Sept. 7-9, pp.239-244, 2016.

[3] J.Nafaa, EL.Lilia, T.Fernando "Modelling and simulation of a BLDC motor speed control system,"Int.J.Electric and Hybrid Vehicles, Vol.8, No.2, *pp.178-194, 2016.*

[4] S. Dridi, I. Ben Salem, L. El Amraoui,‘‘ Modélisation systémique d'un système de propulsion d'un Moteur-Roue du Véhicule Electrique avec les Bond Graphs'', International Conference on Green Energy & Environmental Engineering (GEEE-2018) Vol.39 pp.12-18, 2018.

[5] S. Dridi, I. Ben Salem, L. El Amraoui, ‘‘Dynamic modeling of nonlinear longitudinal automotive system using graphically based techniques'', 7th International Conference on Sciences of Electronics, Technologies of Information and Telecommunications (SETIT), pp.349-354, 2016.

[6] S. Dridi, I. Ben Salem, L. El Amraoui, ‘‘Dynamic modeling of an automotive power steering graphic tool: Bond graph '', International Conference on Electrical Sciences and Technologies in Maghreb (CISTEM), pp.1-8, 2014.

[7] H. Taghouti and A. Mami. How to Find Wave-Scattering Parameters from the Causal Bond Graph Model of a High Frequency Filter A*merican Journal of Applied Sciences*, Vol.7, Issue5, pp. 702-710, 2010.

[8] H. Taghouti and A. MAMI. Discussion around the Scattering Matrix Realization of a Microwave Filter using the Bond Graph Approach and Scattering Formalism. *American Journal of Applied Sciences*, Vol. 9, Issue 4, pp. 459-467, 2012.

[9] S. Jmal, H. Taghouti and A. Mami. A new modeling and simulation methodology of a patch antenna by bond graph approach. International Conference on Electrical Engineering and Software Applications, pp.1-6, 2013.

[10] S. Dridi, I. Ben Salem, L. El Amraoui,‘‘Bond Graph modeling of automotive suspension system using a linear actuator '', International Journal of Scientific & Engineering Research (IJSER), Vol.8, Issue 1, pp. 1837-1844, June-2017 , ISSN 2229-5518.

[11] D. Mzoughi, H.Allagui, A. Mami, ‘‘A comparative study between a 20-sim and a Simulink single PEM cell model, '' 15th international conference on Sciences and Techniques of Automatic control & computer engineering - STA'2014, Hammamet, Tunisia, December 21-23, pp.787-793, 2014.

[12] k. Jaber, B.Ben Salek, A. Fakhfakh, R.Neji, "Modeling and Simulation of Electrical Vehivle in VHDL-AMS," pp.908-911, 2009. (IEEE Conference publication).

[13] K. Jaber, A. Fakhfakh, and R. Neji, "Comparison of SPWM and SVPWM Control of Electrical Vehicle in VHDL-AMS," 6th International Conference on Sciences of Electronics, Technologies of Information and Telecommunications (SETIT), pp.171-176, March 2013.

[14] Logiciel 20sim Controllab Products, 20-sim version 4.1, http://www.20sim.com.

[15] S. Dridi, I. Ben Salem, L. El Amraoui,‘‘ Modélisation systémique basée sur l'outil Bond Graph d'un système de traction de type Moteur-Roue '', International Journal of Scientific Research & Engineering Technology (IJSET), Ðol.6 pp.39-46), Vol.6 pp.39-46, Copyright IPCO-2018ÐSSN 2356-5608, 2018.

Zynq FPGA based and Optimized Design of Points of Interest Detection and Tracking in Moving Images for Mobility System

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***Abstract*—In this paper, an FPGA based mobile feature detection and tracking solution is proposed for complex video processing systems. Presented algorithms include feature (corner) detection and robust memory allocation solution to track in real-time corners using the extended Kalman filter. Target implementation environment is a Xilinx Zynq SoC FPGA based. Using the HW/SW partitioning flexibility of Zynq, the ARM dual core processor performance and hardware accelerators generated by Xilinx SDSOC and Vivado HLS tools improve the system ability of processing video accurately with a high frame rate. Several original innovations allow to improve the processing time of the whole system (detection and tracking) by 50% as shown in experimental validation (tracking of visually impaired during their outdoor navigation).**

Keywords*—Feature detection; harris & stephens corner detector; tracking; extended kalman filter; HW/SW partitionning; zynq SoC; computer vision; memory access; ARM A9; HLS; Interlacing; blancking; progressive video

I. Introduction

The detection and tracking of interest points and corners in real-time from video frames is a key operation in computer vision applied to autonomous mobile systems (e.g. robotics, humanoid robotics, assistive devices for visually impaired). Harris corner detection algorithm is usually used for such characteristics detection because of its algorithmic simplicity and expected level of detection accuracy [1]. For feature tracking, several candidates exist, however only few of them respect the constraints of video real-time. Kalman filter is one of them [2].

Real-time features detection and tracking application raise. The real-time constraints induce additional algorithmic extrinsic (exogenous) constraints as they require larger computation throughput. Furthermore, other requirements such as processing time, used resources, flexibility of implementation (software-hardware co-design) and power consumption, should be also considered for wearable solutions.

FPGAs provide such flexible platform for implementation of algorithms dedicated to wearable systems. Moreover, they simplify and reduce the design cycle, enhance system processing speed and reduce resources demand.

In [3], an architecture for moving object detection and tracking system based on SoPC is proposed; an Altera Cyclone II FPGA platform and NIOS II processor are used. The processing capacity of this implementation need to be confirmed as the NIOS II processor has limited frequency, key parameter especially for processing of large amount of data.

In [4] a solution of task assignment and complex data flow in a system implemented on a mixed DSP and FPGA hardware environment is proposed. Such solutions are possible as new generation of FPGA devices offer unprecedented processing and scalling capabilities:

- New FPGA (FPGA SoC (System of Chip)) allow to implement parallel processing with different programming paradigms having high degree of parallelism on structures such as grids, trees, pyramids with different control strategies (SIMD, MIMD, MISD);
- Unprecedented programmable logic resources [5-6];
- Fast real-time processing, up to billions of MAC operations and memory locations via BRAMs [7];
- Very large memory, up to one gigabyte of DDR3 (SDRAM) [8];

Moreover, the FPGA manufacturers provide support for a sustainable design, such hardware opens the market of big data processing and especially the image processing and computer vision [9] [10].

The efficient and optimal exploitation of available hardware resources become more and more difficult and impose a heavy design load, especially when using the traditional bottom-up design approach. To overcome this complexity, soft processors are proposed which adopt a software design methodology in order to make the FPGA-based design more accessible. Therefore, the co-design and the reasonable hardware-software partition of an algorithm elements play a fundamental role for simultaneous tuning of processing's functional architecture, circuit's architecture and circuit's targeted performance. It fully harnesses the programmable logic performance and the flexibility of soft processing.

ZYNQ-7000 FPGA based SoC family developed by Xilinx displays the scalability, robustness and flexibility of FPGA technology, although it provides high computational performance and easy exploitation [11]. The Zynq-7000 SoC combines a programmable logic FPGA based part and a Cortex-A9 dual-core ARM processor which is completely independent of the programmable units and it can run the software part of the Zynq. The processing subsystem in composed by different peripherals and memory controllers; the programmable logic is composed by millions of programmable units dedicated to implement custom accelerators and expand processing subsystem using its rich bandwidth [3] [12]. We use this platform for hardware-software balanced implementation of algorithms for detection and tracking of corners in video sequences.

Therefore the whole paper is organized as follows. Section II outlines the formal framework for corner detection and their tracking algorithms. Section III proposes a hardware-software co-design of these algorithms implementation in ZYNQ-7000 FPGA SoC. Section IV describes the proposed optimization of memory management of ZYNQ-7000 FPGA SoC. Section V addresses some experimental results, while Section VI concludes the paper and lists its potential extensions.

II. Moving Points of Interest Detection and Tracking: Algorithmic Approach

A. Moving Points of Interest Detection: Harris Corner Detection based

The Harris corner detection [13] is an improvement of the Moravec algorithm [14]. Using pixels' luminosity function derivatives, organized into an auto-correlation matrix, it determines, for each pixel, whether it is a corner or not. The whole computation process requires the following steps:

1) Gradient derivatives computing: The horizontal I_x and the vertical derivatives I_y of a pixel (x,y) luminosity are obtained after the image local convolution with predefined (3x3) masks approximating gradients as shown in (1) and (2).

$$I_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \times I \qquad (1)$$

$$I_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} \times I \qquad (2)$$

The gradients for all pixels of an image are obtained by the convolution of the whole image with the above masks.

2) Computation of the Auto-Correlation matrix: Starting from calculated derivatives and using Taylor series formula, we assumed that are shifting factors over the window w_{xy} where the local interest of the pixel (x,y) is computed by (3).

$$E_{u,v}(x,y) = \sum_{u,v} w_{u,v}\left[I(x+u,y+v)\right]^2 \qquad (3)$$

After applying the Taylor formula, derivatives variation can be expressed as shown in (4) and (5) merged in (6). From the simplifications, one can determine the auto correlation matrix presented in (6).

$$I(x+u,y+v) = I(x,y) + I_x u + I_y v + O\left(u^2+v^2\right) \qquad (4)$$

Wherein,

$$I_x = \frac{\partial I}{\partial x}, I_y = \frac{\partial I}{\partial y}, I_{xy} = \frac{\partial I}{\partial x}\frac{\partial I}{\partial y}$$

After merging (3) and (4), we obtain (5)

$$\begin{aligned} E_{u,v}(x,y) &= \sum_{u,v} w_{u,v}\left[I_x u + I_y v + O\left(u^2+v^2\right)\right]^2 \\ &\approx \sum_{u,v} w_{u,v}\left[I_x u + I_y v\right]^2 \\ &= \sum_{u,v} w_{u,v}\left[(I_x u)^2 + 2I_{xy}uv + (I_y v)^2\right]^2 \\ &= \sum_{u,v} w_{u,v}[u,v]\begin{bmatrix} I_x{}^2 & I_{xy} \\ I_{xy} & I_y{}^2 \end{bmatrix}^2 \begin{bmatrix} u \\ v \end{bmatrix} \\ &= \sum_{u,v} w_{u,v}[u,v] M \begin{bmatrix} u \\ v \end{bmatrix} \end{aligned} \qquad (5)$$

Wherein, auto-correlation matrix is (6):

$$M = w_{u,v}\begin{bmatrix} I_x^2 & I_{xy} \\ I_{xy} & I_y^2 \end{bmatrix} \qquad (6)$$

3) Gaussian filtering (smooting: Gaussian filter aims to reduce noise by smoothing the image window; a 3x3 Gaussian kernel mask is applied to the auto-correlation matrix (6) [13].

4) Harris corner "R" response computing and thresholding: The corner response value, also called R-response is highly important to decide whether the pixel will be considered as a corner or not. Equation (7) presents the equation of R , where *det(M)* is the determinant of the auto-correlation matrix M, *TraceM* is its trace and *k* is an empirical factor that typically varies between 0.04 and 0.06 [16].

$$R = \det M - k(TraceM)^2 \qquad (7)$$

The λ_1 an λ_2 , the characteristics coefficients (eigenvalues) of matrix M, give information about the "interest" value of the pixel (x,y) in the window. Using the relations: $DetM = \lambda_1\lambda_2$ and $TraceM = \lambda_1 + \lambda_2$, the computational formula for the interest value of a pixel (x,y) in its neighborhood w_{xy} is (8):

$$E_{u,v}\left(x,y\right)=D^{-1}\begin{bmatrix}\lambda_1 & 0\\ 0 & \lambda_2\end{bmatrix}D \tag{1}$$

Large values of both characteristics coefficients correspond to maximum of the auto-correlation. This implies that edge curvature variation of the corresponding pixel is big at any direction and the Harris corner response will be at its maximum (and will be more important than the applied threshold); therefore, this pixel is a detected corner.

5) Non-Maximum suppression & Kalman filtering: Kalman tracking is initialized and used to predict the size information and the object location.

Essentially, Kalman filter is an estimation of system behavior (9) through systems states and observations [3] (9):

$$\begin{cases} x_k = A_{x_{k-1}} + w_{k-1} \\ z_k = Hx_k + v_k \end{cases} \tag{2}$$

Where the state vector at the instance t is presented by x_k Process and measurement noises are presented by w_{k-1} an v_k . Measurement vector is z_k , A and H presents respectively the process and observation matrices.

It this paper, we consider two state vectors called V_{s1} and V_{s2} to calculate the size and position prediction of each detected corner. Their corresponding observation vectors are P_1 and P_2 (10-11):

$$\begin{cases} V_{s1} = \left[x,\Delta x, y, \Delta y\right]^T \\ P_1 = \left[x, y\right]^T \end{cases} \tag{3}$$

$$\begin{cases} V_{s2} = \left[u,\Delta u, w, \Delta w\right]^T \\ P_2 = \left[u, w\right]^T \end{cases} \tag{4}$$

Where: $x, y, \Delta x, \Delta y$, express centroid position of a target feature, relative to the movement along x and y directions.

Process and observation matrices are shown in (12):

$$A=\begin{bmatrix}1 & \Delta t & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & \Delta t\\ 0 & 0 & 0 & 1\end{bmatrix}, H=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 0 & 1 & 0\end{bmatrix} \tag{5}$$

Where:

$$\Delta t = t_k - t_{k-1} \tag{6}$$

III. HARDWARE-SOFTWARE IMPLEMENTATION IN ZYNQ-7000 FPGA OF INTEREST POINT TRACKING

Zynq-7000 Xilinx SoCs combines a reconfigurable FPGA area, which represent the programmable logic (PL), with a processing system (PS) part composed by dual-core A9 ARM processor [12]. An accurate embedded system should have the best adequation between hardware acceleration blocks and software execution and processing management, which called a HW/SW co-design environment. Due to the timing and system's speed constraints, hardware acceleration became mandatory, as algorithms implemented in PL will need less execution time compared to pure software-based implementation. Based on these advantages of FPGA, we can accelerate the PS bottlenecks on Zynq SoC using the PL [15]. The proposed architecture was designed and implemented on a Zynq-7020 ZEDBOARD Xilinx HW/SW environment: its internal architecture is shown in Figure 1.

A. Zynq-7000 Data Communication Capabilities

The whole system design is centered on the processing system with a programmable logic extension of the (PS). The primary and principle interface between the programmable logic and the processing system is a set of communication protocols composed of multi channels, called AXI bus interfaces [11] [12]. The role of these dedicated communication protocols and interfaces is to perform a convenient and fast data interaction while processing. To control small amount of data and hang on the accelerator registers (control, address, data) implemented on the (PL) part, the (PS) use a general-purpose interface called AXI_GP. But in case of processing and manipulating large amount of data in a high rate communication between (PS) and (PL), dual core ARM A9 processing system uses a controller called DMA accessible using a high performance AXI interface able to manage 32 and 64-bit data width.

B. Proposed HW/SW partitioning for a Higher Accuracy and Increased Processing Speed

This part outlines the HW/SW partitioning of the whole system and its sub-systems (Harris corner detection and Kalman tracking).

HW/SW partitioning of the whole system.

When dealing with high rate communication speed and large amount of data, three solutions are possible:

1) Run the algorithm in the processing system part completely. However, due to the limited parallelism capabilities of the PS, time and flexibility performance will be bounded;

2) Implement the complete algorithm in hardware (PL). The system will be fast and accurate but the design complexity will be very important;

3) Find an efficient adequacy between the algorithm and the architecture (Zynq-7000 in our case) to achieve the desired performance.

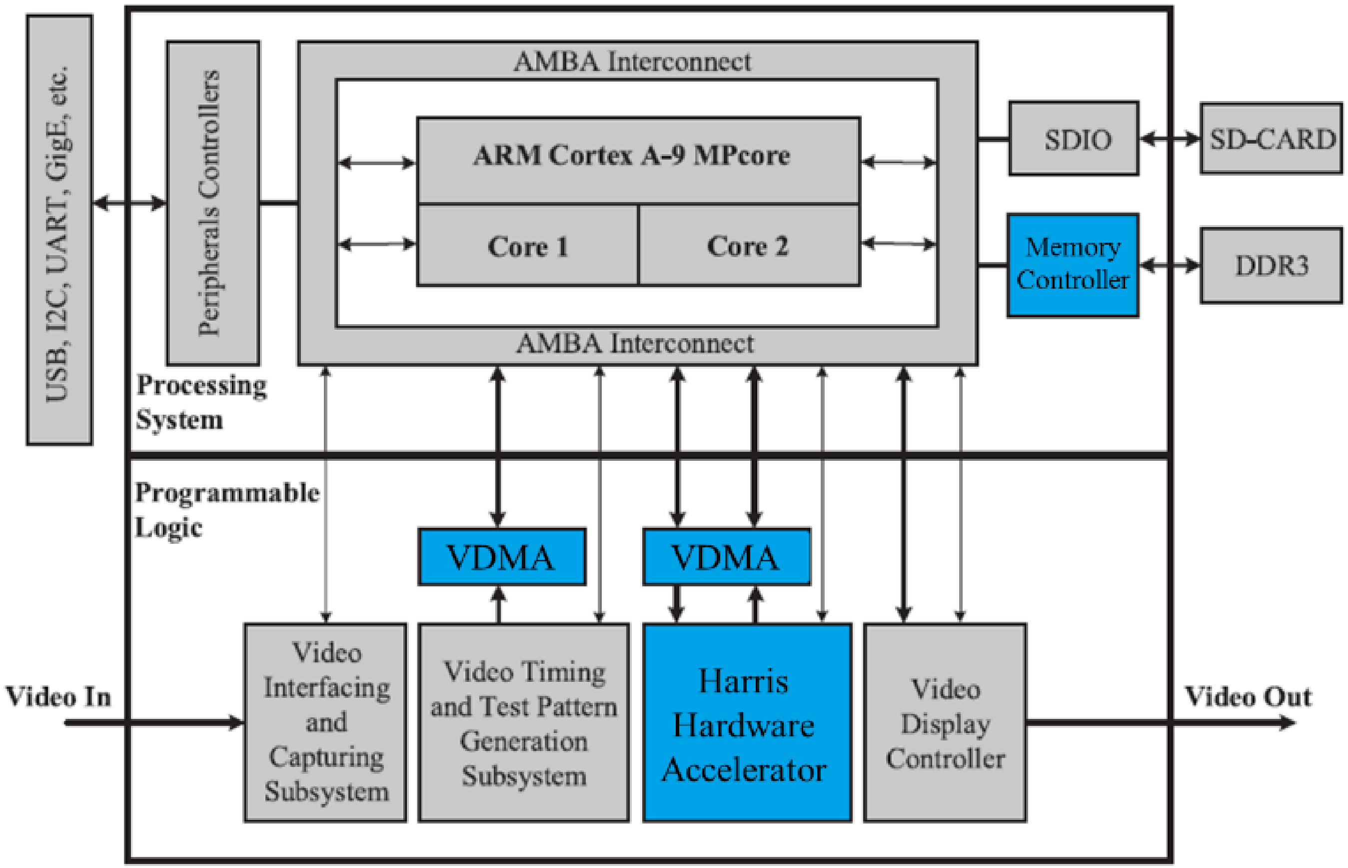

Fig. 1. Proposed Implementation of Ocrner Detection and Tracking in Video Sequences.

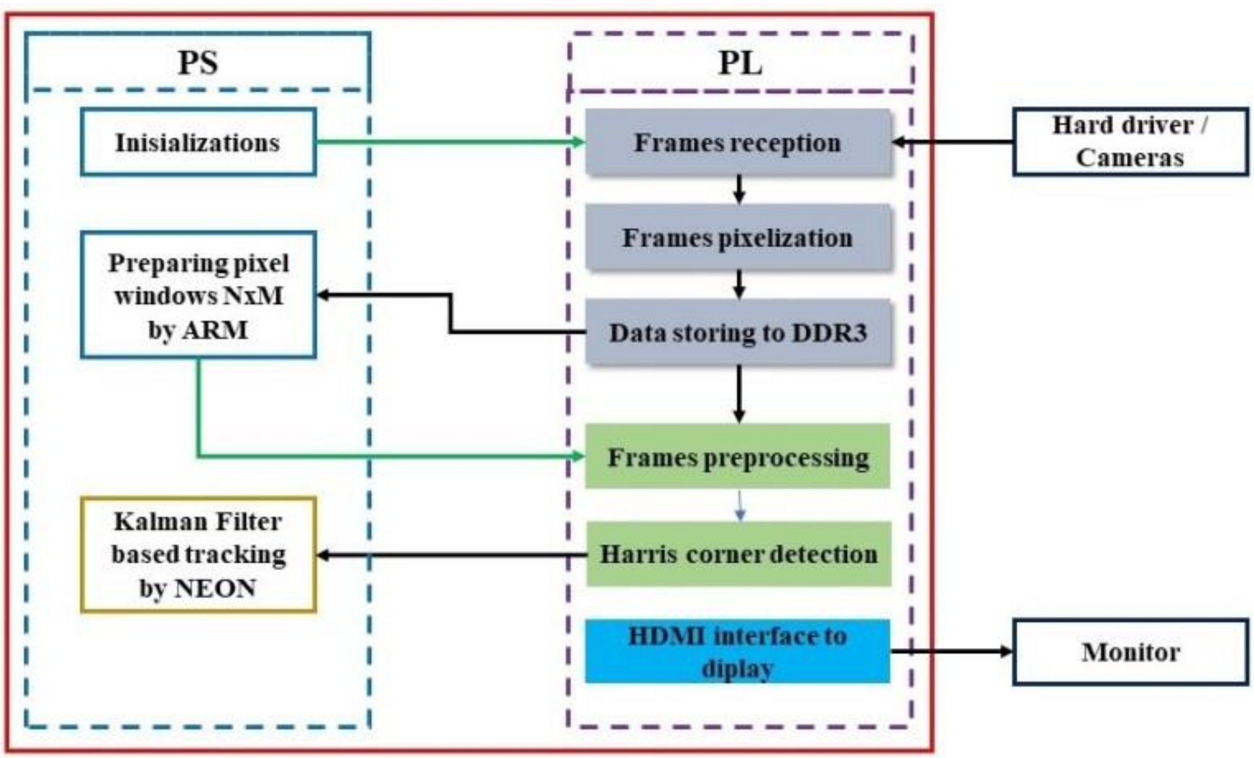

Fig. 2. Hardware-Software Partitionning of the Proposed Processing for Znyc 7000 Soc.

Taking into consideration the Zynq SoC architecture and our algorithm characteristics, we proposed the following hardware and software partitionning of our processing and shown in Figure 2. The system automatic boot and initialization is ensured by software component, and this is using the ARM-A9 processor 1 (which runs an embedded Xilinx Linux distribution dedicated to prepare de hole system to receive data and start the processing). Video data is streamed from cameras through an HDMI external interface, to the programmable logic part (PL). Frames then will be converted to windows of pixels through hardware frame buffers and directly stored in a DDR3 memory through AXI interfaces. Usage of the (PL) to preprocess video data and store them enhances system temporal performance.

Based on the fact that the volume of calculations in Harris corner detection operation is more important than Kalman filter, we proposed to implement it in (PL) part of the Zynq Soc and to assign Kalman based tracking to the ARM based (PS) part.

- Harris corner detection implementation

As discussed in part I, FPGA implementation permits to generate a fully parallel and high-speed core of the algorithm, but classic RTL design of complex algorithms like Harris is hard and needs a long time to validate the implementation. In order to overcome this limitation and improve system development, we used a high-level synthesis methodology based on OpenCV image processing library and Xilinx Vivado HLS design environment. Using this design flow, we generate Harris corner detection accelerator starting from a C++ based description of the algorithm. Figure 3, presents a block diagram of Harris detection generated IP core.

- Kalman based detected corners tracking

Cortex dual core A9 processors run an ARMv7-A set on instructions; it is armed with a high performance floating point SIMD media processing engine called (MPE). This engine is perfectly suitable to execute a multiple range of applications [8] [17]. The advanced single instruction multiple data (SIMD) NEON instructions can give the program the capability to execute image processing applications at an fast rate. For our system, the NEON and the ARM-A9 dual cores are used to accelerate Kalman based detected corners tracking. NEON engine parallelism philosophy is based on the instruction set dedicated to the most significant characteristic.

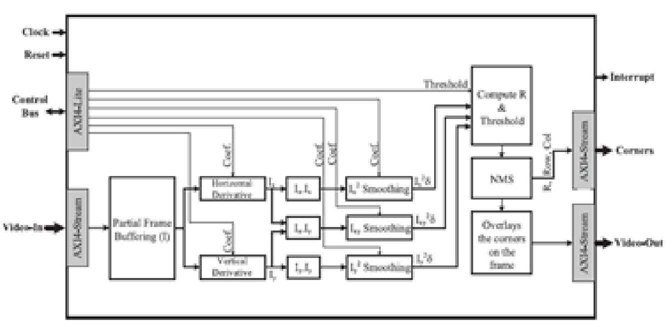

Fig. 3. System Proposed Architecture.

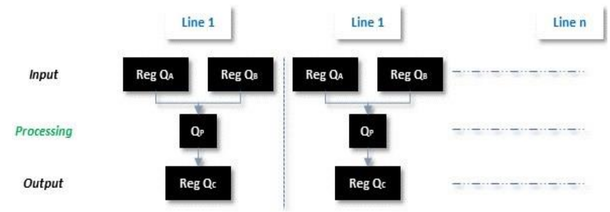

Fig. 4. SIMD Processing Cycle Inside the NEON MPE

Also, this engine has dedicated registers: Q_A and Q_B are input registers that contains N individual input vectors for each [12], as illustrated in Figure 4. A single defined operation is executed between the N input vectors to produce a corresponding set out output vectors which are buffered to an output register called Q_C. Each register can directly load 128 bits from the DDR3. In our case, detected corners will be loaded by the NEON registers for Kalman tracking execution and finally will be stored back to the memory for display.

IV. Optimisation of Memory Resources

In this section, a set of custom blocks integrated in the architecture are presented. Their role is to optimize memory resources needed, improve processing speed and enhance systems security level.

- Frames cropping module

As we are working using 720f resolution, it is necessary to manage frame pixels loaded to the FPGA, so it is necessary to load only the relevant and necessary data for processing achievement. The solution proposed here highly optimizes memory resources dedicated to frames loading and preprocessing, and minimizes the processing time and the energy consumption.

To design an optimized solution it is mandatory to understand the structure of a 720p frame.

720p resolution, also called standard HD, is a progressive video signal with a dimension 1280x720 pixel per frame : 720 horizontal lines and 1280 vertical columns. However, the real 720p frame is bigger than that, because it contains vertical and horizontal blanking, dedicated for many functionalities like ancillary data insertion. Our innovative idea is to load only active region of the frame and ignore all the blanking. To do this we developed a *frame-cropping module*. This block is in charge on the frame cropping functionality. It crops frames starting from pixels data present in the input we called VIDEO_IN, according to a given reference cropping origins, which are SAV flag also known as Start of Active Video, and EAV flag also known as End of Active Video.

Our cropping module could also crop pre-selected areas from frames (through X, Y coordinates), which could be updated through its dedicated registers. Origins are called them CROPPING_X and CROPPING_Y. In addition, the size of the initial frame are detected in real time by two dedicated inputs FRAME_SIZE_X and FRAME_SIZE_Y, that ensure detection in parallel with data streaming. Cropping module specifications are given in Figure 5.

- Frozen video detection module for video loss management.

As we are working on systems that aims to secure, visually impaired peoples, we have think about the systems or camera bug or any kind of incident that could prevent the system to be functional. One of the issues it the frames freeze. So we integrate in our architecture a block the we'ne developed and that deal with frozen frames. Frozen video detection module is designed to assert a flag called "VIDEO_FROZEN" when the video stream is broken or frozen for at least "NB_FROZEN_FRAME" number of frames, see Figure 7. User fixes this number and dedicated registers could modify it. When video is declared as frozen, the information's is sent to a sequencer, which is responsible to act on its outputs accordingly.

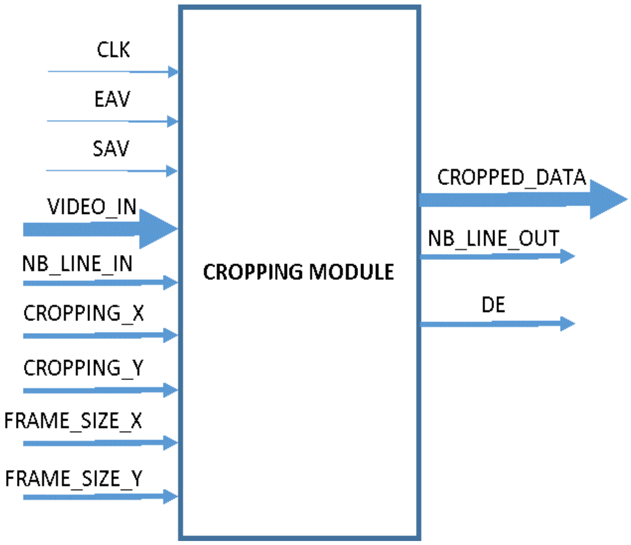

Fig. 5. Cropping Module Specifications.

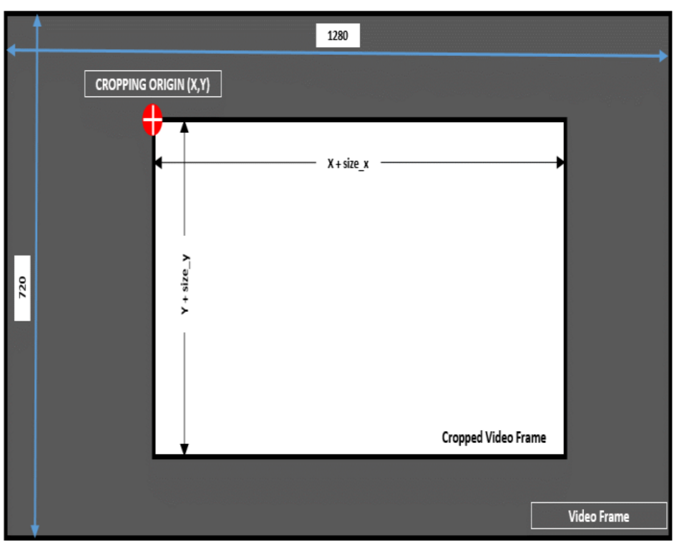

Fig. 6. Frame Cropping using the Proposed HDL Module.

Cropped frame is defined by the Figure 6.

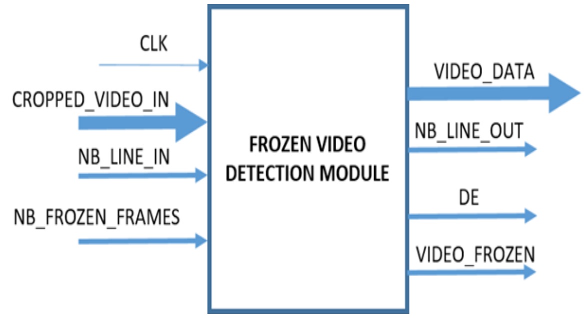

Fig. 7. Video Loss Management Module.

Our management module covers two respective video loss situations: No video input and identical video pattern input.

- No video input

In this case, video signals are inactive; VIDEO_FROZEN flag is active and transmits the information to the sequencer mentioned bellow. This last checks the FIFO dedicated to memorization of loaded video frames. When the FIFO is empty, it continues to transmit black frames.

- Identical video pattern input

A mechanism has been designed to detect several identical input frames, which is considered as an unacceptable behavior, and present a danger for user and the system. To detect and react in case of this incident, a CRC is calculated for every entire current frame and compared with the CRC of the next frame and so on, for a predefined number of frames.

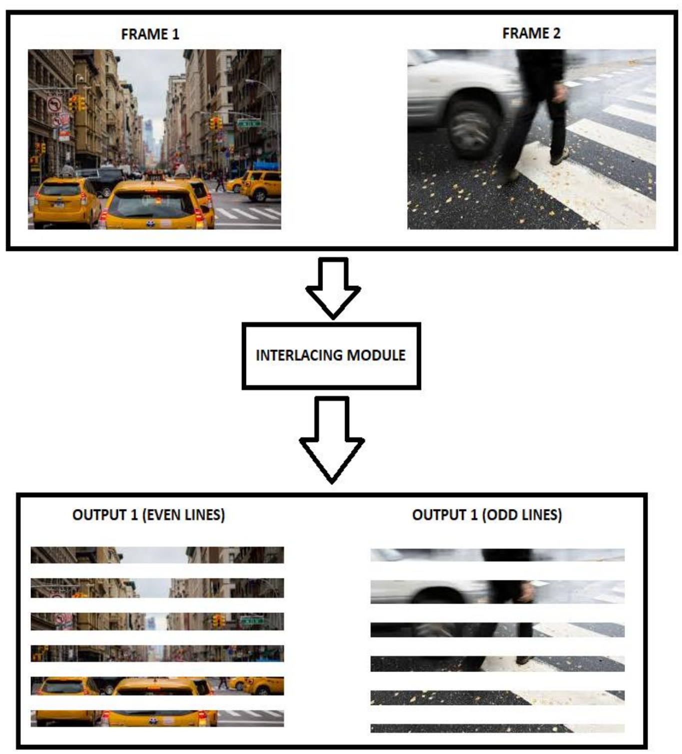

Fig. 8. Interlacing Function.

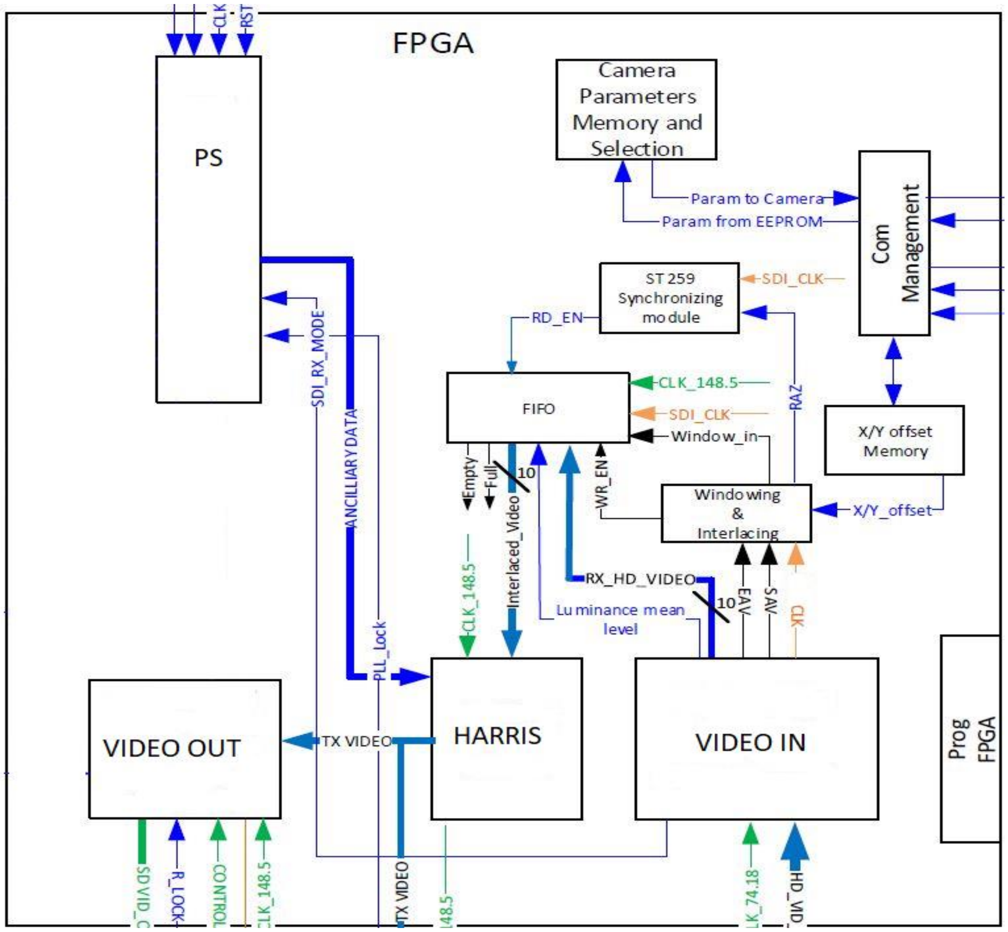

Fig. 9. Global System Architecture.

- Frames interlacing

The video interlacing is another technique for data optimization processing. This technique, never considered for mobile systems, improves by 50% the requirements for energy consumption, processing time and memory size. The idea here is to split every frame into odd and even lines, so for a frame N we take only odd lines and for frames N+1 we load only even lines, and so on. Split frames will alternate at a very high speed between odd and even, what guarantees the claimed improvement.

As shown in Figure 8, the module receives the first frame, the odd lines are transmitted and even lines are discarded. On the next frame, the even lines are transmitted and odd lines are discarded.

The architecture block diagram become as it is illustrate in Figure 9.

V. Results

In this section, some of tests of moving features detection and tracking are realized based on ZEDBOARD Xilinx platform and the system architecture presented in Figures 1, 2, 3 and 4. For implementation we've used a Zynq-7000 based Zedboard platform. It is composed by a 512 Mb RAM, 667 MHz clock frequency ARM A9 based dual core processor that represents the (PS), a 100 MHz frequency (PL) and multiple input and output interfaces. 720p and 1080p video frames are received from a Dell i5-6200U 2.30 GHz laptop via HDMI Input/output interface.

The real experiments track visually impaired persons (VIP) in outdoor scenes. The VIP detects some obstacle using a classic white cane. The video system tracks the VIP and obstacles (represented by interest and edge points – their density creates an illusion of continuous lines). If the VIP is close to an obstacle a specific real-time signal indicates him/her the obstacle. Figures 10 and 11 propose the very first results of the VIP navigation at two different instances. The high quality of the tracking of object features (interest points and edges) can be observed.

Fig. 10. Points of Interest and of Edge Detection and Tracking (t=0).

Fig. 11. Points of Interest and of Edges Detection and Tracking (t=t+n).

The proposed implantation of video tracking on the target system requires 6300 LUTs and 11 18Kb BRAMs of the (PL). Each frame was processed in 638 milliseconds, including data preprocessing, Harris accelerator execution and tracking algorithm with NEON based acceleration. These precision and processing performances permit to integrate our proposed architecture in visually impaired mobility assistive devices.

VI. Conclusion

The paper addresses two topics.

1) A proposition of a robust real time embedded architecture for detection and (Kalman) tracking of (Harris) interest points. Our architecture combines the performances of the Zynq-7000 hardware resources and the flexibility of the software partition based on and ARM A9 dual core processor. The hardware –software implementation of targeted algorithms was co-designed and effectively implemented on FPGA based Xilinx Zynq SoC.

2) Architecture performance enhancement and memory optimization.

We proposed two innovative techniques in order to minimize the quantity of processed data which impact the processing power, memory occupation and processing time. There are : interleacing and blancking cropping.

To enhance our system's security and precision, we proposed a HDL modul that aims to avoid making wrong decisions or display bad or wrong data. This module detects the non presence of frames and detect freezed frames.

The temporal performances of our approach are roughly 50% better than these of classic implementations.

The experimental evaluation with VIP people navigating in outdoor scene clearly show that the system may be integrated in mobility assistance for VIP.

The proposed architectures will be integrated in the VIP mobility control devices such as an "intelligent cane" which will allow to avoid unexpected obstacles. Other test scenarios, which several moving obstacles will be also tested.

We hope that through detailed evaluations new co-design rules would be possible to establish and integrated in an automatic tools for hardware-software implementations.

References

[1] B. Hdioud, A. Ezzahoul, Y. Hadi, R. Oulad Haj Thami, "A real-time people tracking system based on trajectory estimation using single field of camera view", Int. Conf. on Computer Applications Technology (ICCAT 2013), 30 May 2013, pp. 1 – 4.

[2] S. Yang, M. Baum, "Extended Kalman filter for extended object tracking", IEEE Int. Conf. on Acoustics, Speech and Signal Processing (ICASSP 2017), 19 June 2017, pp. 4386 – 4390.

[3] Li Yuejing, Xie Weichen, Shi Yixing, Chen Changmin, "Real time moving object detection and tracking system based on SoPC", J. of Chongqing University of Technology, Vol 25, No.4, Apr. 2011.

[4] Liu Weining, "Object tracking under complicated background based on DSP+FPGA platform", Chinese J. Liquid Crystals and Displays, Vol. 29, No. 6. Dec 2014.

[5] 7 Series FPGAs Configurable Logic Block User Guide 474 v1.8, Xilinx Inc, September 2016.

[6] Zynq-7000 All Programmable SoC Overview Data Sheet 190 v1.10, Xilinx Inc, September 2016.

[7] 7 Series FPGAs Memory Resources User Guide 473 v1.12, Xilinx Inc, September 2016.

[8] Zynq-7000 SoC and 7 Series Devices Memory Interfaces Solutions User Guide 586, Xilinx Inc, April 2014.

[9] B.A. Draper, J.R. Beveridge "Accelerated image processing on FPGAs," IEEE Transactions on Image Processing, Vol. 12, No. 12, December 2003, pp. 1543-1551.

[10] G. Bailey, "Design for Embedded Image Processing on FPGAs," John Wiley & Sons Ltd, June 2011, pp. 1-416.

[11] Xilinx Inc, UG585, "Zynq-7000 all programmable SoC", 2017.

[12] A. Ben Amara, E. Pissaloux, M. Atri, "Sobel edge detection system design and integration on an FPGA based HD video streaming architecture", 11th Int. Conf. on Design & Test Symposium (IDT 2016), 6 February 2016, pp. 1-5.

[13] C. Harris, M. Stephens, "A combined corner and edge detector", 4th Conference of Alvey Vision, Manchester, England, August 1988, pp. 147-151.

[14] Moravec, H., Obstacle Avoidance and Navigation in the Real World by a Seeing Robot Rover, Master Thesis, Stanford University 1980.

[15] Xilinx Inc. DS190, "Zynq-7000 extensible processing platform overview", 2012.

[16] M. Aydogdu, M. Demirci, C. Kasnakoglu, "Pipelining Harris corner detection with a tiny FPGA for a mobile robot", IEEE International Conference on Robotics and Biomimetics (ROBIO), Shenzhen, China, December 2013, pp. 2177-2184.

[17] Xilinx Inc, Xapp 1078, "Simple AMP running linux and bare-metal system on both zynq SoC processors"UG585, 2013

Information Processing in EventWeb through Detection and Analysis of Connections between Events

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***Abstract*—Information over the Web is rapidly becoming event-centric with the next age of WWW projected to be an EventWeb in which nodes are inter-connected through diverse types of links. These nodes represent events having informational and experiential information and analysis of these events has a substantial semantic impact regarding enhancement of information search, visualization and story link detection. Information regarding semantics of EventWeb connections is also important for event planning and web management tasks. In this paper, we devise and implement an event algebra for detection and analysis of event connections. As compared to traditional solutions, we process both context-match operators and analytical operators, cater for all event information attributes, and define the strength of connections. We implement a tool to evaluate our algebra over events occurring in the academic domain. We demonstrate an almost perfect precision and recall for context-match operators and high precision and recall for analytical operators.**

***Keywords*—EventWeb; information processing; event algebra; operators; link detection; link analysis; information analysis; context-match**

I. Introduction

The web of documents or web of information is now converging towards a web of events, which has been typically labeled as the EventWeb, in which each node represents an event which has both informational as well as experiential data, and which is connected to other nodes through different types of links, i.e., referential, structural, relational, and causal [1]. The information flow over the web is influenced by the experiences of the users instead of the reporting authorities or agencies. Hence, information over the web is now becoming more event-centric (as compared to document-centric) with events forming the crux of EventWeb. Moreover, detection and analysis of links between events, i.e., semantic extraction of EventWeb, is significant to users from two perspectives. Firstly, this information facilitates and enhances information search, information visualization and tasks related to story link detection. Secondly, semantic information of connections helps users in decisions related to planning, management and prioritization of events. The context of the events formulates these connections. Data such as location of the event, temporal information, event category, and participants of the event, formulates this context. Events occurring at the same place, time, date or having common participants or same category may have some type of inter-relations or inter-connections. These connections have different strengths depending upon the percentage of the context match and the granularity level of the contextual attributes at which the match takes place. A deeper analysis of the context-based connections is a target of current research in order to explore more connections.

The focus of this paper is to enhance state of the art research in extracting semantic information from EventWeb. Our research objective is to process the contextual event information to detect linkages between events, based on the following three objectives: 1) detecting stories that exist along events but are unseen, 2) enhancing information search and visualization experience over the web, and 3) constructing a formal and extensible representation for representing linkages between events.

To this end, we devise and implement an event algebra for representing and analyzing different connections between events over EventWeb. We generate useful information regarding these connections. Our motivation is to provide a more formal specification of information regarding event descriptions and connections as compared to other state of the art algebras. Our algebra caters for all five event information attributes, i.e., *title*, *location*, *temporal attributes*, *participants*, and *category*. It comprises a number of operators, each of which defines a possible connection between two or more events. These operators represent different types of connections and help in analyzing and producing important information (semantic meaning) from connections. Specifically, *context-match* operators provide a match between the individual contextual attributes of events and *analytical* operators provide an analytical view over the connections (described in Section 3). Our algebra also detects previously unexplored connections and defines the strength of connections that identifies connections at various levels of strength. Collectively, the aforementioned features are not available in previously existing algebras. Finally, our algebra can also be modeled through a relevant ontology or some other modeling technique.

To evaluate our proposed event algebra, we developed a tool called EventWeb Connection Detector, abbreviated EConnDetect, which implements our algebra operators. We apply each operator to the collection of events to detect the connections existing between the events. For evaluation, we focused on events occurring in an academic (university) environment. Our research question is to determine the frequency of connections that EConnDetect is able to identify correctly from a given set of university events. For this, we initially extracted these events from email inboxes of several students and faculty members (with their consent). Using our previous technologies, we then extracted event information attributes by using finite state machines and then used an event classifier to tag the events with proper categories [1, 2]. We then provided these event attributes as input to EConnDetect, and calculated precision and recall for the identified connections as our evaluation metrics. We obtained an almost perfect precision and recall of 99% and 97% with context match operators, and a high precision and recall of 89% and 78% for analytical operators.

II. Related Work

Detecting linkages between events has been addressed by researchers mainly from two perspectives: linking events on the basis of event information attributes (location, date/time, type etc.) [3, 4, 5, 6, 7, 8, 9, 10, 11, 12] and linking events on the basis of information related to events (pictures, news, posts etc.) [13, 14, 15, 16, 17, 18, 19]. For our literature review, we have considered the works that address linkage detection based on event attributes.

To this end, we have classified the existing research broadly into two classes: ontology-based event representation and algebra-based event representation. Ontology-based solutions [3, 4, 5, 6] are generally aimed at modeling events so that the connections between events can be traced easily. The algebra-based solutions [7, 8, 9, 10, 11, 12] are largely focused on defining operators that represent possible linkages between events. In this paper, we are concerned with algebra-based solutions to linkage detection.

The gap analysis over the existing research in this domain is shown in Table 1, which lists the features or characteristics of our proposed algebra, and mentions the status of existing research works with respect to these features or characteristics. Specifically, we indicate the extent to which the research literature addresses these features through three labels: Addressed (A), Partially Addressed (PA) and Not Addressed (NA). In general, most work in event link detection focuses on historical event analysis, which addresses the problem of detecting and analyzing links between events appearing in near future, along with the events that occurred in past. Also, most works in this area have targeted events appearing over news wires or articles etc. In our work, we target events appearing over social text streams and WWW in general.

TABLE I. Gap Analysis: A=Addressed, PA=Partially Addressed, NA=Not Addressed

Research Work	**Features**			
	Linkage Generalization	*Linkage Analysis*	*Identifying Inter-relations of Linkages*	*Linkage Strength*
[3]	A	PA	NA	NA
[4,5]	A	PA	NA	NA
[6]	A	NA	NA	NA
[9]	A	A	NA	NA
[12]	NA	PA	NA	NA
[11]	NA	PA	PA	NA
[7,8]	NA	PA	PA	NA
[10]	NA	PA	NA	NA

A. Ontology-based Approaches

In [3], the authors present a Simple Event Model (SEM) for historical event analysis. They use graphs for event representation. The graphs capture four core event attributes (*title*, *place*, *time*, *actors*) along with several properties that help to identify the linkages between events. The core linkages identified through SEM are determined by the level of similarity with the core attributes. SEM also links the events based on event type. It identifies linkages using types of actors, places and events. However, the authors have not identified inter-relationships between linkages that would have helped them to generate more linkages. Moreover, they do not identify the strength of linkages that could have assisted in clarifying historical linkages. We, therefore, consider this handling of link analysis as partial.

The works of Ilaria Corda et al. [4, 5] also use event ontology to analyze the historical event collection to unveil connections between events. Their objective is to represent essays describing the history of events. For this, they propose the concept of semantic trajectories which represent sequences of events. In a semantic trajectory, any two events which occur consecutively are linked to each other by some semantic link. This link is characterized by one or more attribute(s) that are common in both events. The authors tackle linkage generalization by using a set of different attributes. Moreover, the semantic links are sequenced in the trajectory based on chronological ordering of occurrence. The authors have dealt with analysis over temporal linkages but have not addressed any other linkage type or the strength of linkages. They have also not addressed the identification of inter-relationships of linkages.

In [6], the authors developed the LODE model for representing events with an objective to perform historical event analysis. It covered the four W's (*when*, *where*, *who*, and *what*) to represent and link events. However, the authors do not attempt to identify more linkages, or the inter-linkages between relationships, or the strength of relationships.

B. Event Algebra-based Approaches

Allen presented a seminal work for defining relations between events through an algebra [20]. He defined thirteen temporal relations, i.e., the relations were defined based on temporal attributes of the events. Hence, Allen's algebra only addressed one attribute of the event for representing linkages. Moreover, the event algebra by Chakravarthy et al. was developed for detecting composite events in active databases [11]. This algebra contained operators that could be applied over events to detect links between primitive events. Here, the authors identified only temporal linkages and do not address the identification of linkage strength.

Nagargadde and Sridhar developed an algebra to identify links between events in the sport of Cricket [9]. Their objective was to link basic events to formulate a "meta" or derived event. The authors used three attributes, i.e., *time*, *space* and *label* to detect linkages between events. This work focuses on meta events like "Run Out" and "LBW" which refer to basic events like "ball hits the wicket" and "ball hits the player's leg" respectively. . Hence, the authors use temporal and spatial attributes at a low granularity level. They perform linkage analysis to extract meta events; however inter-relations between linkages and the linkage strength have not been explored.

The EVA algebra detects composite events related to a specific domain [7, 8]. At any time, an event is defined to be a transition in state of an object. Composite events are identified by linking the transition in a specific state of an object at that time. This algebra comprises sequence operators and operators that link primitive events on the basis of time and the attribute over which the transition has occurred. Hence, this algebra is focused over temporal attributes. The authors perform analysis to identify sequences of events and to further identify inter-relations among temporal linkages. However, the authors do not cater for the strength of the linkages.

Uma and Aghila have proposed operators for identifying temporal patterns of events [12]. They have extended Allen's algebra [20] by using an event as a reference for relation between two other events. The events are linked based on the temporal attributes only. The authors have modeled the temporal info using hand-coded rules for identifying the linkages and have suggested that these rules can be fed to ontology for detecting event linkages. Finally, Rink et al. use textual graph patterns for detecting casual relationships between events [10]. These patterns facilitate analysis over the relationships but do not cater for inter-relationships or the strength of linkages.

A. Major Contributions Compared to Related Work

As compared to the related work, our algebra has the following major contributions:

- Our algebra uses five attributes for linking events which haven't been used collectively in any work, i.e., title, location, temporal attributes, participants and category
- Our algebra captures all possible connections that may exist between two events, while each related work identifies only a specific type of linkage, e.g., composition, dependency, or temporal sequence
- Our algebra contains operators that provide an *analytical* view over linkages between events; this feature is not offered by any related work
- Our algebra defines the criteria for identifying the strength of event connections and provides definitions of the operators for various strength levels. Both of these features haven't been proposed or implemented in any related work.

III. Event Algebra for Detection and Analysis of Connections

In this section, we detail our proposed algebra for detecting and analyzing connections between events. As mentioned in Section 1, our algebra has two types of operators, i.e., *context match* operators and *analytical* operators. In Table 2, we give the complete list of these operators and describe them later on in this section. These operators identify inter-event connections and also provide an analytical view over these connections. This view aids in determining the strengths of connections and the prioritization of events.

The analytical operators are composite operators and are defined with two or more simple (context-match) operators. For example, *co-location*, *homology*, *analogy*, *concurrency* and *title-alike* are simple operators that check for matches over location, participants, event category, time/date and title respectively. *Duplication* is a composite operator that comes into a "true" state if the events are collocated, homologous, analogous, concurrent, and have the same title. Figure 1 depicts the composition of all analytic operators in our algebra. Here, composite (analytical) operators are shown in the column on the left, and the simple operators defining these composite operators are shown in the right column. The arrows represent the "definition" relationship, e.g., M-Participation is defined by Co-location, Analogy and Participation. An analytic operator can be used to produce event recommendations for a user or to provide the prioritization aspect. For example, consider that two events *E1* and *E2* are sub-events of an event *E* and a user's (*U1*) previous event participation history shows that she always attends events similar to *E1*. Now, if *U1* has another event *E3* that is overlapping with event *E2*, a recommendation system can recommend *U1* to attend *E2* instead of *E3* in order to avoid missing *E1*. Similarly, suppose that *U1*'s participation history shows she mostly attends events in which another user *U2* is also present. Now for *U1*, all the events in which *U2* is participating are of high priority.

TABLE II. EVENT ALGEBRA OPERATORS

Operator Name	Symbol	Operator Type	Description	Operator's effect
Concurrency	$<<>>^{l}$	Simple	The time interval or point is same	Context Match
Precedence	$<$	Simple	One after another	Context Match
Temporal Subset	Ξ	Simple	[Start time(E1)>start time(E2) and (End time (E1)<End time (E2)	Context Match
Analogy	$<<>>^{e}$	Simple	Same Type or category	Context Match
Co-location	$<<>>^{s}$	Simple	Same Place	Context Match
Homology	$<<>>^{p}$	Simple	Same participants	Context Match
Title-Alike	$<<>>^{l}$	Simple	Same title	Context Match
Participation	$\ni$	Simple	A person participating in an event	Context Match
Duplication	$\equiv$	Composite	All attributes are same	Context Match
Overlap	∞	Composite	Time interval overlaps	Analytical
Dependency	$\Rightarrow$	Composite	Dependent over an event	Analytical
Sub Event	$\ni$	Composite	Part of mega event	Analytical
Periodic	$\subset$	Composite	Repeated after specific intervals	Analytical
M-Participant	$\ni^{M}$	Composite	Participation in two or more related events	Analytical

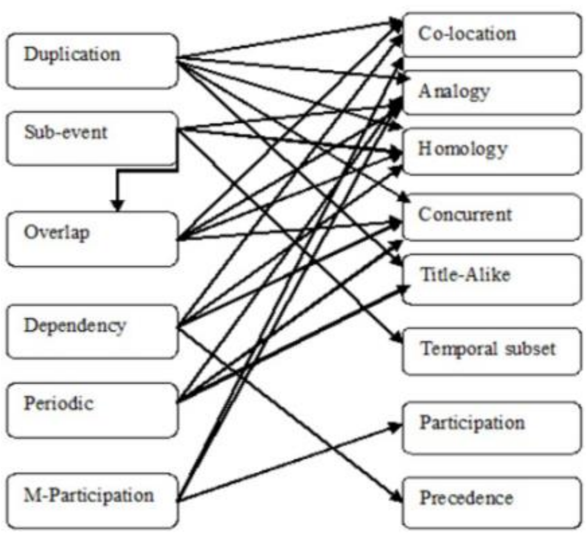


Fig. 1. Composition of Analytical Operators.

Since the operators represent various connections, therefore the strength of an operator is actually the strength of the connection that is represented by the specific operator. As discussed above, the granularity level of the contextual attributes helps in identifying the strength of the operators. Here, the granularity level means the level of detail (or depth) for an attribute. For example, in case of location, we assume that *city*, *area* in city and the (exact) *spot* may be available; however the attributes *country*, *region*, and *continent* may also be taken into account. In our algebra, we have considered five levels of granularity for any attribute, but some attributes may have more depth. The change in granularity will not affect the algebra or the analysis process and hence, any level of granularity can be used for any attribute.

We assume an event title to have at most three words, i.e., a granularity level of 3. We will perform the match for these words and the strength of the match will depend upon the level of granularity at which the match is achieved. For location, we have defined three levels of granularity as mentioned above, i.e., *city*, *area* and *spot*. In case of temporal attributes, since the events are real-world events and not real-time events, therefore we will only provide time in *hours* and *minutes*. For describing the date of an event, we have used *year*, *month* and *day of the month*. Yet, our own event extraction component extracts dates from various types of phrases and converts them to a canonicalized format. While producing the definitions of the connection operators and defining the strength criteria, we have ignored those cases in which the connection cannot exist or may occur rarely.

For applying the algebra operators, we have devised a 5-Tuple description of an event. An event E is described as $E = (L; S; T; C; P)$ where L, S, T, C and P represent title, location, temporal attributes, event category and participants respectively. L, S and T are composite elements. L is further composed of three sub-elements and is defined as a 3-tuple $< w1; w2; w3 >$, where $w1$, $w2$ and $w3$ are the labels depicting the granularity levels. For example, in a title "Bubble-up Cricket Tournament"; w1 = "Bubble-up", w2 = "Cricket" and w3 = "Tournament". Similarly, S is defined as a 3-tuple $< s1; s2; s3 >$, where $s1$, $s2$ and $s3$ represent city, area and spot respectively. T is also defined by a 3-tuple $< dts; dt f; ts; t f >$, where dts, $dt f$, ts and $t f$ represent start date, end/finish date, start time and end/finish time of an event respectively. The terms dts and $dt f$ are further composed of the triplet $(y; m; d)$ where y, m and d represent year, month and day respectively. Similarly, ts and $t f$ are defined by a pair $(h; m)$ where h and m represent hour and minutes respectively. We represent the relationship between an event and its attributes with question mark (?), and between an element of the event description and its sub-elements by dot (.). For example, for an event *E1*, the location is represented as $E1?S$ and $S{:}s1$ represents the city name.

We now move towards a formal description of our operators. Each operator has its own criteria for strength. The symbols for the operators have superscripts and subscripts. The superscript contains the symbol representing the event attribute and the subscript contains the symbols representing the strength of the operator. Attribute symbols, *l*, *s*, *p*, *t*, and *c* stand for *title*=*label*, *location*=*site*, *participants*, *time* and *eventtype*=*category* respectively. For strength, we have used three symbols, , χ and φ, representing the levels of strength of operator in descending order respectively. We need to specify that the notation used for representing our algebra is our own selection. Specifically, we use mathematical symbols to represent the algebra operators. While choosing a symbol to represent an operator, we have tried to select a symbol which, in mathematics, is used to represent a similar relationship. For example, we use $\prec$ for representing the precedence relationship. In mathematical equations, the same symbol is used to represent precedence. Also, the matching of string operators is done using an equality operator.

A. Event Algebra-based Approaches

We have defined eight context-match or simple operators. These operators provide a match between the individual contextual attributes of events. The definitions provided below for these operators are obvious and clearly represent the semantics of the operators.

1) Analogy: An event E1 is analogous to another event E2 if E1 has same type or category as E2. The strength of the connection is either at the highest level when the types of the events match, or it's null, i.e., there is no analogy connection when the events' types are different. This connection is represented by Equation 1.

$$E1 <<>>c\ E2 \qquad (1)$$

2) Homology: An event E1 is homologous to another event E2 if E1 and E2 have same or common participants. The homologous connection has two strength levels. In case all participants are the same in both events, the events are completely homologous. Otherwise, if the participants of one event are a proper subset of the other event then the homology is weak.

$$E1 <<>>^{p}_{\varphi} E2 \text{ if}(E1 \rightarrow p = E1 \rightarrow p) \qquad (2)$$

$$E1 <<>>^{p}_{\chi} E2 \text{ if}(E1 \rightarrow p \approx E1 \rightarrow p) \qquad (3)$$

$$E1 <<>>^{p}_{\varphi} E2 \text{ if}(E1 \rightarrow p\ \ E1 \rightarrow p) \qquad (4)$$

3) Co-Location: An event E1 is co-located to another event E2 if E1 and E2 occur at the same location. The strength of the connection depends upon the granularity level at which the match takes place. A match at only the top level of granularity means a lower level of strength, and a match at the lowest granularity level means highest strength or an exact match. The co-location connection is represented by Equation 5, Equation 6 and Equation 7, representing high, average and low levels of strength for co-location connection respectively.

$$E1 <<>>s\ E2 \text{ if}(E1 \rightarrow S{:}s1 = E1 \rightarrow S{:}s1) \wedge$$
$$(E1 \rightarrow S{:}s1 = E1 \rightarrow S{:}s1) \wedge$$
$$(E1 \rightarrow S{:}s1 = E1 \rightarrow S{:}s1) \qquad (5)$$

$$E1 <<>>s\ \chi\ E2 \text{ if}[\text{f}(E1 \rightarrow S{:}s1 = E1 \rightarrow S{:}s1) \wedge$$
$$(E1 \rightarrow S{:}s3 = E2 \rightarrow S{:}s3)\text{g}\ \_\ \text{f}(E1 \rightarrow S{:}s1 = E2 \rightarrow S{:}s1) \wedge$$
$$(E1 \rightarrow S{:}s2 = E2 \rightarrow S{:}s2)\text{g}] \qquad (6)$$

$$E1 <<>>s\ \varphi\ E2 \text{ iff}(E1 \rightarrow S{:}s1 = E2 \rightarrow S{:}s1)\_(E1 \rightarrow S{:}s2 = E2 \rightarrow S{:}s2)\ \_\ \text{f}(E1 \rightarrow S{:}s3 = E2 \rightarrow S{:}s3)\text{g} \qquad (7)$$

4) Concurrency: The definition of concurrency between two events E1 and E2 is separately given for different granularity levels as we have extended the actual definition of concurrency for our purpose. Specifically, if E1 and E2 occur in the same day, month, and year and the time interval also overlaps, or matches exactly, then the events are concurrent with high strength; this strong concurrency is represented by Equation 8. Equation 9 represents concurrency with average strength. The reason for a lower level of strength is that the time does not match exactly and the duration of one event falls within the duration of other event. The lowest level of concurrency is represented by Equation 10 that captures the case where only year and month or month and day match for two events.

$$E1 <<>>t\ E2\ \mathit{if}\ (E1 \rightarrow T{:}dts = E1 \rightarrow T{:}dt\,f\,)\wedge$$
$$(E1 \rightarrow T{:}dts = E2 \rightarrow T{:}dts) \wedge [\text{f}(E1 \rightarrow T{:}ts = E2 \rightarrow T{:}ts) \wedge$$
$$(E1 \rightarrow T{:}t\,f = E2 \rightarrow T{:}t\,f\,)\text{g}\_\text{f}(E1 \rightarrow T{:}ts < E2 \rightarrow T{:}ts) \wedge$$
$$(E1 \rightarrow T{:}t\,f > E2 \rightarrow T{:}t\,f\,)\text{g}\_\ \text{f}(E1 \rightarrow T{:}ts > E2 \rightarrow T{:}ts) \wedge$$
$$(E1 \rightarrow T{:}t\,f < E2 \rightarrow T{:}t\,f\,)\text{g}] \qquad (8)$$

$$E1 <<>>t\ \chi\ E2 \text{ if}(E1 \rightarrow T{:}dts = E2 \rightarrow T{:}dts) \wedge$$
$$\text{f}(E1 \rightarrow T{:}dt\,f < E2 \rightarrow T{:}dt\,f\,)\ \_\ (E1 \rightarrow T{:}t\,f > E2 \rightarrow T{:}ts)\text{g} \qquad (9)$$

$$E1 <<>>t\ \varphi\ E2 \text{ if}[\text{f}(E1 \rightarrow T{:}dts{:}y = E2 \rightarrow T{:}dts{:}y) \wedge$$
$$(E1 \rightarrow T{:}dt\,f{:}y = E2 \rightarrow T{:}dt\,f{:}y)\text{g}\_\text{f}(E1 \rightarrow T{:}dts{:}m = E2 \rightarrow T{:}dts{:}m) \wedge (E1 \rightarrow T{:}dt\,f{:}m = E2 \rightarrow T{:}dt\,f{:}m)\text{g}\_\text{f}(E1 \rightarrow T{:}dts{:}d = E2 \rightarrow T{:}dts{:}d) \wedge (E1 \rightarrow T{:}dt\,f{:}d = E2 \rightarrow T{:}dt\,f{:}d)\text{g}] \qquad (10)$$

5) Temporal Subset: Two events E1 and E2 are temporal subsets of an event E', if the time intervals of E1 and E2 fall within the time interval of E'. Equation 11 represents the temporal subset connection.

$$E'\Xi_t\, E1_{\text{j}}E2 \text{ if}[(E' \rightarrow T{:}dts = E1 \rightarrow T{:}dt = E2 \rightarrow T{:}dt) \wedge \text{f}(E' \rightarrow T{:}ts \leq min(E1 \rightarrow T{:}dts; E1 \rightarrow T{:}dts))\text{g}\wedge\text{f}(E' \rightarrow T{:}ts \geq max(E1 \rightarrow T{:}dt\,f; E2 \rightarrow T{:}dt\,f\,))\text{g}] \qquad (11)$$

6) Precedene: Two events E1 and E2 are temporal subsets of an event E', if the time intervals of E1 and E2 fall within the time interval of E'. Equation 11 represents the temporal subset connection.

$$E1 \prec_t E2 \text{ if}[\text{f}(E1\ !\ T{:}dt\,f \leq E2\ !\ T{:}dts)\text{g}\ \_\ \text{f}(E1\ !\ T{:}dt = E2\ !\ T{:}dt) \wedge (E1\ !\ T{:}t\,f \leq E2\ !\ T{:}ts)\text{g}] \qquad (12)$$

7) Title-Alike: The titles of two given events E1 and E2 may match exactly or partially. The exact match does not mean that the events are same, as two events with the same name may occur at different locations with different time intervals. Specifically, if the title of E1 and E2 match at all three levels of granularity, i.e., spot, area and city match exactly, then it means that the title of the events match exactly (Equation 13). In all other cases, where the titles match at any granularity level, the events are said to have a Title-Alike connection with a low strength (Equation 14).

$E1$ <<>>l $E2$ iff($E1$! L:$l1$ = $E2$! L:$l1$) ^ ($E1$! L:$l2$ = $E2$! L:$l2$)g ^ ($E1$! L:$l3$ = $E2$! L:$l3$)g 13)
$E1$ <<>>s
φ $E2$ if[f($E1$! L:$l1$ = $E2$! L:$l1$) ^ ($E1$! L:$l2$ = $E2$! L:$l2$)g_
f($E1$! L:$l1$ = $E2$! L:$l1$) ^ ($E1$! L:$l3$ = $E2$! L:$l3$)g_
f($E1$! L:$l3$ = $E2$! L:$l3$) ^ ($E1$! L:$l2$ = $E2$! L:$l2$)g] (14)

8) Participation: The participation operator represents the link between a person and an event. A person P is said to have a connection with an event E, if P is in the participants' list of E. Participation operator is a simple operator and is represented by Equation 15).

$E \ni A$ (15)

B. Analytical Operators

Analytical operators provide analytical perspective to the connections. We have defined six analytical operators. As illustrated in Figure 1, the definitions of these operators depend on context-match operators for providing the analytical view. We formalize these definitions as follows.

1) Duplication: Two events are duplications of each other or related to each other through the duplication operator, if they have the same values for all event attributes. Given two events E1 and E2, the rule for the duplication operator is given by the Equation 16.

$E1$ ≡ $E2$ iff($E1$ <<>>$_l$ $E2$) ^ ($E1$ <<>>$_t$ $E2$) ^ ($E1$ <<>>$_p$ $E2$) ^ ($E1$ <<>>$_c$ $E2$) ^ ($E1$ <<>>$_s$ $E2$)g (16)

2) Overlap: Two events E1 and E2 are said to overlap if they are homologous, analogous, concurrent and co-located. The strength of the connection varies with respect to various combinations and strengths of context match operators. Equation 17, Equation 18 and Equation 19 describe these dynamics of the overlap operator.

$E1$ on $E2$ if[($E1$ <<>>c $E2$) ^ f($E1$ <<>>p $E2$) _ ($E1$ <<>>χp $E2$)g^
f($E1$ <<>>t $E2$) _ ($E1$ <<>>$t\chi$ $E2$)g ^ ($E1$ <<>>s $E2$)] (17)
$E1$ on
χ $E2$ if[f($E1$ <<>>φp $E2$) _ ($E1$ <<>>χp $E2$)g^
f($E1$ <<>>t $E2$) _ ($E1$ <<>>$t\chi$ $E2$)g^
f($E1$ <<>>s $E2$) _ ($E1$ <<>>χs $E2$)g] (18)
$E1$ on $E2$ if[($E1$ <<>>c $E2$) ^ f($E1$ <<>>φp $E2$) _ ($E1$ <<>>χp $E2$)g^
f($E1$ <<>>t $E2$) _ ($E1$ <<>>$t\chi$ $E2$)g ^ ($E1$ <<>>φs $E2$)] (19)

3) Dependency: A dependency between two events E1 and E2 may exist due to various reasons. The reason for occurrence of this dependency relates to its strength. The dependency operator checks for the existence of precedence, homology and co-location connections and based on their existence (or non-existence), defines its own existence. It also considers the strengths of its three simple operators. If precedence, homology, and co-location connections have high strengths, then dependency also exists with high strength. If the events are not co-located but have high precedence, and are homologous with an average strength, then the dependency exists with an average strength. The same scheme is applied for low dependency with a homology with low strength. Equation 20, Equation 21 and Equation 22 represent these dynamics of the dependency operator.

$E1$) $E2$ iff($E1$ ≺t $E2$) ^ ($E1$ <<>>s $E2$) ^ ($E1$ <<>>p $E2$)g (20)
$E1$)
χ $E2$ iff($E1$ ≺t $E2$) ^ ($E1$ <<>>χp $E2$)g (21)
$E1$)
φ $E2$ iff($E1$ ≺t $E2$) ^ ($E1$ <<>>p $E2$)g (22)

4) Sub-Event: Two events E1 and E2 are said to be sub-events of a mega-event EM under 3 conditions: i) E1 and E2 have common participants such that the union of both sets of participants equals the participant set of the mega-event, ii) E1 and E2 are of the same type as the mega-event, and iii) the time intervals of E1 and E2 fall within the time interval of the mega-event. Equation 23 mathematically describes these definitions:

E_M ∋ $E1$j$E2$ if[($E1$ on$_{c\ \varphi}$ $E2$) ^ (E_M $_{<<>>c}$ $E1$) ^

fE_M $_{<<>>p}$ ($E1$ [$E2$)g ^ ($E_M \Xi_t$ $E1$j$E2$)] (23)

5) Periodic: If two events E1 and E2 have a similar title, similar type, and similar dates then the events are strong candidates for being incidences of a same event E_+ that occurs periodically. We represent this mathematically in Equation 24.

E_+ @ $E1$j$E2$ iff($E1$ <<>>$_l$ $E2$) ^ ($E1$ <<>>$_c$ $E2$) ^ ($E1$ <<>>$_{t\varphi}$ $E2$)g (24)

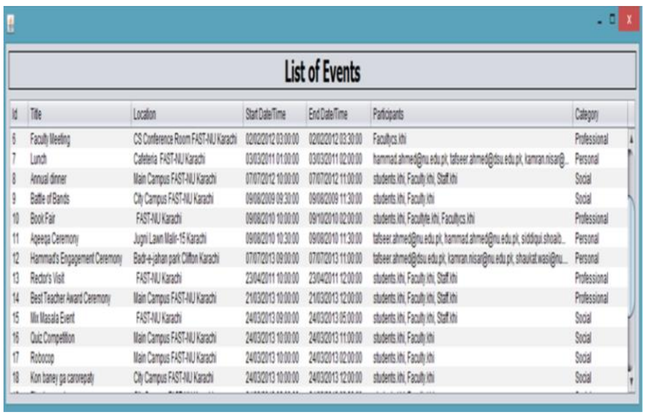
6) M-Participation: If a person P is participating in two events E1 and E2 and the events have a connection between them, then P is said to have M-Participation with E1 and E2. The strength of M-Participation depends upon the strength of the eventevent connection. If E1 and E2 have the same type, or are held at the same location, then the connection between the events and the participant is good, but if E1 and E2 have the same type and the same location, then the connection has a higher strength. These dynamics are represented in Equation 25 and Equation 26.

f$E1$; $E2$g ∋χM P if[($E1$ ∋ P) ^ ($E2$ ∋ P) ^ f($E1$ <<>>s $E2$) _ ($E1$ <<>>c $E2$)g] (25)

f$E1$; $E2$g ∋M P if[($E1$ ∋ P) ^ ($E2$ ∋ P) ^ f($E1$ <<>>s $E2$) _ ($E1$ <<>>c $E2$)g] (26)

IV. DESCRIPTION OF ECONNDETECT

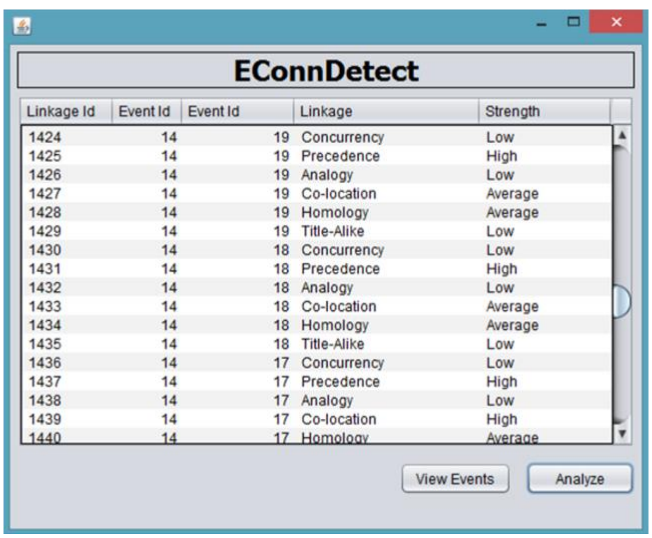
As mentioned in Section 1, we have implemented a Java-based tool called EConnDetect which inputs a set of events that are provided through a text file, and outputs event connections along with the strength of connections. The tool's GUI offers two primary functions, i.e., analysis and viewing of events. The analysis function detects connections in input data, and outputs connection details in an interactive tabular form. Figure 2 shows an EConnDetect snapshot of the collection of events used in our evaluation (described in next section). Here, column names represent event attributes, e.g., title, location, participants etc. Also, Figure 3 presents a snapshot of the output produced by EConnDetect. Here, the output comprises the ID of the linkage, IDs of the two linked events, the linkage found between the events and the strength of the identified linkage. All information shown in Figure 2 and Figure 3 is self-explanatory and hence we do not describe it in detail.



List of Events

Id	Title	Location	Start Date/Time	End Date/Time	Participants	Category
6	Faculty Meeting	CS Conference Room FAST-NU Karachi	02/02/2012 03:00:00	02/02/2012 03:30:00	Facultycs.khi	Professional
7	Lunch	Cafeteria FAST-NU Karachi	03/03/2011 01:00:00	03/03/2011 02:00:00	hammad.ahmed@nu.edu.pk, tafseer.ahmed@dsu.edu.pk, kamran.nisar@...	Personal
8	Annual dinner	Main Campus FAST-NU Karachi	07/07/2012 10:00:00	07/07/2012 11:00:00	students.khi, Faculty.khi, Staff.khi	Social
9	Battle of Bands	City Campus FAST-NU Karachi	09/08/2009 09:30:00	09/08/2009 11:30:00	students.khi, Faculty.khi	Social
10	Book Fair	FAST-NU Karachi	09/08/2010 10:00:00	09/10/2010 02:00:00	students.khi, Facultyfe.khi, Facultycs.khi	Professional
11	Aqeeqa Ceremony	Jugni Lawn Malir-15 Karachi	09/08/2010 10:30:00	09/08/2010 11:30:00	tafseer.ahmed@nu.edu.pk, hammad.ahmed@nu.edu.pk, siddiqui.shoaib...	Personal
12	Hammad's Engagement Ceremony	Badr-e-jahan park Clifton Karachi	07/07/2013 09:00:00	07/07/2013 11:00:00	tafseer.ahmed@dsu.edu.pk, kamran.nisar@nu.edu.pk, shaukat.wasi@nu...	Personal
13	Rector's Visit	FAST-NU Karachi	23/04/2011 10:00:00	23/04/2011 12:00:00	students.khi, Faculty.khi, Staff.khi	Professional
14	Best Teacher Award Ceremony	Main Campus FAST-NU Karachi	21/03/2013 10:00:00	21/03/2013 12:00:00	students.khi, Faculty.khi, Staff.khi	Professional
15	Mix Masala Event	FAST-NU Karachi	24/03/2013 09:00:00	24/03/2013 05:00:00	students.khi, Faculty.khi, Staff.khi	Social
16	Quiz Competition	Main Campus FAST-NU Karachi	24/03/2013 10:00:00	24/03/2013 11:00:00	students.khi, Faculty.khi	Social
17	Robocop	Main Campus FAST-NU Karachi	24/03/2013 10:00:00	24/03/2013 02:00:00	students.khi, Faculty.khi	Social
18	Kon baney ga carorepaty	City Campus FAST-NU Karachi	24/03/2013 10:00:00	24/03/2013 12:00:00	students.khi, Faculty.khi	Social

Fig. 2. Collection of Events used for Evaluation of Proposed Event Algebra.



EConnDetect

Linkage Id	Event Id	Event Id	Linkage	Strength
1424	14	19	Concurrency	Low
1425	14	19	Precedence	High
1426	14	19	Analogy	Low
1427	14	19	Co-location	Average
1428	14	19	Homology	Average
1429	14	19	Title-Alike	Low
1430	14	18	Concurrency	Low
1431	14	18	Precedence	High
1432	14	18	Analogy	Low
1433	14	18	Co-location	Average
1434	14	18	Homology	Average
1435	14	18	Title-Alike	Low
1436	14	17	Concurrency	Low
1437	14	17	Precedence	High
1438	14	17	Analogy	Low
1439	14	17	Co-location	High
1440	14	17	Homology	Average

Fig. 3. A Snapshot of Connections found by EconnDetect.

V. ALGEBRA EVALUATION WITH ECONNDETECT

We evaluated EConnDetect over events occurring in the academic (university) domain. Our data set of university events contains professional and social events; however some events also fall in the category of personal events. This work accomplishes the development of one of the components of our context-based event detection model. Therefore, we have sampled the event email data set constructed for our two previously developed components [21, 2]. Our motivation for sampling the university data set is:

- The email data set contains an extensive variety of event related communications.
- Three general classifications, i.e., Personal, Professional and Social, categorize all types of events in the email data set (social, educational, formal, personal, friendship, family and official events).
- The email data set provides a diverse user base.

We identified two types of users, i.e., Type A (Students) and Type B (Faculty). We categorized the interaction between these users into four types:

- T ype-I: A to A (Personal/Social interaction from Students to Students)
- T ype-II: A to B (Professional/Social interaction from Students to Faculty)
- Type-III: B to A (Personal/Professional/Social interaction from Faculty to Students)
- T ype-IV: B to B (Personal/Professional/Social from Faculty to Faculty).

The selection of our dataset towards the university email corpus itself posed some interesting problems such as the categorization of the variety of event types, spanning from one-one lunch invitations to faculty meetings, office meetings, discussions with the supervisor, wedding invitations, educational and social seminars, conferences, picnic, and sport events etc. that were covered in our dataset [2].

We sampled approximately 100 university events for evaluation of our proposed algebra. This event data was extracted from email inboxes of six students and four faculty members with their consent. The emails were collected in a time span of about six months. The data was extracted using an Event Information Extraction System (EIES) that uses part of speech (POS) based Finite State Machines (FSM) for extraction of event information (title, location, temporal information and participants) from emails [21]. We then used our event email classifier to label the extracted events with an event category (Social, Professional, or Personal) [2]. Finally, the collected contextual event information is stored in CSV format, and fed as input to EConnDetect.

EConnDetect applies our algebra operators to input data. For each operator, we have developed a simple function. Each function outputs a Boolean value that depicts the existence or non-existence of connection, and strength value that depicts the strength of the relationship, in case the connection exists. The function *L* represents the relationship between the operator, event pairs and the output obtained as a result of the application of the operator over the event. The domain and range for *L* are given by Equation 27.

$$L : OS \times ES \rightarrow OS \times B \times S\ t \qquad (27)$$

When an operator *o* 2 *OS* is applied to events (*E*1; *E*2) 2 *ES* ,the output is a triplet (*o*; *bool*; *str*), where *o* 2 *OS* , *bool* takes values from (*true*; *f alse*) and *str* represents the strength (; χ; φ) of the connection. The algorithm representing the process of identifying connections is provided in Algorithm 5.1 and sample pseudo codes for colocation and dependency operators are provided in Algorithm 5.2 and Algorithm 5.3 respectively[2]. These pseudo codes are implementations of equations that represent the connection operators. For detecting the existence of a connection between two events, the events are fed as input to the operator's function. The conditions, represented by the operator's equation, that indicate the existence of the connection are applied over the event attributes. The functions return Boolean values to indicate the existence or non-existence of a particular connection. If a connection is found to exist between two events, then the strength of the connection is also returned by the function.

Algorithm 5.1: *ConnectionDetection(ES; OS)*
for each O_i 2 *OS* **comment:** Simple Operators are applied first followed by Composite ones
do{
for each E_j 2 ES j Flag(E_j) , processed
do{
for each E_k 2 ES ; j , k
do{
Apply O_i to (E_j; E_k)
}
Flag(E_j) = processed
comment: An event is marked as it is processed for link detection } }

Algorithm 5.2: *Co-Location(E1; E2)*

comment: {*E*1; *E*2} 2 *ES*
if {(*E*1 → *S*:*s*1 = *E*2 → *S*:*s*1) ^
(*E*1 → *S*:*s*2 = *E*2 → *S*:*s*2) ^ (*E*1 → *S*:*s*3 = *E*2 → *S*:*s*3)}
then return (1;*Co - Location*; *High*)
else if {[{({(*EE*11→→*SS*:*s*:*s*11==*EE*22→→*SS*:*s*:*s*1)
1)^^((*EE*11→→*SS*:*s*:*s*23==*EE*22→→*SS*:*s*:*s*2) 3)}]]}_
then return (1;*Co - Location*; *Average*)
else if {(*E*1 → *S*:*s*1 = *E*2 → *S*:*s*1) _ (*E*1 → *S*:*s*2 = *E*2 → *S*:*s*2) _ (*E*1 → *S*:*s*3 = *E*2 → *S*:*s*3)}
then return (1;*Co - Location*; *Low*)
else return (0;*Co - Location*)

Algorithm 5.3: *Dependency(E1; E2)*
comment: {E1; E2} € ES
if{
[({(*Co precedence - Location* (*E*1(;*EE*12) ; *E*=2)
(1 =;(1 *Precedence* ;*Co - Location* ; *High*;)) *High* ^)) _
(*Homology*(*E*1; *E*2) = (1; *Homology*; *High*))}]
}
then return (1; *Dependency*; *High*)
else if {{(*precedence*(*E*1; *E*2) = (1; *Precedence*; *High*)) ^
(*Homology*(*E*1; *E*2) = (1; *Homology*; *Average*))}
then return (1; *Dependency*; *Average*)
else if {{(*precedence*(*E*1; *E*2) = (1; *Precedence*; *High*)) ^
(*Homology*(*E*1; *E*2) = (1; *Homology*; *Low*))}
then return (1; *Dependency*; *Low*)
else return (0; *Dependency*)

The co-location operator, provided in Algorithm 5.2, matches the location attributes of the two events that are fed as input. The location attributes are matched at each granularity level. As defined in a previous section, we have assumed 3 levels of granularity for the location attribute and therefore the location attribute S comprises of a 3-tuple < *s*1; *s*2; *s*3 >. Hence *s*1, *s*2 and *s*3 for *E*1 are matched with *s*1, *s*2 and *s*3 for *E*2. If any of the three tuple variables is matched, the function returns 1, indicating the existence of co-location connection. The strength of the connection is determined based on number of tuple variables that match for both events. For a complete and single match, the strength is designated as high and low respectively, and for a two-tuple variable match, the strength is designated as average.

The dependency operator in Algorithm 5.3 is a composite operator and it requires the output of three other operators; precedence, homology and co-location. The precedence operator indicates that ending of one event before or along with the beginning of another event. Homology and co-location operators define same participants and same location respectively. The dependency operator checks for the existence of precedence, homology and co-location connections and based on their existence or non-existence announces it's on existence. It also considers the strengths of the three simple operators that are involved in the process. If precedence, homology, and co-location connections are found with high strengths then the dependency is also found to exist with high strength. If the events are not co-located but have high precedence and are homologous with an average strength then the dependency exists with an average strength. The same scheme is applied for low dependency with a homology with low strength. For rest of the cases, 0 is returned indicating no dependency.

C. Results of Evaluation over University Events

As mentioned in Section 1, our research question is to determine the frequency of events which EConnDetect is able to identify correctly. For this, we calculate the precision and recall parameters, for both context-match and analytic operators. Our collected email dataset comprised social events like sporting events, Mela (a type of celebration event), quiz competition, and farewell dinner. It also comprised several professional events like conference, seminars, and meetings. Finally, personal events like "lunch" or "tea" were also found in the collection.

TABLE III. SAMPLE EVENTS FROM OUR COLLECTED EVENTS

Event ID	Event Title	Location	Date	Time	Participants	Category
E-1	Meta 2013	Main Campus FAST-NU Karachi	10 January 2013	9:00 AM – 4:00PM	Faculty –CS Students-CS Faculty-EE Student-EE	Social
E-2	Seminar	City Campus FAST-NU Karachi	1 January 2012	1:00PM - 2:00PM	Faculty BBA Students BBA	Professional
E-3	Gaming Competition	Main Campus FAST-NU Karachi	10 January 2013	1:00PM - 2:00PM	Faculty-CS Students-CS Students-EE	Social
E-4	Robocup Competition	Main Campus FAST-NU Karachi	10 January 2013	10:00 AM- 1:00PM	Faculty-EE Students-EE Students-CS	Social
E-5	Cricket Match	Main Campus FAST-NU Karachi	3 March 2013	1:00 PM - 4:00PM	Faculty-CS Students-CS	Social
E-6	Lunch	Main Campus FAST-NU Karachi	2 January 2013	2:00 PM	Shaukat, Imran, Hammad, Tariq Jawwad, Zubair	Personal
E-7	Procom	Main Campus FAST-NU Karachi	20 January 2012	9:00 AM – 4:00 PM	Faculty-CS Students-CS Faculty-EE Students-EE Director Campus	Professional
E-8	MS Thesis Evaluation	City Campus FAST-NU Karachi	15 June 2012	9:00AM- 2:00PM	Faculty-CS Faculty-EE	Professional
E-9	Procom	Main Campus FAST-NU Karachi	20 June 2013	9:00 AM-4:00 PM	Faculty-CS Students-CS Faculty-EE Students-EE Director Campus	Professional

Out of approximately 100 events, we manually assigned Professional tag to 55 events, Personal tag to 18 events, and Social tag to remaining 27 events. Although 100 events indicate a limited data set, EConnDetect discovered more than 10000 connections for this dataset. This number is large because there were many repeated connections; most connections are commutative and were counted from both sides. All the context match operators produced good results except concurrency and temporal subset operators; some concurrent events with a high strength of concurrency were identified by the system as concurrent with a lower level of strength. For analytical operators, EConnDetect failed to identify several connections and this was either because of misidentification of concurrency and temporal subset operators, or on our own choice of strength level of the simple operator used in the definition of a given analytical operator.

In Table 3, we show some sample university events from our event collection with their attributes, and in Table 4, we show connection information for a few connections found by applying algebra operators over pairs of events shown in Table 2. Here, columns Event 1 and Event 2 represent the pairs of events.

TABLE IV. SAMPLE EVENT CONNECTIONS RELATED TO PAIRS OF EVENTS (SHOWN IN COLUMNS EVENT 1 AND EVENT 2) FOUND BY APPLYING VARIOUS ALGEBRA OPERATORS SHOWN IN TABLE 2

Event 1 ID	Event 2 ID	Connections	Strength
E3	E1	E3 is a sub-event of E1	High
E4	E1	E4 is sub-event of E1	High
E2	E7	Analogous Co-Located	High Average
E7	E8	Homologous Analogous Co-Location	Low High Average
E7	E9	Periodic Events	High
E3	E4	Overlapping Events	High
E1	E5	Homologous Analogous Co-Location	Low High High

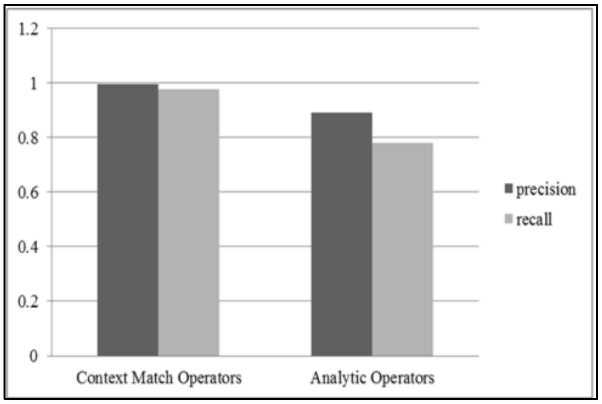


Fig. 4. Precision and Recall for Context-Match and Analytical Operators.

For instance, *E*3 (a gaming competition) and *E*4 (robocup competition) is connected to *E*1 (Mela) as a sub-event because both competitions were part of the Mela3. Through manual activity, we determined that our university event log contained a total of 1300 event connections. Out of these, EConnDetect identified 1267 connections giving an overall recall of 97.5%. Amongst 1267 connections, EConnDetect failed to identify only 44 connections giving an overall accuracy of 96.5%. Out of 1300 connections, 1227 were context matches while the remaining 73 were analytical matches. In Figure 4, we show the precision and recall values for both context-match and analytic operators.

Our system achieved high precision values, i.e., almost 100% for context-match and around 90% for analytic operators. We also achieved a recall of almost 100% for context matches but relatively less for analytic operators (around 80%). This comparatively reduced performance because identification of connections that require an analysis is more complex as compared to those that require context matches. In Figure 5, we show the number of connections detected through each operator of our proposed algebra. As compared to other operators, the analogy, co-location, and homology operators detected most connections (around 300) followed by the precedence operator (around 150). The reason is that the attributes forming the base of these connections are common among various events. For example, all events held in a university premises are linked based on the common location attribute, even if the events have no other inter-relationship. We can apply similar arguments for the analogy and homology operators.

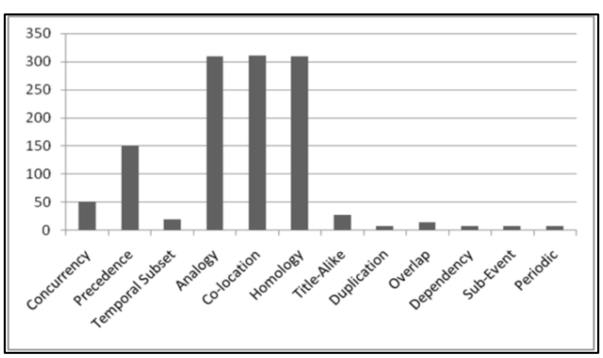


Fig. 5. Frequency of Connections detected through each Operator of Proposed Event Algebra.

VI. Practical and Theoretical Implications and Limitations

Our proposed algebra provides a chronological chain of events with respect to common location(s), participant(s), or categories through context match operators. It also identifies a set of spatial, temporal or categorical linkages between events at a more granular level through analytical linkage operators. In our opinion, these results can be useful in three practical situations. Firstly, they can provide the extra information required to effectively detect unseen stories from a stream of events in a First Story Detection scenario [22, 23]. Secondly, our results can be used to effectively recommend future events and also assign priorities to events in an event-based recommendation scenario [24, 25]. Thirdly, the chronological events and analytical linkages together provide a visualization dimension in the contextual representation of the events (which is our proposed future work direction).
[26].

With respect to theoretical implication, we have provided a formal method of representing linkages between events through an event algebra. Our algebra has a rich, formal vocabulary of operators representing linkages. We can extend it to support new types of event information attributes and event linkages. We can also use it to represent events occurring in any application domain or appearing in any textual media. The core requirement is only to extract the event attributes for the specific domain and identify the possible linkages. Since we have selected the symbols for linkage operators from the set of mathematical operators based on similarity in semantics, therefore it is not difficult to find a meaningful symbol for a new operator. Our context match operators form the primitive group of operators that define any new spatial, temporal or categorical linkage. Finally, we have defined all existing complex analytical operators in our algebra using the primitive context match operators.

Our work has limitations with respect to the size of the processed data. If the data size exceeds the Megabyte level, then we will need to use big data analytics techniques to process our event algebra. For this, we plan to use MongoDB, a world-renowned database for big data as our backend storage. Through the Python programming language, we will encode the EventWeb queries to run over MongoDB by using PyMongo API. If the data is growing exponentially, we can also use the clustered version of MongoDB to store data over a distributed cluster. Another limitation of our work is that we cannot claim our proposed event algebra to function in any selected domain. It is possible that there are domains where we may need to propose more operators. This can only be done at application time.

VII. Conclusions and Future Work

Extracting important information regarding connections between events appearing over EventWeb is an existing requirement of the Web community. In this paper, we have developed an event algebra that extracts semantic information from EventWeb by identifying potential connections between events. We were unable to locate any related research work that collectively incorporates all features of our algebra for information extraction. Specifically, we consider all five event information attributes (title, location, temporal attributes, participants, and category) and we detect previously unexplored connections. We also provide an analytical view over the connections through analytical operators, and we define the strength of connections. We have implemented a tool to implement the operators proposed in our algebra. We applied these operators to a set of detected events in the university domain to extract information regarding connections between these events. Out of 1300 connections that existed among 100 events, our tool correctly identified 1267 linkages. Hence, we achieved a precision and recall of 99% and 97% respectively for context match operators. Similarly, the precision and recall values for analytic operators were found to be approximately 90% and 80% respectively. We believe that these results validate the effectiveness of our algebra.

Our research has addressed the task of information processing in EventWeb, by linking events from multiple unique dimensions. Firstly, we address the two-fold objective behind linking events: 1) assistance in event planning and management, and 2) enhancing the experience of information search, visualization and story link detection over EventWeb. Secondly, in order to meet these objectives significantly, we attempt to identify all possibly existing connections. Moreover, we also cater for connections that required an analysis, along with the simple connections. We formulate all this through a robust event algebra that can is extensible for other domains. Finally, we develop a tool with simple user interface and validate our algebra effectively.

As future work, we are currently working to develop a contextual representation of event information components and connections. We also aim to extend our algebra to identify chains of connections. Moreover, we plan to use the analytical view provided by our operators in conjunction with the previous event participation history of the user for tagging events with priorities and generating recommendations. This will be part of a recommendation system attached to the link detection component, and that will deliver recommendations over event participation to support planning and management of events. We also aim to assign priorities to events by using the analytical operators along with the event participation history. In this context, we can use a participation history and a weightage feature-based approach for identifying the prioritized events. Finally, we intend to evaluate our algebra with events of other domains in the future.

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REFERENCES

[1] S. Wasi, Z. A. Shaikh, S. Qasmi, H. Sachwani, R. Lalani, A. Chagani, Event information extraction system (eiee): Fsm vs hmm, World Academy of Science, Engineering and Technology, International Journal of Computer, Electrical, Automation, Control and Information Engineering 7 (1) (2013) 5–12.

[2] S. Wasi, S. I. Jami, Z. A. Shaikh, Context-based email classification model, Expert Systems 33 (2) (2016) 129–144, eXSY-Oct-13-189.R4.

[3] W. R. van Hage, D. Ceolin, The simple event model, in: Situation Awareness with Systems of Systems, 2013, pp. 149–169.

[4] I. Corda, B. B. Bennett, V. Dimitrova, A logical model of an event ontology for exploring connections in historical domains (2011).

[5] B. B. Ilaria Corda, Vania Dimitrova, An ontological approach to unveiling connections between historical events, in: The 18th International
Conference on Knowledge Engineering and Knowledge Management, Galway City, Ireland, 2012.

[6] R. Shaw, R. Troncy, L. Hardman, LODE: Linking Open Descriptions of Events, Springer Berlin Heidelberg, Berlin, Heidelberg, 2009, pp. 153–167.

[7] A. Hinze, A. Voisard, A parameterized algebra for event notification services., in: TIME, 2002.

[8] A. Hinze, A. Voisard, Eva: An event algebra supporting adaptivity and collaboration in event-based systems, Tech. Rep. TR-09-006, International Computer Science Institute, USA (2009).

[9] A. Nagargadde, V. Sridhar, K. Ramamritham, Representation and processing of information related to real world events., Knowl.-Based Syst. 20 (1) (2007) 1–16.

[10] B. Rink, C. A. Bejan, S. M. Harabagiu, Learning textual graph patterns to detect causal event relations., in: H. W. Guesgen, R. C. Murray (Eds.), FLAIRS Conference, AAAI Press, 2010.

[11] S. Chakravarthy, V. Krishnaprasad, E. Anwar, S.-K. Kim, Composite events for active databases: Semantics, contexts and detection, in: Proceedings of the 20th International Conference on Very Large Data Bases, VLDB '94, Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 1994, pp. 606–617.

[12] V. Uma, D. G. Aghila, Article: Temporal pattern mining and reasoning using reference event based temporal relations (retr), International Journal of Computer Applications 36 (3) (2011) 45–49, published by Foundation of Computer Science, New York, USA.

[13] X. Zhao, P. Jin, L. Yue, Discovering topic time from web news, Inf. Process. Manage. 51 (6) (2015) 869–890.

[14] M. Ruocco, H. Ramampiaro, Geo-temporal distribution of tag terms for event-related image retrieval, Inf. Process. Manage. 51 (1) (2015) 92–110.

[15] L. Derczynski, D. Maynard, G. Rizzo, M. van Erp, G. Gorrell, R. Troncy, J. Petrak, K. Bontcheva, Analysis of named entity recognition and linking for tweets, Inf. Process. Manage. 51 (2) (2015) 32–49.

[16] M. N. Hila Becker, L. Gravano, Event identification in social media, in: Twelfth International Workshop on the Web and Databases (WebDB 2009), Rhode Island, USA, 2009.

[17] H. Sayyadi, M. Hurst, A. Maykov, Event detection and tracking in social streams., in: E. Adar, M. Hurst, T. Finin, N. S. Glance, N. Nicolov, B. L. Tseng (Eds.), ICWSM, The AAAI Press, 2009.

[18] H. Khrouf, R. Troncy, EventMedia : Visualizing events and associated media, in 10th International Semantic Web Conference, Demo Session, ISWC, Eurecom, 2011.

[19] R. Troncy, B. Malocha, A. T. S. Fialho, Linking events with media, in: Proceedings of the 6th International Conference on Semantic Systems, I-SEMANTICS '10, ACM, New York, NY, USA, 2010, pp. 42:1–42:4. doi:10.1145/1839707.1839759.

[20] J. F. Allen, Maintaining knowledge about temporal intervals, Commun. ACM 26 (11) (1983) 832–843.

[21] J. S. Shaukat Wasi, Z. A. Shaikh, Contextual event information extractor for emails, Sindh University Research Journal 43 (1) (2011) 103–108.

[22] S. Petrovic, M. Osborne, V. Lavrenko, Streaming first story detection with application to twitter, in: Human Language Technologies: The 2010
Annual Conference of the North American Chapter of the Association for Computational Linguistics, HLT '10, Association for Computational Linguistics, Stroudsburg, PA, USA, 2010, pp. 181–189.

[23] S. Petrovic, M. Osborne, V. Lavrenko, Using paraphrases for improving first story detection in news and twitter, in: Human Language Technologies: Conference of the North American Chapter of the Association of Computational Linguistics, Proceedings, June 3-8, 2012,

Montreal, Canada, 2012, pp. 338–346. URL http://www.aclweb.org/anthology/N12-1034

[24] A. Q. Macedo, L. B. Marinho, R. L. Santos, Context-aware event recommendation in event-based social networks, in: Proceedings of the 9th
ACM Conference on Recommender Systems, RecSys ’15, ACM, New York, NY, USA, 2015, pp. 123–130. doi:10.1145/2792838.2800187.

[25] X. Ji, Z. Qiao, M. Xu, P. Zhang, C. Zhou, L. Guo, Online event recommendation for event-based social networks, in: Proceedings of the 24th International Conference on World Wide Web, WWW ’15 Companion, ACM, New York, NY, USA, 2015, pp. 45–46. doi:10.1145/2740908.2742742.

[26] N. Gronau, M. Neta, M. Bar, Integrated contextual representation for objects’ identities and their locations, Journal of Cognitive Neuroscience, 20 (3) (2008) 371–388.

Liver Extraction Method from Magnetic Resonance Cholangio-Pancreatography (MRCP) Images

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***Abstract*—Liver extraction from medical images like CT scan and MR images is a challenging task. There are many manuals, Semi-automatic and automatic methods available to extract the liver from computerized tomography (CT) scan images and MR images. However, no method is available in the literature to extract the liver from Magnetic Resonance Cholangio-pancreatography (MRCP) images. Extracting the liver accurately from MRCP images is needed, so that the physician can diagnose the disease easily and plan preoperative liver surgery accordingly. In this paper, we propose a liver extraction method based on Graph Cut algorithm for liver extraction from MRCP images. The experimental results show that the proposed method is very effective for liver extraction from MRCP images.**

***Keywords*—Liver extraction; graph cut algorithm; MRCP images; liver surgery; medical images; liver mask; adaptive thresholding method**

I. Introduction

The healthy body depends on the healthy liver. There are many metabolic functions that performed by the liver for the smooth working of other organs. The unhealthy liver causes different types of diseases like obstruction in vessel, tumor, which need surgery. The physician recommends MRCP imaging test to the liver patients. The MRCP is an advance technology of the MRI technology the MRCP images are noninvasive, inexpensive and do not use any ionizing radiation as compare to CT images [1]. Due to the rapidly increase in the use of MRCP imaging technology an accurate and efficient liver extraction method from MRCP images is needed. An accurate liver extraction will help the radiologist and surgeon in diagnosing the liver diseases and in the planning of preoperative liver surgery as well.

In the computer science technologies the image processing is the most effective techniques which can be helped in different types of medical images. Liver extraction is very important stage in diagnosing the liver diseases. However, it is very difficult and challenging task to extract the liver. Because the liver is non-rigid shape naturally and the intensity value of heart and kidney is similar to liver [2].

Most of the research work for CT scan and MRI images has been conducted on liver extraction. Different type of method like manual, Semi-automatic and automatic methods are available to extract the liver from CT scan images and MR images [5]-[12]. In this paper, we developed an automatic method for liver extraction from MRCP images. Because of no research work has been reported in the literature. In order to fill the gap, a liver extraction method from MRCP images is proposed in this paper.

Our proposed algorithm works as follows. The MRCP images are grayscale, noisy and low contrast images. First of all remove the noise and enhanced the image. Secondly, find the intensity level of the liver and detect the largest region then extract the largest region in the image. Finally, create the liver mask and apply mask on the liver image to extract the original liver region.

The sequence of the paper as follows. Section 2 is about literature review. Section 3 is about proposed solution and implementation. Section 4 shows the experimental results and section 5 concludes the paper with future work discussion.

II. Literature Review

Most of the physicians adopt manual method in which the liver images are traced by mouse clicking on each slice of CT or MR images. The accuracy of manual method is 100%, but it is time-consuming method [3], [4].

In **[**5**]** the authors use the manual method to segment the lever volume from CT scan as shown in Fig. 1. In left lateral having segment II and III, in the caudate lobe having segments I, in left medial having segment IV and right lobe having segments V-VIII, each segment has been traced with the mouse positioning cursor. However, the manual method needs skills and expertise of the physicians.

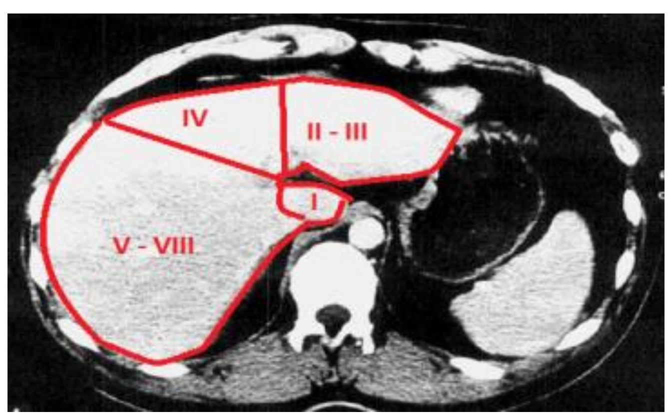

Fig. 1. The Kawasaki Manually Liver Segmentation.

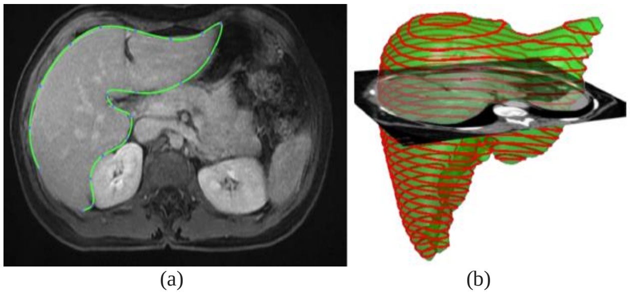

Fig. 2. Manual Extraction of liver. a) Tracing the Liver Boundaries, b) Obtained the Liver Volume by Summing each Slice.

In [6] the authors give the view on manual liver segmentation, according to author the post-processing software loads the Digital Imaging and Communications in Medicine (DICOM) file of CT or MR image. Then trace the liver boundary by the mouse positioning cursor as shown in Fig. 2 (a). Every pixel enclosed within the boundaries is the cross-sectional areas of the slice. Tracing each slice of CT or MR images and each slice multiplies with the thickness of slice and summing the result of all slices give the liver volume as shown in Fig. 2 (b).

In [7] the authors have proposed a semi-automatic method for liver lesion segmentation from CT scan images. The author does work in the following steps. In the first step, select the CT image slice where the liver is clearly appeared and extract the liver by using the morphological reconstruction. In its applied histogram threshold process to separate the liver, an erosion operation is applied to remove neighboring small parts connected to the liver. In last apply the dilation process to reconstruct the liver. In the second step enhanced the image and improve the image quality and subtract the lesion from liver has been shown in Fig. 3. The experimental results have achieve Sensitivity is 92 % and Specificity 99%.

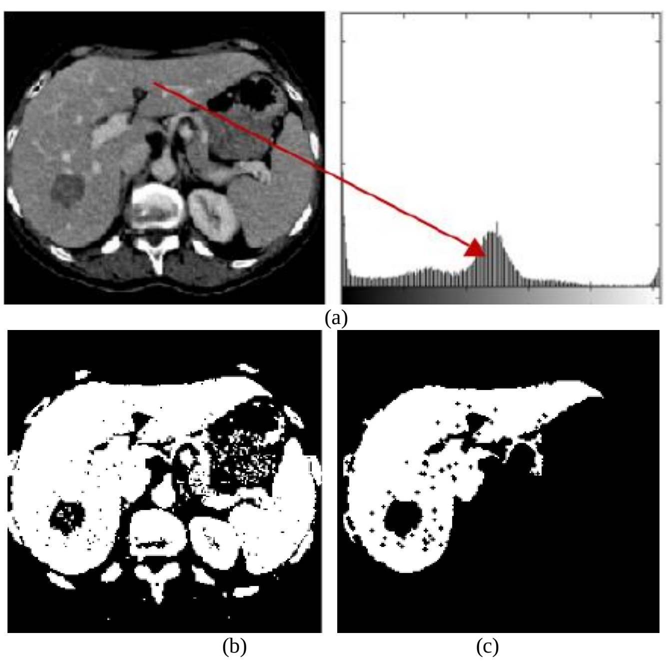

Fig. 3. Semi-Automatic Method for Liver Extraction. a) Original image, b) Histogram threshold, c) Extraction of liver.

In [8] the authors have described a semi-automatic method for liver extraction from the CT scan, which consists of three steps. In the first step, apply the histogram threshold to find the liver likelihood intensity range. Secondly, region growing method is applied in two sub steps. 1) Using get point function, click on the image where the liver mostly found and got the seed. 2) Giving fixed seed point for an image, but it is a very difficult method by giving fix seed point to each image due to liver shape variation. In the third step, apply the morphological operation like fill the holes, erosion, dilation and median filter to refine the liver image as shown in Fig. 4.

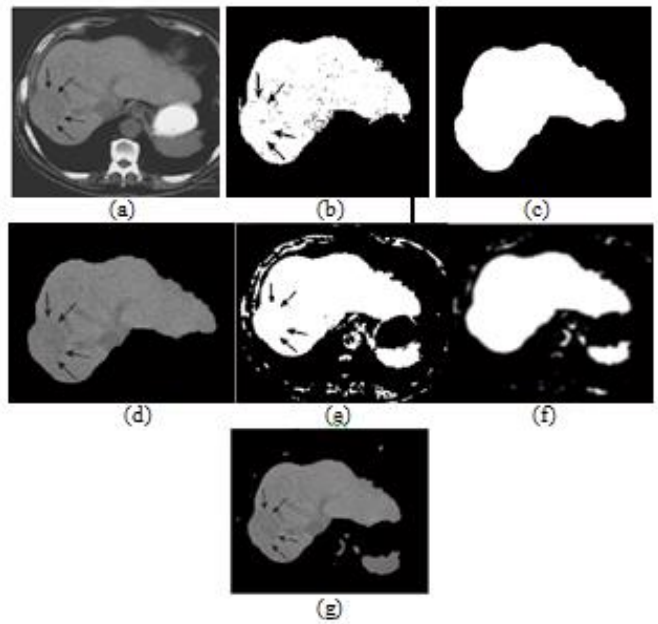

Fig. 4. Semi-Automatic Liver Extraction from CT Images, a) Original Image, b) Region Growing, c) Morphological Function, d) Extract Liver, e) Median Filter Result, f) Morphological Function, g) Final Result of Liver.

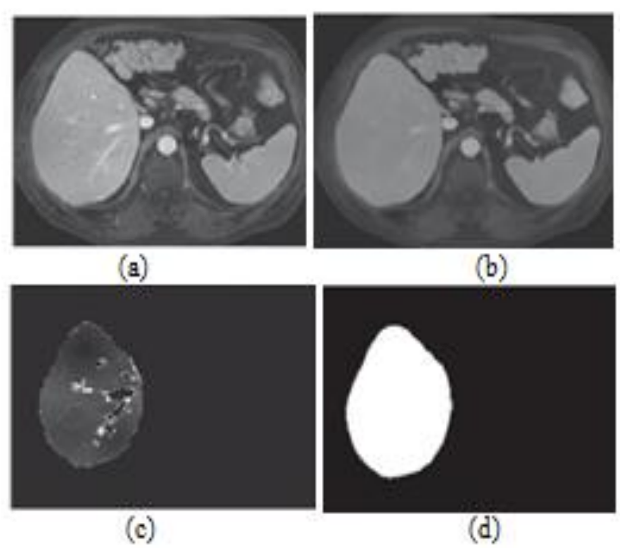

Fig. 5. Automatic Liver Extraction from MR Images. a) Original Image, b) Noise Removed, c) Scale-Specific Gradient Magnitude, d) Geodesic Active Contour Segmentation.

In [9] authors have suggested an automatic liver extraction from MR images. The author extracts the liver in four steps. Firstly, apply the anisotropic diffusion filter to remove the noise from image. Secondly, liver boundaries are enhanced with scale-specific gradient magnitude filter. Thirdly, the liver shape is determined by using the fast marching algorithm. In the fourth step, liver shape is refined by using a geodesic active contour level set algorithm as shown in Fig 5. The experimental results show the sensitivity is 92%, specificity 99.8%, and accuracy is 99%. The average computational time is 1.002 min/case.

In [10] the authors have stated graph cut techniques for liver segmentation from 10 datasets of CT and MR images. The mean shift fitter is applied to remove noise from the original image. Adaptive threshold method is applied for automatic initialization and in the last graph cut technique is applied for liver extraction as shown in Fig 6.

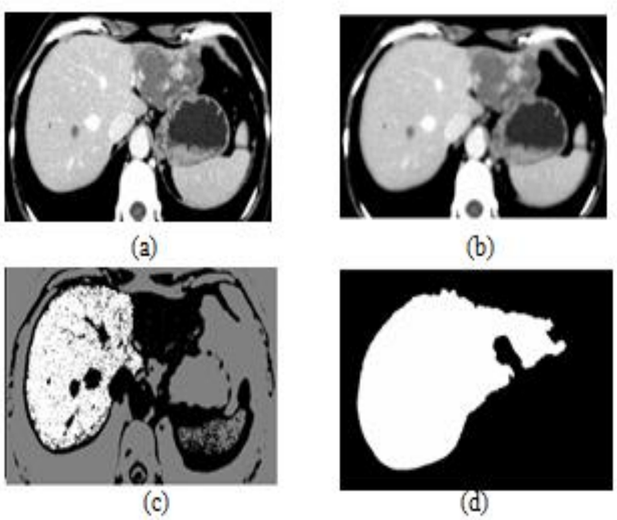

Fig. 6. Automatic Liver Extraction from CT images. a) Original image, b) Mean shift filter, c) Adaptive threshold method, d) Extract liver.

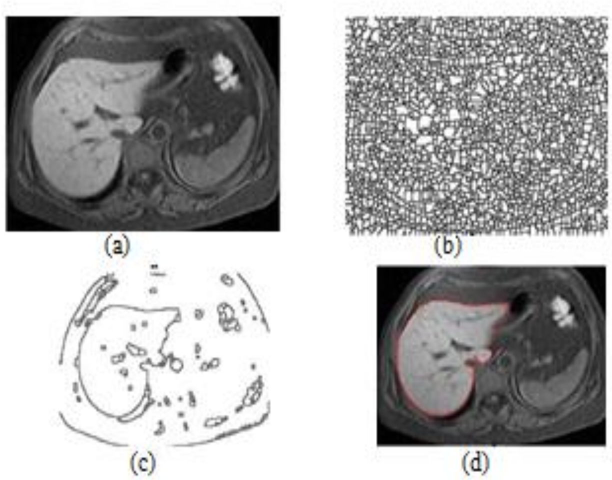

Fig. 7. Automatic Liver Extraction from MR Images. a) Original Image, b) Watershed transformation, c) Applied proposed algorithms, d) Extracted liver region.

In [11] the authors have proposed an automatic solution for liver extraction from MRI images by using an iterative watershed algorithm and artificial neural network. In the preprocessing step remove the noise from the image by using the gaussian filter and morphological gradients. In next step, liver region is extracted by using an iterative watershed transform and in last apply neural networks to refine the liver image as shown in Fig. 7. The author compared the experimental result with active contour model, the accuracy for the proposed solution is 94% and for active contour, the method is 92%. The proposed solution is 1.5 times faster the active contour model.

In [12] the authors have surveyed the automatic method for liver segmentation from MR images. The proposed solution is divided into four stages. In the first stage enhances the image by applying image normalization and gamma correction to adjust the image intensity value. Sharp the edges of the image and fill the small holes for the smooth texture. In the second stage, eliminate small objects, extract the large image and perform morphological steps. In the third stage enhances the image applies the gaussian filter the liver is segmented by using the active contour method. In the fourth stage applying morphological erosion and extract object form images by size as shown in Fig. 8. The experimental results show 95% accuracy.

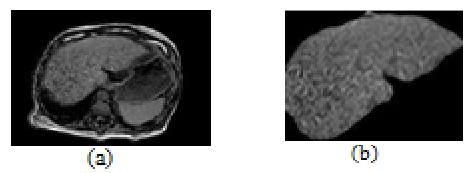

Fig. 8. Automatic Liver Extraction from MR Images. a) Original image, b) Segmented liver.

III. Liver Extraction Method

In this section a liver extraction method for MRCP images presented. Our proposed liver extraction method consists of three main modules namely: 1) Image Pre-processing, 2) Liver Mask Creation and 3) Liver Extraction. The process diagram of liver extraction is shown in Fig 9 and the detail of each of the modules of this method is discussed as follows.

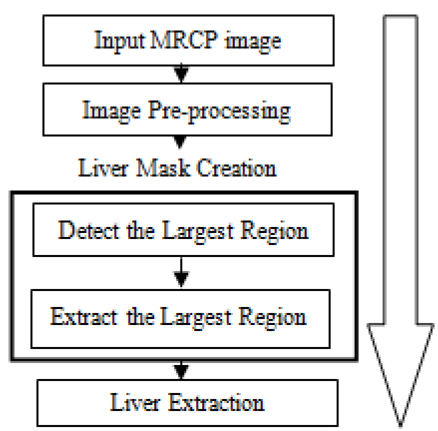

Fig. 9. Process Diagram of Liver Extraction Method.

A. Image Pre-Processing

The MRCP images are noisy and low contrast. The aim of this module is to remove noise and smooth the images before extracting the liver from MRCP images. To achieve this aim first of all, the contrast of the original image is enhanced by applying imadjust function. Secondly, the 5 x 5-pixel frame of the Gaussian filters with standard deviation σ = 2.5 is applied on the enhanced image. The output image is enhanced, smoothed and de noised as show in Fig. 10(a-c).

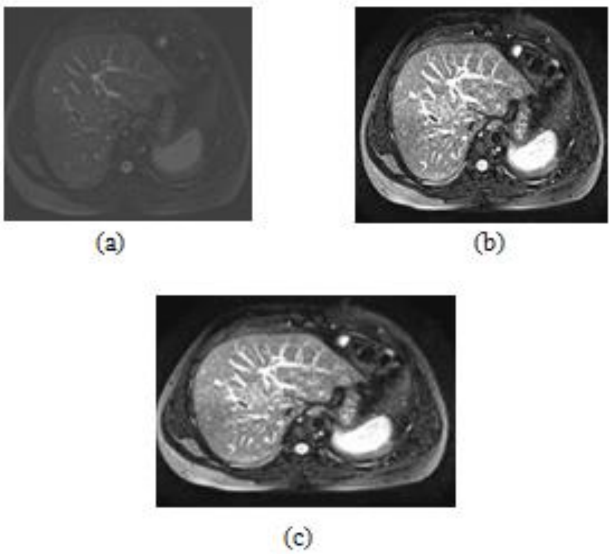

Fig. 10. The result is generated by applying image pre-processing module. a) Original image, b) Result generated by imadjust function, c) Smoothing and de noising the image applying Gaussian filter.

B. Liver Mask Creation

This module uses an observation based approach for liver mask creation. The thresholding method, graph cut algorithm and morphological techniques are used for obtaining the liver mask. This module consists of two sub modules namely: 1) Detect the Largest Region and 2) Extract the Largest Region.

1) Detect the Largest Region: The main objective of this sub module is to detect the largest region (Liver). To do this an adaptive thresholding method is applied on image, it is our observation that the range of threshold used for representing the liver region is in the range of 100 - 210. Each pixel in the image is compared with fixed minimum and the maximum threshold values. If the image pixel values are less than the minimum range or greater than the maximum range then they are set to 0, otherwise set to 1. This threshold is applied on the image Fig. 10 (c) then the output result is get and shown in Fig. 11 (a). Next, bwareaopen morphological function is applied on the resultant image, to remove unwanted small connected components composed of number of pixels less than 5000. The output image is shown in Fig. 11 (b).

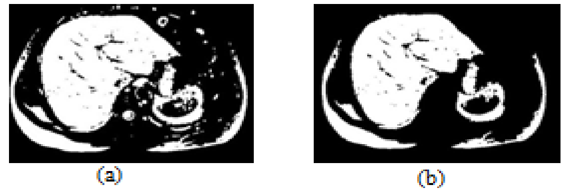

Fig. 11. The result of detecting largest region. a) Applying threshold, b) Remove small connected components.

2) Extract the Largest Region (Liver): There are many approaches are available that can extract foreground from background. Most of them are based on regional or boundary information which does not achieve the required accuracy. The graph cut algorithm provides both regional and boundary information [13], [14], so the aim of this sub module is extracting the largest region (Liver) by applying the graph cut algorithm. After applying the graph cut algorithm on images Fig. 11 (b), the result of boundary information and regional information as shown in Fig. 12 (a, b).

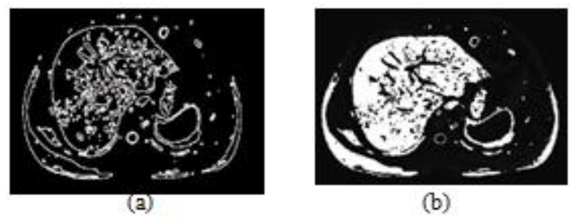

Fig. 12. Applying the graph cut algorithm for getting (a) The boundary information and (b) regional information.

Then added the regional information as shown in Fig. 12 (a) and boundary information as shown in Fig. 12 (b) then the result as shown in Fig. 13(a) and the imfill function is applied on the resultant image to fill the hole in the image and the output as shown in Fig. 13 (b), Next, bwareaopen morphological function is applied to remove the irrelevant connected components to get the liver image mask as shown in Fig. 13(c).

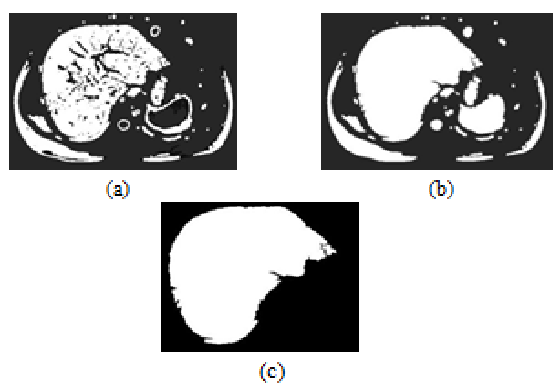

Fig. 13. The result of extracting largest region. (a) Graph cut algorithm output, (b) Fill the holes, (c) Extracting the liver mask.

C. Liver Extraction

The pixel values of mask generated by the previous module are compared with the original image pixel values. In this module, when the corresponding pixel values of the mask and original image become match as shown in Fig. 14(a, b). Then the values of that pixel is set to 1, otherwise its values is set to 0. The extracted liver image is shown in Fig. 14(c).

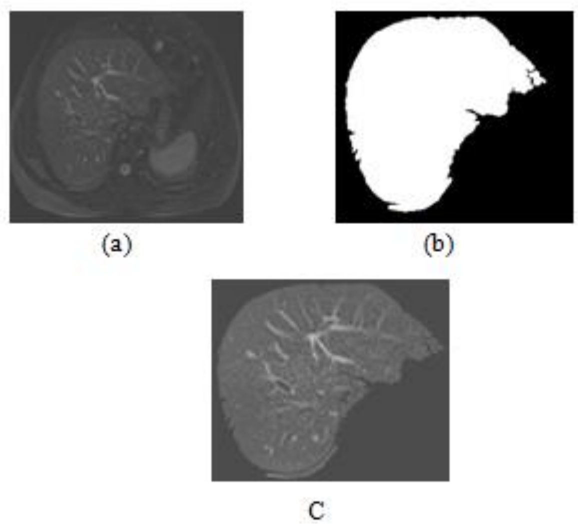

Fig. 14. The result of liver extraction is (a) Original image, (b) Apply the liver mask, (c) Extracted liver.

IV. Experimental Results

In this section evaluation criteria, dataset and results of the proposed method are presented.

A. Evaluation Criteria

A group of 10 experts included doctors and radiologist examine the result which was generated by our proposed method. However, our proposed method was practically implemented in the clinic on 15 easy, 15 average and 15 difficult test cases. The result was considered correct if liver in the image was fully extracted otherwise the generated result was declared as incorrect.

B. Dataset

The MRCP images data was not publically available. So the dataset of MRCP images was collected personally in the last four months (Jan-Apr 2018) from 57 patients (37 male patients and 20 female patients) by using the Echelon Oval 1.5T Hitachi machine in Ayub Medical Teaching Hospital Abbottabad, Pakistan. The dataset images in Digital Imaging and Communications in Medicine (DICOM) format and contained 300 MRCP images with different resolution 320 x 320 pixels to 1362 x 577 pixels are

C. Results

The result of our proposed liver extraction method is shown in Table 1. Our results were evaluated numerically with the help of five parameters namely.

- Overlap error.
- Average Distance.
- Maximum Distance.
- Volume Difference.
- Root Mean square Distance.

TABLE I. Result of our proposed liver extraction method for 15 cases

Cases		**Ovr. Error (%)**	**Score**	**Avg. Dist. (mm)**	**Score**	**Max. Dist. (mm)**	**Score**	**RMS Dist. (mm)**	**Score**	**Vol. Diff. (%)**	**Score**	**Total Score**
1	**Easy**	**20.1**	**67**	**0.1**	**73**	**30.3**	**32**	**2.4**	**65**	**1.4**	**56**	**59**
2		**17.6**	**34**	**1.6**	**43**	**12.4**	**54**	**9.5**	**23**	**-5.3**	**45**	**40**
3		**19.3**	**23**	**4.3**	**23**	**42.1**	**24**	**3.7**	**67**	**16.4**	**67**	**41**
4		**16.0**	**70**	**3.0**	**45**	**20.1**	**56**	**1.9**	**97**	**2.7**	**53**	**64**
5		**21.2**	**99**	**5.2**	**78**	**26.7**	**87**	**4.5**	**54**	**0.5**	**98**	**83**
6	**Average**	**11.5**	**45**	**1.5**	**65**	**56.4**	**43**	**7.8**	**32**	**-14.8**	**86**	**54**
7		**13.4**	**87**	**3.2**	**73**	**45.8**	**78**	**2.7**	**87**	**4.4**	**54**	**76**
8		**18.2**	**74**	**6.2**	**54**	**23.1**	**98**	**9.0**	**44**	**1.9**	**49**	**64**
9		**12.9**	**27**	**2.2**	**87**	**11.5**	**42**	**5.6**	**78**	**5.7**	**78**	**62**
10		**15.8**	**84**	**3.8**	**42**	**14.7**	**89**	**8.3**	**34**	**0.9**	**92**	**68**
11	**Difficult**	**10.2**	**56**	**0.9**	**87**	**21.3**	**23**	**6.9**	**78**	**-18.2**	**45**	**58**
12		**14.9**	**40**	**4.5**	**99**	**19.6**	**79**	**1.6**	**86**	**2.5**	**23**	**65**
13		**23.6**	**90**	**3.2**	**78**	**42.6**	**35**	**7.4**	**54**	**-20.7**	**53**	**62**
14		**17.8**	**63**	**2.1**	**46**	**32.1**	**90**	**1.3**	**75**	**8.9**	**68**	**68**
15		**5.4**	**14**	**0.1**	**20**	**12.0**	**27**	**4.6**	**25**	**6.4**	**95**	**36**
Average		**12.06**	**58.2**	**2.8**	**68.6**	**27.38**	**53.8**	**5.1**	**59.9**	**-7.3**	**67.9**	**56**

Our proposed method is analysis the intensity level of liver. When the intensity value of liver is not laid between the range of 100- 210 then it shows bad output (in cases 2, 6, 13 and 11) in all five parameters otherwise it shows good output (in cases 1, 3, 4,,5, 7, 8, 9, 10, 12, 14, and 15). The performance of the proposed liver extraction method depends on the five parameters. The total average score 89 and the average liver extraction time is 67 seconds (min 23 seconds, max 145 seconds) which is much better than manual extraction.

However, our proposed algorithm had successfully extracted liver from 273 out of 300 MRCP images the average accuracy of our proposed algorithm was 91%.

V. Conclusion and Discussion

The literature is not available for liver extraction from MRCP images. But there is a lot of literature is available for liver extraction form CT and MR images. So with the help of above literature review, we are motivated and introduced the new idea for liver extraction from MRCP images due to rapidly increasing in MRCP technologies. In this paper, we proposed new and automatic method for liver extraction from MRCP images. Our proposed method consists on the following steps. Firstly, threshold is applied on the pre-processing step to find the liver intensity range. Secondly, the largest object in the image is extracted. Thirdly, the foreground from the background is separated and a mask is generated. Finally, the mask is applied on the original MRCP image to extract the liver.

In the future, we will extend our proposed work to extract the biliary tract and segment the liver according to C. Couinaud's liver segmentation theory and label the biliary tract on the segmented parts.

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References

[1] Mehmet Ali, Omer Karahan, "Comparison of Endoscopic Retrograde Cholangiopancreatography (ERCP) and Magnetic Resonance Cholangiopancreatography (MRCP) in Bile Duct Imaging", Scientific Research, Sep 2012.

[2] Mortele, K. J., Cantisani, V., Trosisi, R., "Preoprative Liver Donor Evaluation: Imaging and Pitfalls, Liver Transplantation" Vol 9, No 9, Suppl 1, pp S6-S14, Sep 2003.

[3] Yang Xiaopeng, Jae Do Yang, "Segmentation of Liver and Vessel from CT Images and Classification of Liver Segments for Preoperative Liver Surgical Planning in Living Donor Liver Transplantation", Computer Method and Programs in Biomedicine, May 2018.

[4] Ina Singh, "A Study of Effective Segmentation Technique for Liver Segmentation", International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), Vol 4, April 2015.

[5] S. Kawasaki, M. Makuuchi "Preoperative Measurement of Segmental Liver Volume of Donor for Living Transplantation", American Association for the Study of Liver Diseases, Jun 1993.

[6] Akshat Gotra, Lojan Sivakumaran, "Review: Liver Segmentation: indication, techniques and future directions", Springer Link, Jun 2017.

[7] Belgherbi, A. Hadjidj, I. "A Semi-Automatic Method for the Liver Lesion Extraction From a CT image Based on Mathematical Morphology", iMedPub Journals, Vol 2, 2013.

[8] Shaimma A. Elmorsy, "A Region Growing Liver Segmentation Method with Advanced Morphological Enhancement", IEEE, March 2015.

[9] BUI Dinh Tien "Studying Methods of Automatic Liver Segmentation from MRI Images", Semantic Scholar, 2015.

[10] Laurent Massoptier "Fully Automatic Liver Segmentation through Graph-Cut Technique", IEEE Conference paper, August 2007.

[11] Hassan Masoumi, Aliraza Behrad, "Automatic Liver Segmentation in MRI images using an Iterative Watershed Algorithm and Artificial Neural Network", Elsevier, Feb 2012.

[12] Roaa G. Mohamad, Noha A. Seada "Automatic Liver Segmentation from MRI Images using Active Contours", International Journal of Computer Applications (IJCA), Oct 2017.

[13] Y. B. Yuri, G F. Lea, "Graph Cuts and Efficient N-D Images segmentation", International Journal of Computer Vision 2006.

[14] Zeyun Yu. Ming Xu, "Biomedical Image Segmentation via Constrained Graph Cuts and Pre-Segmentation", IEEE, Feb 2012.

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An Enhanced Method for Detecting the Shaded Images of the Car License Plates based on Histogram Equalization and Probabilities

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***Abstract*—Shadow is one of the major and significant challenges in detection algorithms which track the objects such as the license plates. The quality of images captured by cameras is influenced by weather conditions, low ambient light and low resolution of the camera. The shadow in images reduces the reliability of the sight algorithms of the device as well as the visual quality of images. The previous papers indicate that no effective method has been presented to improve the license plate detection accuracy of the shaded images. In other words, the methods that have been presented for automatic license plate detection in shadowed images until now use a combination of color features and texture of the image. In all these methods, in order to detect the frame of the shadow and the texture of the image, sufficient light is required in the image; this necessity cannot be found in most of the regular images captured by road cameras. In order to solve this problem, an improved license plate detection method is presented in this research which is able to detect the license plate area in shadowed images effectively. In fact, this is a contrast-improving method which utilizes the dual binary method for automatic plate detection and is introduced to analyze the interior images with low contrast, and also night shots, blurred and shadowed images. In this method, the histogram of the image is firstly calculated for each dimension and then the probability of each pixel in the whole image is obtained. As a result, after calculating the cumulative distribution of the pixels and replacing it in the image, it will be possible to remove the shadow from the image easily. This new method of detection was tested and simulated for 1000 images of vehicles under different conditions. The results indicated the detection accuracy of 90/30, 97/87 and 98/70 percent for the license plates detection in three databases of University of Zagreb, Numberplates.com and National Technical University of Athens, respectively. In other words, comparing the performance of the proposed method with two similar and new methods, namely Hommos and Azam, indicates an average improvement of 26/70 and 72/95 percent for the plate detection and 32/38 and 36/53 percent for the time required for rapid and correct license plate detection, even in shaded images.**

Keywords*—Automatic license plate detection; shadowed images; histogram equalization; cumulative distribution; pixel probability

I. Introduction

License plate detection for vehicles is a frequently used technique in the field of image processing. The key role of the license plate detection is controlling as well as managing the implementation of traffic rules automatically in public roads. Each vehicle carries a unique license plate; therefore, no external card, label or transmitter is needed. Furthermore, license plates can be used for traffic management, border control, access control and parking cost. Before this, general technologies such as Vehicle Identification Number (VIN) and electronic labels were used to identify the vehicles, which were quite expensive. On the other hand, if a new vehicle was produced, one of such technologies should have been installed on it in order to enable us to identify such vehicles. To remove this factor, the best method to identify a vehicle is detecting the car license plate identification number, utilizing a simple camera. One of the most important steps for identifying the license plate number of vehicles is detecting the license plate area and extracting it from the image of the vehicle. Most of the license plate detection software deal with challenges while extracting the license plate area from the image; among these challenges, the followings can be addressed: Existence of various types of texts around the license plate, existence of unwanted objects in the image, low ambient light, presence of more than one vehicle in a single image, deviation of the license plate and existence of a shadow fallen on the license plate. Shadow detection is one of the important aspects of most of the detection and object tracking algorithms. Shadows appear in an image when objects block the light emitted from the source of light; therefore, they appear as the surface features. The procedure of shadows detection is divided into three processes: low level, mid-level and high level [1]. The low level process detects the areas that are darker than their surroundings. Shadows are among the dark areas. The mid-level process detects the features among the dark areas such as penumbra and shadow. The location of the object is beside the dark areas. A high level process then merges such assumptions and verifications of stabilities among the light directions estimated from them. The shadow area, generally, is divided into two sections: the shadow itself and the shadow frame. The shadow itself is a part of an object that does not appear by direct light. The shadow frame is the area that appears by the object on the direct path of light. The shadow frame, in the real world, is dependent on the effects of light, as the light beam encounters more than one reflection from the object's surface in its path from the light source. The dark spot is a part of the shadow frame that is completely blocked by the object itself. On the other hand, penumbra is a part of the shadow frame that has blocked the direct light in a scattered manner. These parts are described in Figure 1:

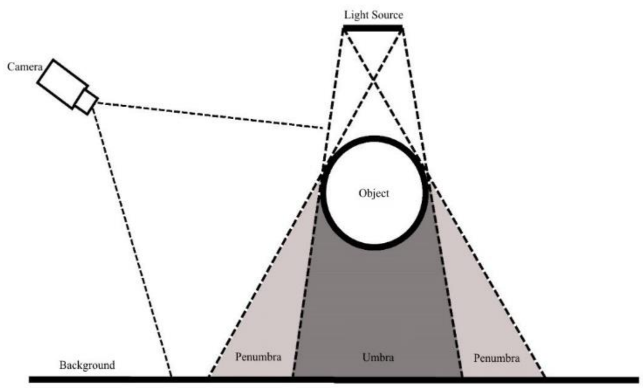

Fig. 1. Cast shadow parts : “umbra” and “penumbra” [2]

A spot light source only causes the appearance of a dark spot in the shadow. An area of light source, however, causes the appearance of both a dark spot and penumbra. When the penumbra is very small, it might be detectable considering the effect of digitalizing the image. A dark spot has a low intensity of brightness due to the fact that it does not receive any light from the light source. Such intensity increases gradually from the dark spot to the penumbra. Shadows might be considered as a part of the object’s backgrounds; in this case, they could lead to the merge of the backgrounds, deviation of the objects’ shape and even their disappearance (considering that the shadow frame has fallen on the other objects as well). Therefore, removing the shadows leads to more accurate detection of the vehicle and consequently, a more accurate background for the license plate algorithms. Several methods have been presented until now to detect the shadows and remove them from the license plate image, including utilization of the Bernsen algorithm [3, 4], utilization of the color features of the license plate [5], the counting algorithm [6, 7], utilization of the Otsu’s threshold [8, 9], detection of the vertical and horizontal edges [10, 11] and utilization of the edge density in order to increase the contrast of the image [12, 13]. All the presented methods are very sensitive to the noise and if the shadow has covered a major part of the license plate and the ambient light is low, these methods face problems. In this research, an improved method is presented to remove the shadow on the license plate and to detect the license plate area. For this purpose, first, the histogram of the image is calculated for each dimension; then after obtaining the cumulative distribution of the pixels and replacing them with the obtained number in the image, we can remove the shadows from the images; then utilizing Tamura contrast improvement, image quality is improved and therefore, we proceed with effective detection of the license plate area within the image. The proposed method has been tested on 1000 images of vehicles under different conditions and has obtained the average performance of 95/62 percent for detecting license plates in all three databases. Also the performance of the proposed automatic license plate detection method was compared with two new Hommos [14] and Azam [15] methods. The proposed automatic license plate detection method provides an average improvement of 20/13 percent for the accuracy of the license plate detection rate and an average improvement of 32/38 percent for the implementation time, compared to other methods. The structure of this article is categorized as following: In the second section, we will address previous works and then the problems of the previous methods are categorized in the third section. In the fourth section, the proposed method is described with necessary details, and then evaluation and analysis of the results are provided in the fifth section and finally, in the sixth section, the article is concluded.

II. RELATED WORK

Since previous decades, there have been several attempts to solve the problem of detecting the license plate area from the image. Various advanced methods, various image processing methods, techniques and algorithms have been utilized for establishing automatic license plate detection methods. Several features such as geometric, texture and color features were either separately or jointly used in order to detect the license plate area. Figure 2 demonstrates the categories of the presented methods for license plate detection. Some of the advanced automatic license plate detection methods and their limitations are summarized and described in the following:

Anagnostopoulos et al. [16] have presented a license plate detection system. The automatic license plate detection phase of this system receives a gray image as the input and utilizes a segmentation technique, called Sliding Concentric Windows (SCW), for selecting the rich texture area in the image. In the analysis of connected components, the parts that are not license plates are rejected based on the surface area, direction and calculation of the Euler number. In the license plate area, however, the Euler number is very sensitive to small noises. To remove the noises, no method is presented in the automatic license plate detection method. This automatic license plate detection method has not considered the effects of the weather conditions, license plate deviation and low contrast of the image and makes no specific effort in order to solve these issues. Kaushik et al. [17] have utilized an improved version of the Sliding Concentric Windows (SCW) that detects the vertical and horizontal edges in order to detect the license plate area. After that, only the rectangular shaped areas are kept on the edge image based on the shape and size of the license plate. In the end, the connected components are extracted from the image and all those that are not license plates are filtered based on the surface area and color information. One of the limitations of this method is the utilization of the rectangular information of the license plate edges for the initial detection, because the detection of the concerned license plate is not always possible from the edge information due to the low contrast between the license plate and the body of the automobile. Furthermore, this automatic license plate detection method has not considered the effects of weather conditions, low contrast and license plate deviation. Wang et al. [18] have presented an automatic license plate detection method based on the Discrete Wavelet Transform (DWT) and the Sliding Concentric Windows. The automatic license plate detection method fails when the edges are unclear due to the low contrast of the image. This automatic license plate detection method contains no phases for analyzing unnecessary edges in various weather conditions and also, there is no specific phase in that for analyzing the horizontal deviation of the license plate and noises. In addition, to locate the license plate, this method only utilizes the edge density; therefore, it is not an appropriate method for detecting the license plates in high-risk situations. Ashim et al. [19] have presented a license plate identification method for the license plates written in Bengali language. The automatic license plate detection phase of this system takes the gray image as the input and utilizes the medium filter in order to remove the noise. Then Sobel vertical operator is applied for detecting the vertical edges of the image. Thresholding is used to extract the candidate areas as license plates and select some rows based on the density of edges. Morphological erosion and dilation are applied to the selected edges in order to remove unwanted objects. In the end, the main license plate area is obtained using the vertical cropping based on the density of edges. To remove the areas that are not license plates, the surface area is utilized only as the main filter. There is no concern about the issue of the effects of weather conditions and license plate deviation in this automatic license plate detection method. This method is not even concerned with analyzing the night shots, blurred and shadowed images. The medium filter is utilized in the initial phase in order to remove the noise which indicates a questionable performance. Another limitation is using the edge density and the amount of threshold (histogram analysis) for horizontal cropping of the image, since an image may include other objects with high edge density; therefore, when several objects overlap with each other, a huge error happens in horizontal cropping. Using the analysis of the connected components instead of histogram analysis can be considered as a better method.

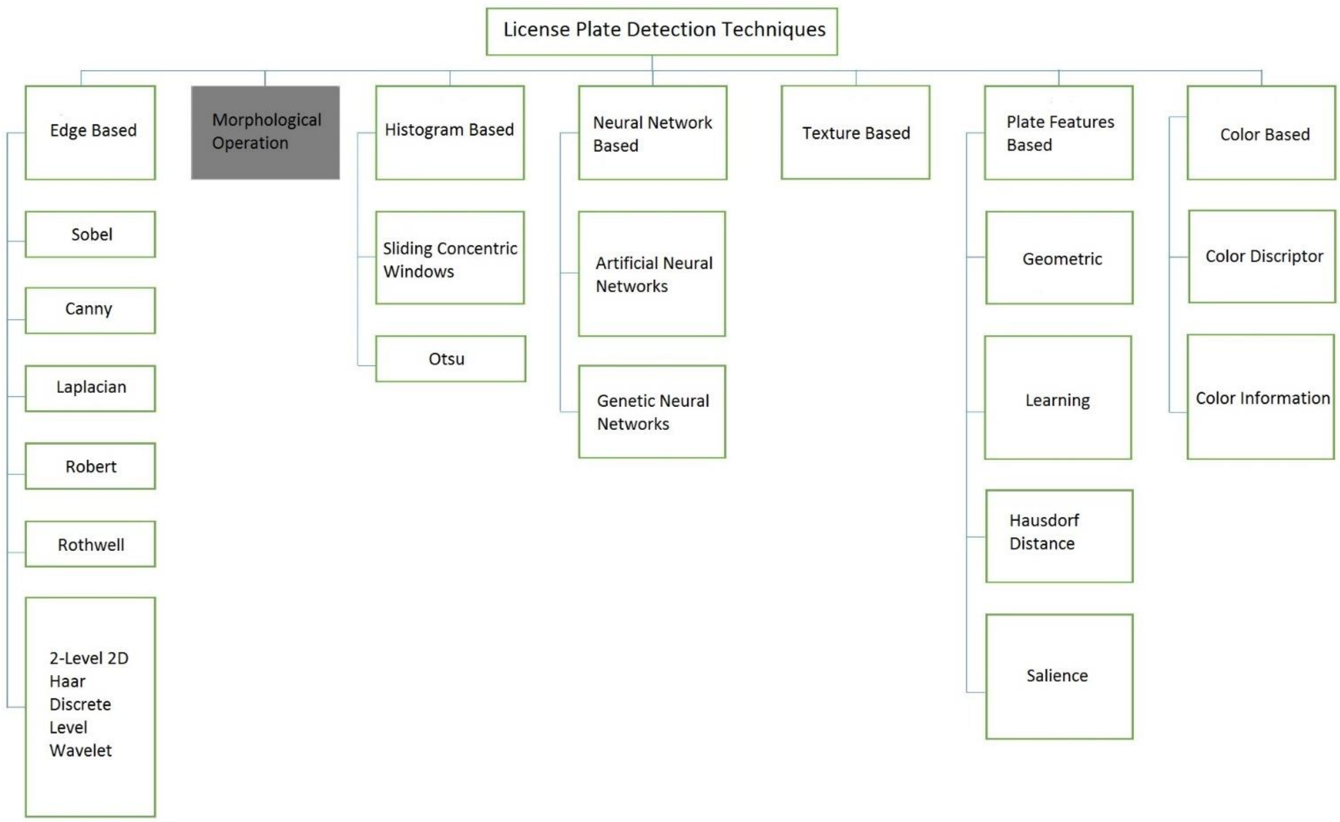

Fig. 2. Classification diagram

Joarder et al. [20] have presented another license plate detection method based on the density of the vertical edge. This automatic license plate detection method uses the density of the edge in order to increase the local contrast. Therefore, the contrast of dense areas increases compared to the low density areas. Nonetheless, this method fails when the edge information is weak in the license plate (night shots or blurred shots should be considered). Another problem is that before applying the contrast improvement method, no noise removing filter is used. Hsu et al. [21] have presented a software-oriented automatic license plate detection method whose parameters can be set in order to be placed in the system for three different programs: access control, rules implementation and road patrol. This method utilizes vertical edge clustering method for detecting dense areas of the edge in the image, in automatic license plate detection phase. Eventually, the areas that are not license plates are rejected based on the surface area, size and direction. This automatic license plate detection method has no techniques for removing the rain drops and improving the contrast of the image. Further, rain drops increase unrelated edges and the low contrast of the image also decreases the detection of sharp edges in the image; this misleads the clustering method and reduces the detection performance of the license plate areas. Nejati et al. [22] have presented a license plate detection system. Their proposed algorithm consists of four main steps including: license plate positioning, segmentation, identification and a combination of the results of multiple identifications. License plate positioning commences with some preprocessing, low sampling, removing the Gaussian noise and dynamic setting of the light intensity range with histogram equalization. Then the histogram of the vertical edges is used to detect the concerned candidate lines including the license plate. Issues such as weather conditions, blurred and shadowed images are not solved in this method. Azam et al. [15] have presented an automatic license plate detection system for rainy weather conditions. In this system, the color image is converted to gray and then rain drops are removed from the image utilizing Fourier transformation discrete. Then Radon transform is used in order to solve the issue of horizontal deviation of the license plate. Whereas Bernsen method is very sensitive to the noise and is used in this research to binarize the image, it fails in conditions such as low contrast and existence of the shadow in the image. Hommos et al. [14] have presented an automatic license plate detection system. This system works on High Definition (HD) images. In this method, first, HD images are converted to Standard Definition (SD) images and then they are resized. In the next step, the color image is converted to the gray image. A series of morphological operations such as erosion and dilation are applied to the gray image and then the binary image is made, using a constant threshold. No special conditions, such as weather conditions, blurriness and existence of the shadow, existence of objects or texts in the image which are similar to the license plate, are considered in this method. Also, there is no particular method expressed in this method for removing the noise or the license plate deviation. Li et al. [23] have presented an automatic license plate detection system in order to detect the license plates of vehicles. In this method, inspired by the success of the Deep Neural Networks (DNNs) in various vision programs, the power of DNNs for learning high level features in a cascade framework is considered, which leads to improved performance both in detection and identification. In the beginning, a class of 37 convolutional neural networks is trained for detecting all characters in an image; compared to other common methods such as categorizing a binary text or a non-binary one, it leads to a high rate of calling. The incorrect items are then removed by the second categorizing of the license plates or non-license plates. Then the box area is refined in order to improve the connectedness intersection ratio based on the information of the license plate edge. The proposed cascade framework extracts the license plates effectively and with a high accuracy and recalling. In the end, after detecting the license plate characters, a method is presented under the title of comet labeling issue. A Recurrent Neural Networks (RNN) with Long Short-Term Memory (LSTM) is trained with a convolutional neural network to identify the sequential features extracted from the whole license plate. The major advantage of this method is its free segmentation. RNN method performs better than the basic segmentation combination and categorization of the deep convolutional neural network through analyzing the background information and preventing errors caused by segmentation; therefore, it reaches high identification accuracy according to the latest scientific advancements. The main focus of this method is on identifying the characters and reading the license plates. In the license plate detection phase, this method assumes that there is no special condition in the image; therefore, it does not consider the existence of the shadows in the images and does not provide any solutions for that either.

III. Problem Statement

As it was addressed previously, to detect the license plates in shadowed images, we face challenges. Previous methods indicate that this dilemma has not been considered accurately and efficiently. An effective method which is able of solving this problem should own the following items:

1) It should be resistant to the noise.

2) It should be resistant to the low ambient light and should be able to coordinate the ambient light.

3) It should be able to remove the shadows in a way that causes no harms to the texture or the details of the license plate.

4) It should be able to operate well on the color images too.

5) It should be able to extract the license plate from the image effectively in different conditions (day, night, blurred or shadowed images).

In the next part, we will present a new method for solving the above mentioned issues.

IV. MATERIALS And METHOD

Unlike Bernsen algorithm that is very sensitive to the noise, the proposed method here is noise resistant. After removing the shadow and improving the ambient light, it will be easy to utilize counting algorithms or vertical or horizontal edge detection algorithms. By utilizing the hysteresis threshold, unlike Otsu's method, it is possible to binarize the image with more details and also, by utilizing Tamura contrast improvement, it is possible to improve the quality of the image. These series of actions will ease the trend of detecting the license plate from the image and make it more accurate. In addition, not only is the proposed method noise resistant, it is resistant to color and gray images as well and therefore, it can be used for color images. Generalities and details of the proposed method are addressed in the following.

V. Generalities of the Proposed Method

Since 2010, new articles have been presented on license plate detection based on morphological and texture methods [14, 15, 24, 25]. Although these methods could solve the problems of license plate detection to some extent, researches conducted in this field were not able to analyze the issues such as having shadows in the images appropriately; therefore, they lacked necessary and sufficient precision for detection. The main focus of this research is on improving the precision and accuracy of license plate detection in shadowed images. In the proposed method, histogram equalization is utilized based on the probabilities of both dimensions of the image to remove the shadows from the images and improve the contrast of the images as well. After noise is removed, using Wiener's method, the image is binarized, using Hysteresis threshold. Morphological operators are employed and finally, the connected components analysis method is utilized. To filter the areas that are not license plates, in addition to size and surface conditions, the value of Entropy (E) is taken into consideration in order to remove the items that are not license plates. Furthermore, in this research, the technique of histogram modification based on probabilities has solved the problems related to the detection of shadowed license plates in previous methods to a great extent; also, having considered the researches and having them compared with other presented methods, we have obtained a higher rate of accuracy and a shorter average performance time in the license plate detection. The proposed automatic license plate detection method has six stages that are demonstrated in Figure 3.

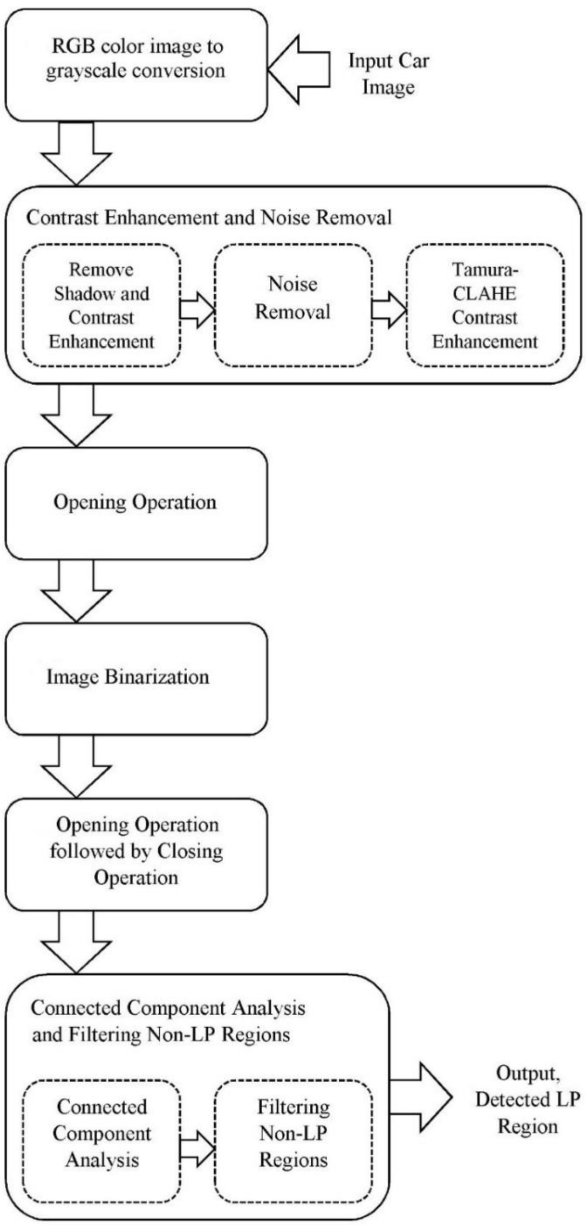

Fig. 3. Sequential stages of the proposed ALPD method

VI. Details of the Proposed Method

Our purpose is to present a new automatic license plate detection method that is able to detect the license plates automatically with an appropriate accuracy, when the images are shadowed. Therefore, in this part, the details of the proposed method are addressed based on Figure 3.

A. Converting the Color Image to the Gray Image

A color image is a combination of three components of the color image: Red (R), Green (G) and Blue (B) with sizes of $M\times N$. The proposed method receives the color image as the input. In most cases, a license plate includes white characters in black background or black characters in white background. Some of the states-owned or diplomatic vehicles have license plates with black characters in green or yellow backgrounds [25]. This color diversity, however, is of no importance in the proposed method since no color information is used for the license plate detection from the image. Color information is very sensitive to non-uniform light and therefore, causes difficulties for detecting the license plate from the image. In the proposed method, thus, the gray image (binary) is used at each stage. Furthermore, compared to the color image, processing the gray image is easier and occupies less space. Relation 1 is used to convert the color image to the gray one [24]:

$$Gray(i,j)=0.30*R(i,j)+0.59*G(i,j)+0.11*B(i,j) \qquad (1)$$

B. Contrast Enhancement and Noise Removal

1) Removing the Shadows and Contrast Improvement

As we know, probabilities indicate the chances for an event to take place. Probability is usually used for describing the subjective (mental) perspective of the statements which cannot be absolutely considered as true [26]. The concerned statements are of the types that state “Will a particular event take place?” our perspective is of the type that states “How sure are we about the occurrence of such event?” The extent of our confidence can be numerically expressed, and such value is a number ranging from 0 to 1 which is called probability [27]. The more probable an event is, the more confident we are that such event will take place. In fact, probability is the extent of our confidence about a (random) event to take place. On the other hand, we know that cumulative distribution is a part of a given sequence. Now, to remove the shadows from the image, probabilities can be used. For this purpose, first the histogram of the image should be used to obtain the existing pixel dispersion. Then the probability of each pixel is calculated and its cumulative distribution in the gray image is obtained. After inserting the obtained number in the image, we will be able to improve the contrast and remove the shadows from it as well. Figure 4 displays a sample of a shadowed image with low ambient light along with its relative histogram. Figure 5 displays the same Figure 4, after applying shadow removal algorithm and contrast improvement. As it is evident in the histogram of this image, after applying the proposed method, the ambient light is improved and shadows are removed from the image. In Figure 4, accumulation of pixels is on the right side of the chart (0 to 100) in the dark area and after applying the proposed technique, the pixels are distributed in the chart and the accumulation is on the right side of the chart and in the light area. This method can be used for color images as well. To do that, it is necessary to apply this method to each dimension of the image. For instance, if we assume an image with the dimensions of $M \times N$, we can calculate the probability of each pixel and the cumulative distribution, using Relations 2 and 3. Figure 6 displays a sample of the proposed shadow removal method.

$$P(z_k) = \frac{n_k}{M \times N} \tag{2}$$

$$Eq(z_i) = \sum_{i=0}^{i=k} P(z_i) \times 256 \tag{3}$$

Where M and N are the image dimensions, n_k is the number of times that z_k light intensity has occurred in the image, and $P(z_k)$ is the occurrence probability of z_k, and $Eq(z_i)$ is the cumulative distribution.

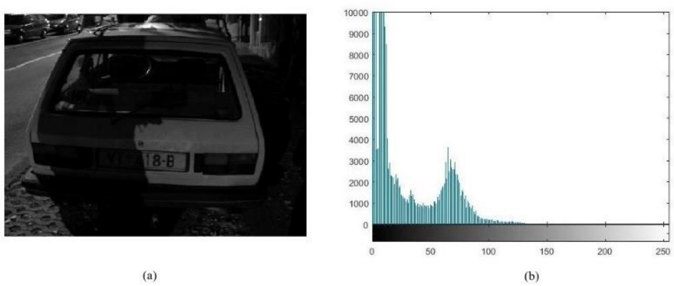

Fig. 4. (a) Shaded gray image in low light region, (b) Image's histogram

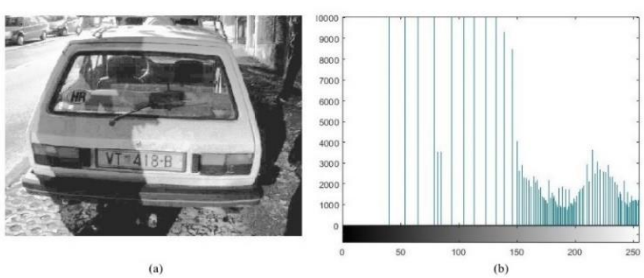

Fig. 5. (a) Output image after noise removal algorithm and enhanced contrast, (b) Image's histogram

Fig. 6. The proposed shadow removal process, (a) Input image, (b) Gray scale image after shadow removal

2) Tamura's Contrast Improvement

The input image, due to different conditions such as night shot, blurred and shadowed images, has a high potential for low image contrast. The vertical and horizontal lines in the image cannot be easily detected in the images shot in the night, due to low ambient light and the effects of the camera's flash and shaking, which in turn affect the performance of the proposed license plate detection method in the next stages. Furthermore, the existence of shadows in the image leads to short sight or low contrast in the image. Here, we consider the shadow removal issue as contrast improvement at this stage. In order to detect the license plate area in the image successfully, we need to improve the noise-removed image. However, contrast improvement, without limitation or having the amount of current contrast of the image, leads to new problems such as increased noise, increased number of candidate areas as license plates and increased areas as license plate borders. For this purpose, a new method is applied that utilizes Tamura's contrast jointly with limited contrast of adaptive histogram equalization [15]. The value of Tamura's contrast gives us the contrast of the image within the range of 0 to 1, and to control the range of contrast in the limited contrast of adaptive histogram equalization, we use Formula 5, for which the Tamura's value is deducted from 1 and then is divided to a constant number. Here, the constant number is the divisor that easily controls the value of Climit. Empirically, the value of this constant number is assumed equal to 200, by which Climit will be a value between 0 and 0.005. Formula 5 displays the procedure for obtaining Climit [15].

$$A = \frac{\mu_4}{\sigma^4} \quad , \quad F_{con} = \frac{\sigma}{A^n} \tag{4}$$

Where F_{con} is Tamura's contrast value, σ is the standard deviation of image brightness, μ_4 is the fourth torque around the mean and n=0.25. The output contrast value of this equilibrium is a number between 0 and 1. A high value of Tamura's contrast indicates a high contrast and a low value of Tamura's contrast indicates a low contrast of the image.

$$C_{limit} = \frac{abs\left(\frac{(1-F_{con})}{div}\right)}{255} \tag{5}$$

In the above formula, div= 200 and F_{con} is obtained from Formula 4. This formula generates the contrast range in a way that if an image has a low contrast, it increases the contrast range and if an image has a high contrast, it decreases the contrast range. When we use the contrast range in the adaptive histogram equalization, it causes effective improved contrast in a noise-removed image and obtains an improved image as well.

C. Opening Operation

Before binarizing the image, we should remove small white particles, unnecessary license plate candidate border areas and narrow connections between large white objects. For this purpose, we use opening morphological operation (erosion and dilation), utilizing the elemental rectangular structure. The size of the rectangle depends on the size of the license plate area. Here, the size of the rectangle is assumed as

3 ×35. In the next step, the image derived from the morphological operation is deducted from the gray image.

D. Binarizing the Image

In a gray image, license plate areas have a considerable disorder due to the brightness intensity of the license plate characters and the background. This means that the occurrence of the brightness intensity change among the pixels is high in the license plate area, considering the contrast between the texture and the background. Here, we use hysteresis thresholding in order to binarize the images [29]. After applying opening morphological operation to the image, the image is binarized using Formula 6. In this formula, $Th_{low} = 0.1$ and $Th_{high} = 0.3$.

$$I_t(x,y) = \begin{cases} foreground\,(strong) & if\ \ I_t(x,y) > Th_{high} \\ background & if\ \ I_t(x,y) < Th_{low} \\ candidate\,(week) & otherwise \end{cases} \tag{6}$$

Any pixel with a value lower than Th_{low} is considered as a background and any pixel with a value higher than Th_{high} is considered as a strong background.

E. Opening operation Followed by Closing Operation

In this stage, the erosion and dilation morphological operations are once again applied in order to remove the small holes and expand the white areas. First, an opening operation is applied to the image (erosion and then dilation) and subsequently, a closing operation (dilation and then erosion) is applied. A similar elemental structure (rectangular shaped) is used in both of these operations with different sizes. The size in the opening operation is assumed as 3× 3 and the size in the closing operation is assumed as 3×19 for the element generation.

3) Noise Removal

The proposed automatic license plate detection method uses local disorders (light intensity transfers) of an image as the initial feature for locating the license plate, since disorders in the area of license plate is high due to the text content. However, existence of the noise (such as small particles of dirt, dust and so on) leads to increased unnecessary disorders in the image and thus, leads to an increased number of candidate areas for license plates. In order to remove small noises, therefore, Wiener's local noise removal filter with the window size of 3×3 is used [28]. Using Wiener's local noise removal filter at this stage assists us to deal with a fewer number of unnecessary elements in the background in the next stage for automatic license plate detection. Figure 7 displays a sample of such noise removal. As it is evident in the image, Wiener's filter has removed small noises without any damage to the details of the image, and this is one of the significant advantages of this filter.

Fig. 7. (a) A noise-induced gray scale image, (b) The image after using Wiener noise filter.

F. Connected Component Analysis and Filtering Non-LP Regions

1) Analysis of the Connected Components

All of the connected components in the image obtained from the morphological operations are labeled in this step based on eight neighborhood connections. Figure 8 demonstrates a sample gray image, improved image, the image obtained from morphological operation, and the image with connected components along with their labels. Among these areas, only one is the target license plate area and the others are not. A filtering or a good analysis is required in the next step in order to locate the target license plate area.

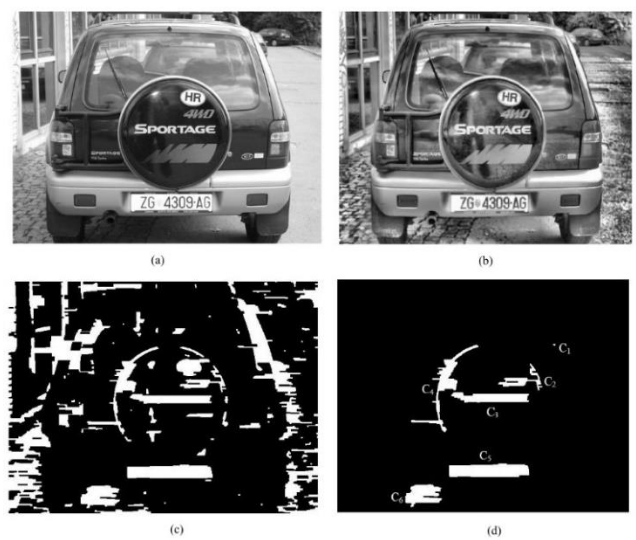

Fig. 8. The process of labeling the connected components, (a) Gray scale image, (b) Enhanced image, (c) Output image from morphological operation stage, (d) The image of the connected component based on 8 neighboring connections.

2) Filtering non- License Plate Areas

After analyzing the connected components, we have a number of license plate candidate areas. Among these areas, however, only one is our target license plate candidate. In the last stage, we filter all non-license plate areas from the candidate areas based on a number of main features such as size, surface area and entropy. For this purpose, the proposed automatic license plate detection method applies the following two steps to the images:

a) Filtering Non-License Plate Areas based on Size and Surface Area

At first, the non-license plates are filtered based on the resolution or the size of the license plate in the image. The text area of the license plates of different vehicles is almost the same in the images that are taken from a specific distance, since license plates usually obey a particular standard while being produced. The images used for this research (with a resolution of 640×480) were shot almost within a distance of 1 to 3 meters; and under this condition, the mean resolution of the unfiltered areas of the license plate is about 40×120. Under this condition, the least values for the length and width of the license plate consist of 60 and 30 pixels, respectively. Therefore, any license plate with a length and width of less than 60 and 30 pixels will be rejected. To filter the non-license plate areas, we use the proportion of length to width (surface area) of the candidate areas as a feature. Almost in all license plates, the horizontal dimension is longer than the vertical one. Even in lopsided license plates, the vertical dimension is no longer. We have empirically found out that those candidate license plate areas, in which the proportion of the length to the width is less than 0.15, are not actually the target license plate areas. Therefore, such candidate license plate areas will be rejected as non-license plates. Figure 9 demonstrates a sample of the images of candidate license plate areas that are rejected based on the surface area and size.

Fig. 9. Examples of candidate LP images which are rejected as non-LP images due to undersized resolution.

b) Filtering non-License Plate Areas based on Entropy

Here, we will use a relatively new method based on measuring the entropy (the amount of information) in order to filter the non-license plate images. Entropy means measuring the average number of the required bits for an image display [15]. Due to the existence of the numbers and words on a license plate (often black texts in a white background), the extent of the dispersion of black and white pixels are higher in such areas. Therefore, before calculating the entropy, a local vertical counter filter with the size of 3×1 is applied to the perimeter of the binary image. Then the perimeter binary image is binarized based on the value of the vertical counting. If the local counting value is 3, then number 1 is assumed and otherwise 0 is assumed. We have assumed entropy as the amount of information in bit per pixel unit at the time of filtering. The highest value of entropy is 1 for binary images. We have empirically found that if the value of entropy is higher than 0.15, then the candidate area is not a license plate and thus, it will be considered as non-license plate area.

In this part, we have addressed and described a new automatic license plate detection method that is capable of solving the issue of shadowed images. Here, the performance of the proposed automatic license plate detection method is evaluated and analyzed using various image data bases. Furthermore, the proposed automatic license plate detection method will be compared with two other new automatic license plate detection methods.

VII. Result

We have tested our proposed method on 1000 images from three databases of University of Zagreb [15], Numberplates.com [30] and National Technical University of Athens [16]. These images included different environmental conditions such as shadowed images, low contrast images and night and day shot images. The samples of license plates detected by the proposed automatic license plate method are provided in Figure 10. Also, Table 1 presents the rate of the license plate detection under different environmental conditions utilizing the proposed automatic license plate detection method.

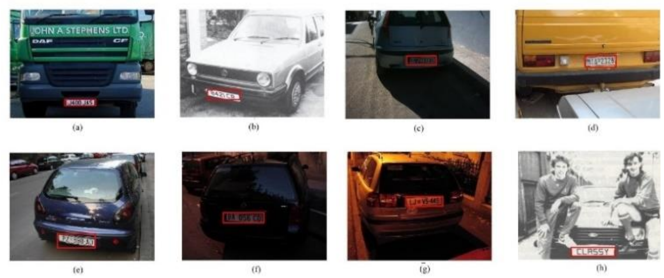

Fig. 10. Examples of license plate detection by proposed automatic license plate detection in different conditions: (a), (d), (e) day light, (b), (h) images with low contrast, (c) shaded image, (f), (g) night shot images.

As it is evident in Table 1, the proposed method has a performance of 97.30 percent in detecting license plates in shadowed images. This is due to the fact that the proposed method uses probabilities and cumulative distribution in the shadow removal and contrast improvement stage and therefore, is able to remove the existing shadow from the image and improve the amount of light in the image (increased brightness). Furthermore, the proposed method is able to reach an accuracy of 76.50 percent in images with low contrast because it uses Tamura's contrast improvement. The reason is that such images face problems in identifying and detecting the license plates due to sharp edges between the text and the background of license plates. Also, before filtering non-license plate areas, candidate areas include all target license plates. However, during the course of filtering, choosing a wrong target license plate leads to a lower rate of license plate detection. In addition, the proposed method has a good performance for the night shot and day shot images, which proves that this method is not exclusive to shadowed images.

TABLE I. Performance of the Proposed Automatic License Plate Detection Method in Different Conditions: Shaded Images, Images with Low Contrast, and Captured Images in Day and Night Light

Condition	**Performance of the proposed automatic license plate detection method in different conditions**		
	Number of Images	**Number of Detected Images**	**Detection Rate in Percent**
Shaded Images	127	124	97/30
Images with Low Contrast	76	58	76/50
Captured Images in Night	166	148	98/20

Captured Images in Day	631	622	98/50

The proposed automatic license plate detection method is evaluated and compared with two other license plate detection methods [14, 15]. These two methods are deployed using MATLABR2015b software and tested on available databases including 1000 images under different environmental conditions. The results obtained from the evaluation of the images from the database of University of Zagreb are summarized in Table 2, the results of Numberplates.com are summarized in Table 3 and the results of National Technical University of Athens are summarized in Table 4.

TABLE II. EVALUATING AND COMPARING THE PERFORMANCE OF METHODS [14, 15] WITH THE PROPOSED AUTOMATIC LICENSE PLATE DETECTION ON IMAGES OBTAINED FROM THE DATABASE OF THE UNIVERSITY OF ZAGREB.

Automatic License Plate Detection	**Evaluating and comparing the performance of methods [14, 15] with the proposed automatic license plate detection on images obtained from the database of the University of Zagreb**		
	Number of Detected LP from 515 Images	**Detection Rate in Percent**	**Average Running Time in Seconds**
Method [14]	370	71/80	2/33
Method [15]	112	21/70	0/83
Proposed Method	466	30/90	0/39

TABLE III. EVALUATING AND COMPARING THE PERFORMANCE OF METHODS [14, 15] WITH THE PROPOSED AUTOMATIC LICENSE PLATE DETECTION ON IMAGES OBTAINED FROM THE DATABASE OF THE NUMBERPLATES.COM.

Automatic License Plate Detection	**Evaluating and comparing the performance of methods [14, 15] with the proposed automatic license plate detection on images obtained from the database of the NumberPlates.com**		
	Number of Detected LP from 330 Images	**Detection Rate in Percent**	**Average Running Time in Seconds**
Method [14]	211	63/93	1/48
Method [15]	94	28/48	2/21
Proposed Method	323	90/30	0/44

TABLE IV. EVALUATING AND COMPARING THE PERFORMANCE OF METHODS [14, 15] WITH THE PROPOSED AUTOMATIC LICENSE PLATE DETECTION IN IMAGES OBTAINED FROM THE DATABASE OF THE NATIONAL TECHNICAL UNIVERSITY OF ATHENS.

Automatic License Plate Detection	**Evaluating and comparing the performance of methods [14, 15] with the proposed automatic license plate detection in images obtained from the database of the National Technical University of Athens**		
	Number of Detected LP from 155 Images	**Detection Rate in Percent**	**Average Running Time in Seconds**
Method [14]	96	61/93	1/13
Method [15]	23	14/83	1/56
Proposed Method	153	98/70	0/88

The shadows are removed from the images and the amount of light is adequately modified due to utilizing the histogram modification, cumulative distribution, probability of the pixels and Tamura's contrast improvement in the image preprocessing stage. This enables the proposed method to reach a higher accuracy than the two other compared methods. The two other compared methods have not presented any techniques for modifying the ambient light; also, to remove the shadows, they have used Bernsen algorithm which is very noise sensitive. All the license plates are extracted from the gathered 1000 images and are categorized in three classes based on the mean intensity of brightness of the license plates: The mean brightness intensity of 0 to 85 pixel (high brightness), 86 to 176 pixels (medium brightness) and 171 to 255 pixels (low brightness). Chart 1 demonstrates the evaluation and comparison of the methods [14, 15] with the proposed method in the above mentioned classes; as it is shown, the proposed method has a high accuracy not only for images with high brightness but also for those with low brightness and shadows.

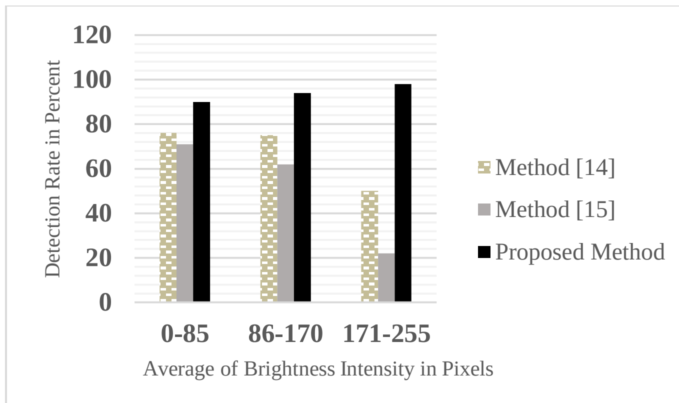

Chart. 1. Evaluating and comparing the performance of the mentioned methods with the proposed method based on the average brightness of plates.

Furthermore, all gathered images are categorized based on the distances of the camera from the license plate, which are 1, 3, 5 and 10 meters. Chart 2 demonstrates the evaluation and comparison of the methods [14, 15] with the proposed method in different distances and based on the categorization of the mean brightness intensity. As it is evident, all three methods had relatively good results within the distances of 1 to 3 meters. However, as the license plate distances from the camera and the existence of unwanted objects in the image increase, the accuracy of license plate detection reduces in all methods. As the distance increases, the size of the license plate varies and becomes smaller and therefore, we face lower accuracy of license plate detection in all methods. Furthermore, as the distance increases, the scope of the view of the image increases as well and therefore, more unwanted objects are observed in the image which in turn leads to an inaccurate detection of license plate area in all methods.

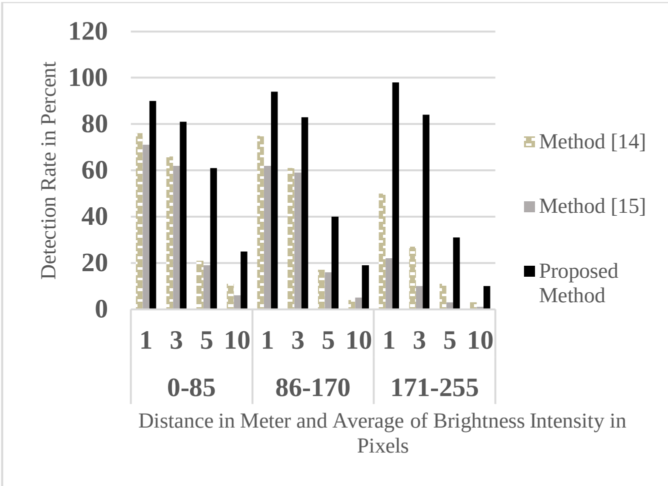

Chart. 2. Evaluating and comparing the mentioned methods with the proposed method at intervals of 1, 3, 5 and 10 meters based on the average brightness of plates.

Compared with other available methods, the introduced shadow removal and contrast improvement method in this research showed a better performance in terms of identification and detection of the license plate. The proposed method, under the shadowed image condition as well as the regular condition, leads to an improved contrast of the image and therefore, results in an increased license plate detection rate. The proposed method was tested on 1000 images from three databases under different conditions and in total, achieved the mean detection rate of 95.62 percent. The results of English written license plates and the images with symbolic license plates are provided. The results prove that, compared to two other available automatic license plate detection methods, the proposed automatic license plate detection method shows a better performance; it also shows much shorter average performance time.

VIII. Conclusion

A new license plate detection method, consisting of six stages, was introduced in this research. In the stage of contrast improvement and shadow removal, the method of histogram equalization based on probability was utilized and therefore, the shadow was identified in the image and then removed, which led to an improved image contrast. The color image was converted into the gray image in the first stage. In the next stage, in order to improve the image contrast and identify and remove the shadows, a new method based on histogram equalization on the basis of probabilities was presented. In this stage and for the purpose of identifying and removing shadows, the histogram of the image was firstly calculated for each dimension and then the probability of existence of each pixel in the whole image was obtained. After calculating the cumulative sum of the pixels and replacing them in the image, we can remove shadows from the image and improve their resolution. The proposed method can also be used for removing the shadows and improving the resolution in color images. For this purpose, it is only necessary to apply the proposed method to all three dimensions of the image and then apply Wiener's noise removal filter to the gray image in order to remove small noises. In this stage, in order to solve the issue of the low contrast of images (for instance, night shots, blurred and shadowed images), Tamura's contrast improvement method is used. In the next stage, morphological opening operation is applied to the improved images and the obtained image is deducted from the gray image. Then the obtained image is binarized using hysteresis threshold and later, morphological operations are again applied in order to fill the holes and expand the white colored areas. In the next stage, all of the connected components (8 neighborhoods) are categorized. Such categorized components are actually the license plate candidate areas for the next stage. Eventually, in the last stage, non-license plate areas are rejected based on size and surface area. Furthermore, the filtering technique based on entropy is applied, in the end, in order to filter other non-license plate areas. After filtering, the remaining license plate candidate areas are assumed as the target license plate areas. The proposed automatic license plate detection method was tested on 1000 images from three different databases and in total, reflected a detection rate of 95.62 percent and an average performance time of 0.39 seconds. The proposed automatic license plate detection method has only considered the rectangular license plates and other shapes of license plates such as square license plates are not included. Also, in this method, no solutions are proposed to solve the issues concerning the horizontal or vertical deviations of the license plates. We attempt to solve such issues in the future. In addition, further researches should be done in this field in order to use the proposed method in everyday applicable programs.

References

[1] Jiang, C. and M.O. Ward, *Shadow identification*, in *Proceedings 1992 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*. 1992, IEEE: Champaign, USA. p. 606-612.

[2] El-Said, S.A., *Shadow aware license plate recognition system.* Soft Computing, 2015. 19(1): p. 225-235.

[3] Zhu, S., S. Dianat, and L.K. Mestha, *End-to-end system of license plate localization and recognition.* Journal of Electronic Imaging, 2015. 24(2): p. 023020-023020.

[4] Fu, R., *The Research and Design of Vehicle License Plate Recognition System in Traffic Management System.* International Journal of Signal Processing, Image Processing and Pattern Recognition, 2016. 9(3): p. 445-456.

[5] Zang, D., et al., *Vehicle license plate recognition using visual attention model and deep learning.* Journal of Electronic Imaging, 2015. 24(3): p. 033001-033011.

[6] Hsieh, J.-W., S.-H. Yu, and Y.-S. Chen, *Morphology-based license plate detection in images of differently illuminated and oriented cars.* Journal of electronic Imaging, 2002. 11(4): p. 507-516.

[7] Tadic, V., M. Popovic, and P. Odry, *Fuzzified Gabor filter for license plate detection.* Engineering Applications of Artificial Intelligence, 2016. 48(5): p. 40-58.

[8] Tian, J., et al., *Chinese license plate character segmentation using multiscale template matching.* Journal of Electronic Imaging, 2016. 25(5): p. 053005-053005.

[9] Dehshibi, M. and R. Allahverdi, *Persian Vehicle License Plate Recognition Using Multiclass Adaboost.* International Journal of Computer and Electrical Engineering, 2012. 4(3): p. 355-358.

[10] Chai, H.Y., et al., *Elimination of character-resembling anomalies within a detected region using density-dependent reference point construction in an automated license plate recognition system.* Journal of Electronic Imaging, 2016. 25(6): p. 061614-061614.

[11] Dey, S., A. Choudhury, and J. Mukherjee, *An Efficient Technique to Locate Number Plate using Morphological Edge Detection and*

Character Matching Algorithm. International Journal of Computer Applications, 2014. 101(15): p. 36-41.

[12] Postolache, A. and J. Trécat, *Pyramidal approach to license plate segmentation.* Journal of Electronic Imaging, 1996. 5(3): p. 402-409.

[13] Dastjerdi, H.V., V. Rostami, and F. Kheiri, *Automatic license plate detection system based on the point weighting and template matching*, in *7th Conference on Information and Knowledge Technology (IKT)*. 2015, IEEE: Urmia, Iran. p. 1-5.

[14] Hommos, O., et al., *HD Qatari ANPR system*, in *International Conference on Industrial Informatics and Computer Systems (CIICS 2016)*. 2016, IEEE: Sharjah, UAE. p. 1-5.

[15] Azam, S. and M.M. Islam, *Automatic license plate detection in hazardous condition.* Journal of Visual Communication and Image Representation, 2016. 36(3): p. 172-186.

[16] Anagnostopoulos, C.N.E., et al., *A license plate-recognition algorithm for intelligent transportation system applications.* IEEE Transactions on Intelligent transportation systems, 2006. 7(3): p. 377-392.

[17] Deb, K., H.-U. Chae, and K.-H. Jo, *Vehicle license plate detection method based on sliding concentric windows and histogram.* Journal of computers, 2009. 4(8): p. 771-777.

[18] Wang, Y.-R., W.-H. Lin, and S.-J. Horng, *A sliding window technique for efficient license plate localization based on discrete wavelet transform.* Expert Systems with Applications, 2011. 38(4): p. 3142-3146.

[19] Ghosh, A.K., et al., *Automatic license plate recognition (ALPR) for Bangladeshi vehicles.* Global Journal of Computer Science and Technology, 2011. 11(21): p. 69-73.

[20] Joarder, M.M.A., et al., *Bangla automatic number plate recognition system using artificial neural network.* Asian Transactions on Science & Technology (ATST), 2012. 2(1): p. 1-10.

[21] Hsu, G.-S., J.-C. Chen, and Y.-Z. Chung, *Application-oriented license plate recognition.* IEEE transactions on vehicular technology, 2013. 62(2): p. 552-561.

[22] Nejati, M., A. Majidi, and M. Jalalat, *License plate recognition based on edge histogram analysis and classifier ensemble*, in *Signal Processing and Intelligent Systems Conference (SPIS 2015)*. 2015, IEEE: Tehran, Iran. p. 48-52.

[23] Li, H. and C. Shen, *Reading Car License Plates Using Deep Convolutional Neural Networks and LSTMs.* arXiv preprint arXiv:1601.05610, 2016. 3(8): p. 1-17.

[24] Kasaei, S.H., S.M. Kasaei, and S.A. Kasaei, *New Morphology-Based Method for RobustIranian Car Plate Detection and Recognition.* International Journal of Computer Theory and Engineering, 2010. 2(2): p. 264.

[25] Rabee, A. and I. Barhumi, *License plate detection and recognition in complex scenes using mathematical morphology and support vector machines*, in *The 21st International Conference on Systems, Signals and Image Processing (IWSSIP 2014)*. 2014, IEEE: Dubrovnik, Croatia. p. 59-62.

[26] Stuart, A. and J.K. Ord, *Kendall's Advanced Theory of Statistics, Volume 1: Distribution Theory, Edward Arnold*. 6 ed. Kendall's library of statistics. Vol. 1. 1994, London, UK: London : Edward Arnold ; New York : Halsted Press. 700.

[27] Feller, W., *An introduction to probability theory and its applications*. 3 ed. Probability and Statistics - Applied Probability and Statistics Section Series. Vol. 1. 1968, New Jersey, USA: John Wiley & Sons London-New York-Sydney-Toronto. 528.

[28] Benesty, J., et al., *Study of the Wiener filter for noise reduction*, in *Speech Enhancement*. 2005, Springer. p. 9-41.

[29] Al Najjar, M., M. Ghantous, and M. Bayoumi, *Hysteresis Thresholding*, in *Video Surveillance for Sensor Platforms*. 2014, Springer New York: NY, USA. p. 147-174.

[30] *Number Plates, Car registrations and DVLA plates - PRICE REDUCTIONS!* 2017; Available from: http://www.numberplates.com/.

A Real-Time Algorithm for Tracking Astray Pilgrim based on in-Memory Data Structures

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Abstract*—Large crowd management presents a significant challenge to organizers and for the success of the event and to achieve the set objectives. One of the biggest events and with largest crowd in the world is the Muslim pilgrimage to Mecca that happens every year and lasts for five years. The event hosts over two million people from over 80 countries across the world with men, women, and children of various age groups and many languages. One of the challenges that faces the authorities in Saudi Arabia is that many of the pilgrims become astray during the event due to the relative complexity of the rituals mainly mountainous landscape and the language barrier. This result in them being unable to perform the required rituals on the prescribed time(s) with the possibility to invalidate the whole pilgrimage and jeopardize their once-in-a-life journey. Last year over 20,000 pilgrims went astray during the pilgrimage season. In this paper we present a tracking algorithm to help track, alarm, and report astray pilgrims. The algorithm is implemented on a server that contains pilgrims' data such as geolocations, time stamp and personal information such as name, age, gender, and nationality. Each pilgrim is equipped with a wearable device to report the geolocations and the timestamp to the centralized server. Pilgrims are organized in groups of 20 persons at maximum. By identifying the distance of the pilgrim to its group's centroid and whether or not the pilgrim's geolocation is where it is supposed to be according to the pilgrimage schedule, the algorithm determines if the pilgrim is astray or on a verge of becoming astray. Algorithm complexity analysis is performed. For better performance and shorter real-time time to determine the pilgrim's status, the algorithm employs an in-memory data structure. The analysis showed that the time complexity is O(n). The algorithm has also been tested using simulation runs based on synthesized data that is randomly generated within a specified geographical zone and according to the pilgrimage plan. The simulation results showed good agreement with the analytical performance analysis.

***Keywords*—In-Memory structure; real-time; tracking algorithm for astray pilgrim; large crowd management**

I. Introduction

Managing of large crowds represent significant challenges to in numerous large-crowd events across the globe. One of the largest, most noticeable and frequent of these events is the Muslim pilgrimage to Mecca (Hajj). Every year around three million pilgrim travel to perform their life duty of pilgrimage. Several challenges face those millions of pilgrims including the fact that they probably have never been to those places before in addition to the lack of knowledge of the Arabic language, the language of the land. Pilgrims also need to visit numerous places as part of their Hajj rituals. The landscape of the majority of those places are mountainous (Such as Mount Arafat and Muzdalifah) or do not have street names but rather a tremendous camp site of tens of thousands of tents (the region on Mena). Those destinations have a relatively small area of a few square kilometre which constitutes very high-density population with many of elderly men, women and children.

A significant challenge that faces the authority is Saudi Arabia is that many of these pilgrims go astray during their once-in-a-lifetime journey which could mean they miss the time window of the rituals thereby invalidating the whole Pilgrimage and waste their lifetime saving. In fact, a published study showed that around 70% of the male pilgrims are over 60 years old and 30% of them are illiterate [1]. In a previous year, around 20,000 pilgrims were went astray during the trip [2].

Existing systems that help guide the lost pilgrims rely on the pull model. In other words, if the authority locates an astray person then they read his/her information that is barcoded on wearable device, such as a bracelet. An authority personal then guides that pilgrim to their destination/group/tent. There could be much time wasted prior to locating an astray pilgrim which increases the possibility that pilgrimage is invalid. In many cases pilgrims are unable to use mobile phones due to poor coverage given the large number of subscribers or due to an empty battery and the unavailability of nearby charging facilities.

A. Previous Work

Previous systems used in the kingdom of Saudi Arabia to track and guide the astray pilgrims are mainly human based. The kingdom has hired thousands of boy scouts during Haj season for the purpose of guiding the lost Haj. But these systems in place are poll-type systems, i.e. the pilgrim has to actually reach to the center of lost Haji's or they have to come across one of the guides. It might be such time before the pilgrim is guided. The guide uses the name tag – that includes very limited information – to identify the pilgrim and their group and/or tent location in Mena [3]. Last year, the Saudi announce the launching of the "Electronic bracelet" project [4]. It includes information about the pilgrim but it is not equipped with a facility to report that the pilgrim is lost neither with the ability to send their location and information over a wireless network. In another work by Mohandes [5] RFID tags were used to store pilgrim information such as name, passport info, country. It was also suggested that the tags can be used to track the pilgrims by placing an RFID reader in the vicinity. Tracking of hundreds of thousands requires thousands of RFID readers while the lost ones are in thousands only. The system does not give the ability to the pilgrim to identify themselves as lost but rather it attempts to detect a lost pilgrim by tracking all of the pilgrim. This solution is an overkill and it also produces many false alarms. In [6], the authors spoke about a smart RFID system but the objectives of such a system was to store the personal information about the pilgrim as well as their medical information that will be of help in emergency situations. The system does not use a GPS module to locate the pilgrim and can only be used for location purposes in shorter ranges (100 meters of so). This is not suitable for the whole pilgrimage area which extends for several kilometers (10 km). In [7], however, the authors introduced a GPS based tracking system to locate each and every Haj and store their medical information. This system requires powerful servers and are implemented in discreet components. The proposed system does not consider the size, cost, and the power consumption. There are commercial products in the market that are designed for children tracking [8]. Examples of those products are AngelSense, hereO GPS, and AmbyGear. Those products however are pricy (from $120 - $170 USD) and the battery life is in around 40 hours. These devices are available as independent devices with no existing intercorrelation with no crowd management capabilities.

Traditional methods of creating databases in-disk suffer from long delays and does not satisfy the real-time performance requirements for many of today's applications. As an example, trading companies need to detect sudden changes in trading processes and act upon this change "instantaneously" (within few milliseconds). Such a targeted response time is impossible to achieve using traditional disk-based storage/processing systems. The solution is to keep the data in the random-access memory (RAM) all the time.

In-memory database systems have been used in the past [10, 11] but those techniques have been challenged by the recent evolution in hardware [12]. Previous work on in-memory data management and processing have focused on several aspects such as indexing [13, 14], data layouts [15], parallelism [16, 17], concurrency control and transaction management [18, 19], query processing [20, 21, 22] and fault tolerance [23, 24]. In this work we present an in-memory database solution for the purpose of large-crowd tracking at real-time.

II. The System Architecture

In a previous work, we presented an overall architecture of an astray pilgrim tracking system [9]. The architecture is shown in Fig. 1. It consists of a client side and a server side. The client is in the form of wearable devices that have a GPS module to transmit the current geo-locations frequently (every hour in normal situations). The devices are also connected to the mobile network via a SIM card from sending the geo-coordinated and receiving commands from the central station. The server side consists of a database storing the pilgrim's information including their ID and their group ID, current (and previous) GPS locations with the corresponding time stamps. The database design with the tables is discussed in the following section.

III. The Transactional Database Design

At the operational or transactional level, the main target of this work is to guide the astray pilgrim by sending them alert messages as well as to their group leader and the authorities. To achieve this objective the system design includes a normalized relational database that supports an improved real time operation. The main function of the central database is to record the pilgrims' geolocations and other necessary information for possible future data analytics. Fig. 2 shows the relational data that supports the storage of pilgrims' information as well as their geolocations and status during the Hajj period. The figure shows four tables; the Pilgrim, the Group, the PilgrimTracking, and the ResponsibleAuthority tables. The Pilgrim table, contains details about each pilgrim while the PilgrimTracking table contains the PilgrimID (GroupID and ID of pilgrim in the group), timestamp, GPSLocation, status of pilgrim and distance between the pilgrim and the centroid of the pilgrim's group. In addition, the information about the groups such as their IDs, leaders, phone numbers are stored in table Groups. Moreover, the table ResponsibleAuthority contains information about the authorities (managers, phone number and office location). Each table in the relational database has a primary key (single or compound). For instance, the primary key of table PilgrimTracking is compound of three attributes. The relationship between the tables are represented by using the concept of foreign keys. For instance, the attributes AuthorityID, PilgrimID, GroupID are foreign keys (FK) that are used to connect the tables of the database together.

IV. A server-side Real-Time Tracking Algorithm

As per the ministry of Haj in Saudi Arabia, a group leader is assigned for every 20 pilgrims. Therefore, we assume that the maximum number m of pilgrims in a group is 20. Each tracking device stores the personal information of the pilgrim. This includes the pilgrim ID which is composed of the original group ID and the number of the pilgrim within the group (maximum 20 pilgrims per group), Name, Date of Birth, phone, spoken language, nationality and gender. The original number of groups is calculated as follows:

Number of Original Groups = Total Number of Pilgrims / Maximum Number of Pilgrims in a group

As per the official document of the Ministry of Haj in Saudi Arabia, the total number of domestic and foreign pilgrims in 2017 was 2.4 Million. Therefore, the estimated number of groups is 2.4 M /20 = 120,000 groups.

A. *Tacking All Pilgrims using Two Dimensional Array as an in-Memory Structre*

Fig. 3 below depicts the processing steps for the server with the numbered circles showing the flow. It is at this stage that the in-memory structures are created and manipulated. Upon system start, each tracking device sends the geolocations and the timestamp to the centralized server via the RF interface. At the receiving end of the server is a dispatcher process. The dispatcher process receives the geolocation and the timestamp information and then stores this information into one of the two data structures, the PilgrimLocationRecord or the LostPilgrimRecord. The PilgrimLocationRecord is a two-dimensional array PilgrimLocationRecord[n, m] (where n is the number of groups (equation 1) and m is the maximum number of pilgrims in a group). Each element of this array is a structure that contains the current geolocation, the current timestamp, the status of the pilgrim (whether astray or not astray) and the pilgrim's distance from their group centroid. A group centroid is calculated as in Equation 1. The PilgrimLocationRecord array is created/updated every hour. The geolocations and timestamps are sent to the centralized server, however, the values of the status and distance from centroid are calculated and updated during processing of the received data. Algorithm 1 provides a concise overview of tracking all pilgrims every hour.

The process of determining lost pilgrims every hour is described as follows (Algorithm 1): Pilgrims move in groups. Each group consists of a maximum of 20 persons. For each group the group centroid is calculated using the GPS coordinates of each member of the group. A group centroid at any time is defined as the point in space where the sum of distances of this point to all group members is minimum. The centroid is given by Equation (1) below.

$$Cent = \min \sum_{ID=0}^{ID=m} LOC_{ID} - LOC_{cent} \qquad (1)$$

The average distance Dav of each group is also calculated based on Equation (2) below

$$D_{av} = \frac{\sum_{ID=0}^{ID=m} D_{ID}}{m} \qquad (2)$$

To determine if a pilgrim is astray it is hypothesized that if its distance to the centroid is three or more times the average distance Dav to his/her group, the an astray pilgrim status is declared. The status value of each pilgrim is either normal (N) if the pilgrim's distance to the centroid is less than three times Dav, or astray (L) if the distance is at least three times the Dav.

If a pilgrim's status is N, then an alert signal is sent to the wearable device to show a green color. If the status is L, however, a continuous red light is shown on the wearable device if L was persistent for three consecutive reads. Otherwise, a flashing red light is shown on the wearable device.

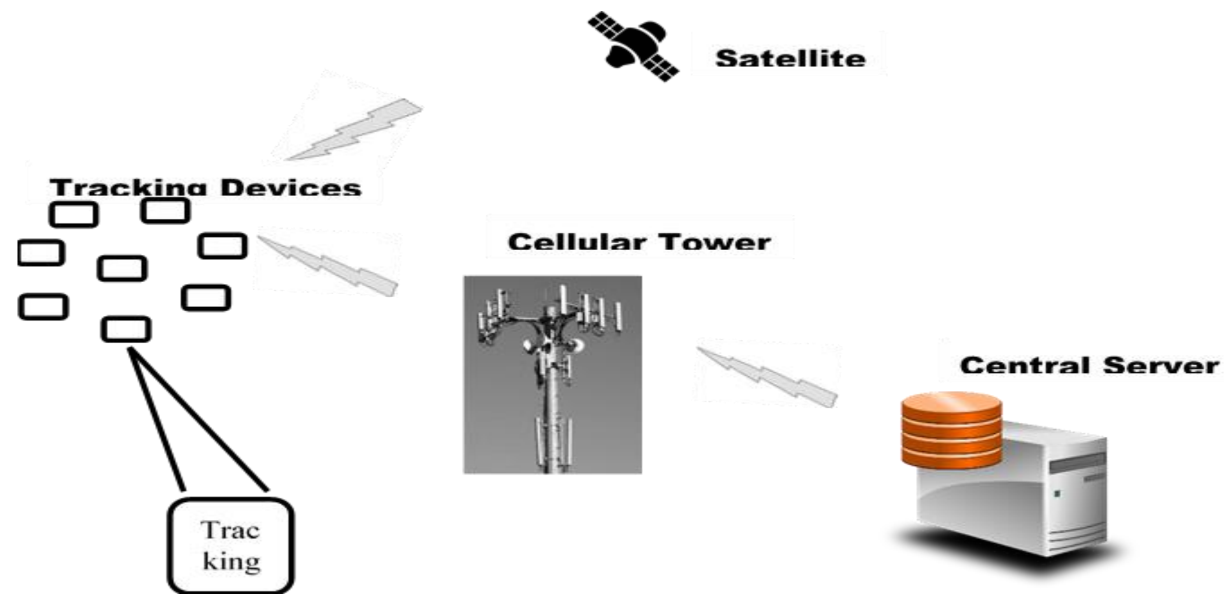

Fig. 1. The Astray Pilgrim Tracking System Architecture.

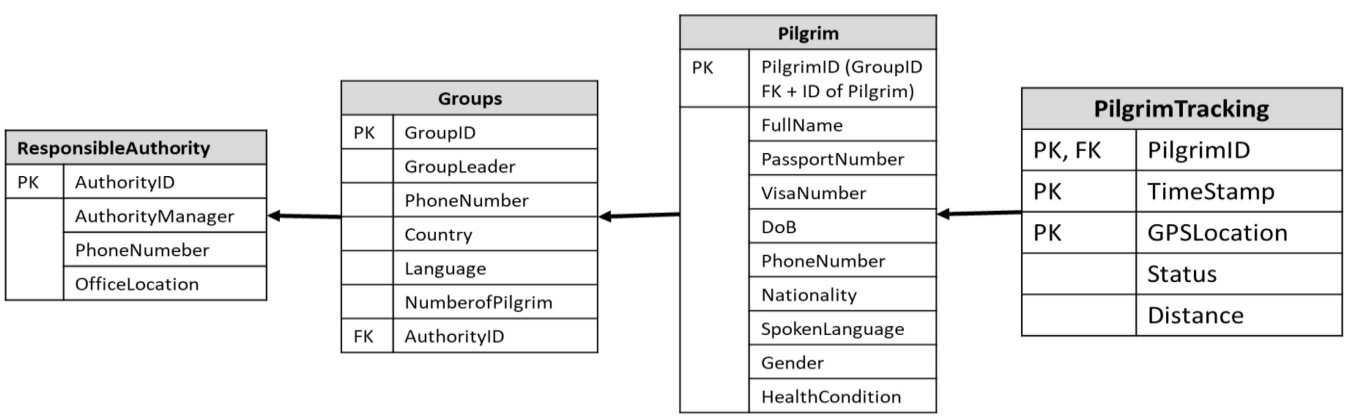

Fig. 2. The Centralized Database design.

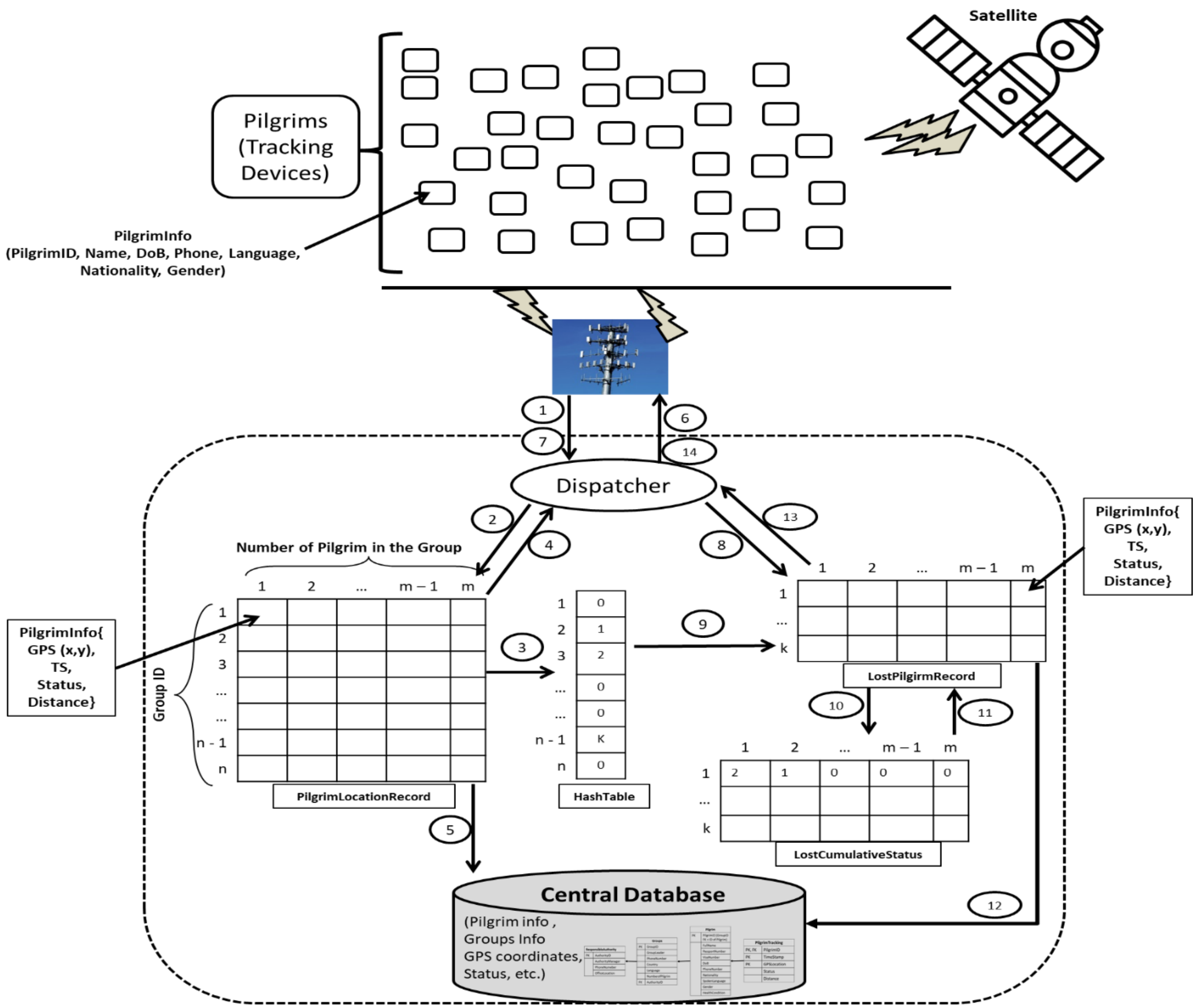

Fig. 3. The in-Memory Data Structures of the Server-Side Tracking Architecture.

The values of the status and the distance between the centroid and each pilgrim's GPS coordinate are updated in the PilgrimLocationRecord structure. If a pilgrim's status indicated a lost or is about to be lost (if the status is L for less than three consecutive times) the values of the PilgrimLocationRecord structure are flushed into the PilgrimTracking table in the central database (Step 5 in Fig. 3). Tracking information for all pilgrim is updated every hour. If a group has one or more lost member, all pilgrims in that group are tracked more frequently (every 10 minutes) to be able to determine the actual status of the pilgrim within the hour. Algorithm 2 shows the key steps of tracking lost pilgrims every ten minutes.

B. Hashing Structure

A hashing mechanism is used to map only the groups with lost pilgrims using their original ID while utilizing sequential places in memory for direct access and minimal memory size. The hashing mechanism is implemented as a one-dimensional array of n integers and is called HashTable (Fig. 3). This array is used to store indexes of groups who have lost pilgrims. Fig. 3 shows an example of the HashTable structure with n integers (where n is the number of original groups). A value of "0" in a given hash location means that this specific group has no lost members. A value other than "0" means there are nonzero lost members and the specific value gives the cumulative sequence number of this group in the lost pilgrims' groups. As an example, the HashTable[1] contains a value of zero and therefore group "1" has no lost members. On the other hand, the values of HashTable[2] and HashTable[3] mean that group 2 and 3 have lost pilgrims. The contents of the HashTable structure in Fig. 3 illustrates that there are k groups (group 2, 3, and n-1) with lost pilgrims. The HashTable structure ensures O(1) conversion of the original group ID to the appropriate index in the LostPilgrimRecord structure (A two dimensional array to track lost pilgrims more frequently (e.g. every 10 minutes)). For instance, the original group "3" is stored in the second row of the LostPLigrimRecord structure because HashTable[3] = 2 (meaning that the third group has lost pilgrim and will be stored in LostPilgrimRecord [2]).

Algorithm 1 Tracking All Pilgrims (every hour)

1. Create a two-dimensional array *PilgrimLocationRecord[n, m]*
2. Receive GPS coordinates and timestamps of all pilgrims' IDs
3. **for** each pilgrimID (*ID*) with GPS coordinate *G* and timestamp *TS* **do**
    - 3.1 Split the PilgrimID (*ID*) to get the group ID (*x*) and the ID (*y*) of the pilgrim within Group *x*
    - 3.2 Update *PilgrimLocationRecord [x, y]*.GPS = G
    - 3.3 Update *PilgrimLocationRecord [x,* y].timestamp = TS
4. Create an array of integers *HashTable [n]*, default value is 0
5. Create an integer variable *Lost*
6. Create a variable *nbGroupLost* and set it to 0 //number of groups with lost pilgrims
7. **for** each group g_i , where i =1,2, …, n **do**
    - 7.1 calculate the centroid c_i of g_i
    - *7.2 Lost* = 0
    - **7.3 for** each pilgrim *j* in group g_i , where *j* =1,2, …, m **do**
        - 7.3.1 calculate the distance *d* between *PilgrimLocationRecord*[i, j].GPS and c_i
        - *7.3.2 PilgrimLocationRecord*[i, j].distance = *d*
        - **7.3.3 if** d > LostDistance **then** // LostDistance = 1000 Meters
            - 7.3.3.1 send flashing signal to Pilgrim (i,j)
            - 7.3.3.2 PilgrimLocationRecord[i, j].status = 1 // 1 means lost, 0 means Not lost
            - *7.3.3.3 Lost* = 1
    - **7.4 If** Lost = 1 **then**
        - 7.4.1 Send request to the RFID tower to track the pilgrims in g_i every 10 minutes
        - *7.4.2 nbGroupLost* = *nbGroupLost* + 1
        - *7.4.3 HashTable*[i] **=** *nbGroupLost*
8. Insert all values of *PilgrimLocationRecord* structure into table *PilgrimTracking* (PilgrimID, TimeStamp, GPSLocation, Status, Distance)
9. Delete *PilgrimLocationRecord* structure from the main memory

C. Tracking Lost Pilgrims using Two-Dimensional Array as an in-Memory Strcuture

Once the groups with astray members are identified and the HashTable is constructed, an in-memory structure called LostPilgrimRecord is created (Fig. 3). This structure is a two-dimensional array with k rows and m columns (k represents the number of groups with astray pilgrims and m is the maximum number of pilgrims in a group). The LostPilgrimRecord array is used to store information about lost pilgrims every 10 minutes. The HashTable is used to get the appropriate index of each original group ID. For example, the information of pilgrim ID 21 (where original group ID is 2 and the ID of the ID of the pilgrim within group 2 is 1) is stored in LostPilgrimRecord [1, 1]. The centroid of each group is calculated and used to update the status and the distance between a pilgrim and his/her group centroid. A two-dimensional array LostCumulativeStatus[k, m] of integers is created to track the consecutive lost status of each pilgrim. Before sending any alert signal to the lost pilgrim, the LostCumulativeStatus (a structure to track the consecutive lost status of pilgrims) is checked to know how many consecutive times a pilgrim is reported lost. The process is as follows (1) If the status of pilgrim LostPilgrimRecord [i, j] is L (Lost), then the value LostCumulativeStatus[i, j] is incremented (2) else if the status of pilgrim LostPilgrimRecord [i, j] is N (Normal or Not Lost), then the value of LostCumulativeStatus [i, j] is reset to 0 and a green light is shown on the wearable device. There are three types of light indicators shown by the wearable device:

- A green light, which means everything is fine and the status is N.
- A flashing red light, which means that the pilgrim has been detected lost by the system for a number of consecutive times less than three.
- A continuous red light, which means that the pilgrim has been detected and confirmed lost.

For example, Fig. 3 shows that Pilgrim (21) has been detected to have been astray for two consecutive sampling times, whereas, Pilgrim (22) was detected lost for only one time. Finally, the values of the LostPilgrimRecord are flushed into PilgrimTracking table in the central database. Algorithm 2 shows the processing steps to track lost pilgrims every 10 minutes.

V. Theoretical Analysis (Size and Performance)

In this section, we discuss the main memory storage requirements and performance for the proposed in-memory structures and algorithms to track astray pilgrims during the haj period.

A. Size Complexity

The main memory storage requirements for the **PilgrimLocationRecord**, **HashTable, LostPilgirmRecord, LostCumulativeStatus** structure are quite impressive.

Algorithm 2 Tracking lost Pilgrims (every 10 minutes)

1. Create a two-dimensional array *LostPilgirmRecord [nbGroupLost, m]*
2. Create a two dimensional array of integers *LostCumulativeStatus [nbGroupLost, m]*
3. Receive GPS coordinates and timestamps of the pilgrims who belong to the groups with lost pilgrim(s)
4. **for** each pilgrimID (*ID*) with GPS coordinate *G* and timestamp *TS* **do**
    Split the PilgrimID (*ID*) to get the group ID (*x*) and the ID (*y*) of the pilgrim within Group *x*
    z = HashTable[x] //convert the original group ID into the corresponding index
    Update *LostPilgirmRecord [z, y]*.GPS = *G*
    Update *PilgrimLocationRecord [z,* y].timestamp = *TS*
5. Create an integer variable *Lost*
6. **for** each group g_i , where i =1, 2, …, *nbGroupLost* **do**
    calculate the centroid c_i of g_i
    Lost = 0
    for each pilgrim *j* in group g_i , where *j* =1,2, …, m **do**
        calculate the distance *d* between *LostPilgirmRecord* [i, j].GPS and c_i
        LostPilgirmRecord [i, j].distance = *d*
        if d > LostDistance **then** // LostDistance = 1000 Meters
            LostPilgirmRecord [i, j].status = 1
            increment *LostCumulativeStatus*[i, j] by 1
            if *LostCumulativeStatus*[i, j] > 2 **then**
                send a continuous signal to Pilgrim (i, j)
            else
                send flashing signal to Pilgrim (i, j)
        else
            LostCumulativeStatus[i, j] **= 0**
            Stop sending signal to Pilgrim (i, j), if any
7. Insert all values of *LostPilgirmRecord* structure into table *PilgrimTracking* (PilgrimID, TimeStamp, GPSLocation, Status, Distance)
8. Delete *LostPilgirmRecord* structure from the main memory
9. Repeat step 1 to 9 every 10 minutes

We suppose that there are *x* pilgrims and *m* pilgrims per group. The size of the pilgrim's GPS coordinate, timestamp, status and distance is *b* bytes. The size of each structure in the memory is calculated as follows:

- **PilgrimLocationRecord**: This structure contains the tracking information (GPS coordinates, timestamp, status and distance) of all pilgrims. It is created every one hour. The size of this structure is $\sum_{i=1}^{i=x} b$ bytes, where b number of bytes needed in each cell and x is the total number of pilgrims.
- **HashTable**: This structure contains the index of all groups with lost pilgrims. The size of this structure is $\sum_{i=1}^{i=n}(\lfloor\log_2 k\rfloor + 1)/8$ bytes, where n is the number of original groups (x/m) and k is the total number of groups with lost pilgrims.
- **LostPilgirmRecord**: This structure stores the tracking information of groups who have lost pilgrims. It is created and updated every 10 minutes. The size of this structure is $\sum_{i=1}^{i=k}(b * m)$ bytes, where k is the total number of groups with lost pilgrims and b is the size of each pilgrim's tracking information and m is the m is the maximum number of pilgrims per group.
- **LostCumulativeStatus**: This structure stores the number of consecutive lost status. It is created and updated evey 10 minutes. Each cell requires one byte to store the number of lost status. The size of this structure is $\sum_{i=1}^{i=k}(m)$ bytes.

Every hour the collective size of the existing memory structures (**PilgrimLocationRecord and HashTable**) is:

$$(\sum_{i=1}^{i=x} b) + (\sum_{i=1}^{i=n}(\lfloor\log_2 k\rfloor + 1)/8) \quad (3)$$

Every ten minutes, the collective size of the existing memory structures (**HashTable, LostPilgirmRecord** and **LostCumulativeStatus**) is:

$$(\sum_{i=1}^{i=n}(\lfloor\log_2 k\rfloor + 1)/8) + (\sum_{i=1}^{i=k}(b * m)) + (\sum_{i=1}^{i=k}(m)) \quad (4)$$

In practice, the required memory capacity of the aforementioned in-memory structure would likely be no more dozen megabytes for huge number of pilgrims. As per the ministry of haj report [reference], the number of haj in 2017 was 2.4 M and there were 20000 lost pilgrim during the five-day haj period. In average, there were 4000 lost pilgrims every day and 167 lost pilgrims every hour. The maximum size of each pilgrim tracking information (GPS coordinate, timestamp, status, distance) is 32 bytes.

The required memory capacity of the in-memory structures every one hour is:

($\sum_{i=1}^{i=2.4M} 32$) + ($\sum_{i=1}^{i=2.4}(\lfloor \log_2 167 \rfloor + 1)/8$) = 76.8 Mbytes + 2.4 Mbytes = 79.2 Mbytes

The required memory capacity of the in-memory structures every 10 minutes:

($\sum_{i=1}^{i=2.4M}(\lfloor \log_2 167 \rfloor + 1)/8$) + ($\sum_{i=1}^{i=167}(32 * 20)$) + ($\sum_{i=1}^{i=167}(20)$) =

2.4 Mbytes + 0.11 Mbytes + 0.00334 Mbytes = 2.513 Mbytes

B. Performance Analysis

Algorithm 1 describes the process by which the central server receives and stores the tracking information of all pilgrims and identifies the lost pilgrims. The processing time overhead to support real time detection of astray pilgrims (Algorithm 1) can be estimated as follows:

- Time to create the two dimensional array *PilgrimLocationRecord[n, m]* is O(n * m), where n is the number of groups and m is the maximum number of pilgrims in a group
- Time to receive and store the GPS coordinates and timestamps of all pilgrims into *PilgrimLocationRecord* is O(n*m). More specifically, the time to receive each pilgrim's tracking information and to store it into the *PilgrimLocationRecord* is O(1) because the pilgrim ID is used to identify the corresponding group ID (row index) and the ID of the pilgrim (column index) within the group.
- Wost case time to calculate the centroid of all groups and to identify the astray pilgrims and to update the status of pilgrims in the *PilgrimLocationRecord* is O(m * n)
- Time to crate the HashTable and to insert the indexes of the groups with loast pilgrims is O(n)

The number of I/O required to flush the tracking information of all pilgrims (*PilgrimLocationRecord)* into the database disk storage is O($\left(\frac{\sum_{i=1}^{i=x} b)}{s}\right)$, where x is the total number of pilgrims (n * m), s is the size of disk block and b is the number of bytes required to store the tracking information of each pilgrim (GPS, timestamp, status and distance). Collectively, the CPU processing time to detect astray pilgrims is O(n * m) and the number of I/O to store the tracking information into the disk storage is O($\left(\frac{\sum_{i=1}^{i=x} b)}{s}\right)$ I/O.

Algorithm 2 shows the steps by which the central server receives and stores the tracking information of lost pilgrims more frequently (every 10 minutes). The processing time overhead to support real time detection of lost pilgrims more frequently (Algorithm 2) can be estimated as follows:

- Time to create the *LostPilgirmRecord* and *LostCumulativeStatus* is O(m * k), where m is the maximum number of pilgrims in a group and k is the total number of groups with lost pilgim(s).
- Time to receive and store the GPS coordinates and timestamps of lost pilgrims into *LostPilgirmRecord* is O(m*k).
- Wost case time to calculate the centroid of all lost groups, to identify the astray pilgrims and to update the status of pilgrims in the *LostPilgirmRecord* is O(m * k)
- Time to access the HashTable is O(k)
- Worst case time to access the *LostCumulativeStatus* and update the consecutive lost status is O(m*k)

The number of I/O required to flush the tracking information of lost pilgrims (*LostPilgirmRecord*) into the database disk storage is O($\left(\frac{\sum_{i=1}^{i=k}(b*m))}{s}\right)$, where k is the total number of lost groups s is the size of disk block and b is the number of bytes required to store the tracking information of each pilgrim (GPS, timestamp, status and distance). Collectively, the CPU processing time to detect astray pilgrims is O(m * k) and the number of I/O to store the tracking information into the disk storage is O($\left(\frac{\sum_{i=1}^{i=k}(b*m))}{s}\right)$ I/O.

The aforementioned theoretical analysis of the size and performance of the proposed architecture demonstrates that the in-memory structure requirements are of an affordable size and the processing overhead is within tolerated limits to support real time detection of astray pilgrims.

VI. Simulations and Results

Actual pilgrimage data showing the path of pilgrims and their geolocations are not currently available since the proposed system is the first of its kind. Therefore, we have used a synthesized data for the purpose of running simulation of the proposed algorithm. A random geolocation data sets were continuously generated within a specific geographical region that correspond to those visited by the pilgrim. Pilgrims were assigned to groups of a maximum of 20 person in each group. At each time slot, a new set of geolocations are generated for all the groups and are used to calculate the group's centroid. In order to simplify the simulation, it was assumed that a pilgrim is considered astray if their distance from the centroid is 1.5 kilometer. Simulation runs for various values of the total number of pilgrims (from 500,000 to 3000,000 pilgrims) were performed and the time to calculate the total number of pilgrims that actually went astray was measured. Fig. 4 shows the variation of the algorithm calculation time with the number of pilgrims. The results showed linear performance which is a good agreement with the analytical analysis.

VII. Conclusions and Future Work

In this work we presented the design and implementation of a distributed architecture and the research challenges of a pilgrim tracking, guiding, and astray-pilgrim detection system. The system consists of a client side that is a wearable device built as a system-on-chip and a server that stores personal information as well as the GPS coordinates and corresponding time stamps during the full duration of the pilgrimage journey (five days). The main objectives to be achieved in this work at the client side is that the wearable device is compact, low cost, and of low-power consumption to allow for a battery life to extend for at least five days. This include employing a power-efficient algorithm by properly selecting the inter-GPS fix times. The designed system automatically determines if a given pilgrim is potentially astray and is likely to miss one of the important rituals of the pilgrimage. On the server side, the entire pilgrimage model is stored including the geolocations of the regions and paths. The system automatically reports any lost or potentially lost pilgrims as well as alerts the pilgrim him/herself and sends alarms to the authorities for timely intervention. The in-memory structure used along with the algorithms enables real-time performance to avoid lengthy database queries. Simulation runs with synthesized data that is randomly generated within a given geographical location was performed. The simulation calculated the time to determine the number of pilgrims at a specific time slot as the number of pilgrims is varied. The simulation results showed a linear time performance which is in a good agreement with analytical analysis performed.

In future work and when real data is obtained, many useful data analytics can be performed which will avail and reveal new information that opens new door for better service and less astray pilgrims.

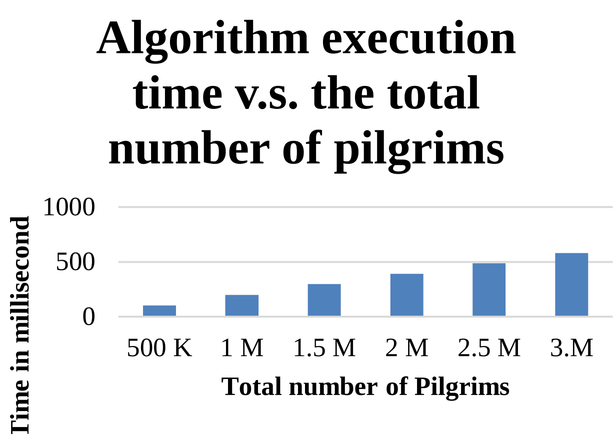

Fig. 4. Algorithm Execution Time vs. the Total Number of Pilgrims.

REFERENCES

[1] "A study requesting to set upper age limits due to the spread of some diseases of the elders" 2006. [Online]. Available: http://www.alarabiya.net/articles/2006/12/28/30302.html [Accessed: 25 – Jan – 2018]

[2] Omar Elhalawy, "60% of pilgrims perform pilgrimage for the first time" 2017. [Online]. Available: http://www.alittihad.ae/details.php?id=41778&y=2017 [Accessed: 25 – Jan. – 2018]

[3] "The Origin and Activities of the ministry of Hajj and Umrah" 2014. [Online]. Available: http://www.haj.gov.sa/arabic/about/opendatapalteform/pages/ministrieorigination.aspx. [Accessed: 25-Jan.-2018].

[4] Shrooq Hisham, "For the first time, applying the electronic bracelet service in pilgrimage" 2016. [Online]. Available: http://www.hiamag.com/منوعات/اخبار/397051-لاول-مرة-تطبيق-خدمة-السوار-الالكتروني-في-الحج [Accessed: 25 – Jan. 2018]

[5] Mohandes, M., Turcu, C. "A Case Study of an RFID-based System for Pilgrims Identification and Tracking" in Sustainable Radio Frequency Identification Solutions, pp. 87–104. InTech, Dahran, Saudi-Arabia, 2010.

[6] Abeer Geabel, Khlood Jastaniah, Roaa Abu Hassan, Roaa Aljehani, Mona Babadr, Maysoon Abulkhair "Pilgrim Smart Identification Using RFID Technology (PSI)" International Conference of Design, User Experience, and Usability DUXU 2014.

[7] KC Rajwade, DH Gawali "Wearable Sensors Based Pilgrim Tracking and Health Monitoring system" International conference on Computing Communication Control and automation (ICCUBEA), 2016.

[8] "The 15 Best GPS Kids Trackers for Parents with Young Kids" 2016. [Online]. Available: https://www.safewise.com/blog/10-wearable-safety-gps-devices-kids/. [Accessed: 25 – Jan. 2018]

[9] M. A. R. Abdeen, "A Distributed Architecture and Design Challenges of an Astray Pilgrim Tracking System" The Fourth *IEEE International Conference* on Big Data Intelligence and Computing (DataCom 2018), Athens, Greece, August, 2018.

[10] H. Garcia-Molina and K. Salem, "Main memory database systems: An overview," IEEE Trans. Knowl. Data Eng., vol. 4, no. 6,pp. 509–516, Dec. 1992.

[11] V. Sikka, F. F€arber, W. Lehner, S. K. Cha, T. Peh, and C. Bornh€ovd, "Efficient transaction processing in SAP HANA database: The end of a column store myth," in Proc. ACM SIGMOD Int. Conf. Manag. Data, 2012, pp. 731–742

[12] Zhang, Hao, Gang Chen, Beng Chin Ooi, Kian-Lee Tan, and Meihui Zhang. "In-memory big data management and processing: A survey." IEEE Transactions on Knowledge and Data Engineering 27, no. 7 ,2015: pp. 1920-1948. D. B. Lomet, S. Sengupta, and J. J. Levandoski, "The Bw-Tree:

[13] A B-tree for new hardware platforms," in Proc. IEEE Int. Conf. Data Eng., 2013, pp. 302–313.

[14] V. Leis, A. Kemper, and T. Neumann, "The adaptive radix tree: ARTful indexing for main-memory databases," in Proc. IEEE 29th Int. Conf. Data Eng., 2013, pp. 38–49. Y. Li and J. M. Patel, "BitWeaving: Fast scans for main memory data processing," in Proc. ACM SIGMOD Int. Conf. Manag. Data, 2013, pp. 289–300.

[15] Z. Feng, E. Lo, B. Kao, and W. Xu, "Byteslice: Pushing the envelop of main memory data processing with a new storage layout," in Proc. ACM SIGMOD Int. Conf. Manag. Data, 2015.

[16] A. Pavlo, C. Curino, and S. Zdonik, "Skew-aware automatic database partitioning in shared-nothing, parallel OLTP systems," in Proc. ACM SIGMOD Int. Conf. Manag. Data, 2012, pp. 61–72.

[17] W. Rodiger, T.Muhlbauer, P. Unterbrunner, A. Reiser, A. Kemper, and T. Neumann, "Locality-sensitive operators for parallel mainmemory database clusters," in Proc. Int. Conf. Data Eng., 2014, pp. 592–603.

[18] V. Leis, A. Kemper, and T. Neumann, "Exploiting hardware transactional memory in main-memory databases," in Proc. Int. Conf. Data Eng., 2014, pp. 580–591.

[19] Z. Wang, H. Qian, J. Li, and H. Chen, "Using restricted transactional memory to build a scalable in-memory database," in Proc. 9th Eur. Conf. Comput. Syst., 2014, pp. 26:1–26:15.

[20] M.-C. Albutiu, A. Kemper, and T. Neumann, "Massively parallel sort-merge joins in main memory multi-core database systems," Proc. VLDB Endowment, vol. 5, pp. 1064–1075, 2012.

[21] S. D. Viglas, "Write-limited sorts and joins for persistent memory," Proc. VLDB Endowment, vol. 7, pp. 413–424, 2014.

[22] O. Polychroniou and K. A. Ross, "A comprehensive study of main-memory partitioning and its application to large-scale comparison-and radix-sort," in Proc. ACM SIGMOD Int. Conf. Manag. Data, 2014, pp. 755–766.

[23] A. Kemper and T. Neumann, "HyPer: A hybrid OLTP & OLAP main memory database system based on virtual memory snapshots," in IEEE 27th Int. Conf. Data Eng., 2011, pp. 195–206.

[24] R. Kallman, H. Kimura, J. Natkins, A. Pavlo, A. Rasin, S. Zdonik, E. P. C. Jones, S. Madden, M. Stonebraker, Y. Zhang, J. Hugg, and D. J. Abadi, "H-store: A high-performance, distributed main memory transaction processing system," Proc. VLDB Endowment, vol. 1, pp. 1496–1499, 2008.

A Decision Support Platform based on Cross-Sorting Methods for the Selection of Modeling Methods

Case of the Hospital Supply Chain Performance Analysis

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***Abstract*—The hospital supply chain performance is a concept that qualifies the good governance, the continuous improvement and the optimization of human and material resources of the hospital system. Thus, several performance analysis methods have been proposed for qualifying organizational flows and resources management. The main goal of the present study is to expose a literature review of the main graphical modeling and performance analysis techniques used in different research projects in the hospital field. The literature review will be analyzed and complemented by a classification study of the previous techniques. It is about a review in which will be proposed a computer platform based on Multi-Criteria Decision Analysis. This platform uses fuzzy pairwise comparisons and cross-sorting methods. Finally, the classification study is chosen in order to highlight the most adapted techniques to the different characteristics and components of the hospital system as part of the overall support decision process.**

Keywords—Hospital supply chain; graphical modeling and performance analysis techniques; multi-criteria decision analysis; fuzzy pairwise comparisons; support decision process; computer platform; cross-sorting methods

I. Introduction

Currently, healthcare system challenges aren't limited to provide high-level service to patients at all costs, but it include optimization of hospitals expenses by decreasing costs and increasing productivity of resources.

In fact, for succeeding these challenges, the hospital decision makers must understand the complexity of the healthcare system at different levels. The authors of [1] have proposed: "*they need to recognize the types of sub-systems that constitute the whole healthcare system, the operations within each sub-system, the main bottlenecks and their causes, which actions are efficient and which are not, and the impact of changes and actions on the overall performance system*".

The major reflection of researchers in the healthcare field is the performance improvement of the hospital supply chain. Indeed, the authors of [2] explain that the improvement needs to be continuous by analyzing continually the performance in order to highlight aspects and action variables that influence directly the hospital system. For this purpose, several research works presented in the literature have treated the performance analysis concept in the hospital field and have used to this purpose different modeling methods. In fact, system performance analysis or improvement will be done by using modeling methods that allow describing the organization of the processes. The next step is about simulating it and comparing the different scenarios, or by analyzing and restructuring them.

In the hospital supply chain context, the development of modeling methods is done by considering the problems from which the system suffers and which hinder its development and performance.

Two types of performance analysis procedures exist [2]:

- **Priori approach:** To establish firstly a model, analyze and apply it to achieve its performance. The result will be compared with the predefined objectives and different changes of the model action variables will be proposed until stabilizing the model.
- **Posteriori approach:** To measure performances of an existing real system. Then, compare these measures with the predefined objectives and propose actions in order to improve the system.

In our present case, we will study the posteriori performance evaluation approach by considering the hospital system as an existing real system that the major studies focus on its identification and improvement.

However, the question is: Which of the several modeling methods to choose for describing effectively the hospital supply chain? Any system must to be modeled with respect to the strategy and the nature of the company's business. Therefore, our main work is based on the research in the literature of the several modeling methods, nature of stakeholders in their uses and recommendations of experts concerning their performances and limitations.

For this reason, we propose in this paper, the multi-Criteria decision analysis based on fuzzy pairwise comparisons to succeed the making decision process dedicated for choosing the best modeling methods.

The remainder of this paper is structured as follows: In section 2, we give an abstract about the different definitions given in the literature to hospital supply chain and its global structure. Then, we propose in section 3, a benchmark of the different modeling methods used in the hospital supply chain.

In section 4, we develop the classification study by identifying our methodology of research, determining criteria and applying the calculation algorithm.

II. Literature Review : Modeling Methods in Hospital Supply Chain

A. *Hospital Supply Chain*

The hospital system has been defined in the literature by all the flows (physical flow, informational flow and financial flow) which ensure the proper functioning of its institutions. The authors of [3] characterized the hospital system by an open system which is in interaction with external entities (logistic or medical service delivery entities). An analogy between hospital system and industrial system was mentioned in [4] and [5] by considering the process of production and in [3] by considering the orientation of flows and nature of stakeholders.

Thus, the performance in hospital supply chain has become instead of the qualification of the medical treatments a qualification of the sector organization and the quality of the care service [6]. Otherwise, the good management of material flow and patient flow are the keys for improving the hospital supply chain performance.

Several definitions of the hospital supply chain have been developed throughout the years. In fact, a set of dimensions have been developed to cover the integral definition of this supply chain (managerial and technical aspects [7]).

The notion of support logistics has been mentioned in [8]; it concerns supply, handling, maintenance and installation activities. The authors of [9] have based the hospital supply chain activities on three main activities: supply, production and distribution. Thus, according to [10] the hospital supply chain consists of the information, service, patients and physical flows management from the suppliers to the patients.

In [7], the author proposes the following definition: “Hospital supply chain is the set of design activities, planning, procurement management, manufacturing (goods and services), delivery and return management, from the provider to the beneficiary (patients), taking into account all the trajectories of the patients in the hospital without which there is no product flows (pharmaceutical). These activities are driven by the information flow between the various partners in the supply chain and lead to financial flows. The aim is to provide optimal service for the quality and safety of patient care”.

After scanning several definitions that were given by the literature, the next section will be dedicated to discover more deeply the structure and the different stakeholders of the hospital supply chain.

B. *Structure of the Hospital Supply Chain*

In this section, we will try to detail the global structure of the hospital supply chain, the different internal flows and those that are in interaction with external stakeholders.

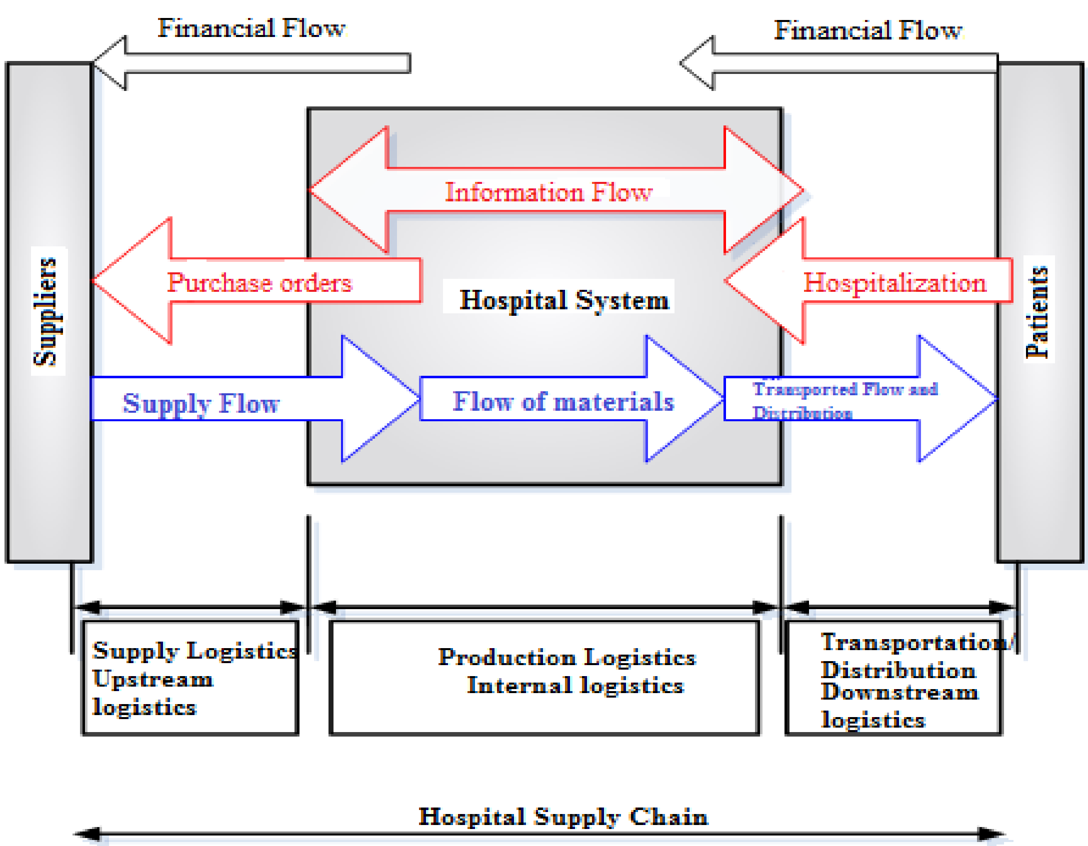


Fig. 1. The Structure of the Global Hospital Supply Chain According to [2].

According to [11], health institutions have five main activities and several types of inputs (patients and primary entrants) and outputs (intermediate and final outputs) are involved for the implementation of these activities. Otherwise, [12] was based to establish its proposal for the hospital supply chain structure on the following five factors which are related to the product life cycle: design, production, exploitation, distribution, destruction or recycling.

Moreover, [7] gives a proposal for the structure which focuses on the pharmaceutical component of the hospital system. Its proposal includes three levels. Firstly, an upstream level where the main actors are the suppliers or manufacturers of the pharmacy; The suppliers ensure the supply of pharmaceutical products to the pharmacy. Secondly, a first downstream level which characterizes the relationship between the pharmacy and the other services. The main activity of the pharmacy is to provide the pharmaceutical products received from the suppliers after or without transformation to the different hospital services. Finally, a second downstream level that concludes stocks management, returns management and the supply of pharmaceutical products to patients.

From the previous definitions, it is proposed a structure that implements the different levels and components of the hospital supply [2] (see Figure1):

C. *Graphical Modeling Methods*

The literature has been enriched in recent years by several researches dealing with the problems of hospital system. In this section, we analyze the different cases treated in the literature that concern the hospital supply chain and in which researchers have proposed performance analysis methods especially the graphical modeling methods.

The modeling studies that are present in the literature concern the main production flow within the hospital, patient flows, administrative flows and resources which are related to primary services as well as operating theaters, emergency units, consultation centers, etc. According to [7], the difficulties of optimizing flows and stocks pushed the managers to find balances and to discover new ways in order to rationalize expenditures and seek refined solutions to these new problems.

The remainder of this work focuses on methods that are used in the modeling and simulation approach. It is about modeling and simulating the action data by evaluating the performance of the system in order to reach the objectives represented by an interesting number of performance indicators [13].

In fact, it can be referred to two different types of studies [14]: studies that concern the planning and optimization of care production units ([15]; [16]) and that of operations management which propose models and the theories dealing with the current problems that the patient circuit knows in the hospital ([17];[18]; [7]; [6]).

For example, the author of [19] have linked in his work the following objectives to the modeling approach:

- Improvement of the decision-making organization and reduction of the hospitalization duration [20]
- Reduction of the waiting time in emergency unit [21]
- Reduction of the time spent by the patient in the emergency units and improvement of its performances [22]
- Restructuration of medical personnel assignment problem [23]
- Minimization of the pharmaceutical supply chain expenditures.

In each case study, the literature includes a framework rich in modeling methods and their attributions.

The modeling and simulation approach has used by the authors [6] to minimize the cycle time of the patient journey in emergency department, to improve the medicine drugs circuit in Moroccan hospital system [1] and to optimize the blood transfusion process in Blood Transfusion Regional Center of Casablanca-Morocco [23].

The authors of [6] used for the modeling part the IDEF3x method and for the simulation part the queue networks. The queuing theory was used by [22] in order to insure the optimal service rate by determining the adequate combinations of human and materiel resources to be attributed to each inpatient unit room. Researchers are also developed and adapted industrial platforms in order to exploit their strengths in producing outstanding results. For example, the industrial planning software (PREACTOR) was used by the author [18] for managing in real time the patient's trajectory in the hydrotherapy and the radiotherapy centers.

In the table below (table I), we indicate works applying modeling methods in the hospital supply chain.

TABLE I. GRAPHICAL MODELING METHODS APPLYED IN HOSPITAL SUPPLY CHAIN

Authors	**Modeling Method**	**Hospital Field**	**Flow Type**
[24]	SADT	Blood transfusion	Informational flow
[25]	UML, SADT Petri Networks	Hospital Processes	Patient flow, informational flow
[26]	SADT	Emergency department	Patient flow
[6]	SADT	Emergency department	Patient flow
[27]	UML	Hospital processes	Patient flow
[28]	UML, SADT Petri Networks	Production and Distribution supply chain	Materials flow
[29]	UML, Petri Net	Hospital supply chain	Drugs flow
[30]	ARIS	Hospital Supply Chain	Supply chain flows
[31]	BPMN	Hospital Materials	Patient and materials flows
[32]	BPMN, SCOR	Drugs supply chain	Drugs flow
[33]	BPM	Hospital Supply Chain	Pharmaceutical Products flow

In a similar study, [34] has attempted to analyze a set of modeling methods using the criteria proposed by CEN [35] to develop a system of performance indicators. In this context, a classification platform that will allow choosing the appropriate modeling method is proposed in the next section.

III. The Decision Support Platform for the Selection of Modeling Methods in the Hospital Supply Chain

A. Research Methodology

The global methodology adopted in this work for analyzing the literature review and developing the decision support platform is summarized on the following steps:

Step 1: To look for the modeling methods used in the hospital system literature. It is about the web-based search in electronic databases. The electronic databases chosen are as follows:

- Thomason Reuters;
- ScienceDirect;
- DPLB;
- Springer;
- IEEE;
- IJACSA,
- Google scholar,

In this step, the following key words were adopted: hospital supply chain; performance analysis techniques; modeling; simulation.

Step 2: To sort the works obtained in the previous step by remaining in the study framework; refine the obtained database and eliminate any work that does not align with the main objective.

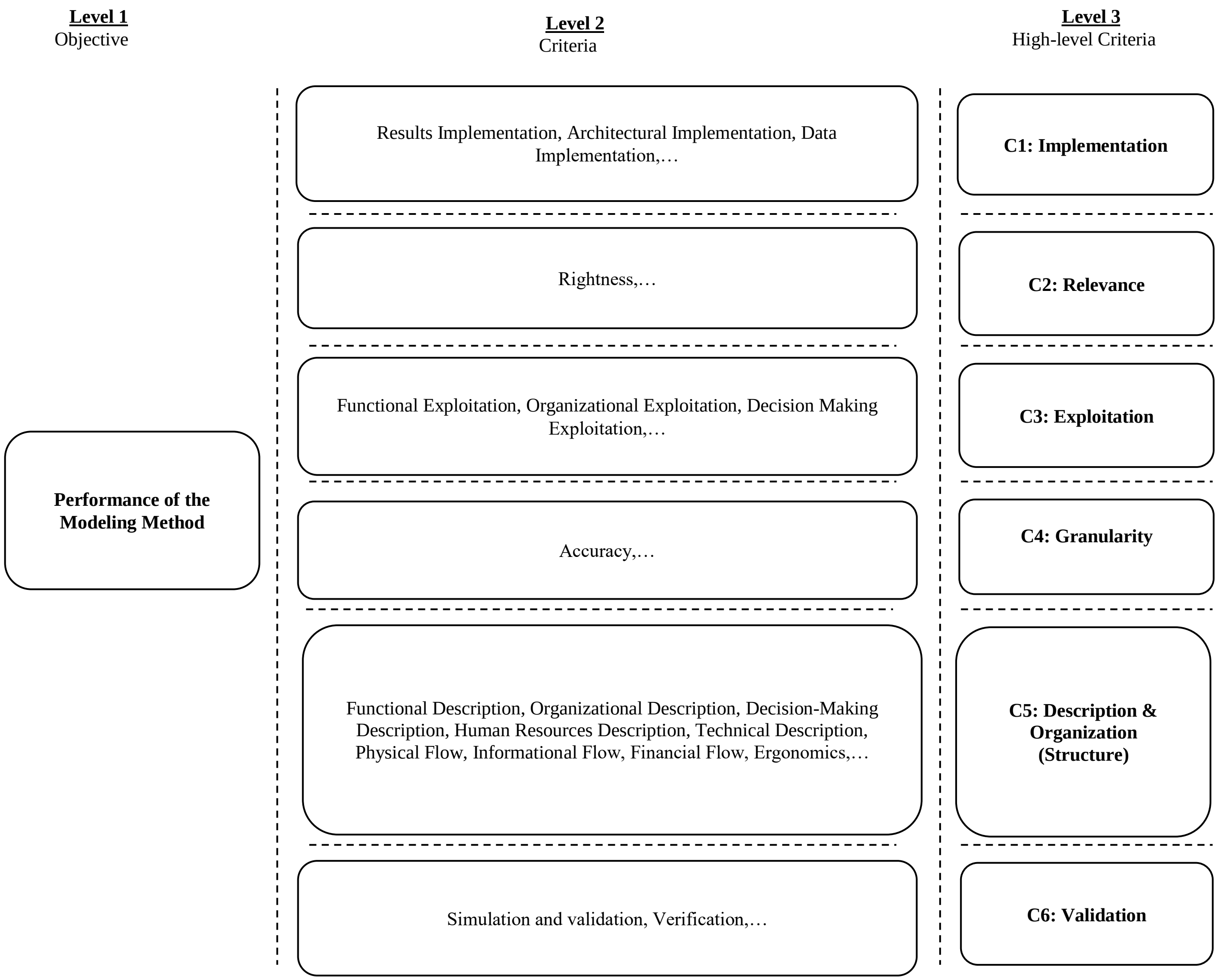


Fig. 2. Criteria of the Modeling Methods Performance.

Step 3: To develop a platform based on the cross sorting methods and fuzzy pairwise comparisons for classifying modeling methods that are used in the literature; this classification framework uses the following criteria: Functional Description, Organizational Description, Decision-Making Description, Human Resources Description, Technical Description, Physical Flow, Information Flow, Financial Flow, Ergonomics, Rightness, Functional Exploitation, Organizational Exploitation, Decision Making Exploitation, Accuracy, Results Implementation, Architectural Implementation, Data Implementation, Simulation and validation, verification.

Step 4: To choose experts and request from them to fill the comparison matrices (comparison matrices of criteria and comparison matrix of methods).

Step 5: To classify methods of the literature according to the platform based on the cross sorting methods.

B. The Modeling Methods: Application of the Classification Study

Our classification study aims to analyze the adaptability of the modeling methods, used in the process of performance analysis, to the various components of the hospital supply chain. To do this, we tried at first to gather the most used techniques in the literature concerning the hospital sector and to classify them according to six criteria as developed on the next section (see Figure 2) by using multi-criterion decision analysis based on fuzzy pairwise comparisons.

1) Criteria of Modeling Methods Performance: In this section, we present criteria that are adopted for the comparison between different modeling methods. At first, the principal criteria of the modeling methods performance will be detailed. Secondly, the criteria will be grouped on six principal axes: Implementation, Relevance, Exploitation, Granularity, Description & Organization (Structure) and Validation (see Figure 2).

2) Calculation of Final Scores (Scores of Criteria and Scores of Modeling Methods)

a) Fuzzy Logic: Definition

The fuzzy logic is based on the use of fuzzy numbers which are defined by distribution of possibility. The membership function μ identify this distribution by associating digital elements with different degrees of the possibility that vary between 0 and 1 [36]. In fact, the membership functions exist in different forms: Triangular, trapezoidal or Gaussian form [37].

The use of the fuzzy logic is large in the literature. In the rest of this work, it is opted for the triangular function adopted by [38] in their extension of the principle of least-squares logarithmic regression for taking into account the inaccuracy. The triangular function is defined by the lower value (c_l), the modal value (c_m) and the upper value (c_u) as shown in the figure below (Figure 3).

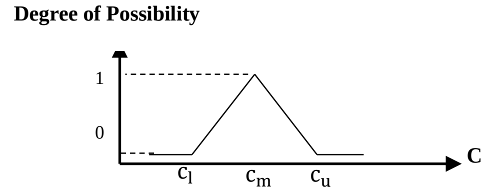


Fig. 3. Triangular Fuzzy Number.

b) Description of the Calculation Algorithm

To determinate the final scores of the studied modeling methods considering the six performance criteria of decision which are cited above, it is opted for the fuzzy multi criteria method proposed by [38] and modified by [39]. The choice of this method was not made arbitrarily but was based on the originality of his theory in terms of taking into account the inaccuracy in spite of the extensions which have been proposed later and which merely adopt other logics which also have their limitations or sometimes violate the assumptions of validity of the initial approach (for example the adoption of FWA algorithm in deterministic methods [36]).

In order to attack the allocation of triangular fuzzy pairwise comparisons, a decision committee of 3 members is defined A1, A2, A3.

The method will be applied in three main phases: Firstly, fuzzy weights $\tilde{\alpha}_i = (\alpha_{il}, \alpha_{im}, \alpha_{iu})$ i=1,…,m will be assigned to the performance criteria of decision based on fuzzy pairwise comparisons $\widetilde{r_{ijk}} = (r_{ijkl}, r_{ijkm}, r_{ijku})$ (i, j=1,…,m) given by committee members k=1,2,3. Secondly, fuzzy weights $\widetilde{\beta_{ij}} = (\beta_{ijl}, \beta_{ijm}, \beta_{iju})$ ($i, j = 1, \dots, n$) will be estimated for methods under each of the criteria separately. Lastly, the final scores of methods ω_j j=1, …, n are calculated by the aggregation of the calculated weights according to the formula below:

$$\omega_j = \sum_{i=1}^{m} \alpha_i \beta_{ij} \quad j = 1, \dots \dots, n \tag{1}$$

In fact, the weights will be estimated by minimizing a logarithmic regression function as shown in the formula (2) below and the fuzzy weights are deduced by the following developed formulas (3,4,5,6,7,8):

$$\ln(\alpha_i) \sum_{j \neq i}^{m} \delta_{ij} - \sum_{j \neq i}^{m} \delta_{ij} \ln(\alpha_j) = \sum_{j \neq i}^{m} \sum_{k \in D_{ij}} \ln(r_{ijk}) \qquad i = 1, \dots \dots, m \tag{2}$$

$$\ln(\alpha_{il}) \sum_{j \neq i}^{m} \delta_{ij} - \sum_{j \neq i}^{m} \delta_{ij} \ln(\alpha_{ju}) = \sum_{j \neq i}^{m} \sum_{k \in D_{ij}}^{m} \ln(r_{ijkl}) \qquad i = 1, \dots \dots, m \tag{3}$$

$$\ln(\alpha_{im}) \sum_{j \neq i}^{m} \delta_{ij} - \sum_{j \neq i}^{m} \delta_{ij} \ln(\alpha_{jm}) = \sum_{j \neq i}^{m} \sum_{k \in D_{ij}}^{m} \ln(r_{ijkm}) \qquad i = 1, \dots \dots, m \tag{4}$$

$$\ln(\alpha_{iu}) \sum_{j \neq i}^{m} \delta_{ij} - \sum_{j \neq i}^{m} \delta_{ij} \ln(\alpha_{jl}) = \sum_{j \neq i}^{m} \sum_{k \in D_{ij}}^{m} \ln(r_{ijku}) \qquad i = 1, \dots \dots, m \tag{5}$$

$$\tilde{\alpha}_i = \left(a \exp(x_{il}), b \exp(x_{im}), a \exp(x_{iu})\right) \ i = 1, \dots, m, \quad / \quad x_{il} = \ln(\alpha_{il}) \ \ x_{im} = \ln(\alpha_{im}) \ \ x_{iu} = \ln(\alpha_{iu}) \tag{6}$$

$$a=\frac{1}{\left(\sum_{i=1}^{m}\exp(x_{il})\sum_{i=1}^{m}\exp(x_{iu})\right)^{\frac{1}{2}}}\ ,\quad b=\frac{1}{\sum_{i=1}^{m}\exp(x_{im})} \qquad (7)$$

$$\tilde{\alpha}_i=\begin{pmatrix}\alpha_{il}\\ \alpha_{im}\\ \alpha_{iu}\end{pmatrix}=\begin{bmatrix}\dfrac{exp(x_{il})}{\left(\sum_{j=1}^{m}exp(x_{jl})\sum_{j=1}^{m}exp(x_{ju})\right)^{\frac{1}{2}}}\\ \dfrac{exp(x_{im})}{\sum_{j=1}^{m}exp(x_{jm})}\\ \dfrac{exp(x_{iu})}{\left(\sum_{j=1}^{m}exp(x_{jl})\sum_{j=1}^{m}exp(x_{ju})\right)^{\frac{1}{2}}}\end{bmatrix} i=1,..,m \qquad (8)$$

c) Develepement of the Decision Support Platform: Application of the Calculation Algorithm

In the present case, it has be appealed to three expert professors and present them the table below (table1) that shows the five used linguistic values (Very High, High, Equal, Low and Very Low) and theirs estimated values on fuzzy numbers (see table II). The experts are required to fill separately the comparison matrix of the six criteria (C1, C2, C3, C4, C5 and C6) (see Figure 2).

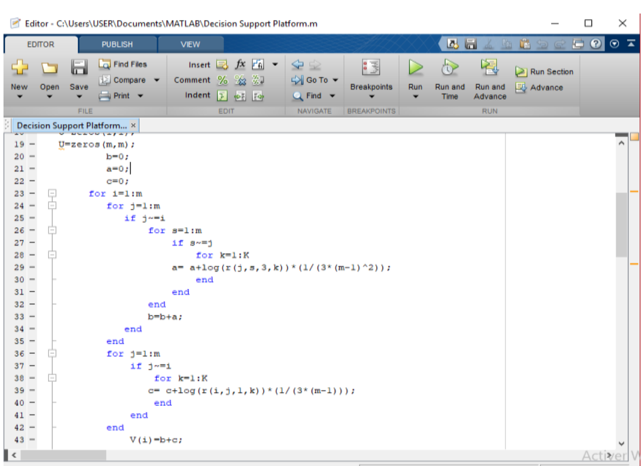
TABLE II. FUZZY NUMBERS VALUES OF LINGUISTIC VALUES

Linguistic Value	Designation	Fuzzy Number Value
VH	Very High	(7,9,10)
H	High	(6,7,9)
E	Equal	(3,5,7)
L	Low	(1,3,4)
VL	Very Low	(0,1,3)

In the order to make easier the calculation, we put α_{nl}=1 and α_{nm}=1 and the algorithm for resolving the three equations and calculating the normalized weights is developed on Matlab R2013a (see Figure 4).

The linguistic values and their correspondences on fuzzy numbers given by the three experts for comparing criteria are given in the table below (see table III).

From the results obtained by the developed platform, it can be noted that the weights of C1, C2, C3 and C4 are irrational fuzzy numbers that don't satisfy the condition "normalized lower value ≤ normalized mean value ≤ normalized upper value".



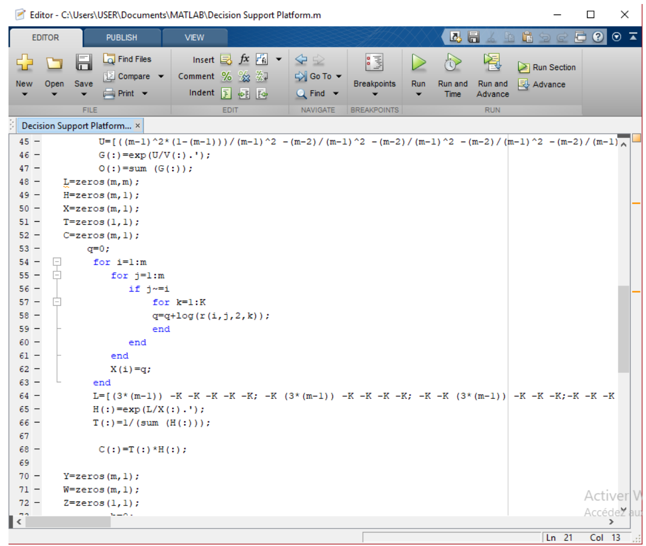


Fig. 4. The Implementation of the Decision Support Platform on Matlab R2013a.

The authors of [40] have already studied this point and criticize works of [38] and [39] in which normalized weights values that are derived from estimates based on ratio scales can generate an irrational ordering of fuzzy number's elements.

They tried to find the conditions on pairwise comparison values in order to get rational outcomes.

The condition is: $\alpha_{il} \leq \alpha_{iu}$

That is equivalent to:

exp((-0.0014*V(1))+(0.009*(V(2)+V(3)+V(4)+V(5))));

XY=exp((0.0017*Y(1))+(0.0087*(Y(2)+Y(3)+Y(4)+Y(5)))+(0 0086*Y(6)));

YX=exp((0.009*(V(1)+V(3)+V(4)+V(5)))-(0.2514*V(2)));

YY=exp((0.0087*(Y(1)+Y(3)+Y(4)+Y(5)))+(0.0086*Y(6))-(0.2517*Y(2))) ;

ZX=exp((0.009*(V(1)+V(2)+V(4)+V(5)))-(0.2515*V(3)));

ZY=exp((0.0087*(Y(1)+Y(2)+Y(4)+Y(5)))+(0.0086*Y(6))-(0.2518*Y(3)));

WX=exp((0.009*(V(1)+V(2)+V(3)+V(5)))-(0.2514*V(4)));

WY=exp((0.0087*(Y(1)+Y(2)+Y(3)+Y(5)+Y(6)))-(0.2517*Y(4)));

VX=exp((0.009*(V(1)+V(2)+V(3)+V(4)))-(0.2514*V(5)));

VY=exp((0.0087*(Y(1)+Y(2)+Y(3)+Y(4)+Y(6)))-(0.2517*Y(5)));

UX=1;

UY=exp((0.0087*(Y(1)+Y(2)+Y(3)+Y(4)+Y(5)))-(0.2517*Y(6)));

The execution of the algorithm on Matlab R2013a gives the fuzzy weights shown on the Table IV.

TABLE III. FUZZY PAIRWISE COMPARISONS OF PERFORMANCE CRITERIA

	C1 : Implementation	**C2 : Relevance**	**C3 : Exploitation**	**C4 : Granularity**	**C5 : Description & Organization (Structure)**	**C6 : Validation**
C1 : Implementation	(1,1,1)	L: (1,3,4) E: (3,5,7) L: (1,3,4)	H: (6,7,9) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) E: (3,5,7)	E: (3,5,7) H: (6,7,9) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)
C2 : Relevance	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	(1,1,1)	H: (6,7,9) E: (3,5,7) E: (3,5,7)	H: (6,7,9) L: (1,3,4) H: (6,7,9)	H: (6,7,9) VH: (7,9,10) E: (3,5,7)	L: (1,3,4) L: (1,3,4) E: (3,5,7)
C3 : Exploitation	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	L: (1,3,4) L: (1,3,4) E: (3,5,7)	L: (1,3,4) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)
C4 : Granularity	$\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{\mathrm{H}}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{H}}:(\frac{1}{9},\frac{1}{7},\frac{1}{6})$	$\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	H: (6,7,9) VH: (7,9,10) E: (3,5,7)	L: (1,3,4) L: (1,3,4) E: (3,5,7)
C5 : Description & Organization (Structure)	$\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{\mathrm{H}}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{\mathrm{H}}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{\mathrm{VH}}:(\frac{1}{10},\frac{1}{9},\frac{1}{7})$ $\frac{1}{\mathrm{E}}:\left(\frac{1}{7},\frac{1}{5},\frac{1}{3}\right)$	$\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{\mathrm{H}}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{\mathrm{VH}}:\left(\frac{1}{10},\frac{1}{9},\frac{1}{7}\right)$ $\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	H: (6,7,9) L: (1,3,4) E: (3,5,7)
C6 : Validation	$\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{\mathrm{H}}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{\mathrm{L}}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{\mathrm{E}}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)

TABLE IV. ESTIMATED NORMALIZED FUZZY WEIGHTS OF DECISION CRITERIA

Criteria	**Estimated normalized weight**		
	$\boldsymbol{\alpha_{il}}$	$\boldsymbol{\alpha_{im}}$	$\boldsymbol{\alpha_{iu}}$
C1	0.0225	0.0275	0.0319
C2	0.0187	0.0308	0.0424
C3	0.1266	0.1310	0.1322
C4	0.1388	0.1468	0.1511
C5	0.4256	0.4483	0.4599
C6	0.1259	0.2252	0.3212

The table V below shows an example of the fuzzy pairwise comparisons matrix of the modeling methods filled by the committee. The comparisons are done based on the Criteria 1.

The computation of $\widetilde{\beta_{ij}} = (\beta_{ijl}, \beta_{ijm}, \beta_{iju})$, corresponding to the fuzzy weights of methods j (j=1,….,n) that are calculated under each criteria c_i (i=1,….,m) separately, is made in the same way by using the same formulas (2-8).

The tables VI to XI present the estimated fuzzy weights of modeling methods under criteria 1 to 6 (See Figure 5).

TABLE V. FUZZY PAIRWISE COMPARISONS OF MODELING METHODS UNDER CRITERIA 1

	M1: GRAI/GIM	M2: ARIS	M3: UML	M4: Petri Networks	M5: BPMN	M6: SCOR
M1: GRAI/ GIM	(1,1,1)	L: (1,3,4) E: (3,5,7) H:(6,7,9)	E:(3,5,7) L: (1,3,4) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	E: (3,5,7) H:(6,7,9) L: (1,3,4)
M2: ARIS	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$	(1,1,1)	E: (3,5,7) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) E: (3,5,7)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	H:(6,7,9) H:(6,7,9) E: (3,5,7)
M3: UML	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	(1,1,1)	E: (3,5,7) E: (3,5,7) L: (1,3,4)	L: (1,3,4) L: (1,3,4) L: (1,3,4)	H:(6,7,9) H:(6,7,9) E: (3,5,7)
M4: Petri Networks	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:\left(\frac{1}{4},\frac{1}{3},1\right)$ $\frac{1}{L}:\left(\frac{1}{4},\frac{1}{3},1\right)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	$\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	(1,1,1)	L: (1,3,4) E: (3,5,7) E: (3,5,7)	H:(6,7,9) VH:(7,9,10) E: (3,5,7)
M5: BPMN	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$ $\frac{1}{E}:(\frac{1}{7},\frac{1}{5},\frac{1}{3})$	(1,1,1)	H:(6,7,9) VH: (7,9,10) H:(6,7,9)
M6: SCOR	$\frac{1}{E}:\left(\frac{1}{7},\frac{1}{5},\frac{1}{3}\right)$ $\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{L}:(\frac{1}{4},\frac{1}{3},1)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{E}:\left(\frac{1}{7},\frac{1}{5},\frac{1}{3}\right)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{E}:\left(\frac{1}{7},\frac{1}{5},\frac{1}{3}\right)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{VH}:(\frac{1}{10},\frac{1}{9},\frac{1}{7})$ $\frac{1}{E}:\left(\frac{1}{7},\frac{1}{5},\frac{1}{3}\right)$	$\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$ $\frac{1}{VH}:(\frac{1}{10},\frac{1}{9},\frac{1}{7})$ $\frac{1}{H}:\left(\frac{1}{9},\frac{1}{7},\frac{1}{6}\right)$	(1,1,1)

TABLE VI. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 1

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0146	0.0533	0.0917
M2: ARIS	0.0508	0.0850	0.1179
M3: UML	0.1220	0.1349	0.1446
M4: Petri Networks	0.3989	0.5414	0.6736
M5: BPMN	0.1535	0.5527	0.7480
M6: SCOR	0.0062	0.0354	0.0645

TABLE VII. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 2

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0169	0.0504	0.0835
M2: ARIS	0.0566	0.0830	0.1080
M3: UML	0.1325	0.1345	0.1330
M4: Petri Networks	0.4186	0.5449	0.6603
M5: BPMN	0.1414	0.5650	0.7450
M6: SCOR	0.0055	0.0361	0.0666

TABLE VIII. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 3

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0080	0.0422	0.0761
M2: ARIS	0.0433	0.0691	0.0938
M3: UML	0.1337	0.1281	0.1190
M4: Petri Networks	0.5414	0.5823	0.6491
M5: BPMN	0.1193	0.6056	0.6887
M6: SCOR	0.0039	0.0271	0.0502

TABLE IX. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 4

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0063	0.0482	0.0900
M2: ARIS	0.0747	0.0850	0.0923
M3: UML	0.0878	0.1060	0.1219
M4: Petri Networks	0.5129	0.5921	0.6488
M5: BPMN	0.1258	0.4265	0.7240
M6: SCOR	0.0079	0.0290	0.0496

TABLE X. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 5

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0088	0.0388	0.0686
M2: ARIS	0.0704	0.0865	0.1007
M3: UML	0.1021	0.1078	0.1108
M4: Petri Networks	0.1378	0.3658	0.5902
M5: BPMN	0.1083	0.3829	0.6547
M6: SCOR	0.0056	0.0271	0.0484

TABLE XI. ESTIMATED NORMALIZED FUZZY WEIGHTS OF MODELING METHODS UNDER CRITERIA 6

Criteria	Estimated normalized weight		
	α_{il}	α_{im}	α_{iu}
M1: GRAI/GIM	0.0346	0.0626	0.0897
M2: ARIS	0.0809	0.0994	0.1157
M3: UML	0.1422	0.1464	0.1470
M4: Petri Networks	0.1979	0.2526	0.3021
M5: BPMN	0.1611	0.4578	0.7504
M6: SCOR	0.0082	0.0375	0.0666

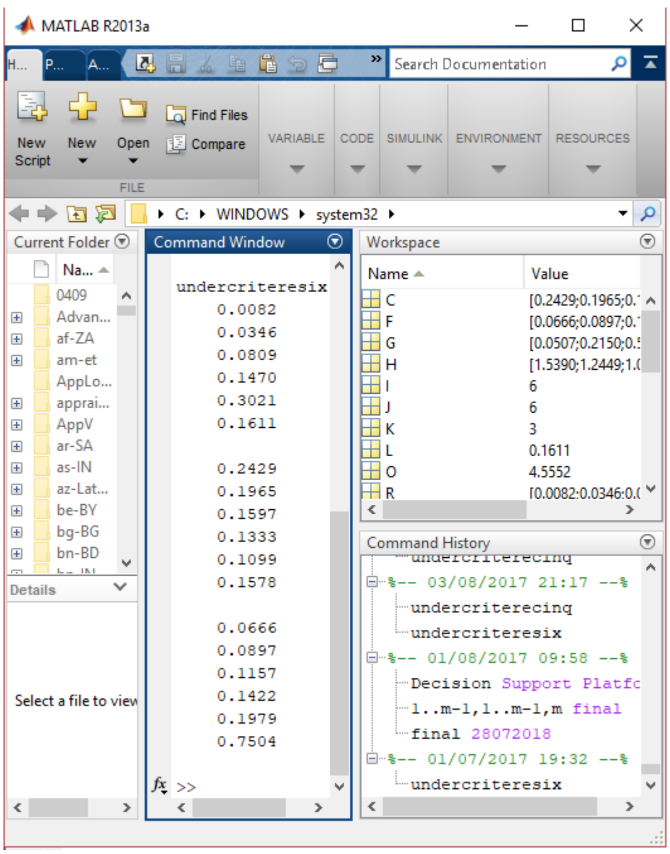


Fig. 5. Results of Weights Obtained by the Decision Support Platform.

Based to the obtained estimated fuzzy weights, the global weight is calculated for each method on the base of the formula N°1.

TABLE XII. FUZZY WEIGHTS OF MODELING METHODS UNDER EACH CRITERIA

Modeling method	Fazzy weighs
M1	(0,0106 0,0471 0,0905)
M2	(0,0582 0,0812 0,1082)
M3	(0,0957 0,1256 0,1464)
M4	(0,2401 0,4926 0,7000)
M5	(0,1050 0,4837 0,8295)
M6	(0,0052 0,0335 0,0843)

From the table above (Table XII) it is noticed that M5 (BPMN) and M4 (Petri Nets) have the best notations (see table XII). So, for this study case (the hospital supply chain), the modeling method adopted will be M5 (BPMN), M4 (Petri Networks) or a hybridization between them.

IV. CONCLUSION

The present work consisted, at the first, on giving a global view about the hospital supply chain and its global structure organization as it is given by the literature. Secondly, a literature review about the modeling methods which are used in the hospital supply chain was presented. The objectives of the modeling approach and its relationship with the performance analysis approach was subsequently justified. Afterwards, the research methodology that is adopted in this work was given for designing our decision support platform. In fact, a classification study based on the cross sorting methods and the fuzzy pairwise comparisons has been developed as part of a computer platform. For that, six criteria were developed in our case and were request from three experts to fill the comparison matrices concerning criteria and modeling methods by considering the hospital supply chain context. This contribution will facilitate the selection of the best modeling methods for our case and the best alternative in a general context. After several iterations, it has been concluded that BPMN and Petri Networks methods had the best notations. In our future work, we plan to improve and automate the decision support platform and to opt for the selected methods or a hybridization of them for modeling the cold supply chain in the hospital.

REFERENCES

[1] Ouzayd, F., Saadi, J., Benhra, J., Proposed a simulation models in medicine drugs circuit with UML and Colored Petri Net: case Moroccan hospital system, International Review of modeling and simulation (IREMOS), Vol. 5. n. 1, pp. 489-496, 2012.

[2] M. Tamir, F. Ouzayd, R.Chiheb, "Literature Review and Classification of Performance Analysis Methods: Hospital Supply Chain", Proceedings of the International Conference on Industrial Engineering and Operations Management (IEOM), Rabat, Morocco, April 11-13, 2017.

[3] V. Andre, P. Fenies, « Modélisation et simulation des flux logistiques du Nouvel Hôpital d'Estaing », Logistique & Management, vol. 15(1), 2007.

[4] A. Artiba, M. Briquet, J. Colin, A. Dontaine, D. Gourc, C. Pourcel, R. Stock, « Modélisation d'établissement de santé ». Actes de la 2ème conférence francophone en Gestion et Ingénierie de Systèmes Hospitaliers (GISEH), Mons, Belgique, 2004.

[5] P. Féniès, M. Gourgand, N. Tchernev, « Une contribution à la mesure de la performance dans la supply chain hospitalière : L'exemple du processus opératoire », Actes de la 2e conférence francophone en Gestion et Ingénierie de Systèmes Hospitaliers (GISEH), 9-11, Mons, Belgique, Septembre 2004.

[6] J. Jlassi, « Amélioration de la performance par la modélisation des flux logistiques des patients dans un service d'urgence hospitalier », Doctoral Thesis, 2011.

[7] T. Hassan, « Logistique hospitalière : organisation de la chaine logistique pharmaceutique aval et optimisation des flux de consommables et des matériels à usage unique ». Doctoral Thesis in Computer Science, INSA de Lyon, 2006.

[8] L. Boyer, M. Poirée, and E., Salin, Précis d'organisation et de gestion de la production, Les éditions d'organisation, Paris, 1982.

[9] G. Chow and TD. Heaver, Logistics in the Canadian , health care industry, Canadian Logistics Journal, Vol. 1, No. 1, December 1994.

[10] ASLOG – Commission logistique hospitalière, Résultats de l'enquête nationale, Hôpital Expo Conférence, Paris, http://www;genecodean.fr/download/nonprotege/d3_nos_manifestation/d312n_hexpo/ASLOG.df, 21 mai 2002.

[11] K. Swinehart, T.W. Zimmerer, S. Oswald, Adapting a Strategic Management Model to Hospital Operating Strategies. Journal of Management Medicine 9 (2): 34-47, 1995.

[12] N. Sampieri-Teissier, Proposition d'une typologie des pratiques logistiques des hôpitaux publics français. Enseignements à partir d'une étude empirique. Logistique et Management 10 (1): 85- 95, 2002.

[13] Elhamdi, M., Modélisation et simulation de chaines de valeurs en entreprise – Une approche dynamique des systèmes et aide à la décision : SimulValor, Sciences de l'ingénieur [physics]. Ecole Centrale Paris, Français, 2005.

[14] Villa, S., Prenestini, A., Giusepi, I., A framework to analy ze hospital wide patient flow logistics:Evidence from an Italian comparative study, Health Policy 115, 196–205, 2014.

[15] P. Bhattacharjee, Ray, P.K., Patient Flow Modelling and Performance Analysis of Healthcare Delivery Processes in Hospitals: A Review and Reflections, Computers & Industrial Engineering, doi: http://dx.doi.org/10.1016/j.cie.2014.04.016, 2014.

[16] A.M. Caunhye, Xiaofeng N., Pokharel S., Optimization models in emergency logistics: A literature review, SocioEconomic Planning Sciences, 46, 4e13, 2012.

[17] A.D. Marshall, Burgos-Liz, L., Maarten, J., IJzerman, Nathaniel, D., Osgood, William, V., Padula, Mitchell, K., Higashi, Peter, K., Wong , Kalyan, S., Pasupathy, William, Crown, Applying Dynamic Simulation Modeling Methods in Health Care Delivery Research: The SIMULATE Checklist :Report of the ISPOR Simulation Modeling Emerging Good Practices Task Force, International Society for Pharmacoeconomics and Outcomes Research (ISPOR), 2015.

[18] Y. Jacquemin, Optimisation de la trajectoire du patient dans les centres de radiothérapie ou d'hadronthérapie, Doctoral Thesis, École doctorale Science, Ingénierie et Santé de Saint-Etienne, 2011.

[19] Khlie K., A.Abouabdellah, Modeling and simulation of the patients pathway with ARENA : Case of the Mother-Child Hospital at MARRAKECH, Xth International Conference on Integrated Design and Production, CPI 2015, December 2-4, 2015, Tangier - Morocco.

[20] G.FONTAN, D.DUROU, C.MERCÉ, "Analyse et modélisation du parcours du patient, Logistique et management", Logistique & Management Journal , Volume 12, 2004 - Issue sup1, 2015.

[21] Y. Shen and Lin Hui L., « Improving the wait time to consultation at the emergency department", BMJ Open Qual Volume 7(1); 2018.

[22] S. Jebbor, A. El Afia, R. Chiheb (2018) "Reducing Crowding in Hospital Inpatient Unit Using Queuing Theory". In: Ezziyyani M., Bahaj M., Khoukhi F. (eds) Advanced Information Technology, Services and Systems. AIT2S 2017. Lecture Notes in Networks and Systems, vol 25. Springer, Cham.

[23] B. Idriss, J. Saadi, A. Bellabdaoui, « Modélisation et Simulation dans les centres de transfusion sanguine : Cas du CRTS de Casablanca », Conference: GISEH, July, 2016.

[24] P. Staccini, M. Joubert, J.F. Quaranta, M. Fieschi (2003). Mapping care processes within a hospital: A web-based proposal merging enterprise modelling and.ISO normative principles. Studies in Health Technology and Informatics, vol 95, pp.200–205, 2003.

[25] A.Vincent, « Modélisation, analyse et pilotage de flux en milieu hospitalier à l'aide d'UML et des réseaux de Petri, Engineering Sciences », Doctoral Thesis, Ecole Nationale Supérieure des Mines de Saint-Etienne, 2008.

[26] M.A. El oualidi, J. Saadi, L. El hiki, A. Artiba, A. Bellabdaoui, « Modélisation et simulation du flux des patients au service des urgences. Cas de l'hôpital Ibn Rochd à Casablanca (Maroc)", Francophone Conference of Management and Engineering of Hospital Systems, 2010.

[27] H. Benabdejlil, « Modélisation des processus de soins : vers une implantation de nouveaux services à valeur ajoutée Hajar Benabdejlil To cite this version », Doctoral Thesis, UNIVERSITÉ DE BORDEAUX, France, 2016.

[28] Q. Laval, A. Ferrarini, S. Rodier, S. Norre, "A Modeling Approach of an Hospital Logistics System: Application to the AP-HM Logistics Platform", Journal Logistique & Management, vol 22(4), pp. 5-22, 2014 (7ème Conférence GISEH 2014. Gestion et Ingénierie des Systèmes Hospitaliers).

[29] F. Ouzayd, « Apport de la modélisation et simulation du flux médicamenteux direct et inverse au sein d'une pharmacie hospitalière : Cas de l'hôpital Ibn Tofail », Doctoral Thesis, Université Hassan II Casablanca, Ecole Nationale Supérieure d'Electricité & de Mécanique, 2014.

[30] M.Chabrol, P. Féniès, M. Gourgand, N.Tchernev, « Un environnement de modélisation pour le système d'information de la Supply Chain. Application au Nouvel Hôpital Estaing », Ingénierie des systèmes d'information, vol. 11(1), pp.137-162, 2006.

[31] R. Iannone, A. Lambiase, S. Miranda, S. Riemma, D. Sarno, "Modelling hospital materials management processes", International Journal of Engineering Business Management, vol 2(1), pp.1-12, 2013.

[32] H. Mezouar, A. El afia, R. Chiheb, F. Ouzayd, "Proposal of a modeling approach and a set of KPI to the drug supply chain within the hospital", Proceeding in Logistics Operations Management (GOL), 3rd International Conference, IEEE, 2016.

[33] W. Chanpuypetch, D. Kritchanchai, « A Process Reference Model for Hospital Supply Chain of Pharmaceutical Products ». Industrial Engineerin & Management Systems, vol 17, No 1, pp.43-61, March 2018.

[34] Matthieu, L.M., Méthodes de diagnostic et d'évaluation de performance pour la gestion de chaînes logistiques : application à la coopération maison-mère – filiales internationales dans un groupe pharmaceutique et cosmétique, Doctoral Thesis, L'institut Nationale polytechnique de Toulouze, 2004.

[35] CEN ENV 40003, Enterprise Integration-Framework for Enterprise Modelling, European Committe for Standardization, 2001.

[36] F. Limayem (2006). Modèles de pondération par les méthodes de tri croisé pour l'aide à la décision collaborative en projet, Doctoral Thesis, France, 2006.

[37] Idri, A., Impacts des techniques de construction des ensembles flous sur la precision d'un modèle d'estimation des couts de logiciels par analogie floue, SETIT, 2007.

[38] P.J.M Van Laarhoven, W. Pedrycz, "A fuzzy extension of Saaty's priority theory". Fuzzy Sets and Systems, vol. 11, pp.229-241, 1983.

[39] C.G.E. Boender, J.G. de Graan and F.A. Lootsma, "Multi-criteria decision analysis with fuzzy pairwise comparisons", Fuzzy Sets and Systems, vol 29, 133-143, 1989

[40] O. Gogus, T. « O. Boucher, « A consistency test for rational weights in multi-criterion decision analysis with fuzzy pairwise comparisons ». Fuzzy Sets and Systems, vol 86(2), pp.129-138, 1997

Opinion Mining and thought Pattern Classification with Natural Language Processing (NLP) Tools

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***Abstract*—Opinion mining from digital media is becoming the easiest way to obtain trivial aspects of the thinking trends. Currently, there exists no hard and fast modeling or classification over this for any society or global community. The marketing companies are currently relying on sentiment analysis for their products. In this paper social sentiment is focused on the form of collective sentiment and individual sentiment; we intend to classify these in the form of Macro and Micro-social sentiment. The sentiment varies among groups, sects etc. and various classes of society are depending on many other characteristics of the society. The social media is available to explore certain ideas, various trends, and their significance. The significance requires further exploration of more patterns and this cycle continues. The exploration cycle focuses on a research outcome. Based on above all the study focuses on the opinion classes towards the general think patterns. The Think Patterns (TP) are developed over time due to social traditions, fashions, family norms etc. The specific community think patterns are very difficult to classify like a female in restricted societies or rural societies of our country. Such trends and patterns are the focus of this study based on various defined parameters. The opinion and sentiment data analysis will be assessed using natural language processing (NLP) tools, Twitter, GATE, Google API's, etc.**

Keywords—Opinion mining; sentiment analysis; natural language processing; think pattern; GATE

I. Introduction

The opinion refers to the processes that lead to decisions, such as political, marketing or purchasing decision. Here, the question is which opinion has an influence, whether it is liberal and individual or controlled by power processes. The Internet supports us in different ways to thrive in all units of industries. All Social media like Twitter, Facebook, LinkedIn, YouTube, Myspace, and many others have won a lot of repute that they could not be overlooked[1]. The Internet deals with efficient ways of communicating and distributing opinion.

People express their opinions in the form of natural language. Opinion mining (OM) is one of the natural language tools to track the mood of the audience about a particular product, either it is negative, positive or neutral[2]. Opinion mining is also recognized as the Sentiment analysis. It aims to control the relationship of the author to measure against working, towards some topic or the overall contextual polarity of an article.

Currently, the internet has provided open access to a vast number of texts that are accumulated, like on specialized feedback sites, social networks, and blogs, in the comments sections of news publications. The automatic detection of text sentiment can be used to solve many important applications, the search in a commercial organization regarding consumers to its products, the development of a recommendation system for buyers of certain groups of goods or services, and the introduction in the human-computer interface. The computer system function is responsible for the adaptation of the behavior of the system to the real emotional state of a person etc.

The difficulty of automatic text analysis to determine the emotional relations is expressed in English terminology as Sentiment Analysis (SA). Opinion Mining was among the active scientific research in the early 21st century [9]-[10].

Sentiment analysis is also beneficial for a lot of important applications, like, the research for a commercial organization of the relations with customers for its production, or the development of a recommendatory system for the customers of specified groups of goods or services. The macro sentiment is the study of the sentiment of the national economy as a whole; on the other hand, micro sentiment includes individual, groups or company level. The micro sentiment is done with controlling units oppositely; the macro has unit production. In macro sentiment, stuff is made, and in micro sentiment, stuff is used.

The opinion of other people has huge influences on our behavior, beliefs, and perspective of the world from which we make choices. Therefore, when it is necessary to make a decision, we are often interested in the opinions of others. Opinions are important not only for individuals but also for organizations. Automatic recognition of opinions in texts finds application in a variety of areas: in marketing research, advisory and search systems, in the human-machine interface, in assessing the sentiment of news, etc. [3]-[4]. One of the main errands in the analysis of opinions is the classification of text by sentiment analysis. The tone of the text is the emotional evaluation of some object, determined by the totality of the constituent text of lexical units [5] and the rules of their combination.

The marketing companies are currently relying on sentiment analysis for their products. However, such trends are equally important for industrial and non-industrial users. The opinion and sentiment mining are interrelated fields but unfortunately considered same and focused carefully in our study to clarify it. The research on our community on this issue is an uprising need of the time to obtain the potential usage of this growing field.

Opinion mining is beneficial for social media monitoring because it permits us to have a general idea of social opinion about some topics. The use of opinion mining is very wide and influential. The capacity to mine ideas from the social data is a way which is extensively used by organizations round the globe. The purpose of the research of opinion is to classify social trends based on moods, opinions, hopes, attitudes, and anticipations of the public or stakeholder groups. In recent years, social networking has transformed into relational communication.

Recent research on language analysis in social networks has focused on its impact on our daily lives, both professional and personal. Natural language processing (NLP) is one of the best favorable approaches to data processing and social networks. NLP is a tool that can assist to run your business progress by providing a visual modality in the minds of the focused audience. However, it is not aimed to change the intuition of a person. There are two different types of a component of NLP: Natural Language understanding and Natural language generation. NLP emphasizes six steps Lexical Analysis, Pragmatic Analysis, Entity extraction, Discourse Integration, Semantic Analysis, and Syntactic Analysis.

Identifying TP is a modest method to understand complex circumstances and develop simply to collect a better understanding of the complex situations and complex covering of a surface of interaction patterns that provoke, drive and direct them [6]. TP helps to understand complex circumstances and develop simple operations to transform them.

The terminologies knowledge discovery, data mining machine learning and pattern recognition in databanks are difficult to detach, using them mainly overlay in their scope. Pattern Recognition is an ability to recognize a set of data regularities, repetitions, similarities or regularities. This feature of the higher cognitive system is being researched for the human perception of cognitive sciences such as perceptual psychology, for machines, however, by computer science. A typical example of the countless application areas is speech recognition, text recognition and face recognition, tasks that are constantly and easily done by human perception. However, the elementary ability of classification is also the cornerstone of conceptualization, abstraction and inductive thinking, and ultimately of intelligence so that pattern recognition has also gained central importance for more general areas such as Artificial intelligence or data mining.

Internet users do not always write constructive and structured feedback on goods or services, considering in detail the pros and cons, exposing the estimates. Much more often the user leaves a spontaneous emotional response in social networks or micro blogging. Further, the spread of smartphones contributes to the increase in momentary feedback and emotional notes on social networks. Like a person after watching a movie, if he did not truly like this, by using a smartphone at the spot without leaving the cinema can warn his friends that it is not worth spending time on this movie. Short notes are written more often and potentially have a greater impact on the friends of the user than the unfolded reviews of strangers. Therefore, for goods, services, media persons and significant events, it is important to collect.

All available collections in Pakistan are collections of reviews belonging to one particular subject area, but not general collections of short texts (micro blogs) or messages from social networks. Therefore, for the task of classifying texts from social networks by tone, a corpus of short texts was built by the micro blogging platform Twitter.

Twitter is a Social network and a micro-blogging facility that permits consumers to inscribe posts in real time. Frequently the message is written from the mobile device directly from the scene, which adds a message of emotionality. Due to platform limitations, the length of the Twitter message does not surpass 140 letters of alphabet. About this feature of the facility, brief messages are issued in real time; individuals practice abbreviates words, spelling miscalculations, smileys etc. Since Twitter has characteristics of a social network, its consumers can actively formulate their view on a diversity of topics from the characteristic of multivariate to the political and economic events in the world.

Classification at the level of expressions and short phrases, instead of whole documents or paragraphs, was conducted by Hoffmann and Wilson, Wiebe [7]. In their work, the writers revealed that it is significant to ascertain the color negative or positive of a particular sentence, not the entire manuscript. In a lengthy article, the writer's view concerning the object be able to replace from negative to positive and positive to negative; the writer can negatively express regarding slight deficiencies, although in general, it remains positive about the object. Furthermore, it is not always possible to classify a long document or a review as positive or negatively colored.

II. Related Work

Vinodhini & Chandrasekaran (2012) explain that Natural Language Processing (NLP) is the domain of sentimental analysis used for tracking the opinion of people on public issues, products, news, and information. The sentimental analysis is also termed opinion mining including the system to gather the views of the public on different blogs of social media (Facebook, Twitter, Instagram, etc.)[1]. In a distinguished manner, the sentimental analysis can be utilized by the users. For example, in marketing, it benefits in mediating the success of the company product.

Zhong et al. (2012) told us that numerous data mining methods had been suggested for beneficial mining arrangements in documentations containing text. In spite of this, how to adequately utilize them and refresh patterns remains a subject of research, particularly in the field of text mining. Meanwhile, the greater part of the techniques for the scholarly investigation of the content implemented term-based methodologies,[2] they experience the difficulties of the considerable number of issues of synonymy and polysemy. Throughout the years, individuals regularly happen in the supposition that the pattern- based methodologies are relied upon to improve the situation than the term-based. However, numerous tests don't affirm this suspicion.

Unnisa, M., et al. (2016) explained that Social media is one of the most important media for expressing opinions. Analysis of sentiment is a method through which the information is taken as of the Feedback report and the feelings of people about the organizations, actions, and their characteristics. SA also recognized as the OM.

Data discover their tactic to social networking websites such as LinkedIn, Twitter, and Facebook. Twitter provides a wide manifesto to predict consumer brands, movie Critics, democratic elections, the stock market, [3] and the admiration of Celebrities. The key objective of SA is to cluster the negative and positive effects on a bunch of tweets.

III. Methodology

We use GATE in our research. GATE is a platform for deploying and developing software constituents, which process like natural language. GATE is used for performing different tasks. In our research, we make corpora of different documents using the power of Gazetteer. Corpora are the collection of different documents. Gazetteer concerns to recognize the objects name within the content formed on the lists.

For identifying the thinking pattern, as shown in Fig. 1, we take text from different sources and then classify this text according to its category, e.g., classification 1 ton. The text passes through NLP tool then define the Metadata of these categories and implement this Metadata into a different classification. We get Dynamic corpus as the outcome of the above procedure. We repeat this again and again, and as a result, our corpus becomes strong and also identifies trivial patterns.

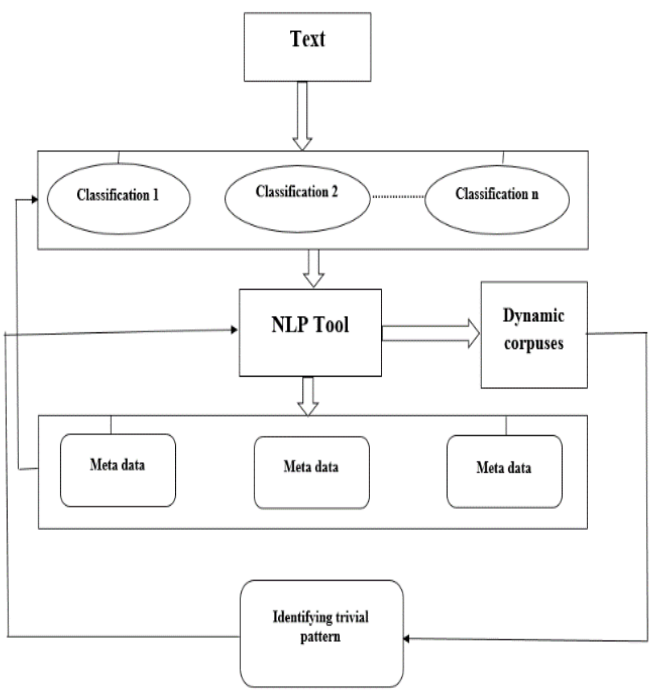

Fig. 1. Exploration Cycle.

Variables:

P: various patterns

S: Sources

T: Various Texts

C: A particular Classification

Crp: corpus

TP: Trivial Patterns

Identifying Pattern

p€ Pi where 1 <= i <= n (1)

Get text from different sources

s€ Sj where 1 <= j <= n (2)

Depends on Patterns and Sources

Tḑ£ PxS; T (3)

Divide it into various classification

Crp: NLP () (4)

=>If dynamic corpora make

Crp => TP (5)

Else obtain metadata and classify again

As Fig 2 demonstrate the flowchart of processing. First of all potentially relevant documents or corpora are identified. The information is retrieved from these documents. These corpora are turned into a machine-readable format so that data can be extracted. The meaningful information is extracted and mined to discover new knowledge. When the information is retrieved and normalized the documents, then textual analysis and entity identification is formed. In the end, the required information is extracted, and knowledge is acquired.

The sentiment of the text is determined by the calculation of the weights of the appraisal words included in it. For each text T from the training collection, two weights are counted, the first of which is equal to the sum of the positive evaluation words, and the second is to the sum of the negative evaluation words:

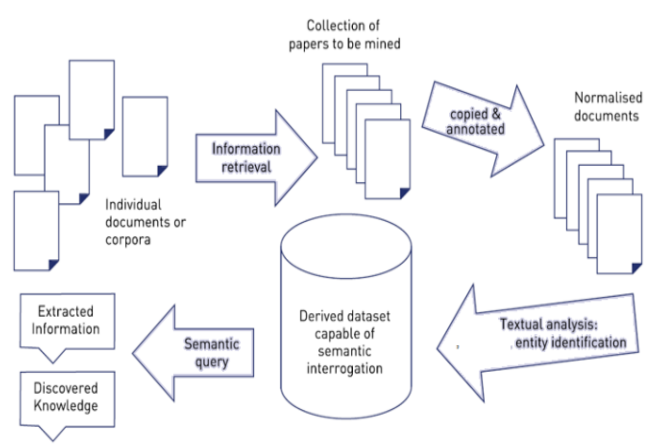

Fig. 2. Processing of Information Extraction [8].

$$W_T^C = \sum_{i=1}^{N_C} |W_i| \qquad (6)$$

Where W_T^C is the weight of the text T for the key C; wi is the weight of the estimated word i; NC - the number of evaluation words for the key C in the text T.

All texts of Ti are placed in a two-dimensional evaluation space (positive sentiment - negative key) by their weights W_T^C. To classify texts by sentiment, a linear function

$$f\,(WT\,pos\,, WT\,neg\,) = WT\,pos\, + \,k\,neg\, * \,WT\,neg \qquad (7)$$

Where $WT\,pos$ is the positive weight of the text T; $WT\,neg$ the negative weight of text T; the $k\,neg$ is a coefficient that compensates for the predominance of positive vocabulary in a speech [9]. If the value of the function f is greater than zero, the text is positive, otherwise - negative.

In this research, our goal is to mine opinion of different people as well as targeting general thinking patterns. The general framework of our research is given below as can be seen in Fig. 3.

First of all, we make corpora of different documents. Data analysis is done in the next phase, and processing phase starts after the analysis and specification of the data. NLP tool GATE is used to make the Gazetteer.

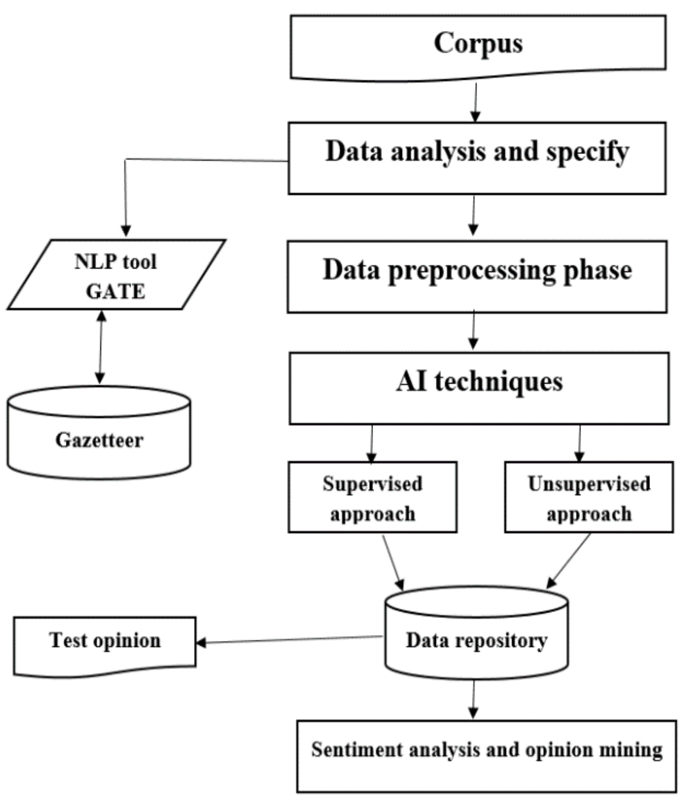

Fig. 3. Framework.

After the preprocessing phase, supervised and unsupervised artificial intelligence techniques are used to retrieve data and enter it into the data repository. By using the data of the repository, we can easily find out the sentiment as well as mining of the opinions. We make corpus that can be related to education, marketing and we can easily mine opinions from these corpora. We find out annotations from these corpora and relate these annotations with education, marketing, and society. Now we have a predefined set of annotations. When these annotations match with that data in corpora, then it is identified that this data supports or relates to that specific area or field. This corpus is used for content filtering and content resemblance. When we want to find the potential category of the document then the content is added into the corpus, it matches to the gazetteer, and we can easily find the potential category of the document, and according to that category, we can mine the opinion. We have corpora which have a large amount of data and go through filtering.

IV. Methodological Issues

A. Making the Relative Corpus

For making different corpus choose Language Resources New GATE corpus, and after that, we have to specify the name of the corpus. In the above pic, it is shown that by using GATE we make corpora of different documents (Fig. 4).

B. Adding Related Data to the Corpus

In corpora, a different type of data is given according to our requirements. We are going to make Education, Business, Teaching, politics, and E-Governess related corpora see Fig. 5. The related data is added to the related corpora [10]. For example, education-related all information is added to the corpus of Education.

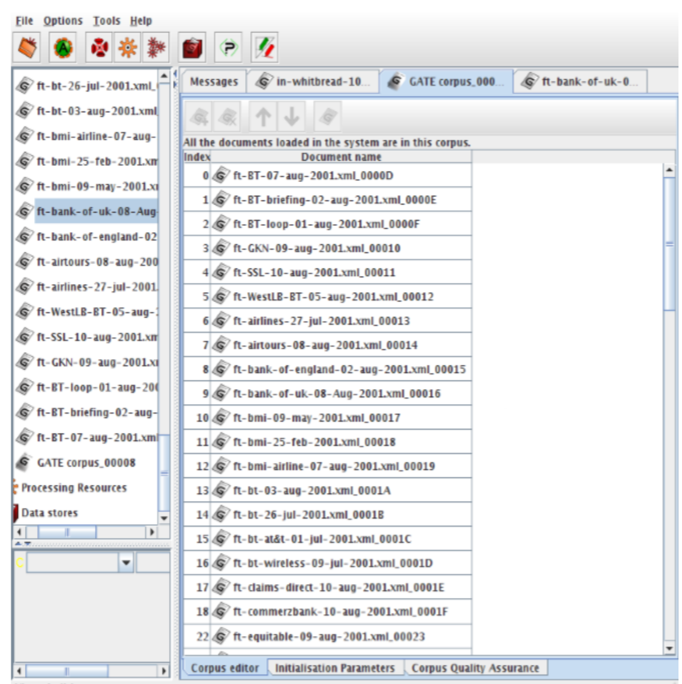

Fig. 4. Different Corpuses.

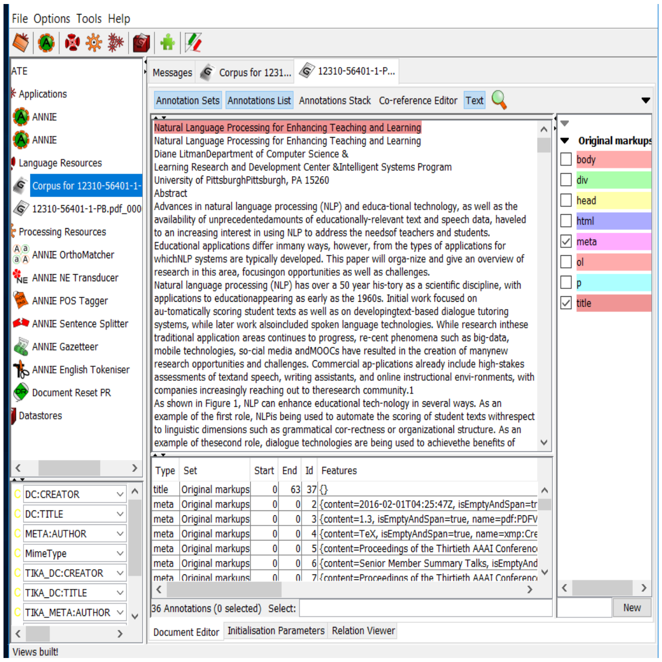

Fig. 5. Adding Data to Corpus.

C. Making Multiple Files for Multiple Types of Gazetteers

A Gazetteer is used for creating annotations. Gazetteer has a large number of sets of lists consisting names of entities like days of the week, cities, organizations, etc. This kind of lists is used to find an occurrence of these names in text. We can add multiple gazetteer processing resources to the controller one gazetteer per list. Def file. The index file particularly references a list file. List files reference major Type, terms, minor Type, list of display name and language. The definition (index) file can comprise list file references. We can insert all lists in one def. File along with each list containing a unique label. A small set of the def list can construct with a related list and also construct a large set of def. Files that change from other lists (see Fig. 6).

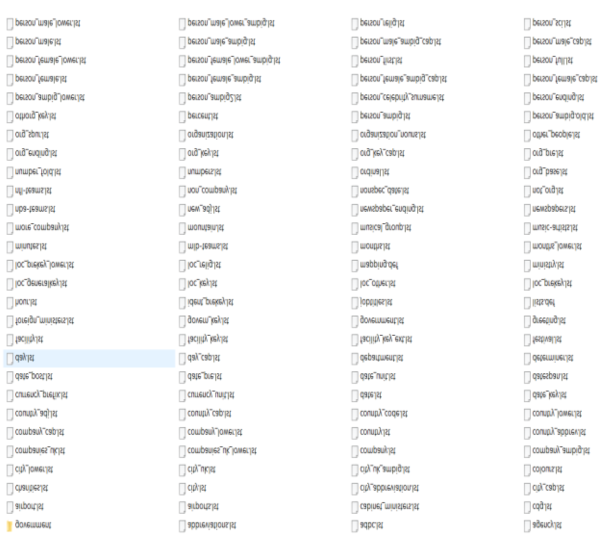

Fig. 6. Multiple Types of Gazetteer Lists.

D. Processing Gazetteers for the Vulnerable Annotation

The double meaning terms have global binding with certain annotations. The intentions of searching text improve with proper use of permutations. The positive and negative permutations as per the search can be classified and improved by training the corpora and jape files.

We have to take different annotations and then sort out the positive and negative annotation. We bring forth a list of positive annotations as well as negative and another list is also created which have contained discarded annotations. For instance, we have the combination of two words X and Y and these two words make the sentiment in the negative direction, and if the major type is X and it is a negative and minor type is Y and Y is positive, then the combination of both will never be highlighted. These types of combination automatically moved towards the rejected list. For illustration, we have a paragraph, and it contains these words runs, scorers and wicket and these words match to our annotation, so it implies to Cricket. We match terms and apply sampling techniques that if these types of words come then, we can identify the topic of the potential text.

We map our words to each other Like, if we have a word and it has negative aspect then we take the second word which is thoroughly positive and combine this word to that word so the results go clear and by intermixing the terms we can change or reduced the content. When we introduced the positive terms, then the search probability and the resolutions will increase and much improved. In most of the cases when one article and one property combines then the results will always be confident. The ambiguous terms which have no proper meaning are combined with the positive terms to improve our search results as shown in Table 1.

TABLE I. ANNOTATION LIST

Meaningless words	Meaningful words
Find Locate Big Small …… …… ……	Children Books Games School ……. …… …….

E. Annotation List and Sets

An annotation set comprises of all individual annotations made by one reviewer or author for course or documents. One annotation set is accessible at a time, but a document can have more than one annotation set. Every annotation inside a set of annotations is related with only one element in a page or a document.

When the set of annotation is created, it automatically creates annotations inside the set see Fig. 7. When we run corpus double click on the loaded application then choose Run and as the resulting corpus that was loaded will be automatically annotated.

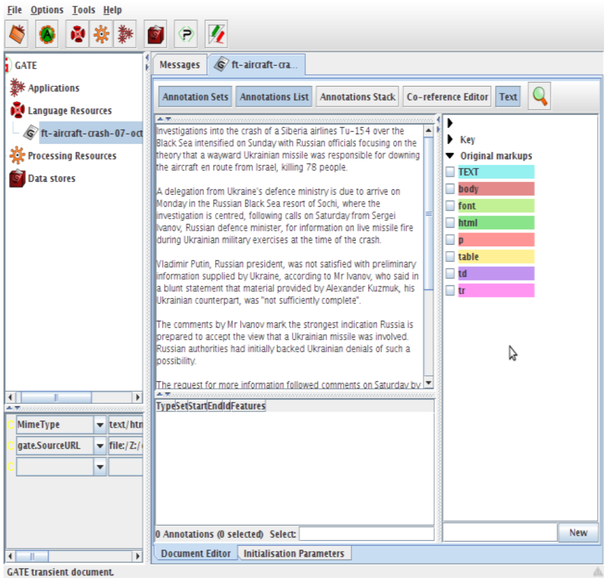

Fig. 7. List and Sets of Annotation.

F. *Taking Annotations from the Internet*

Whaley believes that the annotation will be a Central part of the future of the Internet, and he is working hard to make this vision a reality. Annotation is positive as well as negative. Every interesting topic or agenda has a lot of annotations.

Global annotations or major annotations are made by avoiding the community. The search engine makes annotations, and it makes annotations on the bases of the search of users. Annotation clears the aspects of objects. Annotations are the small notes that help us to keep track of necessary events like goals, necessary mentions, marketing campaigns, downtime of the website, sales promotions, and time specific events and changes in them. They help us to understand the trends, spears in traffic, and uncommon variations. Google annotations are taken as an example. There are two types of Google annotations shared and private. Every person accesses shared annotations while on the other hand, private annotations are only available for one person. Annotations permit you to note down a specific event that may have an impact on your data Creating SEO based corpus.

If we want to do SEO through NLP, then we have to take those annotations which have higher CPC (cost per click). The benefit of SEO based corpora is that we can dominate our business online. Marketing experts in SEO choose the most reliable keywords for sites to obtain a higher ranking.

Capturing the local domain specific annotation

In the local server, we monitor the URLs. We make a Gazetteer of URLs and compare the URLs. In this, we compare the common URLs with search URLs. In search URL the terms come with the + sign and we can perform aging by extracting these terms and database is used in this process.

G. *Uses of AI Techniques*

1) Unsupervised approach: Unsupervised learning is employed to mine adjacent blocks of text from a raw stream of characters as the main logical units of an item.

2) Supervised approach: Supervised learning is used to categorize the blocks of different Meta category data, including authors and associations. Afterward, a heuristic is applied to identify the section of references at the termination of the article and break the link to the series [9]. The sorting order used for sorting the tokens of separate links to further information like the reference year and journal. As a final point, we use named entity recognition methods to get links to funding agencies, research grants, and EU projects.

H. *Making the Data Repositories and Dynamic Corpus*

A repository is a central place where data is stored and managed. A data repository refers to an enterprise data storage entity into which data has been specifically partitioned for an analytical or reporting purpose. The data repository is mostly worked inter-changeably with a data warehouse or mart. It is chosen when a certain type of data storage entity is not identified or is irrelevant to the context [7]. A data repository intends to keep hold of a certain population of data separated so that it can be mined for greater awareness or business intelligence or to be utilized for a specific reporting prerequisite. When data is stored in repositories, dynamic corpora of different type of information is automatically formed.

I. *Use of Jape Files*

JAPE stands for Java Annotation Patterns Engine. JAPE gives limited state transduction upon annotation established given general articulations.

JAPE enables you to perceive general articulations in explanations on archives. The Jape punctuation comprises of a set of segments, every one of which comprises of an arrangement of activity rules. The segments proceed consecutively and establish a cascade of finite state transducers on annotations. The left half of the rules contain portrays of annotation format (Fig. 8). The right-hand side comprises annotation control statements. The explanations comparing to the LHS of the principal can be determined on the RHS by utilizing the names that are joined to design components.

```
Phase:     DateHeader
Input: DCT
Options: control = appelt

Rule: DCT
(
 {DCT}
):tag
-->
{
gate.AnnotationSet tagSet = (gate.AnnotationSet)bindings.get("tag");
gate.Annotation tagAnn = (gate.Annotation)tagSet.iterator().next();

gate.FeatureMap features = Factory.newFeatureMap();


String s = gate.Utils.stringFor(doc, tagAnn);
//String content =
doc.getContent().getContent(tagAnn.getStartNode().getOffset(),
 //                tagAnn.getEndNode().getOffset()).toString();

 if (s.matches("^\\d{8}$") ) {
String s1 = s.substring(0,4) + "-" + s.substring(4,6) + "-" +
s.substring(6,8);

doc.getFeatures().put("document-date", s1);
}

 }
```

Fig. 8. Jape Files Representation.

J. Treat Web as a Mega Corpus

The web offers new conceivable outcomes for information gathering

- Feasible source of the expendable corpus, constructed ad hoc specially appointed for a particular objective
- Important to work with particular dialects

It is Essential to extract web corpus information while manual mining is time-consuming automatically. Web as the corpus is reasonable for a person who reads with little experience and little learning of semantics, corpus, yet further experienced corpus can discover a few gems in there too [11].

As shown in Fig. 9 Sentences are broken down into tokens and after that language is identified. When a language is identified, translate that language and discover the sentiment of sentences either positive or negative or neutral.

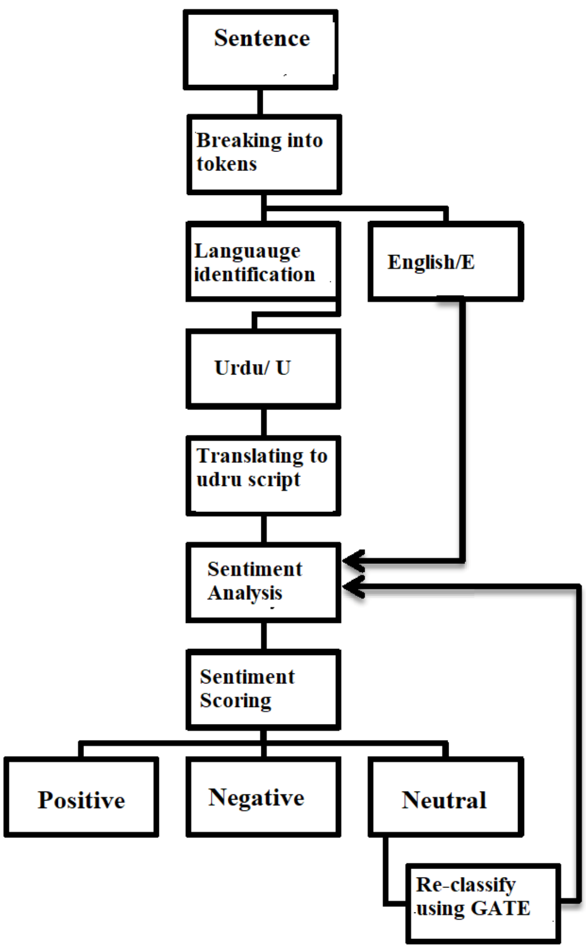

Fig. 9. Flowchart.

V. Application Recommendation

1) Traffic monitoring: Network traffic monitoring is the process of investigating, examining, and processing network traffic or deviations, or a procedure that can influence the performance of network, accessibility, and additional security. We can monitor the traffic of data by using IP addresses, Protocol, and customer parameters.

Analyze the results, and it can be shown in graphical forms or in the form of tables, which is helpful to monitor the real-time usage of internet reporting. In traffic monitoring of internet data, we can check the bandwidth and check the functionality. This traffic monitoring is helpful for commercial as well as personal use. Fig 10 shows the traffic monitoring of GCUF.

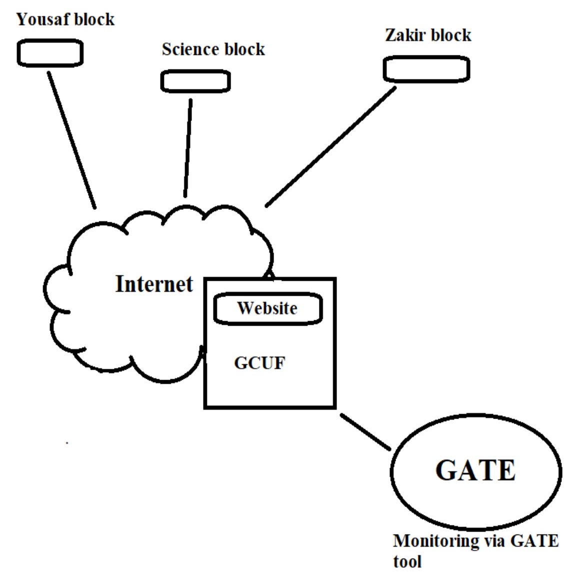

Fig. 10. Traffic Monitoring.

2) URL corpus utilizing for Annotations: People give their URL, and we capture their trends according to the given URLs. People search against URLs. In our server computer 20,000 URLs passes through a day. We make corpora of these twenty thousand URLs, and by making the corpora of these URLs, we get a lot of annotations. By utilizing every annotation, we analyze these annotations.

3) Archived official data processing: It can be maintaining the record the government offices. Like, in a government organization, many workers work in their domains, and they all have their, raw data in a soft-form. We have to take this data to all the employees and make e corpora of all the data, and by making corpora we get an official corpus, and it can also process the records of government offices. Only by entering the required information it can fetch all the useful information which is needed.

4) Local educational annotation identification: Copy the URLs and content of students from the main site, over the computer and make corpora of these URLs. We can know the URL which is used most; frequently we can check this URL either it is related to the educational purpose or not. We can monitor the activities of students by checking their URLs based corpora.

5) General business data analysis: A business firm has a lot of raw documents and emails. We can make the corpus of these emails and process these emails and documents. When we have a lot of corpora, then any time when a business person needs to analyze their data can use these corpora and analyze their data according to their requirements.

6) Timeline study: Timeline demonstrates the sequence of events from the first to the last alongside the line. This makes clear to understand when the entities have happened compared to another event. Time-lines moreover assist you to study the period closer.

In timeline study, the differences of textual patterns are checked like in a corpus one document is added recently, and other documents stored five to ten years ago, we can easily check the textual pattern difference in this report.

7) Textual patterns identification: Different methods are developed for textual pattern identification. The patterns can be viewed as a semantic and syntactic pattern. Identification of textual patterns means that understanding the meaning of the sentence.

Nowadays a lot of information in government, business, institutions, and industries are stored in the form of text in the database, and this database encompasses a large amount of unstructured data. By using Data mining, we can find out the patterns from a huge database [12]. It can also help us to find out the patterns or correlate between lots of fields in the large database. A pattern is called knowledge if it is interesting and certain enough according to the criteria or measures of the user. A system may face a problem when identified or discovered patterns are not interesting to a user. Similar textual patterns also identified. Some work, have different textual patterns but we can find out similar patterns of these words like, we have three words people, society and culture. They have different textual patterns, and we can identify the similar textual patterns of these words by holding in the annotations of these words (Fig. 11).

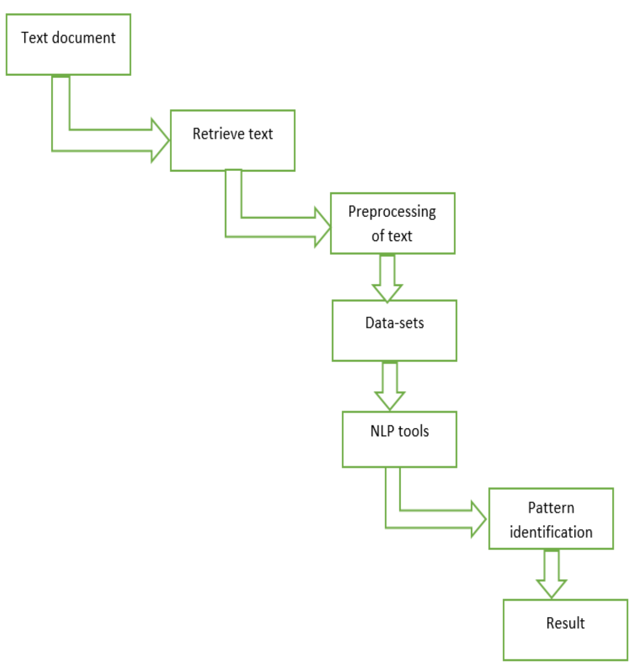

Fig. 11. Identification of Patterns.

8) Improvement in decision making: It can help in, decision making. In our opinion mining research, the sentiment mining, think pattern mining and emotion mining is done all together, and these are helpful in decision mining. We can mine the thinking patterns of the different community. We can mine the opinion and the sentiment of people about a product, and this can be helpful in decision making either we have to change our product or not because we have meaningful information about our product that what people think about the product either they like or dislikes.

VI. Summary

In our opinion mining research, the sentiment mining, think pattern mining and emotion mining is done, and these all together are helpful in decision mining. It can also be helpful to find out the patterns or correlations between a lot of fields in the large database.

If someone desires to make his/her marketing ad, he/she can stimulate the analysis of NLP from us, that what type of keywords he uses, which are the most popular keywords at the same time in marketing. Many marketing companies depend upon SA for their products. GATE is utilized in our research study. Exploration cycle is focused as the outcome. Weights of the words can easily find out using the algorithm. NLP is a very effective approach for multiple domains like teaching, business, E-commerce, politics, and community health. We practice NLP in our research. NLP supports a machine to read the text and also helps to translate it into the natural language in understandable human form. NLP techniques are becoming more common day by day, and these methods are using a lot of data from the internet. NLP is used for information abstraction, classification of sentiment, recognition of E-mail, segmentation of text, language training, and automatic translation, etc. It has two major methods of machine learning and statistical inference [9]. We use GATE (general architecture for text engineering) tool for our research. It is a tool for developing software components which process like natural language. It processed annotations and text directly and parsed this text. We implement Parts of speech; make different lists of the gazetteer. I make a corpus of the university, government school, teaching, industry and also make multiple corpora (corpus within the corpora). I use the power of Gazetteer on the corpora. Gazetteer list is a list of lookups of entities which gathered different files that helps to identify the annotations. I make different corpora, and in these corpora, I find out multiple annotations and add related data to the corpora, and after that, I make multiple files for multiple types of gazetteers and process this gazetteer for vulnerable annotations.

In my research, I take lots of annotations from the internet. I take Google annotations which helps us to understand the trends, monitor the traffic and variations among different trends. I also make SEO based corpora which is very helpful for businesses for getting a higher ranking. I compare the URLs by making gazetteer.

AI techniques supervised, and unsupervised approaches also used to extract the information. Dynamic corpus is generated from the data repositories. We can also make the corpora of websites. We treat the web as a mega corpus and extract the data which we require. Traffic monitoring of the network is done. We can monitor the traffic by using IP addresses and protocol of the network. The record of government offices is also maintained by making different corpora of their data. We can identify the local education annotation and also analyze the data of the business. The patterns of similar text and identification of patterns are performed by checking the annotations of words and documents. We can mine the opinion and also classify the thought pattern by using a natural language processing tool GATE.

REFERENCES

[1] Bandorski D, Kurniawan N, Baltes P, Hoeltgen R, Hecker M, Stunder D and Keuchel M 2016 Contraindications for video capsule endoscopy World J. Gastroenterol. 22 9898–908

[2] Liu B 2012 Sentiment Analysis and Opinion Mining Morgan & Claypool Publishers Lang. Arts Discip. 167

[3] Junaid S M, Jaffry S W, Yousaf M M, Aslam L and Sarwar S 2017 Sentiment Analysis and Opinion Mining - A Facebook Posts and Comments Analyzer 22 98–104

[4] Kasthuri S, Jayasimman L and Jebaseeli A N 2016 Procedure of Opinion Mining and Sentiment Analysis Techniques: A Survey Mach. Learn. 573–5

[5] Zhang L, Ghosh R, Dekhil M, Hsu M and Liu B for Twitter Sentiment Analysis

[6] Pipanmaekaporn L and Li Y 2012 A pattern discovery model for effective text mining Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics) 7376 LNAI 540–54

[7] Hertveldt K, Robben J and Volckaert G 2006 Whole genome phage display selects for proline-rich Boi polypeptides against Bem1p Biotechnol. Lett. 28 1233–9

[8] JISC 2012 The {Value} and benefits of text mining Jisc

[9] Chiappe L M 2010 Enantiornithine (Aves) Tarsometatarsi and the Avian Affinities of the Late Cretaceous Avisauridae Author (s): Luis M . Chiappe Published by : The Society of Vertebrate Paleontology Stable URL : http://www.jstor.org/stable/4523457 ENANTIORNITHINE (AVE Society 12 344–50

[10] Anon citation-309438853

[11] Dictionary C S 2012 Methodology for Text Classification using Manually Created

[12] Vinodhini G and Chandrasekaran R 2012 LR... fig 2...Sentiment Analysis and Opinion Mining: A Survey Int. J. Adv. Res. Comput. Sci. Softw. Eng. 2 282–92

Undergraduate's Perception on Massive Open Online Course (MOOC) Learning to Foster Employability Skills and Enhance Learning Experience

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***Abstract*—The Massive Open Online Course (MOOC) is a very recent development in higher education institutions in Malaysia. As in September 2015, Universiti Teknikal Malaysia Melaka (UTeM) has introduced Mandarin course under Malaysia MOOCs. The study has focused on undergraduate's perception of MOOC in Mandarin subject in fostering their employability skills as a research variable. The researcher used qualitative and quantitative method as a research design. An interview was used to investigate their perception of MOOC in Mandarin subject to foster their employability skills. An online survey was also conducted to investigate the effectiveness of MOOC learning. Undergraduates in UTeM were selected as the respondents of this study. The findings show that among all the employability skill, students believe Mandarin Massive online learning course fosters two employability skills which are 'information gaining skill' and 'system and technology skill'. This study on MOOCs is important for the decision-making of the government and relevant institution to make sound decisions. This research is also significant for its contribution towards teaching practices in higher education institution.**

Keywords—MOOCs; mandarin; employability skills; perception; undergraduates

I. Introduction

Higher education plays an integral role to produce graduates to enter the workforce. Morshidi et al. [1] indicated that "Malaysia has confirmed a target of 100,000 international students by 2010 and is currently implementing strategies to become a major exporter of higher education in the Asian region" (p.52). In education, approaches to enhance teaching and learning have always been an issue among academicians. According to Zaharim et al. [2], one of the factors that contribute to the increased unemployment rate is graduates who are not ready to enter the workforce. Feedback from the industries indicated that the communications and interpersonal skills of graduates are still below satisfactory [3]. This is supported by Cismas [4] as good presentation skill of the employee is still highly demanded in the engineering industry, business education, social and cultural sectors. Hence, as presentation skills are closely related to language which is the medium for communication, therefore there must be some effort on the enhancement of language proficiency in the higher education institution to equip the future employee with satisfactory communication skill. Omar et al. [5] also indicated that the most required soft skills sought by employers were communication skills and foreign language proficiency ranked third. It shows besides English, emphasis should be placed on foreign languages such as Mandarin language competency at the work place because of the popularity of the language.

The Massive Open Online course (MOOC) is a very recent development in the Higher education institutions (HEIs) in Malaysia. According to Dodson et al. [6], MOOCs is the domain of higher education, and the ultimate goal of MOOC is to produce quality course accessible to the mass. MOOC is a modern evolution of distance learning since 2008 [7]. According to Siemens [8], MOOC means massive (involving a huge amount of students), Open (in terms of access), Online (activities happen online), and Course (activities occur during the set times of the course offering). McAuley et al. [9] defined MOOC as 'an integration of the connectivity of social networking, the facilitation of an acknowledged expert in a field of a study, and a collection of freely accessible online resources'. Autonomy, diversity, openness, and interactivity are characteristics of a MOOC. Students can take control on their learning such as where, when, how, what and with whom they learn [10]. Universiti Teknikal Malaysia Melaka (UTeM) has also showed its effort to launch Mandarin MOOC on 7 September 2015 in order to introduce Mandarin course under Malaysia MOOCs [11]. Mandarin MOOC is an ideal selection in learning because it allows the learners to learn Mandarin in anytime and anywhere. MOOC can cater the needs of different learning community. More importantly, students found readily in learning Mandarin using MOOC [12]. As students are learning beyond the classroom activities, quality assurance on MOOC is needed for long term sustainability purpose. It is supported by Gamage et al. [13] who highlighted that many universities who create MOOCs do not pay much attention to their instructional design or the pedagogy.

This issue needs to be addressed as people will start to question on MOOCs's effectiveness due to the high dropout rates in MOOCs. It is agreed by Jordan [14] and Gamage et al. [15] as they found that the completion rate in MOOC did not exceed 20% but ranging from 7% till 13%. Furthermore, learner claimed the ineffectiveness of MOOC as there is no proper mechanism to measure accurately of the user experiences in MOOC platform [16] and lack of general prospect of conceptualizing educational quality in higher education [17].

As Mandarin has become an important foreign language at present, the effort to introduce Mandarin MOOC to the public is an ideal decision. All the stakeholders who are responsible for Mandarin MOOC need to ensure the effectiveness of Mandarin MOOC in learning. Besides personal interest, the participation of MOOCs students could be driven by workplace requirement.

This study has focused on study the undergraduate's awareness on employability skill and their perception of Mandarin MOOC in fostering their employability skills. As employers prefer to hire competent employees who are equipped with employability skills, therefore, undergraduates should aware of the employability skills needed at the workplace. These two areas of study enable the researcher to find out the enhancement method to increase graduate employability skills in UTeM. The study on MOOCs is important for the decision-making of the government and relevant institution to make sound decisions. This research is also significant for its contribution towards teaching practices in higher education institutions.

II. Related Work

Employability skills are influenced by many different factors [18]. Existing models include (Business, Industry and Higher Education Collaboration Council [BIHECC] 2007) [19], Work-Integrated Learning [20] highlighted certain skills that can be integrated into curriculum to foster graduates' employability skills. The skills include team working, communication, self-management and analytical skills. In Malaysia, Singh and Singh [21] conducted a study on Malaysian graduates' employability skills from the employers' perceptions and graduates' perceptions. The employability skills studied include communication skills, English proficiency, ICT skills, interpersonal skills, team working skills, leadership skills, problem solving skills, adaptability skills, risk taking skills, creativity skills, and personal organization & time management skills. In 2012, Rasul and Rauf [22] and Rasul et.al [23], proposed an employability skills assessment tool for technical graduates. The skills proposed were interpersonal skills, thinking skills, personal qualities/values, resource skills, system and technology skills, basic skills and informational skills. Later research by Collet et.al. [24] proposed employability skills from knowledge-based industry perspectives. The skills are knowledge/learning, enterprise leadership, business function, technical management, team worker, interprofessional collaboration, leadership, life-long learning, progress/innovation skills, and create skills.

From Work Integrated Learning, 21st Century Learning until Knowledge-Based Industry Perspectives, employability skills were proposed depending on various factors and requirements. To the best of researcher's knowledge, researches on employability skills in relation to MOOC learning have not been done before. Thus, to suit the samples from technical university, the researchers have chosen employability skills model as proposed by Rasul & Rauf [22] or Rasul et. al. [23] in the study.

III. Methodology

A. Procedures

In this study, qualitative and quantitative approaches were used. The research was carried out to Mandarin MOOC learners delivered via blended learning mode to 231 students at Universiti Teknikal Malaysia Melaka (UTeM). There are 44 e-activities and one e-assessment (report writing and group project video submission) offered in Mandarin MOOC. Marks obtained from 18 e-activities were counted as 10% of students' course work.

For qualitative approach, the researchers used single case single issue (SCSS) as methodological position. Case study allowed the researchers to study in depth by focusing on only eight UTeM's undergraduates as informants. This research approach is supported by Liyanagunawardena et al. [25] who found that most researches in MOOC have investigated the learner's perspective. It shows that the researchers value the learner's achievement throughout the learning process via MOOC. The selection of respondents was purposeful sampling method. The respondents were the students who registered for Mandarin course for duration of 14 weeks in their second semester 2015. The research design used in this study was qualitative in nature and interview method was used to capture and focus on the targeted scope of study. Respondents were well informed of the objective of the research. They were assured about the confidentiality of their responses and that the data would only be utilized for the purpose of this study. Consent letters were given to the informants before the interview started and the explanation of the objectives of the interview was done.

For quantitative approach, an online survey was distributed to all Mandarin MOOC students enrolled during the semester.

B. Instrument

The interview questionnaire was suitable for the target setting and respondents which the content, form, and the nature of the questions were at the satisfactory level. The reliability and validity of the interview questions have been proven by the experts. The length of time to complete the interview question was within ten minutes for each respondent in one-to-one manner. The semi-structured interview was adopted to permit an open exploration which allowed the participants to provide any information or interpretation if necessary. The interview started with the opening statement from the researcher, and finally the direct question to get the data for the research questions. Additional questions were added to follow up or to clarify the responses given by the students. The researcher also makes sure the appropriate order of the interview question asked during the interview session. There was only one interview for each respondent. This decision made by the researcher where there were no new insights or information as the information has been saturated.

The online survey was used to find out students' perception on the effectiveness of learning through MOOC. It comprised of two parts: Part 1 is demography items where students were required to give perceptions on their overall course experience and understanding of the MOOC lessons before and after taking the MOOC. The items are measured using a likert scale from 1 to 5 (1-Poor; 2-Fair; 3-Good; 4-Very Good; 5-Excellent) options. Part 2 consists of 31 items classified into 4 constructs: Learning Design (LD), Content Design (CD), Learning Attitude (LA), and Enhancement in Teaching & Learning (E). The items are measured using a likert scale from 1 to 5 (1-Completely Disagree; 2-Somewhat Disagree; 3-Somewhat Agree; 4-Strongly Agree; 5-Completely Agree) options.

C. Analysis

Interview questions were analyzed using thematic analysis at individual response level. Responses were also grouped by degree type to identify any trends in themes. Data gathered using online survey was analyzed at the end of the semester.

For the on-line survey, a total of 123 responses identified as valid responses were analyzed.

IV. Results and Discussion

This section presents the results of the study. The study was carried based on the conceptual framework shown in Fig. 1.

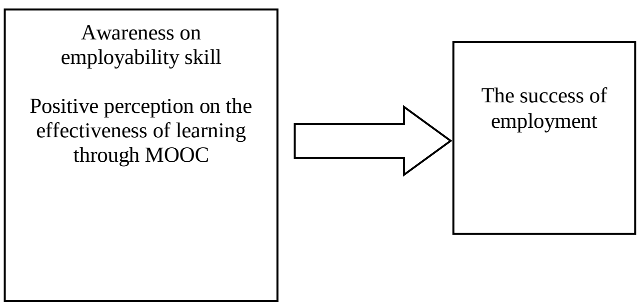

Fig. 1. The Relationship Among Variables.

Interviews were conducted in English and the transcriptions of the interviews were based on their original given information. Analysis followed the principle of grounded theory by searching the transcripts for common themes or categories. The measurement scale on employability skills developed by Rasul and Rauf [22][23] was used as a check list to examine the undergraduate's awareness of the employability skills. Besides, undergraduate's perception on Mandarin MOOC in fostering their employability skill was investigated.

A. Undergraduate's Awareness on Employability Skill

In the interview, undergraduates indicated that they were aware of the importance of employability skills as shown in Table I.

Five out of eight respondents indicated that they were aware of the importance of employability skills such as 'positive attitude like hardworking' stated by student 3, 'thinking skill which shows how we solve the problem and 'information gaining skill like how they find information online' stated by student 4, 'system and technology skill like they know how to use the technology when they are working' or 'technologically incline, they have to know their skill on using technology' stated by student 4 and student 5, and 'good in language' or 'communication skill' stated by student 3, student 5 and student 7.

TABLE I. Undergraduate's Awareness on Employability Skills

Respondent	Statement of Comment
student 2	Skill is important in employment.
student 3	The employee must have positive attitude like hardworking and good in language
student 4	I think the employer will want to have employee with thinking skill, it shows how we solve the problem and next is information gaining skill like how they find information online and last is system and technology skill like they know how to use the technology when they are working
student 5	Every future employer will want their worker to be technologically incline, they have to know their skill on using technology but at the same time they would love to look at them on their communication skills also because we can't only base them by technology but if they can't present themselves
student 7	The important element in employability skill is communication.

B. Undergraduate's Perception on the Effectiveness of Online Learning Experiences

There is a significant change of higher institution from the traditional role due to globalization. MOOC is one of the online learnings which will improve teaching, and encourage the institution to develop mission [26]. The initiative by UTeM to introduce Mandarin MOOC is to keep abreast with the 21st century learning requirement. In the process of planning Mandarin MOOC, learner's prior learning experience must be considered to ensure the successful of an initiative. The respondents have reported that they have experience in online learning and have used online learning in some courses taught in UTeM such as Tamadun Islam and Tamadun Asia (TITAS) and entrepreneurship. Their statements are as follows.

"I have experience using online learning for the TITAS Tamadun Islam and Tamadun Asia subject." (Student 1)

"Last semester I have used online learning when I learn TITAS subject. The lecturer has introduced the class to use this online learning for revision. Sometimes the lecturer also wants our class member to discuss online." (Student 2)

"In semester 1, I used MOOC to study TITAS." (Student 3)

"I have used online learning for TITAS subject last semester." (Student 4)

"I have used online learning for TITAS and also technology entrepreneurship." (Student 5)

"I have used online learning, one of the subject was entrepreneurship." (Student 6)

"I have used online learning for industrial engineering subject." (Student 7)

"I have used online learning, one of it is entrepreneurship another one is project management. Actually UTeM also have their own online learning system for student which is called ULearn."

According to Bruff et al. [27], flexibility, customization, and accessibility are three of the encouraging elements in an online learning for students to have self-paced learning. The above experiences mentioned by undergraduates in the online learning proved that it is a good foundation to allow them to explore the new learning subject through online learning such as MOOCs.

Data gathered from the online survey were analyzed to see the effectiveness of using MOOC to students learning. From a total of 231 students, 123 were identified as valid responses and analyzed. Results of Part I: demography analysis showed that overall, more than 90% of the students agree that course experience are good (Excellent-19.5%, 35%-Very Good, 38.2%-Good) and students understanding after using MOOC had increased 10.6% to Excellent, 36.6% to Very Good, and 8.9% to Good.

Analysis from Learning Design dimension shows that majority students decided that learning design is between Very Good and Good as shown in the following Table II.

TABLE II. LEARNING DESIGN DIMENSION

Learning Design			
	Item	**Mean**	**SD**
LD1	The course is well designed	3.87	0.78
LD2	Learning through MOOC meets my learning needs	3.85	0.74
LD3	The sequence of learning activities help my understanding of the subject matter	3.91	0.74
LD4	The learning schedule (course plan/lesson plan) suits my learning pace	3.88	0.81

Table III shows Content Design aspect where the data shows that majority respondents chose between Somewhat Agree and Strongly Agree where the course materials cover the essential aspects of the course (CD1: 3.95), The course materials is well organized (CD2: 4.00), the course materials are clear (CD3: 4.05), the course activities able to enhance their understanding of the topic covered, Overall, the course materials help their understanding of the topics covered (CD4: 3.94, CD5: 3.98), the course materials provided meet their learning needs, the course activities provided meet their learning needs (CD6: 3.95, CD7:3.97), and useful for student’s learning (CD81-83: 4.15, 4.13, 4.17; CD91-94: 3.59, 3.3, 3.46, 3.53).

Table IV shows the dimension from the Learning Attitude. The research analysis shows that majority respondents agree that they can follow the course at their own pace (LA1: 3.8), accomplish the course activities on their own (LA2: 3.83), learning using MOOC, allows personalization (students can interact one-to-one with the instructor) (LA3: 3.8), and respondents engage more with lecture video and dialogue video to understand better (LA4-5: 4.06, 3.97).

TABLE III. CONTENT DESIGN

Content Design				
	Item		**Mean**	**SD**
CD1	The course materials covers the essential aspects of the course		3.95	0.77
CD2	The course materials is well organized		4.00	0.71
CD3	Overall, the course materials are clear		4.05	0.73
CD4	Overall, the course activities able to enhance my understanding of the topic covered		3.94	0.78
CD5	Overall, the course materials help my understanding of the topics covered		3.98	0.76
CD6	The course materials provided meet my learning needs		3.95	0.75
CD7	The course activities provided meet my learning needs		3.97	0.79
CD81	The following course materials (e-content) are useful for my learning:	Lecture video	4.15	0.79
CD82		Dialog video	4.13	0.80
CD83		Lecture slide	4.17	0.73
CD91	The following course activities (e-activities) are useful for my learning:	Quiz	3.59	1.09
CD92		Essay writing	3.3	1.00
CD93		Self-video presentation	3.46	1.07
CD94		Listening assessment (audio)	3.53	1.03

TABLE IV. LEARNING ATTITUDE

Learning Attitude			
	Item	**Mean**	**SD**
LA1	I am able to follow the course at my own pace	3.8	0.75
LA2	I am able to accomplish the course activities on my own	3.83	0.73
LA3	Learning using MOOC, allows personalization (students can interact one-to-one with the instructor)	3.8	0.75
LA4	I engage more with lecture video to understand better	4.06	0.77
LA5	I engage more with dialogue video to understand better	3.97	0.77

The Enhancement in Teaching and Learning in Table V shows the data that majority respondents chose Somewhat Agree and Strongly Agree that MOOC enhances their learning experience (E1: 3.97), Learning via MOOC is enjoyable (E2: 4.02), they learn more effective using MOOC (E3: 3.98), students are satisfied in learning using Mandarin MOOC (E4: 4.06), students believe the use of MOOC for learning Mandarin is feasible (E5: 4.07), and learning via MOOC help the students to remember, understand, and apply learning more effectively (E61-3: 4.11, 4.13, 4.12).

TABLE V. ENHANCEMENT IN TEACHING AND LEARNING

Enhancement in T&L				
	Item		**Mean**	**SD**
E1	MOOC enhances my learning experience		3.97	0.83
E2	Learning via MOOC is enjoyable		4.02	0.79
E3	I learn more effective using MOOC		3.98	0.81
E4	Overall, I am satisfied in learning using Mandarin MOOC		4.06	0.84
E5	I believe the use of MOOC for learning Mandarin is feasible		4.07	0.79
E61	Learning via MOOC help me to:	Remember (facts)	4.11	0.69
E62		Understand (concepts, principles, processes)	4.13	0.71
E63		Apply (what I have learned)	4.12	0.69

C. *Undergraduate's Perception on the Effectiveness of Mandarin Massive Open Online Course in Fostering their Employability Skills*

The findings of Cranmer [28] cast doubt on the assumption that employability skills can be effectively developed within classrooms. It shows there are limitations of face to face teaching and learning approach. Realizing this, besides face to face approach, online course such as Mandarin MOOC could play a good role to foster graduate's employability skills.

According to Fadzil et al. [29], the reasons for adoption of MOOCs in higher education institutions are to provide quality education to everyone, promoting an institution's brand, attracting new learners to enroll at an institution, potential for collaborating with other institutions, potential for research and development in online education as well as transforming traditional teaching and learning approaches. In the interview, undergraduates indicated that they have positive perception on the effectiveness of Mandarin MOOC in fostering their employability skills. The data is presented in the Table VI.

TABLE VI. UNDERGRADUATE'S PERCEPTION ON THE EFFECTIVENESS OF MANDARIN MASSIVE OPEN ONLINE COURSE IN FOSTERING THEIR EMPLOYABILITY SKILLS

The effectiveness of Mandarin Massive Open Online Course in fostering employability skills	**Students**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Basic skill								
Thinking skill								
Resource Management skill								
Information Gaining skill	xx	xx	xx	xx				xx
Interpersonal skill								
System and Technology skill		xx		xx	xx	xx	xx	xx
Personal quality								

Yorke and Knight [30] stressed that those who has desire to design new curriculum has to consider the potential of their program to develop students' employability skills. Among all the employability skills, students believe Mandarin MOOC fosters two employability skills which are 'information gaining skill' and 'system and technology skill'. Five out of eight students have showed their positive perception on the effectiveness of Mandarin MOOC in fostering their information gaining skill. It is supported by Carver and Harrison [31] that the MOOC's collaborative design incorporates opportunities to encourage cultural exchange and reinforce diverse approaches to problem solving. Students enjoy the learning experiences especially opportunity given to search information through internet. These findings show that Mandarin MOOC could play a good role to foster graduate's employability skills.

V. CONCLUSION

The Higher Education Institution in the world is constantly changing in pursue of quality, recognition and progression to become world class higher education provider. Engagement technology in education will create new learning environment where emphasis is on student-centered learning, constructivist and collaborative learning. Research shows that active learning using ICT approach is a new trend in higher education [32]. The use of computer and internet is a necessity in order to create a quality learning environment. The importance of a quality learning environment is to ensure that students would not left out from the world of technology.

In Malaysia, education is the biggest challenge for the government and education is a way to make year 2020 become a reality. How to produce well equipped citizen with education is always a question which is needed to be answered. One solution is to use technology as a medium or a new teaching approach in order to bring education to the masses. Higher education has to change because it needs more innovation for today's need [33]. Some existing traditional public universities or private universities and colleges have worked out to take up this challenge by utilizing the latest technologies to improve the delivery systems. Their effort results a new learning system in Malaysia which is MOOC. According to Renz et al. [34], instructional designer should contribute in MOOC to enable steady improvement of the media and content platform.

This study has managed to answer the research questions which show that the undergraduates are aware of the employability skills needed at the work place. They are found to have good foundation of online learning experiences. Besides, they have showed their positive perceptions on effectiveness of Mandarin MOOC which can foster their employability skills such as information gaining skill as well as system and technology skill. The limitation of this study is only eight respondents were chosen for an interview which lasted for 10 minutes each. This study is significant in determining the content of Mandarin MOOC material which may lead to an effective learning process. Future studies should focus on more variables to enhance performance in learning. To evaluate the effectiveness of Mandarin MOOC in fostering undergraduate's employability skill, more researches should be done to evaluate whether this course can address the need of the diverse population.

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REFERENCES

[1] S . Morshidi, B. Rosni, and Y. L. Koo, "International student mobility Malaysia." in the international mobility of students in Asia and the Pacific. France: The United Nations Educational, Scientific and Cultural Organization, 2013.

[2] A. Zaharim, Y. M. Yusoff, M. Z. Omar, A. Mohamed, N. Muhamad, and R. Mustapha, "Perceptions and expectation toward Engineering graduates by employers: a Malaysian study case," Wseas Transactions on Advances in Engineering Education, vol. 6(9), 2009, pp. 296–305.

[3] M. Y. Yuzainee, A. Zaharim, and M. Z. Omar, "Employability skills for an entry-level engineer as seen by Malaysian employers," in Global Engineering Education Conference (EDUCON) IEEE, 2011, pp. 80–85.

[4] S. C. Cismas, "Globalization in Engineering Education: advances in teaching presentation skills," in 6th WSEAS International Conference on Engineering Education, 2009, pp. 236–240.

[5] N. H. Omar, A. A. Manaf, R. H. Mohd, A. C. Kassim, and K. A. Aziz, "Graduates' employability skills based on current job demand through electronic advertisement," Asian Social Science, vol. 8(9), 2012, pp. 103–110.

[6] M. N. Dodson, K. Kitburi, and Z. L. Berge, "Possibilities for MOOCs in Corporate Training and Development," Performance Improvement, vol. 54(10), 2015, pp.14–21.

[7] J. Lin, and L. Cantoni, "A new definition of Massive Open Online Course: Arise from content analysis of 84 publications between 2008 and 2016".https://www.researchgate.net/profile/Jingjing_Lin/publication/312378247, 2017.

[8] G. Siemens, "Massive Open Online Courses: Innovation in education," Open educational resources: Innovation, research and practice, vol. 5, 2013, pp. 5–15.

[9] McAuley, B. Stewart, G. Siemens, and D. Cormier, "The MOOC model for digital practice". [Online] Available: https://s3.amazonaws.com/academia.edu.documents/43171388, 2010.

[10] J. Mackness, S. Mak, and R. Williams, "The ideals and reality of participating in a MOOC," in 7th International Conference on Networked Learning 2010. University of Lancaster, 2010, pp. 266–275.

[11] Centre for Instructional Resources & Technology (PSTP) and Council of Public Higher Education Institutions e-Learning Coordinators of Malaysia (MEIPTA), 2018. "Malaysia MOOCs Analytic Dashboard". [Online] Available: https://mooc.utem.edu.my/mymooc/

[12] K. M. Cheong, L. M. S. Khoo, J. Zanariah, and H. Hanipah, "The readiness of the administrators and undergraduates in using Massive Open Online Course (MOOC) in the Mandarin Subject," The Social Sciences, vol. 11(12) , 2016, pp. 3017–3023.

[13] D. Gamage, I. Perera, and S. Fernando, "What do star rates for MOOCs tell you? An analysis of pedagogy and review rates to identify effective pedagogical model," in W. Chen.et al. (Eds.) in 24th International Conference in Education. India: Asia-Pacific Society for computers in Education, 2016.

[14] K. Jordan, "Initial trends in enrolment and completion of Massive Open Online Courses,"The International Review of Research in Open and Distributed Learning, vol. 15(1), 2014, pp. 133–159.

[15] D. Gamage, S. Fernando, and I. Perera, "Factors leading to an effective MOOC from participiants' perspective" in Ubi-Media Computing (UMEDIA), 2015 8th International Conference, 2015, pp. 230–235.

[16] J. P. Espada, V. García-Díaz, C. Castillo Rodríguez, and R. GonzálezCrespo, "Method for analysing the user experience in MOOC platforms," in Computers in Education (SIIE), 2014 International Symposium, 2014, pp. 157–162.

[17] J. Raffaghelli, P. Ghislandi, and N. Yang, "Quality as perceived by learners: Is it the dark side of the MOOCs," Rem–Research On Eduacation and Media, vol. 6(1), 2014, pp. 121–136.

[18] L. Pool, and P. Sewell, "The key to employability: Developing a practical model of graduate employability", Education and Training, vol. 49, no. 4, 2007, pp. 277–289.

[19] (Business, Industry & Higher Education Collaboration Council [BIHECC] 2007) , "Graduate employability skills", Canberra: BIHECC.

[20] D. Jackson. 2015 "Employability skill development in work-integrated learning: Barriers and best practice", Journal Studies in Higher Education, vol. 40(2), 2015, pp. 350–367.

[21] G. K. G. Singh, and S. K. G. Singh, "Malaysian graduates' employability skills", UNITAR e-journal, vol. 4, No. 1, January 2008.

[22] M. S. Rasul, and R. A. A. Rauf, "Pembangunan alat ukur tahap kemahiran Kebolehdapatan kerja". Penerbit Universiti Putra Malaysia, 2010.

[23] M. S. Rasul, R. A. A. Rauf, A. N. Mansor, and A. P. Puvanasvaran, "Employability skills assessment tool development", International Education Studies, vol. 5, No. 5, 2012, pp. 43–56.

[24] C. Collet, D. Hine, and K. du Plessis, "Employability skills: Perspectives from a knowledge-intensive industry", Education and Training, 57(5), 2015, pp. 532–559.

[25] T. R. Liyanagunawardena, A. A. Adams, S. A. Williams, "MOOCs: A systematic study of the published literature 2008–2012," The International Review of Research in Open and Distributed Learning, vol. 14(3), 2013, pp. 202–227.

[26] J. Daniel, "Making sense of MOOCs: Musings in a maze of myth, paradox and possibility," Journal of interactive Media in education, vol. 3, 2012.

[27] D. O. Bruff, D. H. Fisher, K. E. McEwen, B. E., Smith, "Wrapping a MOOC: Student perceptions of an experiment in blended learning," MERLOT Journal of Online Learning and Teaching, vol. 9(2), 2013, pp. 187–199.

[28] S. Cranmer, "Enhancing graduate employability: best intentions and mixed outcomes," Studies in Higher Education, vol. 31(2), 2006, pp. 169–184.

[29] M. Fadzil, L. A. Latif, and T. A. Munira, "MOOCs in Malaysia: A preliminary case study," in E-ASEM Forum: Renewing the lifelong learning agenda for the future, Bali, Indonesia, 2015, pp. 1–17.

[30] M. Yorke, and P. Knight, "Embedding employability into the curriculum", vol. 3. York: Higher Education Academy, 2006.

[31] L. Carver, and L. Harrison, "MOOCs and democratic education," Liberal Education, vol. 99(4), 2013.

[32] R. Rena, "Emerging trends of higher education in developing countries," Scientific Annals of The Alexandru Ioan Cuza University Of Iasi: Economic Sciences Series, 2010, pp. 301–316.

[33] B. Wildavsky, A. P. Kelly, and K. Carey, "Reinventing higher education: the promise of innovation," Harvard Education Press, Cambridge, 2011.

[34] J. Renz, F. Schwerer, and C. Meinel, "openSAP: Evaluating MOOC usage and challenges for scalable and open enterprise education," International Journal of Advanced Corporate Learning., vol. 9(2), 2016, pp. 34–39.

Roadmap to Project Management Office (PMO) and Automation using a Multi-Stage Fuzzy Rules System

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***Abstract*—The Project Management Office (PMO) has proven to be a successful approach to enhance the control on projects and improve their success rate. One of the main functions of the PMO is monitoring projects and ensuring that the adequate processes are applied if a project starts to slip. Due to the high complexity of the parameters involved in choosing the actions to take depending on the type and status of the projects, organizations face difficulties in applying the same standards and processes on all projects across the organizations. In this paper, the authors will provide an overview of the main functions of the PMO, suggest a roadmap to start a PMO function within an organization and the authors will propose an architecture to automate the monitoring and control function of a PMO using a multi-stage fuzzy rules system.**

***Keywords*—Roadmap to build a PMO; automating the PMO; multi-stage Fuzzy System**

I. Introduction

There is no general agreement on the definition of a PMO [1]. Historically, the PMO was created in industries such as aerospace and heavy construction, that have multiple critical projects running simultaneously [2]. The PMO roles were to ensure that knowledge is shared between projects, to standardize the use of methodologies, standards and best practices across all projects, to measure the PKIs of the project and to provide reports for upper management [2]. Due to the proven success of the PMO [3], more industries, companies and governmental entities decided to build their own PMO.

A PMO has three core roles: monitoring, support and enforcing standards. Many companies added more functions to the PMO, such as strategic planning, quality assurance, process improvement and even the project managers capability, which is usually called the Project Portfolio Management (PPM). Although this approach is sometimes justified due to financial or business constraints, it is not the main job of the PMO and special care needs to be provided so that the PMO does not lose focus on its core functionalities.

Moreover, the PMO's goal is to insure the success of the project, which in some cases may be in direct conflict with the goals of the other functions that have been added to the PMO. It is not a good idea to assign to the PMO conflicting roles as it will often place it in a position of conflict. This will limit the assertiveness of the PMO and thus limit its success. For example, the PMO often needs to report projects' data to higher managers that would result in putting the project under governess focus and thus putting pressure on the project manager of this project. If the PMO is assigned the role of the PPM, the PMO will find itself in a conflicting position of having to defend the project manager as the PPM, and also to increase this pressure as the PMO.

Building a PMO costs money, thus the decision on when to build it and what roles should be assigned to the PMO is business driven. A company may decide to focus on some PMO roles and delay the implementation of other roles depending on the business need of the company. It is understood that a partially implemented PMO will not provide the expected effect of a fully functional PMO, which explains the contradictions that were found in several studies on the impact of PMO [4] and [3].

In the next section, a summary of the state of the art will be provided, then the paper will explain in more details the functions of the PMO. Next the paper will propose a roadmap to building the PMO, then it will propose the automation of the monitoring function of the PMO using intelligent agents and fuzzy logic. The conclusion will be provided I the final section.

II. Literature Review

The Project Management Institute (PMI) defines the PMO as "a management structure that standardizes the project-related governance processes and facilitates the sharing of resources, methodologies, tools, and techniques." [5]. The PMI defines three types of PMO: Supportive PMO whose role is restricted to providing consultations, Controlling PMO whose role is to provide consultation and impose standards and Directive PMO whose role is to directly manage the projects. The problem with these definitions is that they do not try to explain the core functions of the PMO and they do not identify the optional functions that may be assigned to the PMO. The effect of the lack of definitions of the core functions of the PMO can be seen in several research papers, where authors evaluated incomplete or immature PMOs, and thus provided results that are not pertinent to the PMO.

The business survey conducted by KPMG in 2017 [6] points out the problems many organizations face to define the role of the PMO, to ensure the long-term success of the PMO and to maximize the advantages of having a PMO. In this survey, the main reasons that were behind the organizations' decision to build a PMO was to improve governance, to prioritize investment, align and adjust to business strategy and to enable consistency of delivery. Nevertheless, the ambiguous role of the PMO and its incomplete implementation often limits the effectiveness of the PMO. Moreover, there is usually a gap between what the organizations' executives expect from the PMO and what it actually does. KPMG recommends that the role of the PMO should become more visible and that the PMO should focus more on project support, guidance and alignment with the strategic plan of the organization.

In [7], the authors point to the problem of determining the value of the PMO despite the variation in the mandate and functions of a PMO from one organization to another. They suggest measuring the value of the PMO by determining the purpose for which it was created and evaluating if it was capable of fulfilling this purpose, by determining the values of the capabilities the PMO brings to the organization or by measuring the improvement in the KPIs related to the performance of the portfolio of projects.

In [4], the authors tested the effect of having a PMO on meeting the project schedule, on abiding to the budget and on following standardized project management. The authors found that there is no evidence that a PMO presence will affect the project schedule or the project management standardization, but it does improve the ability to complete a project within budget. In our opinion, the authors did not take into consideration the level of maturity of the PMOs of the companies included in the study. This is a direct result of the fact that the roles and responsibilities of a PMO are not well defined. One of the main goals of our research is to define what are the minimum functions that need to be present to consider that a PMO has reached a level of maturity and effectiveness to qualify as an active PMO.

In [3], the authors did not consider that project reviewing was part of the PMO. Instead, they considered that the PMO role was limited to process improvement and providing support for PMs. Furthermore, they measured the effect of project review and of the PMO separately. They found that both PMO and project reviews improve project performances; they both have a strong effect on projects with high uncertainty.

In [8], the authors investigated the effect of the Project Management Office role in the delivery of technology projects in mobile communication companies in Kenya. They found that the PMO has a high impact on the success of projects and they strongly recommend the adaptation of the PMO.

Using fuzzy logic to adequately calculate the status of a complex system has been an active area of research since Lotfi Zadeh invented fuzzy logic [9]. To deal with complex systems having multiple fuzzy input variables, many researchers has proposed building multi-stage systems, with each stage having a limited number of input variables, thus making it easier to design.

III. The PMO Functions

Before explaining the functions of the PMO, the roles and functions of the Project Managers' Practice need to be explained as there is often confusion between the roles and responsibilities of the PMO and the PM practice.

Often, the company will contain multiple practices for PMs, developers, testing and analysts. The PM practice focuses on the PM. The PM practice cares about the PM as a resource, provides support, trains the PMs, builds the career path for each PM, hires PMs, allocates PMs, increases their utilization and handles any problem related to the PM. The process improvement may be inside the PM practice, inside the PMO or a standalone entity with collaboration with the PPM and the PMO.

On the other hand, the PMO's focus is on the project as a business asset of the organization. Often, the PMO will use the project's PM as the single point of contact to collect the KPIs of the project.

The core functions of the PMO are monitoring, providing support and enforcing standards. The PMO may be assigned other roles such as project auditing, process improvement, collection of best practices and availing Subject Matter Experts (SMEs).

The monitoring projects function focuses on collecting projects' data regularly. The monitoring team processes this data to generate various reports to each manager based on the manager's level and responsibilities. The monitoring team continuously analyzes the data to assess the status of each project and to detect potential problems.

The support role of the PMO is provided when there is a need for it. This need may arise while the project is still in the green or when the PM is facing a business or technical problem that is placing a risk on the project. When the project starts to fall behind, a root cause analysis is conducted under the supervision of the PMO and a Go-To-Green plan will be developed as a result of this effort. The level of details required in the root cause analysis and the Go To Green plan depend on various factors such as the percentage of slippage, the potential loss, the importance of the sector and how such a slippage may affect the reputation of the organization, thus affecting its ability to obtain new projects.

This support offered by the PMO may be provided in the following forms:

- Assigning technical people that will join the project for a limited time or permanently
- Consulting technical architects that will review the solution and the plan of the project
- Consulting senior PMs that will challenge the Go-To-Green plan.
- Consulting other PMs in the organization that have experience with the technologies and tools used by the project and in the business sector of the project.
- Providing the lesson learned from the lesson learned repository for project that have faced comparable problems.
- Consulting financial and sales teams that help obtain CRs from the customer
- Asking for support from the legal team for contract negotiation and for persuading the customer to respect the conditions and scope of the contract

The PMO is also responsible for enforcing standards. In fact, the organization may decide to adopt a new process, technology or tool due to a business need to acquire experience in a strategic area, to increase the quality of the product or to increase the customer satisfaction. In this case, the PMO is responsible for imposing the process of adoption of the change and for handling the resistance that may face the adoption of this change. This resistance may be justified from the point of view of the PM and the project team members as this change may induce delays and place stress on projects that are already facing difficulties.

The PMO will be responsible for determining the criteria based on which of the projects adopting this change first will be chosen. This choice will be a function of parameters such as the phase of the project, the financial parameters of the project, the project sector or technologies used. The PMO should not try to impose any change on the PM as the PM should be in full control of the project. Instead, the PMO should increase the priority of the implementation of this change and leave the decision on when to adopt it to the PM. An alternative approach is to request from the PM to provide an estimate in the cost and time if this change is adopted immediately or if it is adopted at the start of the next phase or iteration. These estimates may be challenged by the PMO team and the decision of when to adopt this change should be made in light of these revised estimates.

The PMO is often made responsible for other functions. Most notably, it is often a good practice to assign the PMO with the responsibility to collect the lesson learned. Otherwise, the lesson learned collection responsibility will be distributed between multiple practices and geographical locations, making the access to these lessons learned hard, if possible at all. Auditing the project may also be assigned to the PMO, as they are already responsible for collecting the KPIs of the project.

IV. Roadmap to Building the PMO

To build the PMO, the following steps are recommended:

1) Conduct analysis sessions to determine the KPI for all the projects and the level of detail that will be made available to each level of management. KPIs may be different from one sector to another, depending on the importance of the sector and the strategic areas on which the company is focusing.

2) Determine the different views and level of details that are made available to the managers, as a function of the manager level, role and sector.

3) Determine the report content, look and graphs used.

4) For each KPI, determine the actions to be taken in case of slippage of the PKIs of a project.

There are multiple parameters that may affect the choice of the action to be taken in case of project slippage. These parameters include:

- KPI value, reflecting the amount of slippage in time, expense and amount of scope creep
- The importance of the sector of the project
- The importance of the customer
- Financial parameters:
  - o Total cost of the project
  - o Expected gain from the project
  - o Potential loss due to penalties
- Project stage
- The history with the customer from the point of view of collaboration, acceptance of Change Requests and respect of the agreed upon features.
- Risk on reputation, as the preservation of the company reputation may make losses acceptable.

5) Determine when the information will be provided by the PMs. This may vary depending on the sector, project total value, project financial state (ahead of schedule, below cost, at cost, small financial slippage, large financial slippage) and the project schedule state (on schedule, small time slippage, large time slippage).

6) Determine how the PMO will communicate with other functions and practices and impose rules on when the PMO input is recommended or required.

7) Determine the phases during which the PMO will affect the project

8) Determine the tools that will be used to produce these reports. These tools may be simple excel files, commercially available products or custom made software.

The best approach is to implement the PMO in phases. The first phase will run using simple document templates. Then, the PMO initiative success will be evaluated and processes, reports and actions will be revisited. After the PMO team becomes confident of the maturity level of the PMO, the decision to buy a commercial application or to use a custom made software will be made. There is a trade-off between the two approaches. Using commercial applications or tools will usually be cheaper and the availability of these tools and applications will be faster, but the process of adapting these tools and applications to the needs of the company, the training required to use the tools and the preparation of the data in a format that the tools can understand at each reporting cycle may be a real burden. On the other hand, using custom software is usually easier, the software will retrieve the data from the available sources and there is a better control on the look of the produced report and the data that is available for different managers. Nevertheless, custom software is usually more costly and will take longer to become available. The decision on the approach to take is a business decision and the PMO team should explain clearly the benefit and pitfalls of each approach to the managers to help them choose the solution that better satisfies the needs of the company.

9) Determine how the PMO should be adopted. The PMO implementation could use a big-bang approach, in which case all the projects will start using the PMO on a specific date. This approach will enforce the culture of using the PMO and will send a clear message across the organization that the PMO adoption is not a choice but a requirement. On the other hand, the big-bang approach poses a risk as the limited knowledge of the modified processes could cause delays that will affect many projects. Moreover, there will be a limited number of experts familiar with the tools and processes, making helping all the projects at once and training all the PMs a challenging task.

Most organizations that have implemented the PMO have chosen to use a gradual approach, where the team of PMO experts will focus on a limited number of projects. After the successful adoption of the PMO and after the members of these projects have gained enough hands on experience on how to adopt the PMO, the PMO team will use another set of projects and will use the members of the teams that have already implemented the PMO as junior experts to help speed up the rolling out of the PMO.

In this case, it is recommended that the PMO imposes the criteria that will be used to select which of the projects should adopt the PMO first. In fact, if the choice is left to the practice, they may choose projects that are too easy or too complicated with a lot of issues, in which case the evaluation of the PMO results may not reflect the true value of the PMO. The criteria on which the projects are chosen may depend on the remaining time, the total cost, the current phase the project is in or the time or percentage of effort remaining to finish the phase the project is in.

The authors recommend that the PMO adoption should be used mainly at the beginning of new phases in the projects, as the implementation in the middle or toward the end of a phase may introduce confusion. Furthermore, it may require time to learn the new tools and understand how to adopt the new processes, which may introduce delays or may affect the quality of the final product.

V. Automating the Functions of PMO using Intelligent Agent

Monitoring a project is a complex task due to the various parameters of the project that needs to be considered. Based on these parameters, the state of each project will be evaluated to choose the most appropriate action plan to be taken if needed. These parameters may vary from one company to another based on the type of company, the company's expertise and the company's business processes.

TABLE I. The List of Parameters and their Types

Parameter Name	Parameter Type
Customer importance	Manual
Contract Value	Formula
Time Slippage	Formula
Cost Slippage	Formula
Solution Technical Difficulty	Manual
Customer Cooperation History	Manual
Scope Creep	Manual
Penalty Risk	Manual
Reputation Risk	Manual

Some of these parameters represent abstract concepts and cannot be measured. These parameters are entered manually by the stakeholders who decide the value for these parameters. Parameters that are entered manually use a slide bar starting from 0% to 100% with 10% increments. Examples of such parameters is the complexity of the technical solution and the level of collaboration of the client. Other parameters will be directly calculated using a formula from the data of the project, such as the parameter reflecting the time slippage and that reflecting the cost slippage of the project.

Table 1 presents the parameters that were chosen in our system to monitor the projects and whether they are manually entered or evaluated using a formula.

Next, the crisp values of these parameters are fuzzified using custom membership functions to transfer these parameters into fuzzy parameters with 3 labels: Low, Medium and High.

To simplify the design of the system, it is implemented into multistage fuzzy system [10]. The rules used to give values to the intermediate fuzzy variables are subjective and the solution provided in this paper is only given as a guideline. The overview of the system is given in Figure 1.

In the first stage, using the parameters ***penalty risk*** and ***cost slippage***, the ***potential cost slippage*** is calculated through fuzzy rules. Table 2 is used to summarize the fuzzy rules used to calculate the potential cost slippage.

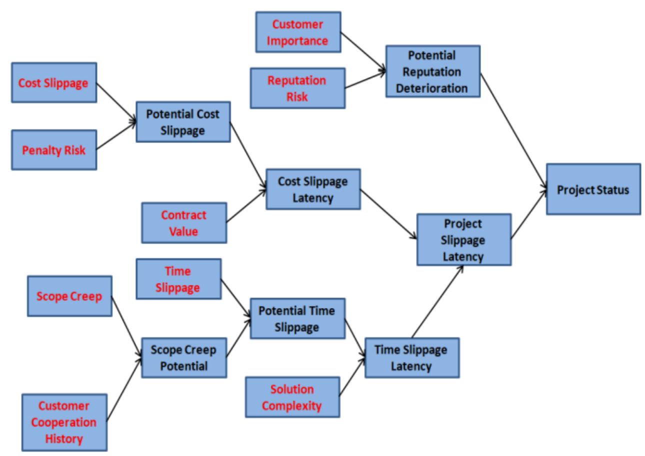

Fig. 1. Overview of the System Stages.

TABLE II. The Calculation of the Potential Cost Slippage

Potential Cost Slippage		Cost Slippage		
		Low	Medium	High
Penalty Risk	Low	Low	Medium	High
	Medium	Medium	High	High
	High	High	High	High

TABLE III. The Calculation of the Potential Cost Slippage

Cost Slippage Latency		Potential Cost Slippage		
		Low	Medium	High
Contract Value	Low	Low	Low	Medium
	Medium	Low	Medium	High
	High	Medium	High	High

In the second stage, using the parameters contract value and potential cost slippage, the cost slippage latency is calculated through fuzzy rules. Table 3 is used to summarize the fuzzy rules used to calculate the cost slippage latency.

In the third stage, the parameters customer cooperation history and scope creep are used to calculate the Scope Creep Potential as shown in table 4.

TABLE IV. THE CALCULATION OF THE POTENTIAL COST SLIPPAGE

Scope Creep Potential		Customer Cooperation History		
		Low	Medium	High
Scope Creep	Medium	Medium	Low	Low
	High	High	Medium	Low
	High	High	High	Medium

In the fourth stage, the parameters time slippage and scope creep potential are used to calculate the potential time slippage as shown in table 5

TABLE V. THE CALCULATION OF THE POTENTIAL TIME SLIPPAGE

Potential Time Slippage		Cost Slippage		
		Low	Medium	High
Scope Creep Potential	Low	Low	Medium	High
	Medium	Medium	High	High
	High	High	High	High

In the fifth stage, the parameters potential time slippage and solution complexity are used to calculate the time slippage latency as shown in table 6.

TABLE VI. THE CALCULATION OF THE TIME SLIPPAGE LATENCY

Time Slippage Latency		Potential Time Slippage		
		Low	Medium	High
Solution Complexity	Low	Low	Low	Medium
	Medium	Low	Medium	High
	High	Medium	High	High

In the sixth stage, the parameters cost slippage latency and time slippage latency are used to calculate the Project Slippage Latency as shown in table 7.

TABLE VII. THE CALCULATION OF THE PROJECT SLIPPAGE LATENCY

Project Slippage Latency		Time Slippage Latency		
		Low	Medium	High
Cost Slippage Latency	Low	Low	Medium	High
	Medium	Medium	High	Very High
	High	High	Very High	Critical

In the seventh stage, the parameters reputation risk and customer importance are used to calculate the potential reputation deterioration as shown in table 8.

TABLE VIII. THE POTENTIAL REPUTATION DETERIORATION

Potential Reputation Deterioration		Customer Importance		
		Low	Medium	High
Reputation Risk	Low	Low	Low	Medium
	Medium	Low	Medium	High
	High	Medium	High	High

TABLE IX. THE CALCULATION OF THE POTENTIAL STATUS

Project Status		Potential Reputation Deterioration		
		Low	Medium	High
Project Slippage Latency	Low	Low	Medium	High
	Medium	Medium	High	Very High
	High	High	Very High	Critical
	Very High	Very High	Critical	Critical
	Critical	Critical	Critical	Critical

In the eighth and final stage, the parameters project slippage latency and potential reputation deterioration are used to calculate the project status as shown in table 9.

The system uses a set of fuzzy rules to choose the best actions to take depending on the values of the intermediate and final fuzzy variables. These rules would be used to determine the rate of the review meeting, the Go-To-Green steering committee members, the level of the managers that will be briefed about the project, the corrective actions that may be taken, such as adding members to the project team; using the consultation of senior PMs, risk managers, SMEs, technical architects, the sales team and the legal team; performing a root cause analysis; retrieving information about similar problems from the lessons learned database; deploying a crisis team on the customer's site and eventually the decision to terminate the project. All projects that facing potential problems will start appearing in the reports with the level of details varying depending on the manager's level and business interest. The decision on the amount of information that will appear in reports and the levels of the manager that will see these reports is part of the analysis made during the construction of the PMO.

```
FUNCTION_BLOCK CostSlippageLatencyAgent

VAR_INPUT // Define input variables
    potentialCostSlippage:REAL;
    contractValue:REAL;
END_VAR

VAR_OUTPUT  // Define output variable
    costSlippageLatency: REAL;
END_VAR

FUZZIFY potentialCostSlippage  // Fuzzify input variable 'potentialCostSlippage': {'low', 'medium' , 'high'}
        TERM low := (0, 1) (20, 1) (50,0) ;
        TERM medium := (20, 0) (50,1) (80,0);
        TERM high := (50, 0) (80, 1) (100, 1);
END_FUZZIFY

FUZZIFY contractValue  // Fuzzify input variable 'contractValue': {'low', 'medium' , 'high'}
        TERM low := (0, 1) (20, 1) (50,0) ;
        TERM medium := (20, 0) (50,1) (80,0);
        TERM high := (50, 0) (80, 1) (100, 1);
END_FUZZIFY

DEFUZZIFY costSlippageLatency // Defuzzify output variable 'potentialCostSlippage' : {'low', 'medium', 'high' }
        TERM low := (0, 1) (20, 1) (50,0) ;
        TERM medium := (20, 0) (50,1) (80,0);
        TERM high := (50, 0) (80, 1) (100, 1);
        METHOD : COG;           // Use 'Center Of Gravity' defuzzification method
        DEFAULT := 0;           // Default value is 0 (if no rule activates defuzzifier)
END_DEFUZZIFY

RULEBLOCK No1
        AND : MIN;     // Use 'min' for 'and' (also implicit use 'max' for 'or' to fulfill DeMorgan's Law)
        ACT : MIN;     // Use 'min' activation method
        ACCU : MAX;    // Use 'max' accumulation method
    RULE 1 : IF potentialCostSlippage IS low AND contractValue is low THEN costSlippageLatency IS low;
    RULE 2 : IF potentialCostSlippage IS low AND contractValue is medium THEN costSlippageLatency IS low;
    RULE 3 : IF potentialCostSlippage IS low AND contractValue is high THEN costSlippageLatency IS medium;

    RULE 4 : IF potentialCostSlippage IS medium AND contractValue is low THEN costSlippageLatency IS low;
    RULE 5 : IF potentialCostSlippage IS medium AND contractValue is medium THEN costSlippageLatency IS medium;
    RULE 6 : IF potentialCostSlippage IS medium AND contractValue is high THEN costSlippageLatency IS high;

    RULE 7 : IF potentialCostSlippage IS high AND contractValue is low THEN costSlippageLatency IS medium;
    RULE 8 : IF potentialCostSlippage IS high AND contractValue is medium THEN costSlippageLatency IS high;
    RULE 9 : IF potentialCostSlippage IS high AND contractValue is high THEN costSlippageLatency IS high;

END_RULEBLOCK

END_FUNCTION_BLOCK
```

Fig. 2. Definition of the Cost Slippage Latency Agent.

An alpha cut-off of 20% is used to prevent rules with a low level of truth value to be triggered and thus preventing the initiation of unnecessary actions.

The system was implemented based on the fuzzy logic library JFuzzyLogic [11] with some modifications made to improve the library's support for multi-stage computation of fuzzy rules. An agent was used to compute the value of each intermediate or final fuzzy variables. Figure 2 shows the definition of the Cost Slippage Latency Agent.

In our implementation, agents used fuzzy rules to determine the suitable value of each intermediate fuzzy variable. Nevertheless, other techniques may be used instead if needed.

The calculation of the project status is conducted in multiple stages. In the first stage, intermediate agents, which have all their input parameters obtained from the customer or from formulas, are calculated. The system then iterates several times, evaluating the output of all agents whose input parameters are ready. This is repeated till the final stage is calculated and the value of the project status is calculated.

VI. Conclusion

The PMO has proven to play an important function in the success of organizations. This paper proposes a roadmap to build the PMO that is business driven and it also points to pitfalls that may reduce the success of the PMO. With multi-national companies conducting projects in several countries, it is hard to enforce manual processes that are applied equally across the organization. Automating the PMO's function of monitoring projects and choosing the most suitable actions to mitigate project slippage seems the correct approach, thus providing an efficient method to intervene at early stages of project slippage to improve the chances of resolving the project issues.

Due to the complexity of the parameters involved in controlling projects, automating the PMO's monitor and control function is a challenging task. In this paper, a multi-agents architecture using fuzzy logic has been proposed that reduces the complexity of the system by using a multi-stage approach to calculate the project status and to choose the proper set of actions that should taken. The system described in this paper is provided only as a guideline and companies should adapt the proposed model to represent the company goals and processes.

References

[1] Hobbs, B., 2007, "The Multi-project PMO:: A Global Analysis of the Current State of Practice", white paper, PMI, 44 pages.

[2] Desmond, C., 2015, "Project Management Office", in IEEE Engineering Management Review, Volume 43, number 1, IEEE, pages 15-16

[3] Liu, L. , Yetton, P. , 2007 , "The Contingent Effects on Project Performance of Conducting Project Reviews and Deploying Project Management Offices", in IEEE transactions on Engineering Management, Volume 54, number 4, IEEE, pages 789-799.

[4] Martin, N.L. , Pearson, J.M., Furumo, K.A. , 2005, "IS Project Management: Size, Complexity, Practices and the Project Management Office", in Proceedings of the 38th Annual Hawaii International Conference on System Sciences, IEEE.

[5] Project Management Institute, 2017, "A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Sixth Edition", Project Management Institute, 756 pages.

[6] KPMG, 2017, "Driving Business Performance: Project Management Survey", 2017, on-line: https://assets.kpmg.com/content/dam/kpmg/nz/pdf/July/projectmanagementsurvey-kpmg-nz.pdf

[7] Van der Linde, J., Steyn, H., 2016, "The effect of a Project Management Office on project and organisational performance: A case study", South African Journal of Industrial Engineering, vol.27, n.1, http://dx.doi.org/10.7166/27-1-1114

[8] Munyoki. K. K., & Njeru, A. W., 2014, "The Effect of Project Management Office Role in the Delivery of Technology Projects in Mobile Communication Companies in Kenya", in International Journal of Humanities and Social Science, Vol. 4 No. 3; pages: 211- 215

[9] Zadeh, L., 1996, "Fuzzy sets." Fuzzy Sets, Fuzzy Logic, And Fuzzy Systems, pages 394-432

[10] Yeh, Z.M., Li, K.H., 2004, A systematic approach for designing multistage fuzzy control systems, In Fuzzy Sets and Systems, 2004, Elsevier, Volume 143, Issue 2, Pages 251-273, https://doi.org/10.1016/S0165-0114(03)00203-3

[11] Cingolani, P., & Alcala-Fdez, J., (2012). JFuzzyLogic: a robust and flexible Fuzzy-Logic inference system language implementation. In Fuzzy Systems (FUZZ-IEEE), 2012 IEEE International Conference on (pp. 1-8). IEEE, https://doi.org/10.1109/FUZZ-IEEE.2012.6251215

Fixed Point Implementation of Tiny-Yolo-v2 using OpenCL on FPGA

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***Abstract*—Deep Convolutional Neural Network (CNN) algorithm has recently gained popularity in many applications such as image classification, video analytic and object detection. Being compute-intensive and memory expensive, CNN-based algorithms are hard to be implemented on the embedded device. Although recent studies have explored the hardware implementation of CNN-based object classification models such as AlexNet and VGG, there is still a rare implementation of CNN-based object detection model on Field Programmable Gate Array (FPGA). Consequently, this study proposes the fixed-point (16-bit) implementation of CNN-based object detection model: Tiny-Yolo-v2 on Cyclone V PCIe Development Kit FPGA board using High-Level-Synthesis (HLS) tool: OpenCL. Considering FPGA resource constraints in term of computational resources, memory bandwidth, and on-chip memory, a data pre-processing approach is proposed to merge the batch normalization into convolution layer. To the best of our knowledge, this is the first implementation of Tiny-Yolo-v2 object detection algorithm on FPGA using Intel FPGA Software Development Kit (SDK) for OpenCL. Finally, the proposed implementation achieves a peak performance of 21 GOPs under 100 MHz working frequency.**

***Keywords*—FPGA; CNN; Tiny-Yolo-v2; OpenCL; detection**

I. Introduction

Convolutional Neural Network (CNN) is a well-known deep learning architecture inspired by the artificial neural network. It has been primarily employed in various applications including image classification [1] [2] and object detection [3] [4] [5]. Unlike the traditional machine learning algorithms, CNN algorithms are extremely computationally expensive and memory intensive. The state-of-the-art of CNN algorithms usually require millions of parameters and billions of operations to process a single image input. This is a great challenge to implement CNN algorithms on an embedded system due to severe hardware constraints such as computational resources, memory bandwidth, and on-chip memory. Hence, in recent year, Field Programmable Gate Array (FPGA) has become an attractive alternative solution to accelerate CNN-based algorithms due to its relatively high performance, flexibility, energy efficient and fast development cycle, especially with the new release of High-Level-Synthesis (HLS) tool: OpenCL. It greatly reduces the complexity of programming by enabling the auto-compilation from a high-level program (C/C++) to register-transfer-level (RTL).

Prior works [6] [7] have shown the effort of accelerating CNN classification model: AlexNet and VGG through the implementation of 3-Dimension (3D) convolution as General Matrix-Matrix Multiplication (GEMM). Data rearrangement on-the-fly technique is proposed to reduce the memory footprint. In this work, the idea of mapping 3D convolution as GEMM and data rearrangement on-fly are borrowed and these techniques are further applied to perform object detection algorithm: Tiny-Yolo-v2 on both Pascal VOC [8] and COCO [9] object detection datasets. Prior work [10] takes a different approach to accelerate the CNN classification in a deeply pipelined manner. In addition, they proposed the insight of "performance density" as an alternative performance evaluation metric for the fair comparison between their work and prior research work. However, their design implemented floating-point arithmetic which it is unfriendly to the hardware computation. Hence, in this work, the fixed-point arithmetic instead of floating-point arithmetic is implemented to better improve the bandwidth and resources utilization. In addition, a technique to merge the batch normalization into convolution is proposed to reduce the data redundancy. The key contributions are summarized as follows:

- A CNN-based object detection algorithm: Tiny-Yolo-v2 with 16-bit fixed-point arithmetic running on FPGA
- A systematic in-depth analysis on the impact of the precision of the weights on the two detection datasets: Pascal VOC 2007 and COCO.
- A novel approach of merging batch normalization layers and convolutional layer to reduce data redundancy during the inference process.

The rest of the paper is presented as follows. Section 2 briefly describes the background of the research work. In this section, the overview of OpenCL development flow, the architecture of Tiny-Yolo-v2 and performance evaluation metrics are presented in detail. Section 3 briefly discuss the proposed design and the case studies on the impact of precision of the weights for Tiny-Yolo-v2 on the two detection datasets: VOC [10] and COCO [11]. It also studies the mathematical approach to merge the batch normalization operation into the convolutional layer. Section 4 briefly presents the experimental results. Section 5 concludes the paper.

II. Background

In this section, a detail description of the overview of OpenCL based FPGA development flow, the architecture of

Tiny-Yolo-v2 and the performance evaluation metrics used in this work is presented.

A. Overview of OpenCL

Intel FPGA Software Development Kit (SDK) for OpenCL [12] [13] allows the user to avoid the traditional hardware FPGA development flow by using HLS tools. It is an alternative approach to traditional RTL design concepts such as Verilog or VHDL with C or C++ synthesis. Fig. 1 illustrates the OpenCL-based FPGA accelerator development flow. In the OpenCL framework, the Central Processing Unit (CPU) acts as the host and it has bridges interconnect the Cyclone V PCIe FPGA board which it serves as an OpenCL device, forming a heterogeneous computing system. An OpenCL code is translated into hardware image, supported by OpenCL runtime driver. Furthermore, on the host side, C/C++ code runs on the CPU, providing vendor specific Application Programming Interface (API) to communicate with the implemented kernels on the Cyclone V PCIe FPGA board.

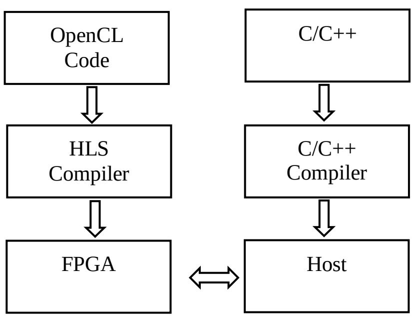

Fig. 1. OpenCL based FPGA Development Flow.

B. Architecture of Tiny-Yolo-v2

In this section, a detail exploration of the Yolo object detection framework is briefly discussed. Unlike prior object detection algorithm [6] which repurpose classifiers to perform detection, Yolo [7][8] uses a different approach to apply a single convolutional network to the full image and predict multiple bounding boxes and class probability for those boxes. Fig. 2 shows the architecture of Tiny-Yolo-v2, which consists of 9 convolutional layers, each with a leaky rectified linear unit (ReLU) based activation function and batch normalization operation interspersed with 6 max-pooling layers and a region layer. Tiny-Yolo-v2 takes input image size 416 x 416 to 20 output classes in VOC datasets whereas 80 output classes in COCO datasets.

C. Convolutional Layer

Tiny-Yolo-v2 employs feedforward process for object detection. A previous study [14] has proved that the convolutional layer will occupy over 90 % of the feed-forward computation period. Hence, in this work, the optimization of the convolutional layer will be the main focus to improve the performance of accelerator. Convolution layers involve billions of multiplication and addition operations between the filters and local regions of input for a single input image. The operations can be represented in (1) as followed:

$$X^{(i)} = \sum_{i=1}^{n} (x^{(n)} \times w^{(k)}) + b \tag{1}$$

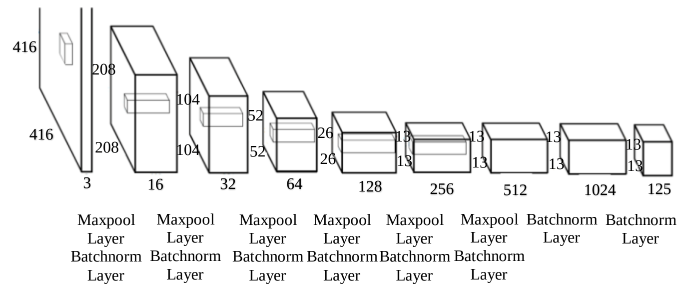

Fig. 2. Tiny-Yolo-v2 Achitecture.

Where:

$X^{(i)}$ = Pixel of output feature0

$x^{(j)}$ = Pixel of input feature

$w^{(k)}$ = Convolution weights

b = Convolution bias

The total amount of operations in the convolution layer can be approximately calculated as shown in (2). Noted that, this equation ignores the number of operations for the batch normalization and leaky activation for each layer.

$$\#\text{Operations} = 2 \times N_{in} \times K \times K \times N_{out} \times H_{out} \times W_{out} \tag{2}$$

Where:

N_{in} = Number of channels of input feature

K = Filter size

N_{out} = Number of filters

H_{out} = Height of output feature

W_{ou0t} = Width of output feature

The memory requirement is described as space complexity. The main parameter in the Tiny-Yolo-v2 is the weight which is used in the convolutional layer. The number of weights in the convolutional layer can be expressed as (3):

$$\#\text{Weights} = N_{in} \times K \times K \times N_{out} \tag{3}$$

Where:

N_{in} = Number of channels of input feature

K = Filter size

N_{out} = Number of filters

Tiny-Yolo-v2 takes approximately 7 billion operations with 15 million weights just for one image input in Pascal VOC. On the other hand, Tiny-Yolo-v2 takes approximately 5.7 billion operations with 12 million weights just for one image input in COCO dataset.

D. Activation Function

Activation function in a CNN architecture is used to transform the input before the pooling layer. Sigmoidal activation functions were most often used in CNN. However, sigmoidal activations are bounded by a maximum and minimum value and thereby causing the saturated neuron in higher layers of the neural network. Alternatively, Leaky ReLU has recently been proposed as an activation function as it can cause the weight update which makes it never activate on any data point again. Leaky ReLU along with respective equation is shown in Fig. 3.

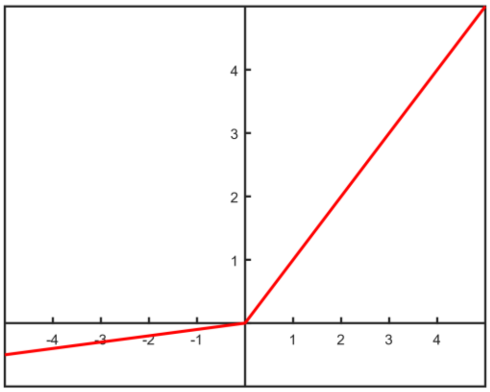

Fig. 3. Leaky Rectified Linear Unit(Leaky ReLU).

E. Pooling Layer

Pooling layer, in general, is a form of dimensional reduction used in CNN. Its goal is to throw away unnecessary information and only preserve the most critical information. Typical pooling functions are maximum pooling and average pooling layer. Max pooling returns the maximum value from the input, where average pooling returns the average value. The formula of max-pooling and average-pooling are illustrated as follows:

$$S[i, j] = \max\{S[i;, j']: i \le i' < i+, j \le j' < j + p\} \tag{4}$$

$$S[i, j] = \mathrm{average}\{S[i;, j']: i \le i' < i+, j \le j' < j + p\} \tag{5}$$

F. Batch Normalization Layer

Batch normalization layer is implemented after the convolutional layer to provide any layer in Tiny-Yolo-v2 with inputs that are zero mean or unit variance. The equation of batch normalization is shown in (6). The normalization is performed to previous output of the convolutional layer by subtracting the batch mean and dividing by the batch variance. After batch normalization operation, the output will be shifted and scaled by the bias and scale. The value for these variables: means, bias, scale, and variance are generated in CNN training stage. These values allow each layer to learn in a more independent way and reduce the overfitting because it has a slight regularization effect.

$$X^{(j)} = \frac{(X^{(i)} - \mu)}{\sqrt{\sigma^2 + \xi}} \tag{6}$$

Where:

$X^{(j)}$ = Output Pixel after batch normalization

$X^{(i)}$ = Output Pixel after convolution

μ = Mean

σ^2 = Variance

ξ = Constant

G. Evaluation Metric

This section presents the detail description of the evaluation metric used to measure the performance of the proposed accelerator for Tiny-Yolo-v2 implemented on Cyclone V PCIe Development Kit FPGA board. Prior works [6] [7] [8] measure their accelerator design in term of accuracy and throughput. However, these two metrics are invalid in this case. This work is running object detection model instead of object classification. In contrast to classification task, object detection must localize and classify a variable number of objects on an image which indicates that the output of object detection may change from image to image. Hence, the accuracy of proposed accelerator is measured in term of mean average precision (mAP). Besides, to make a fair comparison on the throughput of proposed accelerator running on Cyclone V PCIe Development Kit to previous accelerator design that running on other FPGA such as Stratix V and Aria 10 GX, performance density is used as the main factor to evaluate the performance of proposed design. To make a fair comparison between the performances achieved in different hardware, the normalized performance of throughput is introduced in work [8]. The equation to calculate performance density is listed as follow:

$$\mathrm{Perf.Density} = \frac{\mathrm{Throughput}}{\mathrm{DSP\_Consumed}} \tag{7}$$

III. Research Methodology

This section presents a detail description on how to implement of 3D convolution as GeMM in the accelerator. In addition, the approach of merging the batch normalization layer into the convolutional layer to reduce the data redundancy is described. Lastly, an in-depth analysis of the precision study of the weights of Tiny-Yolo-v2 on two different object detection datasets: Pascal VOC and COCO object detection datasets is provided.

A. Implementation of 3-Dimension (3D) Convolution as General Matrix-Matrix Multiplication (GeMM)

CNN employs a feedforward process for object detection, involving billions of multiplication and addition operations. Noted that the convolution operation essentially performs multiplication and accumulate operations between the filters and local region of inputs. To take advantage of this, the similar GeMM based convolution with data rearrangement on-fly is used to accelerate the algorithm. Fig. 4 shows that how the first layer of convolution layer of Tiny-Yolo-v2 is flattening and rearranged vertically into a 2-Dimension (2D) matrix through data rearrangement process. For example, the dimension of the input layer for Tiny-Yolo-v2 is 416 × 416 × 3 (Hin × Win × Nin) and the size of the kernel is 3 × 3 (K × K). The input image is flattened and rearranged into matrix B with a dimension of 416 × 416 × 3 × 3× 3. After that, a vector from matrix B is multiplied with a vector from matrix A. The result will be accumulated to be one output in matrix C.

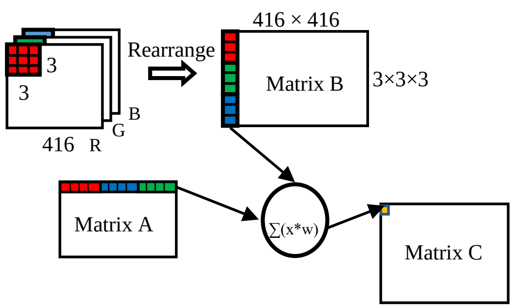

Fig. 4. Convert 3D Convolution into GeMM.

Notice that previous operation comes at the cost. It causes the expansion in memory size if the stride is smaller than the kernel size as pixels are overlapping and duplicated in the matrix. The expansion of memory increases the memory requirement to store the rearranged input feature matrix. To get rid of this, pseudo below is used to perform the similar operation on-the-fly by storing the corresponding pixels into FPGA's local memory before the matrix multiplication.

1) Get current work-item id (global_x, global_y, local_y, local_x, block_x, block_y)

2) Compute current output pixel (channel_out, height_out, width_out) based on current work-item id

3) Compute the actual input feature image (channel_in, height_in, width_in) based on computed output pixel coordinate.

4) Read the actual pixel value

5) Value = 0 < id ≤ input_dimension? Input[id] : 0

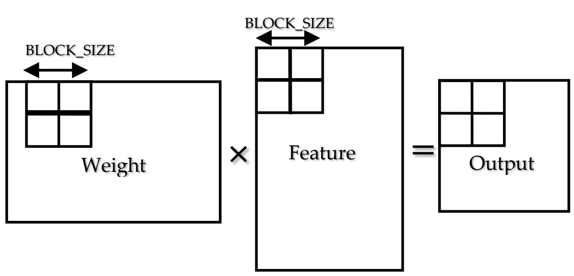

Fig. 5. Block Tiling of GeMM.

Fig. 5 illustrates that the way of how the tiled multiplication is implemented in the design. Instead of fetching the data and performing multiplication one value by one value, the performance is further improved by performing the multiplication in block. Two scalable design parameters BLOCK_SIZE and SIMD vectorization factor are introduced to determine the scale of the block. The BLOCK_SIZE determines how many data is fetched and perform multiplication at one time. In contrast, SIMD determines the factor by which data are vectorized and executed in Single Instruction Multiple Data (SIMD) manner. These parameters are scalable depends on the resources available in FPGA. The performance of the object detection is determined by choosing an appropriate of SIMD and BLOCK_SIZE factor.

B. Data Pre-Processing by Merging Batch Normalization into Convolutional Layer

Batch normalization is implemented after the convolution process in Tiny-Yolo-v2 to improve the stability of the neural network. The formula of convolution is shown in (1) and batch normalization is shown in (6). Taking advantage of the fact that the input of batch normalization operation is exactly the output of previous convolutional layer. Hence, the input, x(i) in (6) could be substituted with (1) and it will form the equation as shown in (8).

$$X^{(j)} = \left(\frac{\left[\sum_{n=1}^{n} \left(x^{(n)} \times \omega^{(\kappa)} \right) + b \right] - \mu}{\sqrt{\sigma^2 + \xi}} \right) \tag{8}$$

where:

X(j) = batch normalization output

x(n) = convolution input

w(k) = convolution weights

b = convolution bias

μ = batch normalization mean

σ^2 = batch normalization variance

ξ = Constant

To further simplify (8), the complicated equation is further rearranged to become (9).

$$X^{(j)} = \left(\frac{\sum_{n=1}^{n} \left(x^{(n)} \times \omega^{(\kappa)} \right)}{\sqrt{\sigma^2 + \xi}} \right) + \frac{(b - \mu)}{\sqrt{\sigma^2 + \xi}} \tag{9}$$

Now, it is worth noting that all the output of convolution must be divided by value = $\sqrt{\sigma^2 + \xi}$. By obeying the mathematic Distributive Law; that is, a(b+c) = ab+bc, the equation in (9) could be simplified to become (10).

TABLE II. PRECISION STUDY FOR TINY-YOLO-V2 WEIGHTS ON PASCAL VOC 2007 AND COCO DATASETS

Layer	Pascal VOC 2007				COCO			
	min	max	8-bit precision loss (%)	16-bit precision loss	min	max	8-bit precision loss	16-bit precision loss
1	-25.43982	26.42148	9.6%	0.0%	-18.71754	28.54190	6.3%	0.0%
2	-0.66461	0.47238	19.5%	0.2%	-0.65677	0.51022	17.8%	0.1%
3	-1.00267	1.31331	24.9%	0.1%	-0.96951	1.56696	26.1%	0.1%
4	-0.61135	0.79291	20.5%	0.1%	-0.64109	0.76376	19.1%	0.1%
5	-0.44413	0.73024	24.3%	0.1%	-0.41294	0384003	25.2%	0.1%
6	-0.51432	0.63433	29.9%	0.1%	-0.30638	0.63954	34.2%	0.1%
7	-1.39691	1.47183	15.7%	0.1%	-1.58541	1.85696	20.4%	0.1%
8	-0.02337	0.02339	3.6%	0.0%	-0.07274	0.05593	19.0%	0.1%
9	-0.23489	0.19417	6.1%	0.0%	-0.80548	0.54988	18.0%	0.1%

$$X^{(j)} = \sum_{n=1}^{n} \left(x^{(n)} \times \frac{\omega^{(\kappa)}}{\sqrt{\sigma^2+\xi}} \right) + \frac{(b-\mu)}{\sqrt{\sigma^2+\xi}} \tag{10}$$

Finally, since the value of batch mean, batch standard deviation, weights and constant are pre-trained offline, and all these values will only be loaded one time during the inference process. Hence, to reduce the number of operations and data redundancy, the equation in (10) is transformed to become equation in (11), which is similar to (1) with fine-tuned weights and biases: b_{new} and w_{new}. This b_{new} and w_{new} can be pre-processed before the inference which helps to reduce the number of operations and improve the hardware utilization.

$$X^{(j)} = \sum_{n=1}^{n} \left(x^{(n)} \times \omega^{(\kappa)}{}_{new} \right) + b_{new} \tag{11}$$

Where:

$$w_{new} = \frac{\omega^{(\kappa)}}{\sqrt{\sigma^2+\xi}}$$

$$b_{new} = \frac{b-\mu}{\sqrt{\sigma^2+\xi}}$$

C. Precision Study for Object Detection Datasets

Tiny-Yolo-v2 is trained using Graphic Processing Unit (GPU) in a 32-bit environment. Hence, the trained weights and bias are usually stored in 32-bit floating point format. However, such high precision is not necessarily in an inference machine. To reduce data redundancy, the best precision required for model Tiny-Yolo-v2 is explored using both COCO and Pascal VOC pre-trained weight from darknet framework. The analysis is done using the MATLAB Fixed-Point Designer Toolbox. Table I shows the range [min, max] of the fine-tuned weight w_{new} (as discussed in the previous section) for all 9 layers in Tiny-Yolo-v2 running on Pascal VOC and COCO object detection datasets. The table also explains the comprehensive precision loss of weights in: 8-bit and 16-bit fixed point representation. Based on the report generated by the toolbox, the 8-bit precision can contribute up to 29.9% of precision loss in Pascal VOC datasets and 34.2% precision loss in COCO datasets. According to this report, the performance of the accelerator is expected to be significantly degraded if the data is represented in 8-bit precision. Hence, 16-bit precision for the convolution weights and 32-bit precision is proposed for the intermediate inner product of weights and input in this work.

IV. RESULTS AND DISCUSSION

This section first briefly reports the hardware resource utilization. Then, the proposed design is compared to software implementation (CPU) with the two scalable design parameters BLOCK_SIZE=32 and SIMD=4. Finally, the comparison between the implementation and prior work. The resource utilization report on the Cyclone V PCIe FPGA board is shown in Table II. The proposed design with floating point is unable to fit into the board, as it consumes 161% of logic, 140% of RAM and 64% of DSP blocks which exceed the board hardware limitation. With the proposed data pre-processing technique presented in section 3.2, the design manages to reduce approximately 21% of logic usage, 8% of RAM usage and 6% of DSP usage. To further enhance the optimization, 16-bit of fixed-point arithmetic is implemented as discussed in section 3.3. The hardware resources are significantly reduced compared to floating point arithmetic. Finally, this design achieves 97% improvement in logic consumption, 30% improvement in RAM consumption and 18% in DSP consumption.

TABLE III. SUMMARY OF HARDWARE RESOURCE UTILIZATION

	Logic	RAM	DSP
Floating point	161 %	70 %	59 %
Floating point (with data pre-processing)	140 %	62 %	53%
Fixed-point (16-bit arithmetic with data pre-processing)	64%	40%	41%

TABLE IV. SUMMARY OF THE COMPARISON OF THE PERFORMANCE BETWEEN SOFTWARE IMPLEMENTATION AND FPGA IMPLEMENTATION

Layer	CPU (Intel R Core TM i7-7700)		FPGA	
	Pascal VOC	COCO	Pascal VOC	COCO
1	0.083	0.082	0.047	0.050
2	0.123	0.117	0.028	0.027
3	0.112	0.110	0.020	0.020
4	0.094	0.096	0.018	0.018
5	0.096	0.095	0.017	0.017
6	0.098	0.096	0.018	0.018
7	0.372	0.369	0.063	0.064
8	0.381	0.382	0.128	0.064
9	0.019	0.018	0.004	0.005
Total Execution Time (s)	1.378	1.365	0.339	0.278

The performance comparison between the proposed accelerator for Tiny-Yolo-v2 on VOC dataset and COCO dataset and CPU (Intel® Core™ i7-7700) is depicted in Table III. In overall, the proposed accelerator achieves 21.57 GOPs which is approximately 4 times speedup over software implementation.

In Table IV, the work is compared to other prior HSL-based designs. In this work, the board used: Cyclone V PCIe FPGA which is different from the hardware used in the previous study. To make a fair comparison, the performance density of the proposed design is measured. It clearly indicates that the proposed design implementation achieves comparable performance compared to previous work.

Pictures tested by the design are shown in Fig. 6(a) and Fig. 7. In this work, despite the computation is carried out at lower precision (16-bit) than original Tiny-Yolo-v2 (32-bit), all objects in images can be detected and tagged correctly. Finally, the design achieves the mAP similar with original Tiny-Yolo-v2 running in floating point, and the difference is no more than 1%.

TABLE V. COMPARISON TO PREVIOUS WORK

	[8]	[6]	This work
Device	Stratix-V GXA7	Stratix-VGXA7	Cyclone V PCIe
FPGA Capacity	622K LUTs	622K LUTs	113K LUTs
Model	AlexNet, VGG	AlexNet, VGG	Tiny-Yolo-v2
Design Scheme	OpenCL	OpenCL	OpenCL
Frequency	181MHz	120MHz	117MHz
Precision	float	Fixed(8-16bit)	Fixed(16bit)
Throughput	33.9 GOPs	117.8GOPs	21.6 GOPs
DSP Consumed	162	246	122
Performance Density	0.21GOPS/DSP	0.29GOPS/DSP	0.18OPS/DSP

Fig. 6. Tested Image of Car.

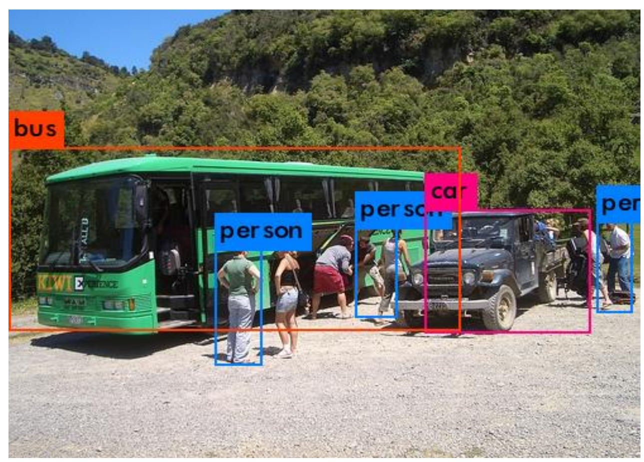

Fig. 7. Tested Image of Bus, Person, and Car.

V. CONCLUSION

In this work, a scalable CNN-based object detection algorithm is implemented on FPGA with fixed-point implementation using OpenCL approach. Further, a way of merging batch normalization layer in the convolutional layer is proposed to improve the performance and reduce the hardware resource. Finally, Tiny-Yolo-v2 is implemented on Cyclone V PCIe FPGA and achieved comparable performance density of 0.18 GOPs/DSP compared to previous work. The proposed implementation can achieve a peak throughput of 21 GOPs under 100 MHz working frequency.

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REFERENCES

[1] A. Krizhevsky, I. Sutskever and GE. Hinton, "Imagenet classification with deep convolutional neural networks", Advances In Neural Information Processing Systems, 2012, pp. 1097-1105,

[2] K. Simonyan, and A.Zisserman, "Very deep convolutional networks for large-scale image recognition", arXiv preprint arXiv:1409.1556, 2014.

[3] S. Ren, K. He, R. Girshick, and J. Sun, "Faster r-cnn: Towards real-time object detection with region proposal networks", Advances In Neural Information Processing systems, 2015, pp. 91-99.

[4] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, "You only look once: Unified, real-time object detection", Proceedings of IEEE Conference on Computer Vision and Pattern recognition, 2016, pp. 779-788.

[5] J. Redmon, and Farhadi, "A. YOLO9000: better, faster, stronger", arXiv, 2017.

[6] N. Suda, V. Chandra, G. Dasika, A. Mohanty, Y. Ma, S. Vrudhula, J.S. Seo, and Y. Cao, "Throughput-optimized OpenCL-based FPGA accelerator for large-scale convolutional neural networks," in ACM/SIGDA International Symposium on Field-Programmable Gate Arrays, 2016, pp. 16-25.

[7] J. Zhang, and J. Li, "Improving the performance of OpenCL-based fpga accelerator for convolutional neural network", Proceedings of the 2017 ACM/SIGDA International Symposium on Field-Programmable Gate Arrays, 2017, pp. 25-34.

[8] D. Wang, J. An, and K. Xu, "PipeCNN: An OpenCL-Based FPGA Accelerator for Large-Scale Convolution Neuron Networks", arXiv, vol. 1611.02450, 2016.

[9] J. Ma, L. Chen, Gao, "Hardware Implementation and Optimization of Tiny-YOLO Network", International Forum on Digital TV and Wireless Multimedia Communications, Springer, Singapore, 2017, pp. 224-234.

[10] M. Everingham, L. Van Gool, C.K. Williams, J. Winn and A. Zisserman, "The pascal visual object classes (voc) challenge", International journal of computer vision, 2010, 88(2), pp.303-338.

[11] T.Y. Lin, M. Maire, S. Belongie, J. Hays, P. Perona, D. Ramanan, P. Dollár, and C.L. Zitnick, "Microsoft coco: Common objects in context", European conference on computer vision, Springer, 2017, pp. 740-755.

[12] FPGA SDK for OpenCL Programming Guide., Intel, 2017, pp. 70-80.

[13] FPGA SDK for OpenCL Best Practice Guide, Intel, 2017, pp. 17-20.

[14] J. Cong, and B. Xiao, "Minimizing computation in convolutional neural networks", International Conference on Artificial Neural Networks, 2014, pp. 281-290.

Designing a Switching based Workflow Scheduling Framework for Networked Environments

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***Abstract*—Due to the dynamics of the power of resources in non-dedicated computing environments such as Grid, and on the other hand, the autonomy of these environments and, consequently, the impossibility of repeating the operating scenarios to compare the algorithms created in this context, creating an environment by providing such conditions is necessary. In this paper, a framework for evaluating workflow-scheduling algorithms has been created, focusing on the dynamics of the power of resources in distributed environments. This framework based on a switching model that is capable of considering the change in the processing power of resources with high precision. Using the ability of this framework, the effectiveness of several different workflow scheduling algorithms has been evaluated.**

Keywords—Scheduling framework; workflow scheduling; grid; switching based framework

I. Introduction

The issue of finding suitable allocation of tasks to resources, also referred to as scheduling, is one of the issues that has long been considered by researchers, and so far many studies have been done about it. These studies have often presented several solutions considering different assumptions regarding the characteristics and structure of tasks (independent or heterogeneous [1]) or resources (homogeneous or heterogeneous [2] proprietary or non-proprietary, with complete or incomplete communication, etc.) and by pursuing different goals (reducing run-time [3], minimizing cost [4] and reducing energy consumption [2]). Due to the many applications in various areas, the scheduling of the workflows is still considered a matter of interest to researchers. Workflow scheduling is a process in which resources are assigned to the tasks included in the workflow. Grid is one of the most important computational platforms for deploying and executing workflows. Workflow management systems such as Pegasus, DAGMan/Condor and Karajan/Globus manage the definition, management, and execution of workflows on computational resources [5]. These software systems perform these tasks using the low-level services provided by the middleware of the grid. In general, the workflow characteristics are generated by the user using the workflow modeling tools. These attributes define workflow activities (tasks) and the data and control dependencies between them. At runtime, the grid workflow engine controls the execution of the workflow using the middleware of the grid.

For those who are not access to these platforms, creating such platforms is expensive and time-consuming. However, even those who have access to such platforms cannot use the resources to the desired extent, and the experiment is usually limited to a small number of resources. In addition, the use of these platforms requires empirical skills in deployment, high budget and long time to get results. It is also difficult to provide specific experimental scenarios, and even in some situations it is impossible, unrepeatable and uncontrollable. To overcome such constraints, creating a simulation framework is required. There are different simulators or frameworks for supporting simulation-based studies in the grid environment. A simulation framework is needed to accurately model the behavior of the environment in order to obtain logical results. One of the obvious features of the resources in the grid environment is fluctuation of the amount of their shared computing power for processing of the tasks assigned to the Grid environment, however, in current simulators, these resource fluctuations are not considered accurately. Given this, the results provided by these simulators lack the precision about the effect of the change in the power provided by the resources on the performance of scheduling algorithms.

In this paper, a framework is developed that provides an accurate assessment of the performance of work flow scheduling algorithms in distributed platforms with non-dedicated resources that are prone to encountering irregular changes in processing power. Unlike other existing simulation tools (Section 2), this framework is based on the theoretical model [6], which is based on linear switching state space. This model is able to represent and accurately describe the process of executing tasks in a distributed platform with arbitrary computing and communication properties and structures in the desired time scales (Section 3). In this paper, by introducing the above modeling method, we will discuss how to use it to create a framework that is capable of considering the dynamics of the power of the resources during the execution of workflows. The Structure of this paper is as follows: In section 2, some of the frameworks and simulation tools in the grid and cloud computing platforms are presented. In section 3, we introduce the linear switching model and then present the proposed simulator architecture based on this model. In section

4, the experiments are carried out and the results have been discussed. Finally, in Section 5, the conclusion of this paper is presented.

II. Literature Review

There are many different frameworks and simulators with different objectives for distributed platforms, such as grid and cloud .These tools have been created with the goals such as facilitating common tasks or providing the ability to perform experiments in a controlled and repeatable environment.

In general, the frameworks are seeking to facilitate the accomplishment of some common tasks that are needed in a field. For instance, in [7], the *signac* framework is proposed to facilitate the integration of different formats of specialized data, tools, and workflows. The signac framework provides all basic components required to create a well-defined and thus collectively accessible and searchable data space, simplifying data access and modification through a homogeneous data interface that is largely agnostic to the data source, i.e., computation or experiment. In recent years, due to the spread of cyber attacks and the importance of providing strategies and solutions for cyber-security, development and deployment of intrusion detection systems has gained special attention. These systems should permanently control ongoing operations in the environment in order to identify potential attacks, thus requiring high - power computational platforms to support this volume of computation. In [8], a framework is presented which provides the appropriate distribution of these calculations with regard to the security requirements and variable availability of the computational resources(including personal and enterprise resources, as well as cloud services), and also keeping in mind to minimize the cost associated with the use of external resources (cloud services).

One of the objectives of the simulation tools is the study of architecture, components and functionality of the simulated platform. Bricks simulator [9] is a Java simulation framework used to evaluate the performance of programs and scheduling algorithms in Grid environments. The Bricks simulator includes a discrete event simulator, simulation of computing environment and grid data, as well as network components. This simulator provides an analysis and comparison of different scheduling algorithms on simulated grid settings, taking into account the impact of network components on overall efficiency. The GridSim simulator [10] is also a simulation model for Grid and Grid applications. The simulator consists of a network simulation component that is used to simulate network topologies, connections and switches, as well as resource failures in Grid applications simulation. GridSim simulator lacks the direct support to schedule workflows. The BeoSim simulator [11] is implemented with the purpose of studying the scheduling algorithms of parallel tasks in the field of multi-cluster computational Grid. This simulator can be driven by real or artificial load. Simbatch simulator [12] provides the ability to evaluate scheduling algorithms for batch schedulers. The Monarc 2 simulator [13] is a simulation framework designed to provide a design and optimization tool for large-scale distributed computing systems. Although Monarc 2 has provided two simple scheduling modules, its main purpose is to provide a realistic simulation of distributed computing systems designed to process physics data, and to propose a flexible and dynamic environment to evaluate the performance of a range of data processing architectures. The GSSIM simulator [14] has been developed based on the GridSim toolkit. The simulator provides a simple Grid scheduling framework which capable of simulating a wide range of scheduling algorithms in heterogeneous Grid infrastructures in several levels. However GSSIM faces problems such as slow execution and scalability.

None of the aforementioned simulators have direct support for workflows, so in recent years several simulators have been developed for such applications. TSM-SIM [15] is a simJava-based simulator that supports the simulation of dynamic resource grid and tasks and provides an interface for sending workflow programs as a unit. The tGSF tool [16] extends the Teikoku Grid scheduling framework, which provides a platform for simulating the scheduling of workflows and parallel tasks in the trace-based grid. Supporting workflow scheduling is loosely coupled in which work, selection, and assignment strategies are performed independently. Another example of grid scheduling simulators is WorkflowSim [17]. The focus of this simulator is on failures and on cluster-based scheduling algorithms. The WorkflowSim simulator is based on the features and services provided by CloudSim [18].

Among the simulators above, only the TSM-SIM simulator [15] explicitly considers the dynamics of resources by employing a background load generator and taking into account statistical distributions, while other simulators considered the computing power of resources at a constant value which is based on the average amount of resources processing power. In the next section, the system is firstly modeled using linear switching, and then the structure and performance of the proposed simulator are discussed.

III. The Proposed Simulator

In this section, at first, the system modeling will be introduced by the linear switching model that defines the basis for the proposed framework and then we will look at the structure and function of the proposed simulator components.

A. Modeling Task Scheduling problem in State Space

The problem of scheduling tasks in a heterogeneous resource environment has a nonlinear nature, but it can be transformed into a linear space switching model with a number of nonlinear constraints on the input vector. Due to the nature of the scheduling problem, there are complex and numerous relationships for the space state form of the system that may lead to complexity of design based on them, so the scheduling problem is represented in the form of relation (1)(At each step k).

$$X[k+1] = \max\left(0, X[k] - \Delta T * \mathrm{Diag}\left(\left[\frac{1}{\theta_{ij}}\right] * U\right)\right) \quad (1)$$

In the following sections, we define variables used in the above modeling of task scheduling problem.

1) Status Variable (X): The variable X is a vector whose number of elements is equal to the number of task in input workflow and the value of each element is a number between 0 and 1 that determines the amount of work remained for that task in step k. The initial value of the state variable is usually equal to one. The system state variable with n task is displayed as follows:

$$X[k]=\begin{bmatrix} x_1 \\ x_2 \\ . \\ . \\ . \\ x_{n-1} \\ x_n \end{bmatrix} \quad x_i\in[0,1]\subset R \quad ,i=1,2,\ldots,n \qquad (2)$$

For example, suppose that state variable of a system with 5 tasks in step k is as follows:

$$X[k]=\begin{bmatrix} 0 \\ 1 \\ 0.4 \\ 1 \\ 0.8 \end{bmatrix}$$

The values in the above state variable states that task 1 is fully executed, tasks 2 and 4 have not yet been executed, and 40% and 80% of tasks 3 and 5 is remained respectively.

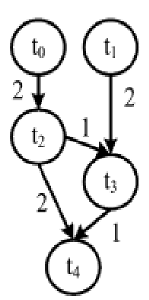
2) Control Vector(U): The control vector U is a matrix with m rows (number of resources) and n columns (number of tasks).

The element $u(i,j)$, $(i = 1,2,\ldots,m\text{،} j = 1,2,\ldots,n)$ determine the amount of use of the resource i for the task j, which is a number between zero and one. In each step, maximum number of none zero elements in each row of this matrix is one, and the remaining elements of that row are all zero. This restriction implies that at every step, each resource is only able to perform one task.

3) Runtime Length Matrix (θ): θ is a matrix with n rows and m columns, which its element θ_{ij} specifies the execution time of the task i on the resource j.(m is the number of system resources and n the number of tasks in the workflow).

4) Example of problem solved by the proposed Model: In Figure 1, a directed acyclic graph (DAG) for an application and execution time of its tasks on two resources *P0* and *P1* are provided. The aim is to schedule this application by the controller. ($\Delta t = 1$)

a



b

Task	p0	p1
t0	5	8
t1	11	15
t2	4	7
t3	6	7
t4	1	2

Fig. 1. An Example of a DAG and the Corresponding Computational Cost Table.

Figs 2 and 3 show an assignment of runtime matrix (θ) and control vector (U) to clarify how a sample schedule can be represented using linear switching state space for above DAG. In Fig. 4, the Gantt chart corresponding to this schedule is shown. As can be seen, DAG execution ends in time of 25.

U(k) Matrix

k ≤ 8		8 ≤ k ≤ 11		11 ≤ k ≤ 15		15 ≤ k ≤ 16		16 ≤ k ≤ 22	
0	1	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0

22 ≤ k ≤ 24		24 ≤ k ≤ 25		k ≥ 26	
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	1	0	0	0

Fig. 2. The U Matrix Generated based on the DAG Shown in Fig. 1.

θ Matrix

	P_0	P_1
T_0	5	8
T_1	11	15
T_2	4	7
T_3	6	7
T_4	1	2

Fig. 3. The θ Matrix Generated based on the DAG Showed in Fig. 1.

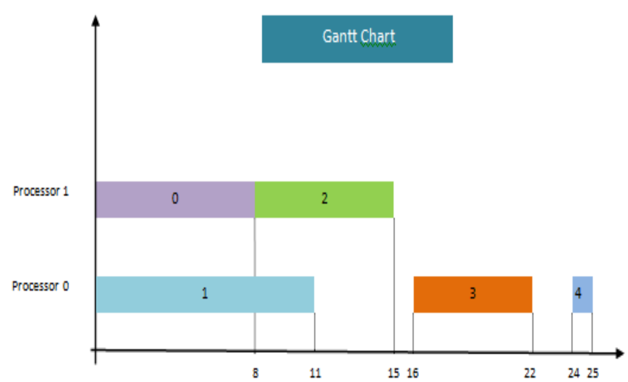


Fig. 4. Gantt Charts of Example Fig. 1.

5) Modeling the resource processing power uncertainty: Processing power of each resource determines the duration of each task's execution, therefore, uncertainty in the processing power of a resource can be shown by changing the time needed to execute tasks on that resource. Because this information is stored in the θ matrix, the change in this matrix corresponds to the change in the processing power of the resources. Therefore, the proposed model is capable of displaying uncertainty in processing power.

B. Architecture of Proposed Simulator

Due to the ability of the representation and modeling of uncertainty in the processing power of the resources available in the environment by linear switching state space model mentioned in previous section, we use it to create a tool to simulate execution of workflows in networked environments. To do this, we propose a simulator with layered loosely coupled architecture which is shown in Fig 5. In following we introduce each of the proposed simulator components.

Fig. 5. Architecture of the Proposed Simulator.

1) Event manager: The event manager is responsible for recording, storing and reporting the occurrence of internal events to other simulator components. The event manager uses SimJava [19], which provides an inter threaded interfacing framework that allows the sending of tagged events from one entity to another in a Java process. SimJava entities are connected through ports and can communicate with each other by sending and receiving objects related to tagged events.

2) Resource manager: The resource manager is almost the main component in the proposed simulator, which has several important responsibilities. This component acts as task acceptance manager by interacting with the higher layer of itself, and by accepting the ready tasks and their related mappings provides the conditions for executing them on the resources. More precisely, the resource manager, according to the amount of required processing of the tasks, and the current computing power of the resources on which each of the tasks is mapped, will determine the duration of their execution, and will notify their execution termination event to the event manager.

It is worth noting that in the proposed simulator, it is assumed that each resource can only accept a task at any time. On the other hand, this component is responsible for monitoring and tracking changes in each resource and, if any changes occur, will take appropriate action. One of these changes could be the change in resource computing power, resource failure, and resource release. Some of these events are fully managed by the resource manager, while for other events, after the necessary steps are taken, the event will be re-notified to other interested simulator components.

3) Workflow management layer: Topmost layer of the simulator is the workflow management layer which consists of three components of the workflow manager, the workflow engine and the scheduler.

The workflow manager is responsible for the interactions with below layer and the coordination of other components in this layer. The workflow engine operates similar to the workflowSim [17] workflow engine component. This component determines the ready tasks for execution, using the existing dependencies between the tasks as well as the tasks whose execution is completed, and then places them in the ready tasks repository.

The scheduler is considered as an abstract component, so it can be extended by user to schedule tasks in the desired method. For this purpose, the necessary information has been provided to the scheduler, which includes a ready- task repository, input workflow structure, specification and current status of the available resources in the environment. According to this information, scheduler should create proper mapping.

4) Adaptation of the linear switching state space model and proposed simulator: In the proposed simulator, the process of simulating a workflow is divided into several execution phases. In each execution phase, environment conditions are assumed to be constant. From environment conditions, we mean the resources computing power and the mapping of tasks to resources. A new execution phase will start with each event occurring. As mentioned before, the resource manager is the main component in the proposed simulator and a large part of the simulator function and consequently the implementation of the Linear switching state space model is implemented by it. One of the most important tasks of the resource manager is the reflection of the required changes in the model parameters at the end of each execution phase. In the following, we will focus more precisely on the functions of this component.

One of the responsibilities of the resource manager is maintaining and keeping track of the status of the tasks. According to the linear switching state space model, the execution state of a workflow is shown at any time using the status vector X, so, the resource manager in order to handle this responsibility should update the values of this vector at any time in accordance with the current status of the tasks.

Another responsibility of the resource manager is to take appropriate actions in the face of changes in resource conditions, such as computing power fluctuation and failure. In the linear switching state space model, the matrix θ shows the amount of time required to execute each task according to the current processing power of each resource. As the change in the processing power of a resource is considered to change the amount of time required to execute the tasks on the resource, therefore, in order to reflect the desired change in the switching model, the elements related to the resource in runtime matrix must be changed. Given the pursuit of changes in resource computing power by resource manager, it will also be responsible for maintaining and enforcing the necessary changes to the θ matrix.

Now, we deal with the resource failure and how it reflects in the switching model. To do this, it should be noted that the failure of a resource in addition to the change in the resource condition (θ matrix) may also cause changes in the execution status of the tasks (X vector) as well. In order to reflect the failure of a resource, the resources manager set elements corresponding to the resource in question in θ matrix to infinity value. In addition, if the resource was executing a task, the status of the task will also be changed to its original value (value 1). If the failed resource is healed, the resource manager resets the elements corresponding to the resource in θ matrix to original processing power.

The third component of the switching model is the control matrix U. As discussed in the previous section, the control matrix determines the mapping of tasks to resources. Given that the mapping of tasks on resources is assigned to the scheduler, the determination of the values of this matrix will also be carried out by the scheduler. However, the actual maintenance of this matrix is carried out by the resource manager; In fact, the scheduler creates only its intended mapping and by providing this mapping to the resource manager resource manager, the resource manager will create a control matrix.

With these components, the resource manager at any time will be able to determine the state of execution. For this purpose, as state above, the resource manager needs to apply any change in conditions in the corresponding components. The resource manager at the end of each execution phase, with respect to the stability of the environmental conditions in the execution phase (values of the matrices θ and U) and given duration of the execution phase (ΔT), calculates the processing requirements of each task, and determine the new values of the status vector (X). In fact, the resource manager at the end of each execution phase determines the status vector values (X) before the change occurs in the components of the switching model (matrix θ or U). In Fig. 6, the function and role of each of the simulator components are displayed in the process of executing a workflow. It is necessary to express that in this diagram only a part of the function of the simulation components is shown.

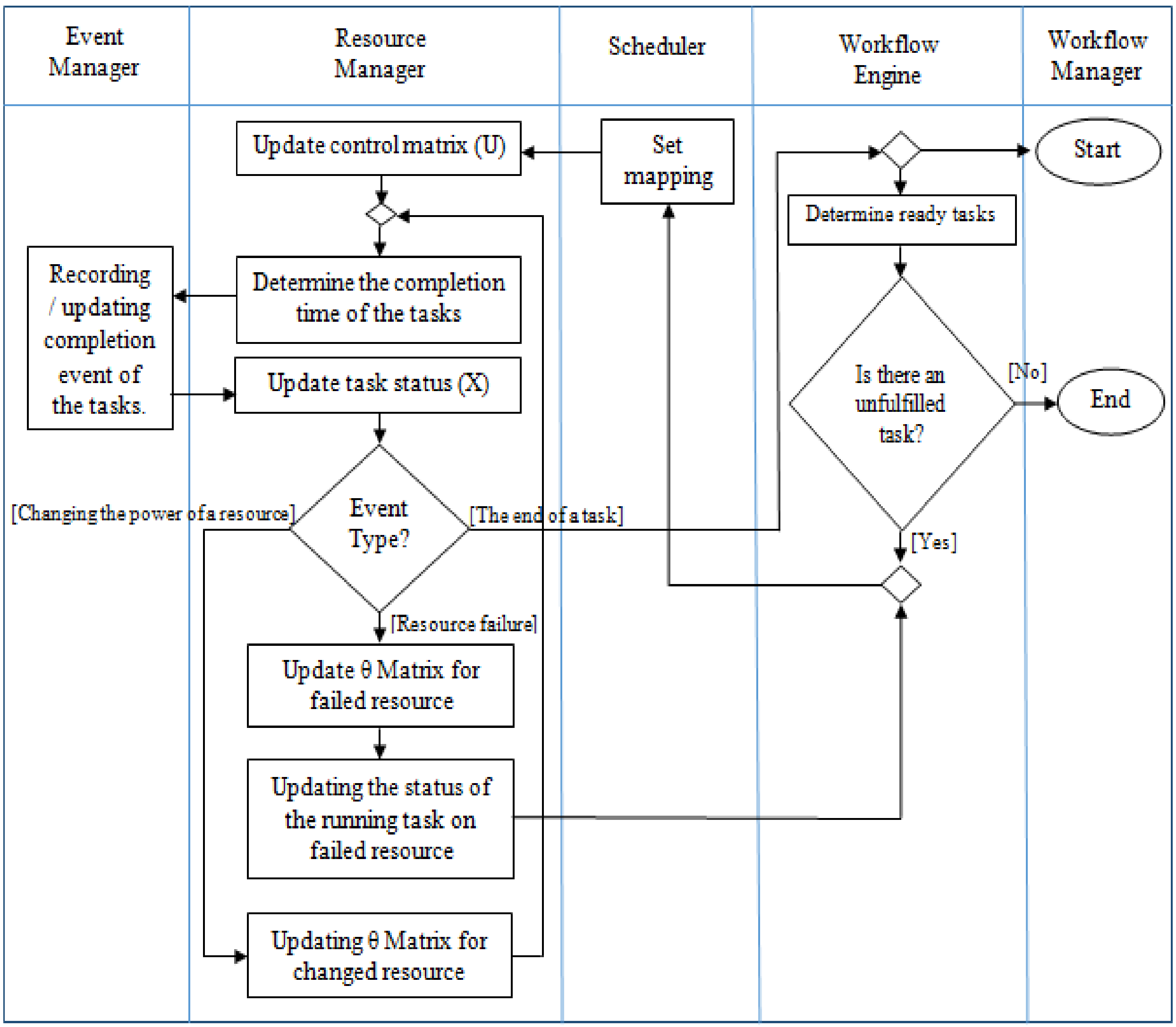


Fig. 6. The Functions of Each Simulator Component in the Process of Executing a Workflow.

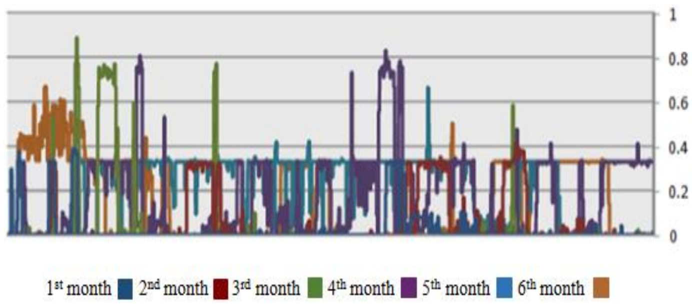


Fig. 7. The Amount of Resource No. 1515 Load at the Notre Dame University in the First Six Months of 2007.

IV. Experiments and Results

In order to evaluate the proposed simulator, five different scheduling algorithms, FCFS, MCT, MinMin, MaxMin and BNCP have been tested under different conditions of resource computing power. The NGB benchmark [20] has been used to investigate the effect of power resource fluctuations on different workflows. In the next section, a brief introduction of this benchmark are given at first, and then data set used in experiments to make changes in the conditions of the resources including computing power changes and failures are introduced. In the final section, the results of simulating the execution of this benchmark by the mentioned algorithms are presented and discussed.

A. NGB Benchmark

NGB benchmark, designed by NASA, is based on the NAS parallel benchmark [20]. These benchmarks are defined as dataflow diagrams, in which the nodes and edges respectively represent computations and communications. The NGB benchmark includes four families of problems include Embarrassingly Distributed (ED), Helical Chain (HC), Visualization Pipeline (VP) and Mixed Bags (MB)[15]. ED presents a class of grid programs called the study of parameters. HC models grid application with long chains of repeating programs, such as a set of flow computations executed in order. The VP models the workflow programs of the grid that combine multiple chains of composite processing. This benchmark, models Grid programs that the final step of their repeating tasks are visualization/analysis. MB models grid applications that combine their preprocessing tasks, calculations, and calculations of visualization, but combine with asymmetric communication.

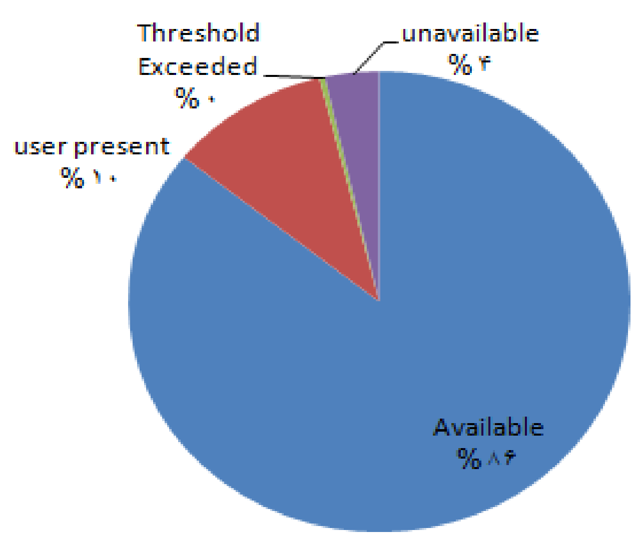
B. Used scheduling Algorithms

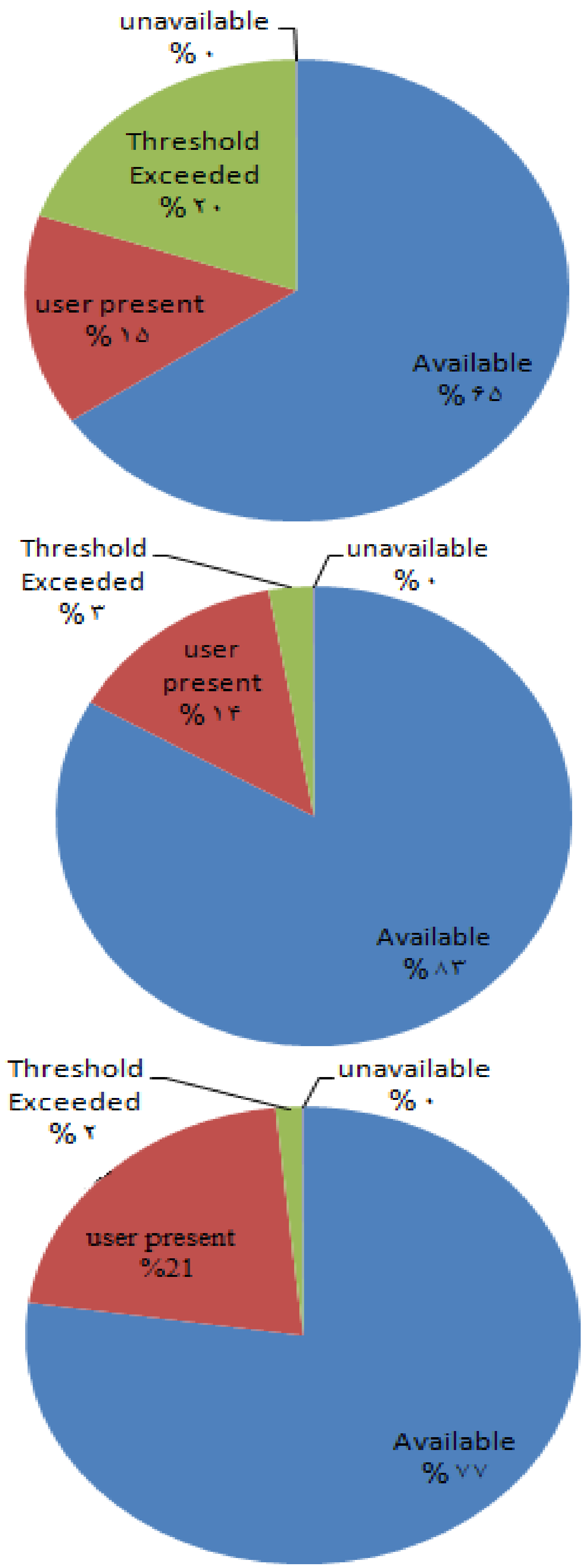
Four scheduling algorithms have been used to evaluate the performance of the proposed simulator: FCFC, MCT, MinMin, MaxMin and BNCP.

- **FCFC**: The initial version of the scheduling algorithm that used in this simulator. In this algorithm, each task is assigned to the next available source in the order of its entry, regardless of the expected completion time required. If multiple resources are available, one of them is selected at random.
- **MCT** (Minimum Completion Time): This algorithm [21] assigns to each task a resource with the best completion time in an arbitrary order.
- **MinMin**: This algorithm [22] initially begins with a set of ready tasks and then arranges them in the order of their completion time. In the following, a task with a minimum completion time is selected and assigned to its corresponding resource. Then, the task that has just been mapped will be sent to the queue and the process will be repeated until all ready tasks are scheduled. The idea of this algorithm is to create an optimal path to reduce the total runtime.
- **MaxMin**: Similar to the MinMin algorithm, the MaxMin algorithm selects tasks with a maximum completion time, and assigns it the best available resource. The idea of MaxMin is to avoid long-term tasks.
- **BNCP**: This algorithm [23] is a list-based algorithm which similar to other list-based algorithms composed from two steps include prioritizes tasks and assigning them to nodes. In the task prioritization phase, a simple mechanism is used in which critical tasks are selected as soon as they are ready. At the node assignment phase, in order to remove unnecessary delays that may occur due to the slowness of communication, a replication based mechanism is used, in which a resource is selected for the current assignment, which can significantly improve the execution time of the current task by replicating the critical task parent.

C. Changes in Resource Status

To simulate changes in resource status, including changes in processing power, and also failures and malfunctions, data from the resources trace of the Notre Dame University in early 2007, which is part of the FTA dataset [24] has been used. This trace includes the CPU load (percent) and the idle time (seconds). In Figure 7, the loading rate in the first 6 months of the resource number 1515 used in the experiments is shown. In Figure 8, the percentage of this resource is shown in each of the states in each month. It should be noted that in conducting experiments, the availability of a resource in any of status other than the Available status, is considered as non-Availability, in other words, failure.





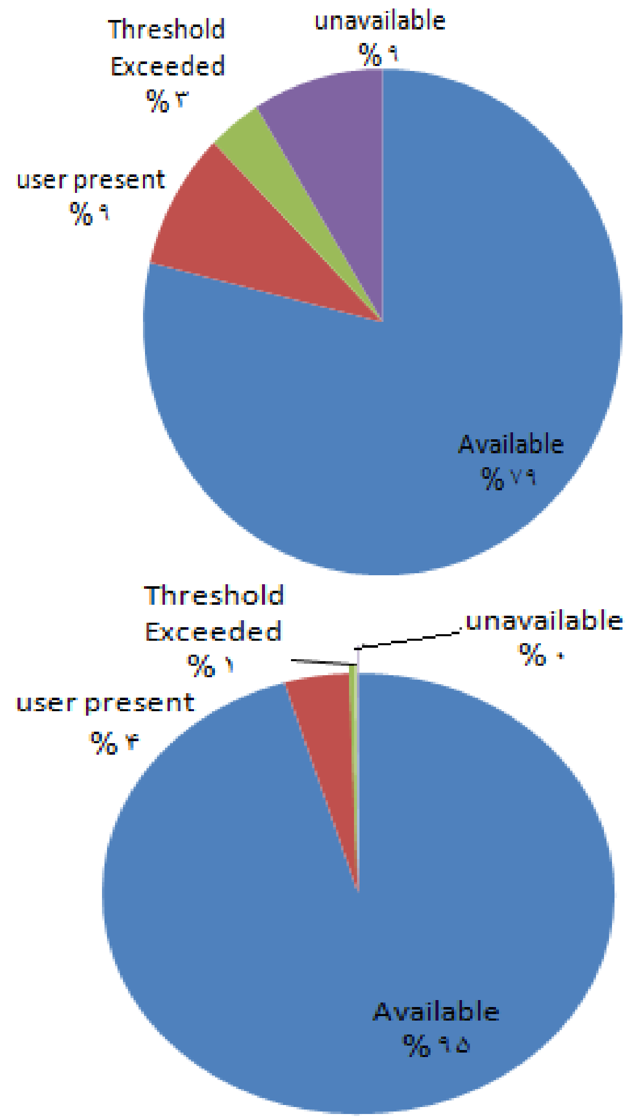


Fig. 8. Proportion of Availability of Resource No. 1515 in Different Situations.

D. Evaluation Results

In the experiments, the load for the second month of the data set introduced in the previous section is used as the base load. In order to simulate the low - load conditions of the system, this base load is reproduced in different scales. For example, to double the workload on resources, the load on the base load is multiplied by 2. Additionally, a collection of each NGB Grid application is generated by different types of families (ED, HC, VP, and MB) and provided as input to the simulator. The simulation environment is considered as a collection of 10 processing resources in a fully connected network. The power of each resource is determined by MFLOPS (the number of floating point commands that run s in one second, in millions). Table 1 shows the processing power of each of these resources.

TABLE I. THE COMPUTING POWER OF THE RESOURCES USED IN SIMULATION

resource Number	Processing Power (MFLOPS)
1	9320
2	9320
3	10400
4	6400
5	6400
6	6400
7	12000
8	9320
9	12000
10	9320

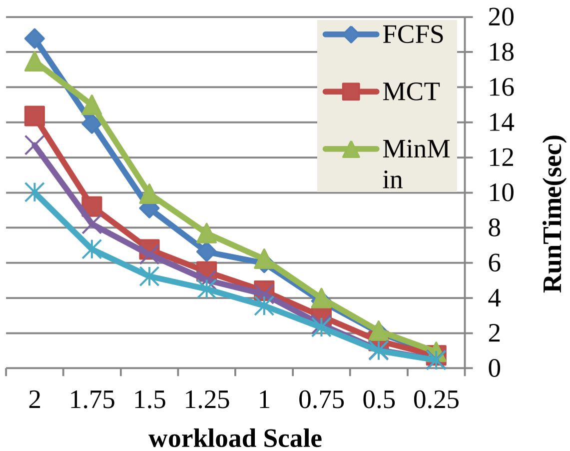


Fig. 9. The Effect of the Load Change on the VP Workflow Class.

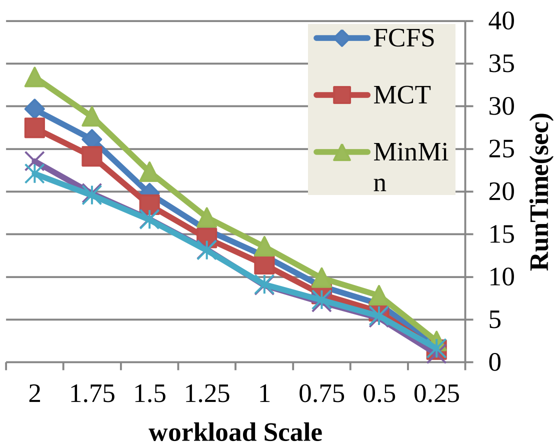


Fig. 10. The Effect of the Load Change on the MB Workflow Class.

In Figs 9 to 12, the results of the time required to complete each class of input flow types under different load conditions are shown with the five scheduling algorithms mentioned in the previous section.

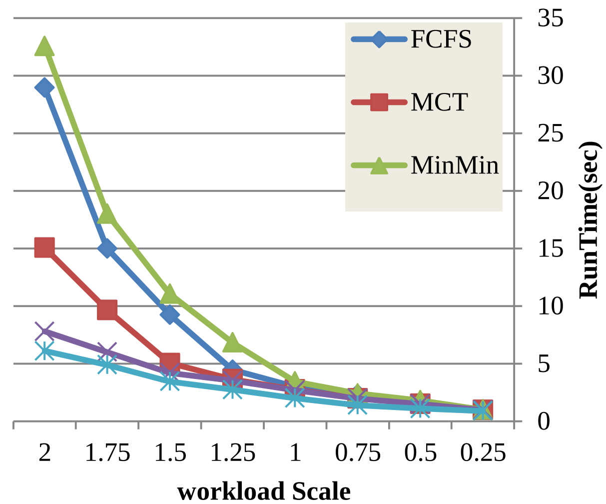


Fig. 11. The Effect of the Load Change on the ED Workflow Class.

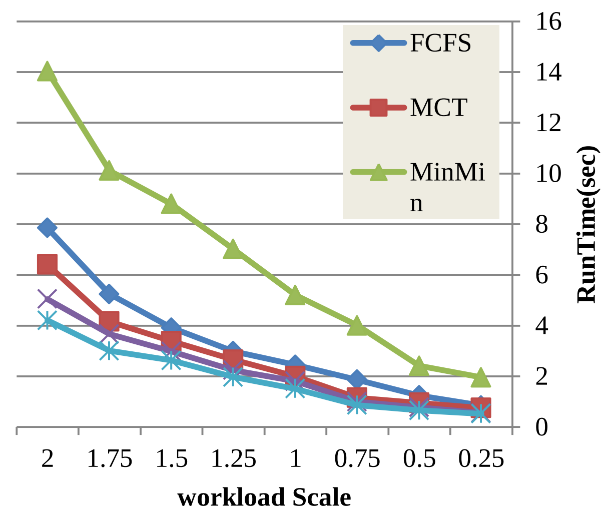


Fig. 12. The Effect of the Load Change on the HC Workflow Class.

Regarding Figures 9 through 12, as expected, increasing the amount of load in the resources will increase the time needed to execute the workflow. However, among the scheduling algorithms used, the BNCP and MaxMin algorithms exhibit the best performance and MinMin's worst performance. According to the obtained results, between different types of workflow, HC and ED classes have demonstrated higher sensitivity to increasing the load level of their resources so that by increasing the load, the execution period of the work streams is substantially increased. These results are similar to those reported in [15].

V. Conclusion and Future Work

In this paper, a simulator for evaluating workflows based on linear switching model is presented. The linear switching model used is capable of accurate representation of variation in computational resources processing power, so the simulator has been able to accurately assess the performance of workflow scheduling algorithms in the face of variation in the power of resources. By using this simulator, five workflow scheduling algorithms were evaluated to execute workflows created on the basis of the NGB benchmark. Due to the high rate of failures in distributed environments, the issue of dealing with them has been an important place in the recent researches, and scheduling algorithms are introduced with the approach of dealing with the failures. As the future work, we can also add the possibility of supporting this kind of algorithms, which are for instance the check-pointing algorithms.

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References

[1] Q.Y. Chen, et al. “Research of Dependent Tasks Scheduling Algorithm in Cloud Computing Environments,” InITM Web of Conferences 2016 (Vol. 7, p. 08001). EDP Sciences.

[2] Nesmachnow S, et al. “Energy-aware scheduling on multicore heterogeneous grid computing systems,” Journal of Grid Computing. 2013 Dec 1;11(4):653-80.

[3] Dolkhani E, et al. “Assignment look-ahead HEFT for scheduling workflows of communicating tasks,” InTelecommunications (IST), 2016 8th International Symposium on 2016 Sep 27 (pp. 649-653). IEEE.

[4] S. Selvarani, G.S. Sadhasivam. “ Improved cost-based algorithm for task scheduling in cloud computing,” InComputational intelligence and computing research (iccic), 2010 ieee international conference on 2010 Dec 28 (pp. 1-5). IEEE.

[5] J. Yu and R. Buyya, “A taxonomy of workflow management systems for grid computing,” Journal of Grid Computing, vol.3, no. 3-4, pp. 171-200, 2005.

[6] H.tabatabaee, "(static and Dynamic) Task scheduling Modeling by linear switching state space ", PhD thesis, 2011.

[7] Carl S. Adorf, et al., “Simple data and workflow management with the signac framework”, Computational Materials Science, 220–229, 2018.

[8] José Francisco Colom, et al., “Scheduling framework for distributed intrusion detection systems over heterogeneous network architectures”, Network and Computer Applications, S1084-8045(18)30041-9, 2018.

[9] A. Takefusa, et al. “Overview of a performance evaluation system for global computing scheduling algorithms,” In High Performance Distributed Computing, 1999. Proceedings. The Eighth International Symposium on, pp. 97-104. IEEE, 1999.

[10] A. Sulistio, et al., “A toolkit for modelling and simulating data Grids: an extension to GridSim,” Concurrency and Computation: Practice and Experience, vol. 20, no. 13, pp. 1591-1609, 2008.

[11] W. M. Jones, et al., “Characterization of bandwidth-aware meta-schedulers for co-allocating jobs across multiple clusters,” The Journal of Supercomputing, vol. 34, no. 2, pp. 135-163, 2005.

[12] Y. Caniou and J.-S. Gay. “Simbatch: An API for simulating and predicting the performance of parallel resources managed by batch systems,” in European Conference on Parallel Processing. 2008. Springer.

[13] C. Dobre, F. Pop, and V. Cristea. “A simulation framework for dependable distributed systems,” in 2008 International Conference on Parallel Processing-Workshops. 2008. IEEE.

[14] K. Kurowski, et al. “Grid scheduling simulations with GSSIM. in Parallel and Distributed Systems,” 2007 International Conference on. 2007. IEEE.

[15] M.A. Belkoura and N. Lopez-Benitez, “TSM-SIM: A Two-Stage Grid Metascheduler Simulator,” International Journal of Grid Computing & Applications, vol. 2, no. 4, pp. 11, 2011.

[16] A. Hirales-Carbajal, et al. “A grid simulation framework to study advance scheduling strategies for complex workflow applications,” in Parallel & Distributed Processing, Workshops and Phd Forum (IPDPSW), 2010 IEEE International Symposium on. 2010. IEEE.

[17] W. Chen and E. Deelman. “Workflowsim: A toolkit for simulating scientific workflows in distributed environments,” in E-Science (e-Science), 2012 IEEE 8th International Conference on. 2012. IEEE.

[18] R.N. Calheiros, et al., “CloudSim: a toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms,” Software: Practice and Experience, vol. 41, no. 1, pp. 23-50, 2011.

[19] F. Howell and R. McNab, “SimJava: A discrete event simulation library for java,” Simulation Series, 1998. 30: p. 51-56.

[20] M. Frumkin and R.F. Van der Wijngaart, “Nas grid benchmarks: A tool for grid space exploration,” Cluster Computing, vol. 5, no. 3, pp. 247-255, 2002.

[21] T.D. Braun, et al., “A comparison of eleven static heuristics for mapping a class of independent tasks onto heterogeneous distributed computing systems,” Journal of Parallel and Distributed computing, vol. 61, no.6, pp. 810-837, 2001.

[22] J. Blythe, et al. “Task scheduling strategies for workflow-based applications in grids,” in CCGrid 2005. IEEE International Symposium on Cluster Computing and the Grid, 2005. 2005. IEEE.

[23] A. Atef, et al. “Lower-bound complexity algorithm for task scheduling on heterogeneous grid,” Computing. 2017:1-21.

[24] B. Javadi, et al. “The Failure Trace Archive: Enabling the comparison of failure measurements and models of distributed systems,” Journal of Parallel and Distributed Computing, vol. 73, no. 8, pp. 1208-1223, 2013.

Reliable and Energy Efficient MAC Mechanism for Patient Monitoring in Hospitals

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***Abstract*—In medical body area network (MBAN) sensors are attached to a patient's body for continuous and real-time monitoring of biomedical vital signs. Sensors send patient's data to hospital base station so that doctors/caregivers can access it and be timely informed if patient's condition goes critical. These tiny sensors have low data rates, small transmission ranges, limited battery power and processing capabilities. Ensuring reliability in MBAN is important due to the critical nature of patient's data because any wrong/missing/delayed data can create a situation in which doctors may take wrong decisions about patient's health which can have fatal results. Data transmission reliability in MBAN can be ensured by retransmissions, acknowledgments or guaranteed time slot mechanism but it causes more power consumption. We propose an efficient MAC mechanism to achieve both reliability and energy efficiency at an acceptable trade-off level. The proposed MAC mechanism not only overcomes the limitations of ZigBee MAC mechanism such as inefficient CSMA/CA and underutilization of guaranteed time slots, but also adapts for different traffic types such as emergency and normal traffic. Our results show that application level throughput and packet delivery ratio increase and packet loss decreases. We also optimize energy utilization by tuning macMaxCSMABackoffs and macMinBE parameters of ZigBee MAC mechanism.**

***Keywords*—Medical Body Area Network; MAC Protocols; ZigBee MAC Mechanism; Guaranteed Time Slot Allocation Scheme**

I. Introduction

Wireless sensor network is composed of tiny sensors for the purpose of sensing or monitoring different environmental or physiological parameters and conditions[1]. Wireless sensor network(WSN) attained a world wide attention and is one of most promising research areas because of its diverse applications and a number of advantages over conventional networks such as ease of deployment, low cost, scalability, flexibility, reliability, etc. Application areas of WSN are military, security, agriculture[2], industrial, medical[3], [4], [5], [6], [7], environmental monitoring and home and office automation etc[8]. Some other examples of WSN applications are real time monitoring of wheel condition of train[9], exploration of underwater environment[10], monitoring of concentration of volatile organic compound at risky sites[11] and fire monitoring[12] etc. Medical body area network(MBAN) is a subclass of wireless sensor network in which both internal and external sensors[13] can be attached to a person's body for the purpose of continuous and real-time monitoring of biomedical vital signs in order to provide timely healthcare facilities[14]. Applications of body area network other than healthcare include entertainment, Lifestyle and Sports, Military etc[15]. Network environment of body area network is different from wireless sensor network[16],[17]. There are some minor differences among body area network and other applications of wireless sensor network, such as topology is known in a body area network, communication is hybrid, replacement of batteries is possible but difficult, and information is both identity centric and data centric etc.

Sensor devices are low cost, low powered, small sized, have small memory and are less in processing and computing power, and can be classified into sink and source nodes. Source nodes monitor the surroundings and sink node collects data from these source nodes in the network and sends it to the base station. Some important characteristics of a good wireless sensor network include scalability, responsiveness, reliability, energy efficiency and mobility.

In a medical body area network, medical sensors attached to a patient's body to monitor the patient's vital signs and forward data to sink node for further processing and taking actions. Sink node sends this information to the base station from where doctors or caregivers can access patient's information in order to take necessary actions. There are a number benefits of medical body area network such as continuous and real time patient monitoring, early detection of patient's critical health conditions, timely treatment, and solving the issues of medical staff shortage, etc. Medical body area network also enables doctors to give timely treatment if any patient has critical condition. Medical body area network can be used in remote patient monitoring applications such as at homes or old people houses[18] and it can be used within hospitals[19] for continuous monitoring of critical patients in ICUs or sitting in waiting rooms of hospitals. Another application of the medical body area network is to monitor the victims during the time of disasters by attaching medical sensors to their body. This application is very useful because during the time of disasters, there are high numbers of victims and it is not possible to look after all patients at the same time. All these applications of the medical body area network have two major benefits. First benefit is continuous monitoring of critical patients. This is not possible if nurses attend to patients because every hospital have limited nursing staff and each nurse has to attend multiple patients periodically. Second major benefits of the medical body area network is that we can attend to a large number of patients at a time by attaching medical sensors to their

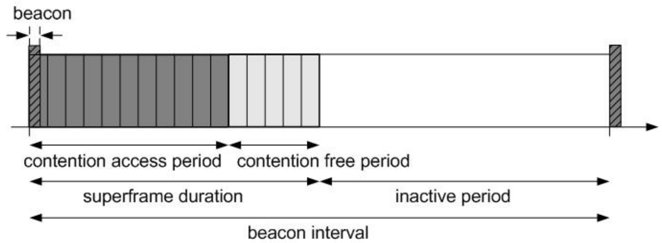

Fig. 1. Zigbee Superframe Structure [21]

bodies to monitor and analyze their vital signs. Medical body area network has gained much attention in research because of its important and beneficial applications for mankind. A huge research has been done in the field of body area network, including applications, architectural design and challenges of the medical body area network. Research on architectural design of the medical body area network is important because it has always a significant impact on network performance.

Although medical body area network is a very beneficial application of wireless sensor network, but there is still a space for improvement in this field because improving reliability and energy efficiency is really a big challenge[20]. Research is going on in the field of medical body area network for efficient routing, reliable communication and energy efficiency, etc. Reliability is important because any corrupt data or late delivery of data can cause critical results for the patient's health. We need energy efficiency because sensor nodes have limited battery power and it is very difficult to replace the batteries. In this paper, we focus on improving reliability and energy efficiency in medical body area network and propose an enhancement in ZigBee MAC mechanism to achieve these performance outcomes.

Rest of the paper is organized as follows: Section II gives an overview of ZigBee MAC mechanism. Section III discusses the related work such as existing solutions to achieve reliability and energy efficiency in medical body area network. In section IV we present our proposed solution and implementation details. After that we discuss results and future discussion in section V. Finally, we conclude the paper in section VI.

II. Overview of ZigBee MAC Mechanism

IEEE 802.15.4[21] is standard for personal area network for short range communications with low data rates i.e. 250 kbps. It defines the lower layers of protocol suite such as physical layer and MAC layer. However ZigBee is IEEE 802.15.4 based standard and it defines the upper layer of protocol suite. It is used in different applications of wireless sensor network and medical body area network such as home automation, agriculture, military, and healthcare, etc. Wireless sensor nodes with limited capabilities need a lightweight protocol for wireless communication in order to minimize power consumption, but not on the cost of network performance such as reliability, minimal delay, shortest latency etc. These are most important requirements of medical body area network because of critical nature of patient's data. In this section we discuss about the functionality of the ZigBee MAC mechanism.

ZigBee MAC supports two types of devices in network i.e. full-function devices (FFD) and reduced-function devices (RFD). Personal area network (PAN) coordinator, which acts as an in-charge of the whole network is a full-function device and it is capable of performing high duty jobs in network such as data collection and processing, storage of information, network management etc. Intermediate router in wireless sensor network is also a full-function device. Source nodes with limited functionality in the network are reduced-function devices which sense and collect data from the network and forward it to PAN coordinator. ZigBee MAC can support star and peer to peer topologies in order to connect these devices with each other in the network. In star topology, source nodes are connected to PAN coordinator and cannot directly communicate with each other. PAN coordinator manages the network and collects data from the sensor nodes. In peer to peer topology, nodes can directly communicate with each other. These nodes are capable of transmitting their own data and can cooperatively pass on the data of neighboring nodes to the sink node. ZigBee MAC provides two types of services, e.g. data service and management service. Data service includes transmission and reception of data at the MAC layer and the management service includes the management of PAN and coordination among the nodes.

Beacon enabled and non-beacon enabled are two network operating modes supported by ZigBee MAC in order to enable two way data communication in the network. Beacon enabled mode is best suited for battery powered PAN coordinator and end devices because of duty cycling. PAN coordinator periodically wakes up and sends beacon packets to end devices in the network. Similarly, end devices periodically wake up to check for incoming beacon packets from PAN coordinator. In non-beacon enabled modes, some devices remain active all the time such as PAN coordinator and router while other end devices such as source nodes remain in the sleep state. Active devices in non-beacon enabled mode have high power consumption, so they need a continuous power supply. Both beacon and non-beacon enabled operating modes of ZigBee can manage different traffic types such as periodic data, burst data, etc. In beacon enabled network, slotted CSMA/CA scheme and an optional guaranteed time slot (GTS) allocation scheme are used for channel access and unslotted CSMA/CA channel access scheme is used in non-beacon enabled network. For the body area network applications we focus on beacon enabled network because this mode is considered to ensure reliability in the network. The Superframe structure of ZigBee MAC is shown in Fig. 1 in which beacon interval is divided into superframe duration and an inactive period. In an inactive period all nodes go into a partially sleep mode to save battery power. Superframe duration is further divided into sixteen equal sized time slots. In the first slot of every superframe, PAN coordinator node broadcast a beacon packet to advertise the network information among the nodes connected to it. All those nodes who are willing to communicate in the network, capture network information from beacon packets and synchronize themselves with the network. Next fifteen time slots are divided into contention access period and an optional contention free period. Alternate terms for the contention access period and contention free period are GTS-off mode and the GTS-on mode respectively. GTS stands for guaranteed time slots. We use these alternate terms instead of conventional names such CAP and CFP in the rest of our paper. We discuss about these GTS-off and GTS-on modes in the following subsections.

A. GTS-off Mode

Default working mode of ZigBee is GTS-off in which CSMA/CA mechanism is used for the purpose of contention avoidance in the network. In this mode every source node maintains three variables which are backoff exponent (BE), number of backoffs (NB) and contention window (CW) for each transmission attempt in the network. BE refers to a number of backoff periods a node should wait before trying to access channel. Backoff period is a basic time unit equal to 80 bits(0.32ms). NB refers to the number of backoffs required by the CSMA/CA algorithm while trying to attempt current transmission. If NB is exceeded by maximum number of backoffs, then the algorithm reports failure and device terminates its current channel access attempt. CW is length of backoff period, which need to be clear before any transmission attempt. The default value of BE is in the range from 3 to 5 i.e. macMinBE and macMaxBE refer to minimum and maximum values of BE in Zigbee MAC. The default value of NB is 4 and of contention window is 2. Each node which has data to send, competes for free channel access and if it gets free channel then it transmits its data. If the channel is busy then node backoff its transmissions for random period of time and try to access channel after that time. In CSMA/CA, after each successful clear channel assessment (CCA), value of CW decrement (CW = CW - 1) until its value reaches 0. If CW = 0, the node transmits its packet, otherwise the algorithm performs another CCA. After finding the channel busy each time the state of NB and BE is updated by increment in the values of NB, BE and CW such as NB is incremented as NB = NB + 1 until the NB $<$ macMaxCSMABackoffs, and increment in the BE is as BE = min (BE+1, macMaxBE) and the size of CW resets to 2.

CSMA/CA is a good mechanism to avoid collisions in the network, but it is not as much efficient as needed for medical body area network because the operating state of the network is always changing and network traffic especially emergency traffic is totally random and unpredictable. This type of traffic not only needs a collision avoidance mechanism but also needs a mechanism which should be able to cope with such conditions when there is a high packet drop rate due to collision in the network in order to ensure reliability at an acceptable level. That is why there is a need of a flexible CSMA/CA mechanism which adapts itself according to network conditions.

B. GTS-on Mode

Along with collision avoidance mechanism, ZigBee MAC provides the facility of reliable data transfer by offering a GTS allocation mechanism in which nodes can send GTS requests in current superframe for advance reservation of a time slot in the next superframe. The GTS allocation mechanism is used for two way communication between PAN coordinator and source node in the network. PAN coordinator can only allocate GTS to nodes on first come first serve basis. GTS always appear at the end of superframe structure, i.e. contention free period. PAN coordinator allocates GTS to the source nodes on the basis of GTS requests from particular node and available capacity in superframe. Available capacity for GTS allocation in superframe can be determined by minimum contention access period length, which is equal to 440 symbols when use GTS allocation mechanism in ZigBee MAC. A single GTS can span more than one slot in superframe and it allows a node to transmit in network within that portion of the superframe while other nodes defer their transmission in that portion and remain in sleep mode which helps to reduce energy consumption and avoid collision in the network. The drawback of the GTS allocation scheme is that it is not a flexible scheme. It follows the first come, first serve mechanism which causes some nodes to fail to get the GTS because those nodes who send GTS request earlier get the slot and avail all available slots in superframe structure. Similarly, if a selfish node joins the network who always gets a guaranteed time slot while other nodes having critical data to send fail to reserve a slot in next superframe. In both cases, nodes shall not be able to transmit their data which results in packet loss due to buffer overflow. Another inflexibility of the GTS allocation scheme is that each node can send a request for the fixed number of slots irrespective of its bandwidth requirements. If a node has a small amount of data to send but according to standard it has to reserve a fixed number of slots which are larger than its requirement causes bandwidth under-utilization.

In the next section we present literature review for reliability and energy efficiency in medical body area network and background study of ZigBee MAC for ensuring these requirements of medical body area network.

III. Related Work and Background

Fatima et al.[22] presented a survey on network architecture and research challenges in medical body area network and discussed research challenges of the medical body area network such as reliability and energy efficiency. Marwa et al.[23] presented a survey on technologies to cope with reliability and fault tolerance issues in body area network. Manish et al.[17] presented a survey on different mac protocols for body area network. Yu-Kai et al.[24] proposed an adaptive GTS allocation scheme to achieve low latency and fairness in body area network. In the proposed scheme, nodes reserve guaranteed time slots in advance either they have data to send or not and priority of each node is set on basis of time slot usage by that node. Liang et al.[25] proposed a GTS allocation scheme in which more than one device can share a single time slot in order to solve the problem of bandwidth under-utilization. Yong et al.[26] proposed a GTS allocation scheme in which they increase the number of slots by decreasing the size of time slots in a contention free period according to super-frame order values. Bharat et al.[27] proposed an algorithm for optimization of the GTS allocation scheme in which nodes send a GTS request only if the number of packets cross the buffer threshold to improve reliability and bandwidth utilization. Hyung et al.[28] proposed an utilization aware GTS allocation scheme in which coordinator node maintains state of nodes on the basis of their network joining time, allocated GTS and utilization and desire for GTS allocation to improve the bandwidth utilization and reduce the latency in the network. Shrestha et al.[29] presented a Markov model hybrid communication in the network in which, if a node gets a guaranteed time slot then it will defer its transmission in CAP and only send in the CFP otherwise the node will transmit its data in the CAP. De-Thu et al.[30] proposed an enhancement in Zigbee by enabling an adaptive duty cycling to reduce energy consumption in body area network. Sherstha et al.[31] enhanced their work presented in [29] for wireless propagation and also evaluated the performance of proposed mechanism using a wheel chair body area network scenario. Nam-Tuan et al.[32] proposed an unbalance GTS allocation scheme to allocate GTS to nodes with different slot durations in wireless personal area network in order to solve bandwidth underutilization problem. Ho et al.[33] proposed a multi-factor dynamic GTS allocation scheme which considers the size of data, delay and GTS utilization to allocate GTS to nodes to improve the performance of network by reducing delay and increasing throughput in the network. Zhisheng et al.[34] proposed a QoS driven scheduling approach which uses Markov model to adjust the transmission order of nodes by using a threshold based scheme and addresses the packet delivery probability and energy efficiency. Mohammad et al.[35] proposed a GTS allocation scheme for emergency traffic using parameters such as traffic type and data rates in which traffic with the highest data rate will have higher priority. Haoran et al.[36] proposed a superframe based GTS allocation scheme in which priority of each node to be allocated a maximum number of slots is defined on the basis of sample rate, buffer size and slot utilization to improve energy efficiency in medical body area network. Jin et al.[37] proposed an adaptive slot allocation scheme in which contention access period is divided in to three phases and restricts the nodes to send their data on the basis of data type. Kong et al.[38] proposed a slot allocation scheme which uses two heuristic algorithms which are sampling rate oriented algorithm and successive approximation algorithm to determine the amount of data in buffer and to set priority of each node on the basis of sample rate. This scheme also takes a benefit from fixed topology of a wireless body area network. Tuomas et al.[39] proposed a dynamic GTS allocation scheme to solve the problem of unfairness in the GTS allocation scheme by including the number of packets and priority of each single packet in the GTS request packet.

Pradnya et al.[40] proposed a modification in super-frame structure of IEEE 802.15.4 in which a fixed contention access period is used for the activities such as GTS management, network management etc to address the issues of scalability and interference etc. Maman et al.[41] proposed a wake up radio mechanism which considers two types of traffic in network, i.e. normal traffic and emergency traffic and uses a separate channel to send wakeup radio in order to ensure energy efficiency in body area network. Mario et al.[42] proposed an adaptive access parameter tuning of ZigBee MAC such as macMinBE and macMaxCSMABackoffs to achieve a desirable level of reliability and energy efficiency in body area network. Simone et al.[43] presented a comparison of proposed mechanisms of parameter setting in the ZigBee MAC to improve reliability and energy efficiency in body area network. They compared the proposed approaches such as measurement based adaptation proposed by Mario et al.[44], model based adaptation proposed by Mario et al.[42] and offline computation proposed by Pangun et al.[45] and concluded that flexible and adaptive tuning of parameters is better because network operating conditions tend to change from time to time. Shuanglong et al.[46] proposed an adaptive tuning algorithm in which they jointly tune the number of retransmissions which is a MAC parameter and sampling rate which is a parameter of control system for the purpose of finding a parameter set to attain the energy efficiency and a stable control system in the network.

ZigBee MAC is suitable for other applications of wireless sensor network, but it is not best suited for medical body area network requirements. Because in medical body area network, network conditions and traffic pattern are variable and random. There is also a very high demand of reliability, energy efficiency and minimum delay for communication in medical body area network. That is why there is a need of a flexible and adaptive MAC layer mechanism to improve performance of the medical body area network. In the next section we discuss about our proposed MAC scheme to overcome the limitations of ZigBee MAC and to improve reliability and energy efficiency in medical body area network.

IV. Proposed Solution

We propose a reliable and energy efficient MAC mechanism which can adapt two different operational modes alternatively i.e. GTS-off and GTS-on. The proposed MAC mechanism adapts different traffic pattern in a network such as normal traffic and emergency traffic, and switches its modes according to it. In the proposed mechanism nodes transmit normal traffic in GTS-off mode and in order to ensure reliability, nodes use guaranteed time slot scheme to transmit emergency data in the network. PAN coordinator allocates guaranteed time slots to nodes on their GTS request basis. Nodes send request for GTS according to the amount of data present in their buffer. We propose some flexibility in the GTS allocation scheme of ZigBee MAC to make it suitable for patient monitoring in medical body area network. We also propose tuning of some CSMA/CA parameters to improve the shortcomings of ZigBee MAC and to ensure reliability and energy efficiency in medical body area network during the GTS-off mode. In the methodology section we discuss the proposed MAC mechanism in detail.

A. Methodology

We subdivide the details of proposed MAC mechanism into three parts i.e. GTS-off mode, GTS-on mode and adaptive MAC and discuss each of them in separate sections. In GTS-off mode subsection, we discuss the proposed mechanism of parameter tuning of CSMA/CA mechanism. In GTS-on mode subsection, we talk about the proposed flexible GTS allocation scheme and in adaptive MAC subsection, we discuss that how the proposed adaptive MAC mechanism takes decisions and switches its modes on traffic type basis.

1) GTS-off mode: In the GTS-off mode of ZigBee MAC all nodes in the network who have data to send, compete for free channel access which causes collision and packet transmission failure in network. According to ZigBee standard, in CSMA/CA mechanism a small range of BE i.e. from 3 to 5 is used to avoid packet collisions among the nodes, but due to such a small range of BE parameter packet collisions are high because of early recovery of nodes from backoff state and become part of network again. On the other hand, if we increase the range of BE it helps to reduce packet collision rate, but it also introduces the delay in the network because in this case most of nodes remain in an inactive state and do not take

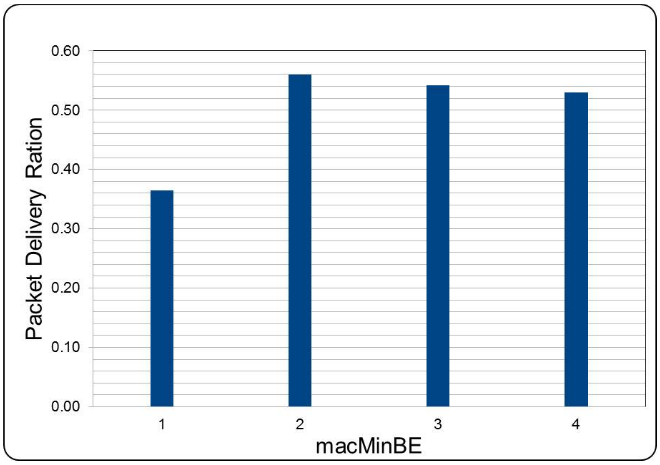

Fig. 2. Effect of Changing Values of macMinBE on Packet Delivery Ratio

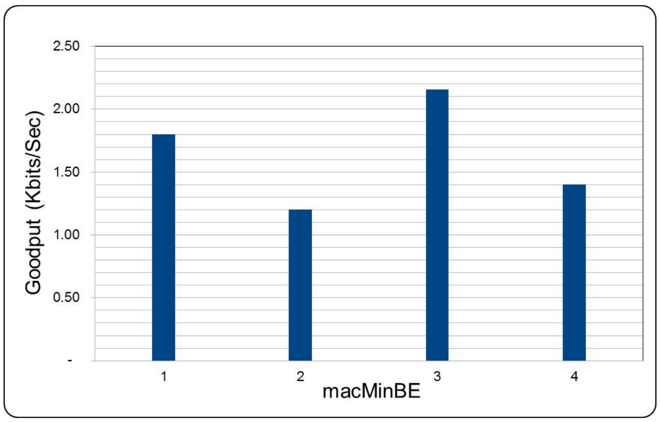

Fig. 3. Effect of Changing Values of macMinBE on Goodput (Kbits/Sec)

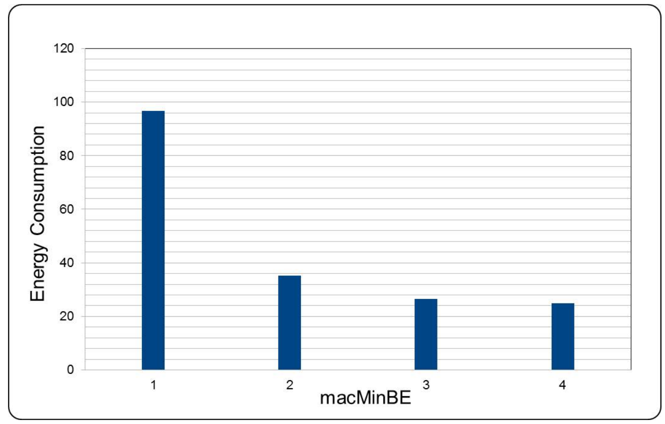

Fig. 4. Effect of Changing Values of macMinBE on Energy Consumption

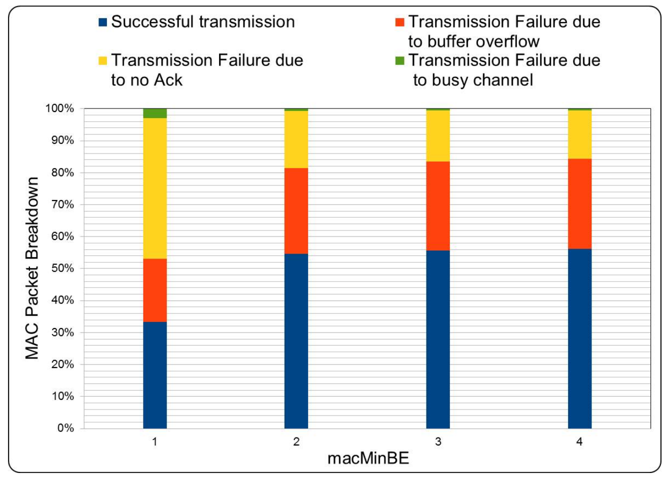

Fig. 5. Effect of Changing Values of macMinBE on MAC Packet Breakdown

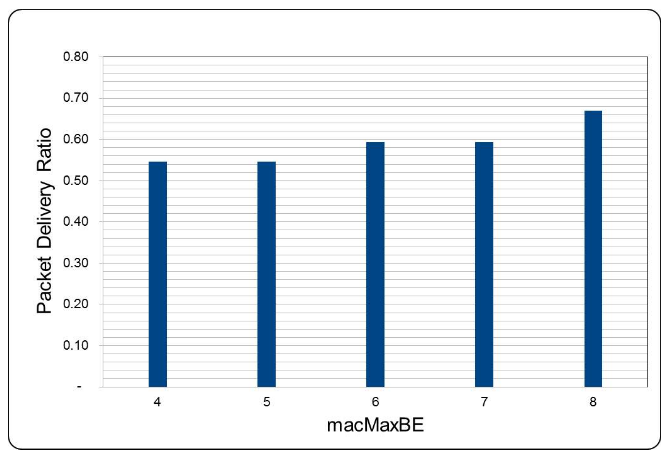

Fig. 6. Effect of Changing Values of macMaxBE on Packet Delivery Ratio

part in communication for most of the time. Similarly, small value of macMinBE decreases the overall delay in the network, but on the cost of reducing network throughput because of the high collision rate and high energy consumption. The reason is that due to the small value of macMinBE nodes come into active state within a short time which again causes contention among the nodes. We simulate the network to show effect of changing of these parameters. Fig. 2, Fig. 3 and Fig. 4 show the effect of these different values of macMinBE on packet delivery ratio, goodput (Kbits/Sec) and energy consumption in term of number of packet retransmissions. Fig. 5 shows the effect of changing values of minMinBE on MAC packet breakdown.

If we keep the value of macMinBE constant and change the value of macMaxBE, increasing value of macMaxBE increases the packet delivery ratio and goodput (Kbits/Sec) but on the cost of increasing energy consumption as shown in Fig. 6, Fig. 7, Fig. 8 and Fig. 9. These figures show the effect of different values of macMaxBE on packet delivery ratio, goodput (Kbits/Sec) and energy consumption and MAC packet breakdown.

Transmission failure due to collisions increases the number of retransmissions, which leads to high energy consumption in the network. Another problem with ZigBee MAC is that smaller value of macMaxCSMABackoffs makes a node to terminate the algorithm after failure of few attempts of clear channel assessment and nodes have to start the algorithm from the very first state which causes delay in packet transmission. The larger value of macMaxCSMABackoffs introduces delay in the network because nodes try to access channel again and again when there is no possibility of channel free because of high contention in the network. Another problem with

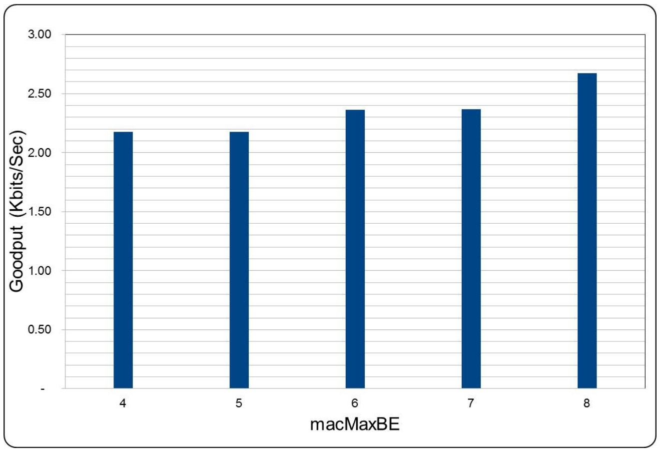

Fig. 7. Effect of Changing Values of macMaxBE on Goodput (Kbits/Sec)

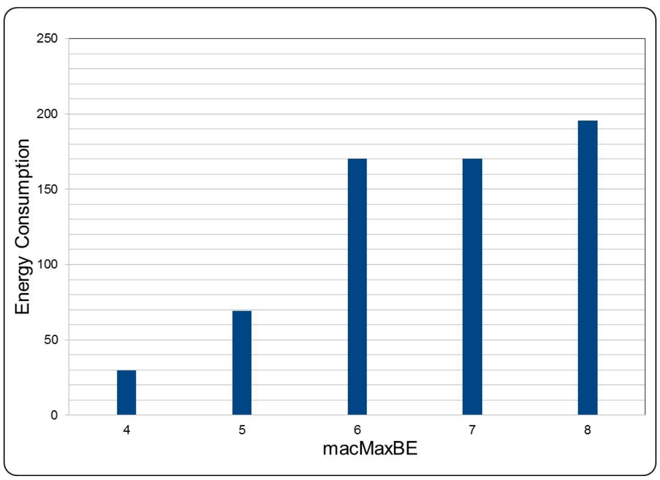

Fig. 8. Effect of Changing Values of macMaxBE on Energy Consumption

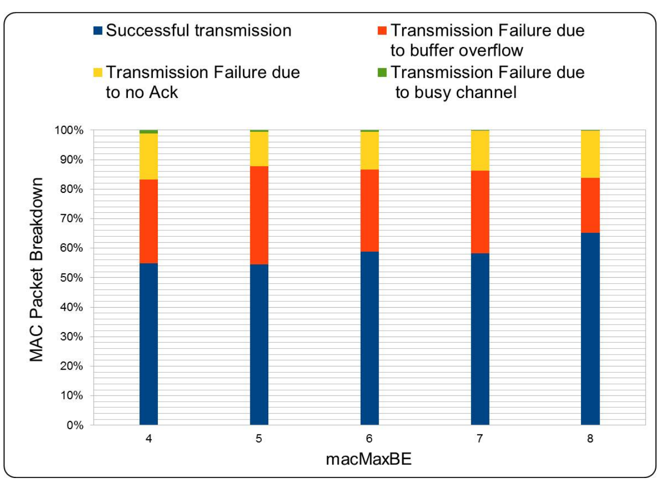

Fig. 9. Effect of Changing Values of macMaxBE on MAC Packet Breakdown

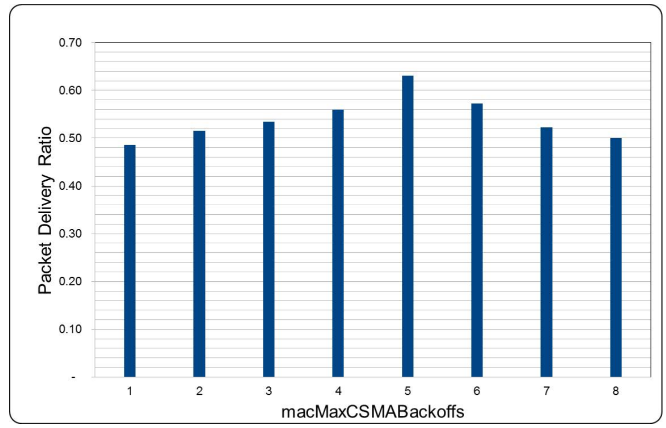

Fig. 10. Effect of Changing Values of macMaxCSMABackoffs on Packet Delivery Ratio

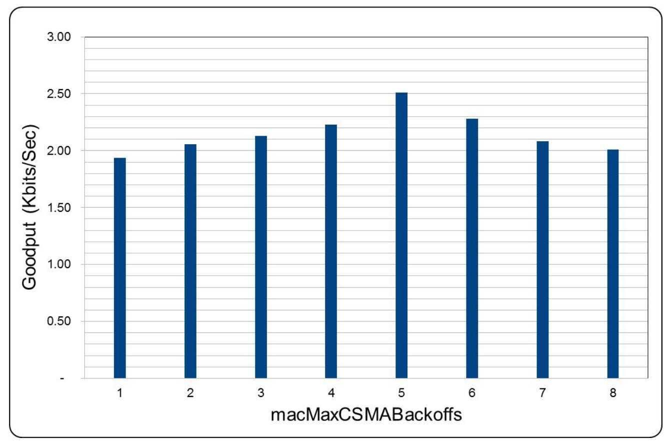

Fig. 11. Effect of Changing Values of macMaxCSMABackoffs on Goodput (Kbits/Sec)

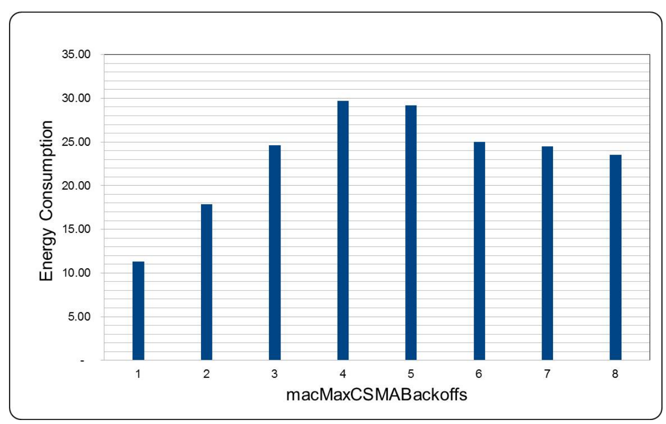

Fig. 12. Effect of Changing Values of macMaxCSMABackoffs on Energy Consumption

ZigBee MAC is transmission failure due to acknowledgment loss. Increasing packet loss in the network also increases the retransmissions in the network, which causes high energy consumption. The packet delivery ratio also decreases due to packet transmission failure, which introduces the reliability issues in medical body area network. Effect of changing value of macMaxCSMABackoffs is shown in Fig. 10, Fig. 11, Fig. 12 and Fig. 13.

In order to solve these problems we propose a mechanism for flexible tuning of CSMA/CA parameters i.e. macMinBE and macMaxCSMABackoffs to avoid unnecessary retrans-

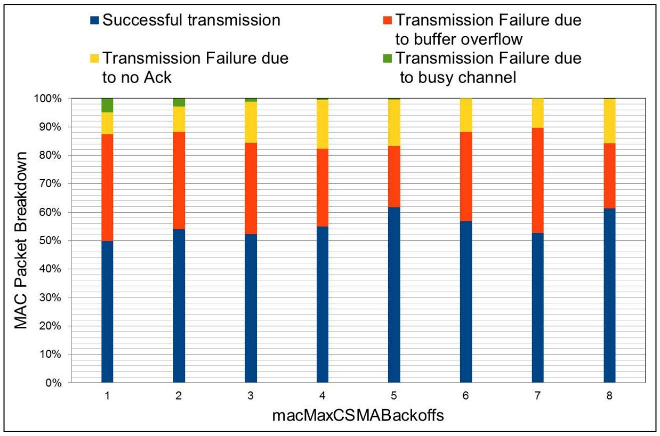

Fig. 13. Effect of Changing Values of macMaxCSMABackoffs on MAC Packet Breakdown

TABLE I. VALUES OF MAC PARAMETERS

Zigbee MAC parameters	**Default Values [11]**	**New Values**
macMaxFrameRetries	3	2
macMaxCSMABackoffs	4	Range: 4 to 7
macMinBE	3	Range: 2 to 7
macMaxBE	5	7
requestGTS	Fixed no of slots	Depends on buffer size

missions and to improve reliability and energy efficiency in the network at acceptable level. In the proposed mechanism these parameters adapts best value set according to different network conditions such as contention among the nodes and packet collisions in the network etc to improve the network performance. In the proposed solution we also change some default values of some MAC parameters as shown in Table I.

In the proposed mechanism we reduce the value of macMaxFrameRetries because there is no need to retransmit a packet again and again when packet loss is due to contention in the network. There is also a need to avoid the circumstances causing energy wastage such as retransmissions, but it is also important to take some necessary actions to reduce collisions in the network. We propose tuning of two ZigBee MAC parameters macMinBE and macMaxCSMABackoffs to improve performance of ZigBee MAC in terms of reliability and energy efficiency by reducing the transmission failure rate and retransmissions.

a) Flexible macMaxCSMABackoffs: We define a new range of macMaxCSMABackoffs and its tuning in which value of macMaxCSMABackoffs increases or decreases according to clear channel assessment result. If there is no contention or small contention in the network and nodes are not competing for channel access then there is no need to set a larger value of CSMABackoffs. That is why, we propose that when CSMA/CA is successful and node successfully transmits it packets for consecutive 3 times then macMaxCSMABackoffs decrements as follows:-

If ((macMaxCSMABackoffs $>$ defaultmacMaxCSMABackoffs) && (macMaxCSMABackoffs $\leq$ 7)) { macMaxCSMABackoffs– ; }

When there is a channel access failure in the network it means that there is high contention among the nodes in the network. When a large number of nodes have data to send and they try to access the channel at the same time they encounter channel access failure. In this case they have to terminate the algorithm after a few attempts because of smaller value of macMaxCSMABackoffs. Terminating an algorithm and start it from first step introduces some delay in the network. In order to solve this issue we propose an increment in value of macMaxCSMABackoffs after three consecutive CSMA/CA failures. A mechanism to increase the value of macMaxCSMABackoffs after three consecutive CSMA/CA failures is as given below:-

If ((macMaxCSMABackoffs $\geq$ defaultmacMaxCSMABackoffs) && (macMaxCSMABackoffs $<$ 7)) { macMaxCSMABackoffs++; }

b) Flexible macMinBE: We define a new range of macBE from 2 to 7. We also propose flexible tuning of macMinBE according to network conditions such as packet collision rate and acknowledgment loss. When a large number of nodes try to transmit their data at the same time, then there is a possibility of packet collision in the network. In order to avoid collisions using CSMA/CA mechanism, we propose an increment in value of manMinBE after three consecutive collisions in network. By this way, in case of high collision in the network, we put some nodes to be in backoff state in order to reduce the contention in the network. Proposed mechanism for the increment in value of manMinBE is as follows:-

if ((macMinBE $\geq$ defaultmacMinBE) && (macMinBE $<$ macMaxBE)) { macMinBE++ ;}

When there are small number of collisions due to less contention in the network, then there is no need for a node to be in a backoff state for a longer time. It only introduces unnecessary delay in the network. To resolve this issue we propose a decrement in value of macMinBE. A mechanism to decrement in value of macMinBE is given below:-

if ((macMinBE $>$ defaultmacMinBE) && (macMinBE $\leq$ macMaxBE)) { macMinBE– ;}

2) GTS-on Mode: In order to solve the problem of bandwidth underutilization in the Zigbee MAC as shown in Fig. 14, Fig. 15, Fig. 16 and Fig. 17, we revise the mechanism of sending GTS request of node to PAN coordinator. We propose a mechanism in which, if a node has emergency data to send, first of all it will try to access channel using CSMA/CA. If the channel is free, the node will immediately send its emergency data otherwise it will store the data into an emergency buffer and send a request to reserve a guaranteed time slot.

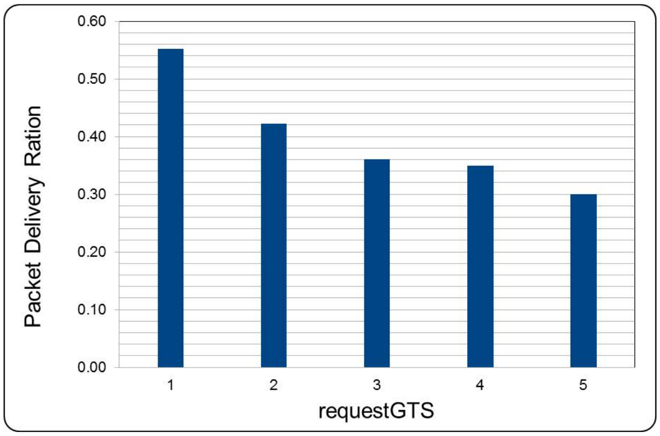

Fig. 14. Effect of Changing Values of requestGTS on Packet Delivery Ratio

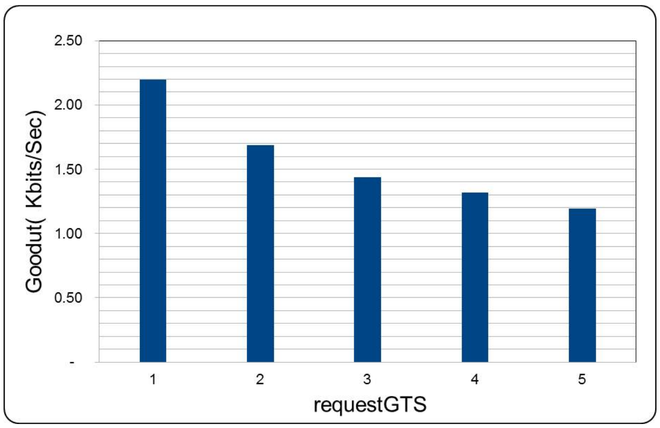

Fig. 15. Effect of Changing Values of requestGTS on Goodput (Kbits/Sec)

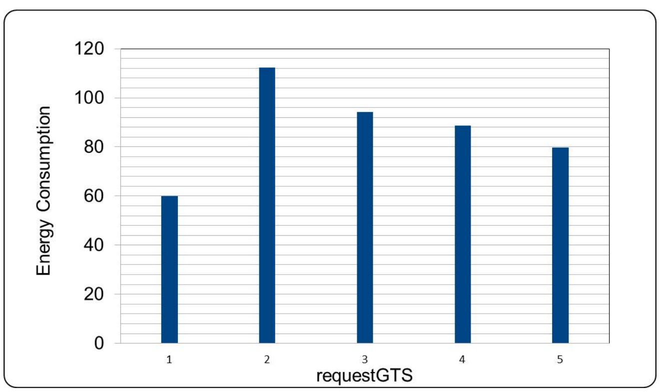

Fig. 16. Effect of Changing Values of requestGTS on Energy Consumption

We also propose that instead of sending a request for a fixed number of slots, each node check total number of packets in its buffer and send a GTS request according to buffer size. Proposed mechanism for sending GTS request is given below.

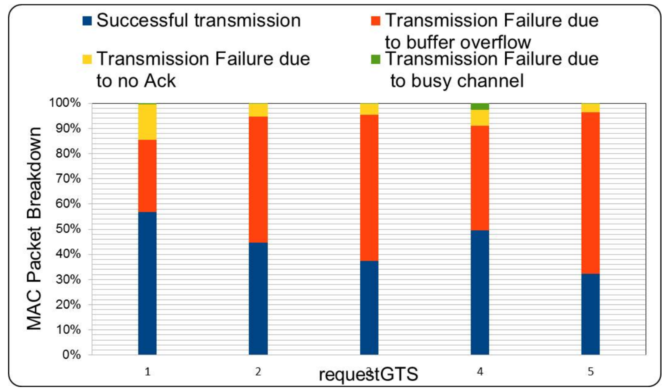

Fig. 17. Effect of Changing Values of requestGTS on MAC Packet Breakdown

If ((GTSbuffersize $\geq$ 1) && (GTSbuffersize $\leq$ 7))
GTSrequest = 1;

else if ((GTSbuffersize $\geq$ 8) && (GTSbuffersize $\leq$ 14))
GTSrequest = 2;

else if ((GTSbufersize >14) && (GTSbufersize $\leq$ emergencyBfr))
GTSrequest = 3;

3) Adaptive MAC: Traffic in medical body area network is hybrid and it depends on the patient's health conditions. If the values of the patient's vital signs do not exceed a certain threshold, we consider it as normal traffic. Emergency traffic will be transmitted if condition of the patient goes critical and values of patient's vital signs exceed certain threshold level. In order to discriminate the normal and emergency traffic, we set threshold values for different vital signs of patient. For example normal body temperature is 36 to 37 degrees Celsius. We set thresholds for a human body temperature i.e. minimum threshold, if body temperature is less than 36 degrees Celsius and maximum threshold, if temperature of human body is equal to or more than 40 degrees Celsius. These two thresholds indicate the life threatening medical emergency and requires immediate medical treatment. If any of vital sign exceeds its threshold limit, data will be sent as an emergency traffic.

Emergency traffic needs high reliability as compared to normal traffic because of the critical condition of patients. We propose a mechanism which enables the algorithm to adapt its modes i.e. GTS-off and GTS-on according to traffic type. Proposed mechanism for adapting modes of MAC is given below.

if sensor value $\geq$ maxThreshold || sensor value $\leq$ minThreshold // emergency traffic
then packet will send in GTS-on mode (CFP)
else packet will send in GTS-off mode (CAP)

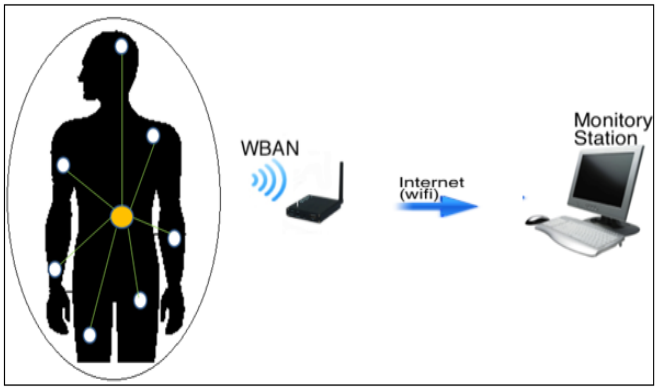

Fig. 18. Medical Body Area Network

TABLE II. IMPLEMENTATION SCENARIO

Simulator	Castalia
Field Size(x,y)	10 meter
Topology	Star
(PAN Coordinator, Source Nodes)	{(1,1)(1, 2)(1, 3)((1,5)(1,8)(1, 10), (1, 15)(1, 20)(1, 30)(1, 40)(1,50)}
Packet Size	48 bytes
Routing Protocol	None
No of Simulation Runs	30

B. Implementation

We represent the medical body area network for patient monitoring in Fig. 18. Details of network implementation are given in Table. II. The proposed mechanism is implemented in an Omnet++ based Castalia Simulator. We set the field size to 10 meters and select star topology because it is best suited for short range communications in medical body area network. We take simulations for different network scenarios by changing the number of source nodes or by changing packet rates. There is no need of routing protocol because of predefined routing path in star topology.

V. RESULTS AND DISCUSSIONS

We select four performance metrics to compare the performance of the proposed mechanism with the ZigBee MAC which are packet delivery ratio, goodput(bits/Second), MAC packet break down and energy efficiency. Packet delivery ratio represents the ratio of the number of packets successfully received at destination divided by total number of packets sent at the application layer. Unit for goodput is bits per second and it is an application layer throughput which represents the actual data communicated from source to destination per unit time. The MAC packet breakdown has four sub performance metrics, i.e. transmission failure due to buffer overflow, transmission failure due to acknowledgment loss, transmission failure due to busy channel and the rate of successful packet transmission at MAC layer. We calculate energy efficiency in term of retransmissions overhead, e.g. smaller the number of retransmissions and duplicate packets, smaller the energy consumption of network.

We compare simulation results of both MACs against six different scenarios based on different packet rates and number of nodes. In scenario 1 packet rate of all nodes is same but the number of nodes are different. In scenario 2, packet rate is different such as 1 packet/Sec 2 packets/second, 3 packets/second, 5 packets/second and 10 packets/second but number of nodes remains constant. In this scenario, there are 10 source nodes and one PAN coordinator in the network. In scenario 3 20% nodes in the network have a packet rate of 1 packet/second and 80% nodes have 5 packets/second packet rate. In scenario 4 packet rate of 20% nodes in the network have 5 packets/second and 80% nodes have 1 packet/second. In scenario 5 50% nodes in the network have a packet rate of 1 packet/second and 50% nodes have 5 packets/second. In the last scenario, each node in a network has a different packet rate between the range of 1 packet/second to 8 packets/second.

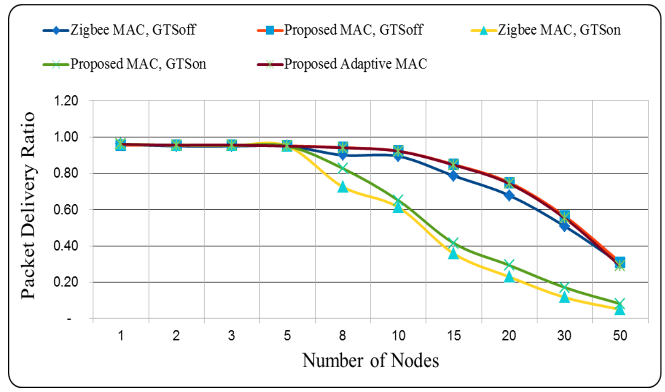

Fig. 19. Packet Delivery Ratio of Scenario 1

A. Simulation Results

We subdivide this section into packet delivery ratio, goodput(Bits/Second), MAC packet break down and energy efficiency.

1) Packet Delivery Ratio: Fig. 19 and Fig. 20 show the simulation results of proposed MAC mechanism and ZigBee MAC of scenario 1 and 2 respectively. Simulation results for scenarios 3, 4, 5 and 6 are shown in Fig. 21. From the simulation results we can see that all modes of proposed MAC mechanism perform better than ZigBee MAC when we increase the number of nodes in the network or increase the packet rates. Proposed MAC performs better in case of setting different packet rates for each node as shown in Fig. 21.

2) Goodput(Kbits/Sec): Fig. 22 and Fig. 23 represent the goodput of both MACs for scenario 1, 2 and Fig. 24 shows the results of scenario 3, 4, 5 and 6. If we compare the performance of both MACs we can see that all modes of proposed MAC mechanism have better performance as compared to ZigBee MAC. When we compare the simulation results of scenario 3, 4, 5 and 6 we can see that when 80% of nodes have high data rates, such as 10 packets/second and only 20% nodes are sending 1 packet/second the goodput of the network is high as compared to scenario in which 80% of nodes are sending

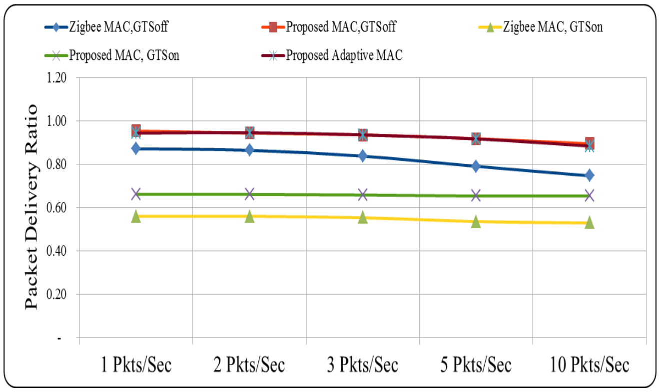

Fig. 20. Packet Delivery Ratio of Scenario 2

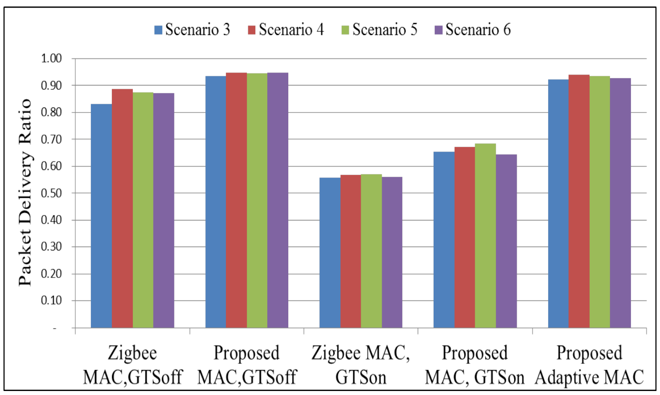

Fig. 21. Packet Delivery Ratio of Scenario 3, 4, 5 & 6

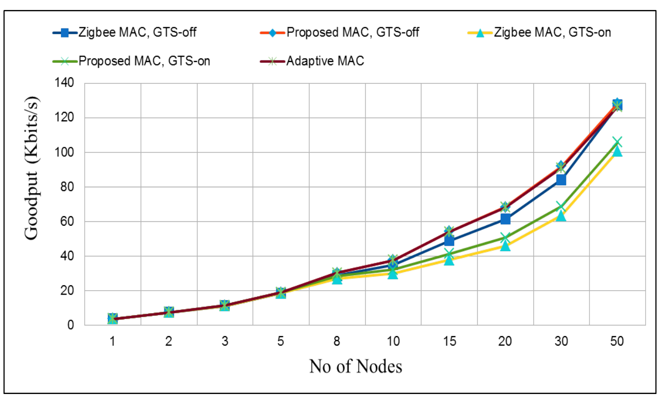

Fig. 22. Goodput (Kbits/Sec) of Scenario 1

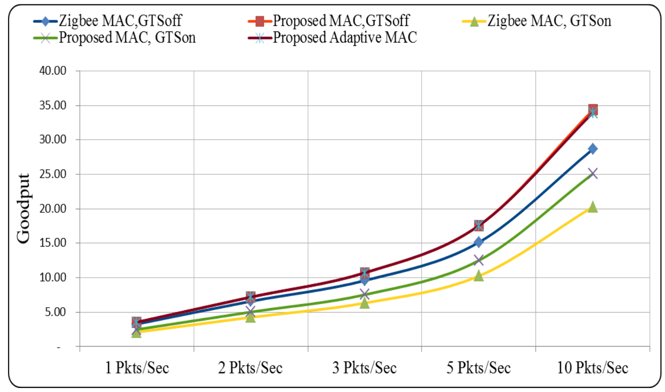

Fig. 23. Goodput (Kbits/Sec) of Scenario 2

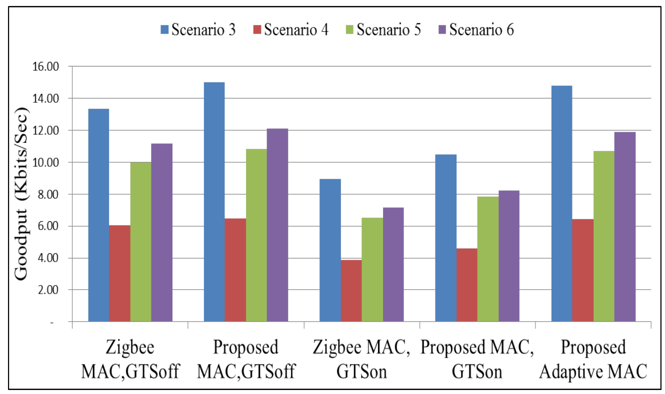

Fig. 24. Goodput (Kbits/Sec) of Scenario 3, 4, 5 & 6

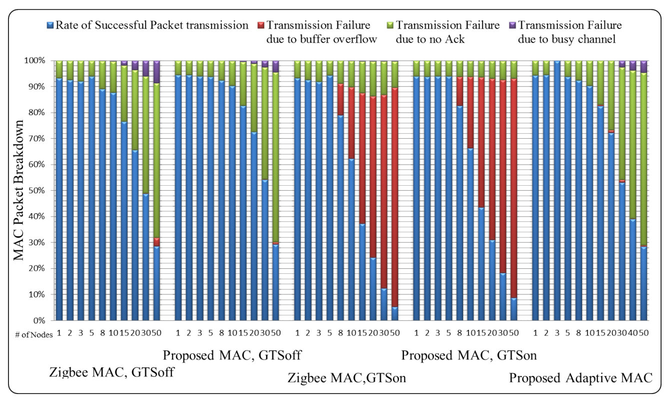

Fig. 25. MAC Packet Breakdown of Scenario 1

packets at packet rate of 1 packet/second and remaining 20% nodes are sending 5 packets/second. Proposed MAC has better goodput as compared to ZigBee MAC in all scenarios.

3) MAC Packet Breakdown: The MAC packet breakdown is one of most important performance metrics. Under this performance metric we have further four performance sub-metrics such as transmission failure due to buffer overflow, transmission failure due to acknowledgment loss, transmission failure due to busy channel and the rate of successful packet transmission at MAC layer. Basically, it shows that what actually happened to a packet at MAC layer when a node tries to send it to sink node. If the packet fails to transmit, there can be multiple possible reasons of this failure. We can also know that how many packets successfully received at the destination out of total packets sent at the MAC layer and how many packets failed to transmit and discarded at MAC layer due to contention among the nodes. Fig. 25 shows the MAC packet breakdown of scenario 1 in which we compare the performance of three modes of proposed MAC mechanism with ZigBee MAC. Fig. 26 shows the results of ZigBee MAC, GTS-off, Proposed MAC, GTS-off, Zigbee MAC, GTSon, Proposed MAC, GTS-on and Proposed Adaptive MAC from left to right.

Rate of transmission failure due to buffer overflow in GTS-

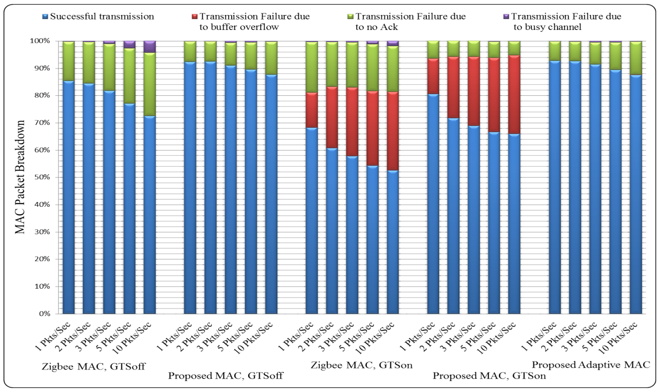

Fig. 26. MAC Packet Breakdown of Scenario 2

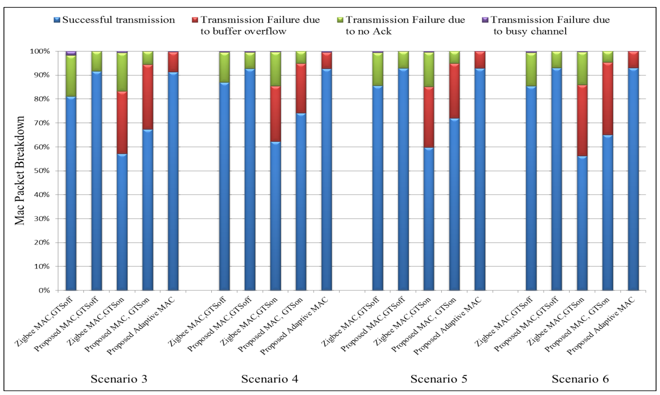

Fig. 27. MAC Packet Breakdown of Scenario 3, 4, 5 & 6

on mode is highest. The reason is that only nodes which are able to get guaranteed time slots can send their packets and other nodes have to wait. Those nodes, which are waiting for time slots and have buffer filled have to drop their packets. If we compare the performance of proposed and ZigBee MAC with GTS-on mode, proposed MAC mechanism shows better performance as compare to ZigBee MAC.

Packet failure due to buffer overflow in GTS-off modes is minimal because in these nodes, each node competes for channel access whenever it has a packet to transmit. Nodes transmit their data as soon as they get a free channel and buffer remain empty or partially filled. There is higher rate of transmission failure due to acknowledgment loss in GTS-off mode because of high traffic rate. High traffic rate causes packet collision or acknowledgment loss in the network. After transmitting a packet, a node has to wait for the acknowledgment for a specific time period. If an acknowledgment does not receive at the source node within that time, then node declares the failure of transmission. In the GTS-on mode, transmission failure due to acknowledgment loss is small because each node only transmits its data in the portion of allocated guaranteed time slots of the superframe. During that time other nodes defer their transmission and go into an inactive state. That is why chances of packet collision or acknowledgment loss are less in the network. If we compare the transmission failure due to busy channel, it is clear from the results that proposed MAC mechanism performs better in all scenarios. There is no transmission failure due to a busy channel in GTS-on mode

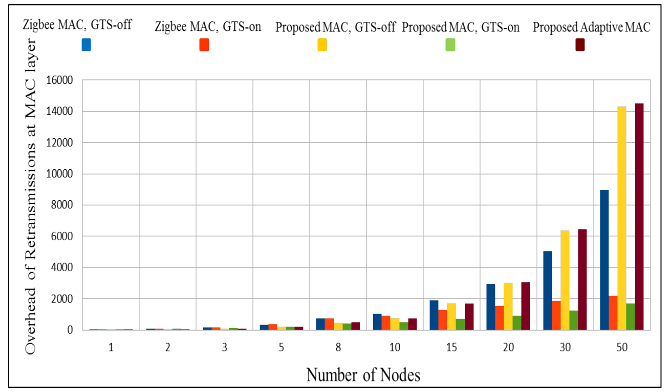

Fig. 28. Energy Consumption of Scenario 1

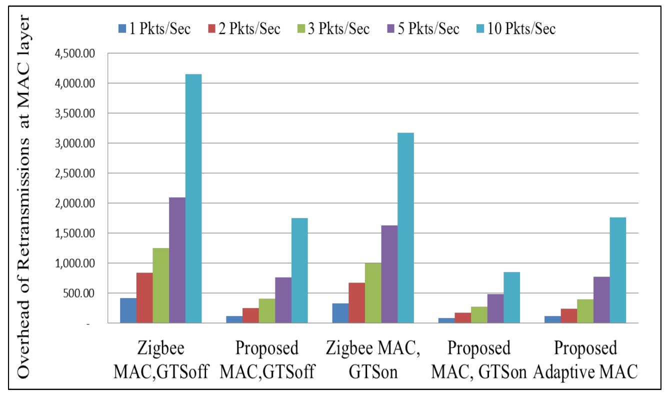

Fig. 29. Energy Consumption of Scenario 2

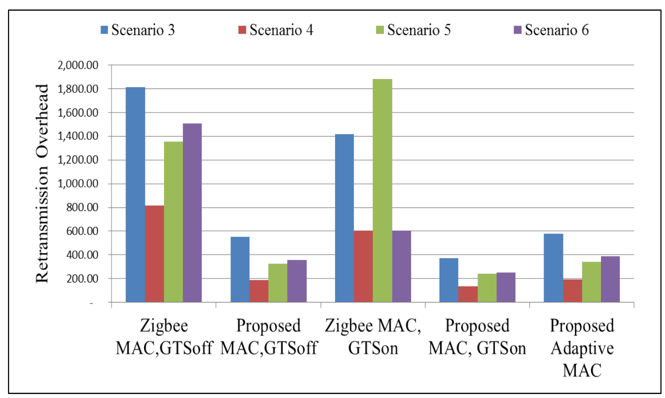

Fig. 30. Energy Consumption 3, 4, 5 & 6

because of the same reason that each node transmits its data only in allocated time slot.

Fig. 26 shows the simulation results of scenario 2 and Fig. 27 shows the combined graph of results of scenario 3, 4, 5 and 6. From the results we can see that all modes of proposed MAC mechanism show better MAC packet breakdown performance for as compare to ZigBee MAC in all scenarios.

4) Energy Efficiency: In this section we compare the energy efficiency of both proposed and ZigBee MAC mechanisms. Simulation results are shown in Fig. 28, Fig. 29

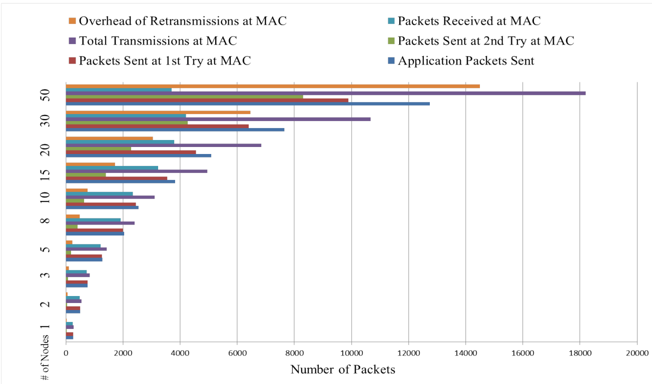

Fig. 31. Retransmission Overhead of Scenario 1

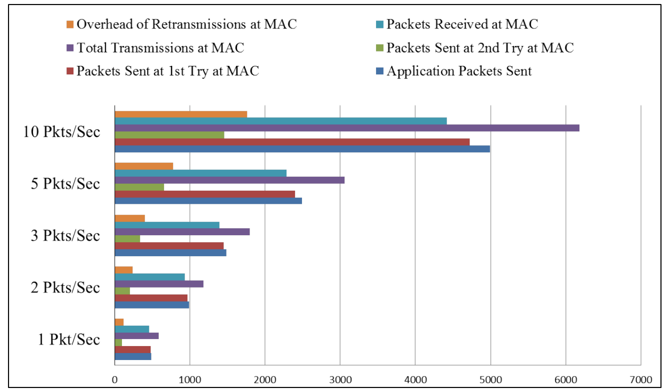

Fig. 32. Retransmission Overhead of Scenario 2

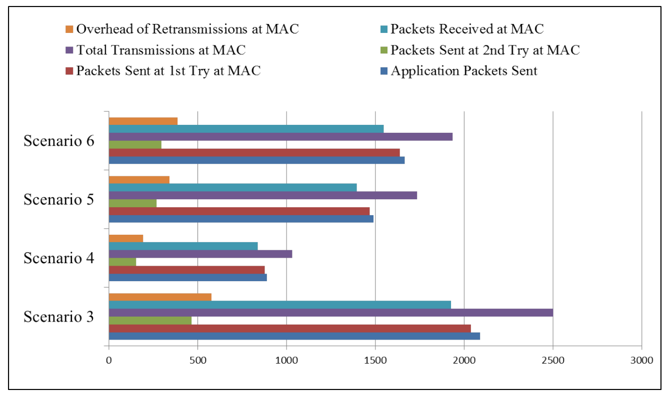

Fig. 33. Retransmission Overhead of Scenario 3, 4, 5 & 6

and Fig. 30. In Fig. 28 we show simulation results of both MAC mechanisms for scenario 1. This is an obvious fact that when there are small numbers of nodes in the network, retransmission overhead is less because of small contention in the network so that less energy consumption. But energy consumption in network increases when contention increases due to increasing number of nodes. The reason is that increasing number of nodes increases the rate of transmission failure due to collision in network. We cannot omit hundred percent transmission failure but reduction is possible. From the result shown in Fig. 28, with increasing number of node energy consumption is also increasing, but the important point is that our proposed MAC mechanism maintains an efficiency in energy consumption above the certain level as compared to ZigBee MAC mechanism. When there are large numbers of nodes and there is high collision rate in the network, our proposed mechanism maintains an acceptable balance between the energy consumption and reliability by increasing number of retransmissions to a certain level. We cannot see this type pf behaviour in results of ZigBee MAC mechanism.

Fig. 29 shows simulation results of scenario 2. In this scenario, we increase the packet rate and calculate the energy efficiency of both proposed and ZigBee MAC mechanisms. This fact is understood that increasing network traffic leads to increase in packet collision and so the retransmission rate. Results show the same behavior in network that by increasing packet rate in the network, retransmission overhead is also increasing and energy efficiency is decreasing. Keeping this fact in mind when we compare the results of both proposed and ZigBee MAC mechanisms, our proposed mechanism has better energy efficiency as compared to ZigBee MAC mechanism. Similarly Fig. 29 shows low retransmission overhead of proposed MAC mechanism as compared to ZigBee MAC mechanism. We can see the same performance trend in Fig. 30 which shows the results of scenarios 3, 4, 5 and 6. In all scenarios, proposed MAC mechanism has less retransmission overhead as compared to ZigBee MAC mechanism. In other words our proposed mechanism has better performance as compare to ZigBee MAC mechanism.

Results shown in Fig. 31, Fig. 32 and Fig. 33 represent the details of packet transmission and retransmission of adaptive proposed MAC mechanism in all scenarios. These results show the total number of packets created as an application layer, total packets transmitted at the MAC layer, number of packets sent at first try and second try, total number of retransmission and comparisons of the retransmission overhead of both MACs. Fig. 31 shows the results of scenario 1, Fig. 32 shows the results of scenario 2 and Fig. 33 shows the simulation results of scenario 3, 4, 5 and 6. The proposed MAC mechanism compromise on energy efficiency in order to keep reliability at an acceptable level if there is high contention in network by increasing retransmissions.

5) Application Level Latency: In this section we compare the application level latency in ms of proposed MAC mechanism and ZigBee MAC. In results, number of packets sent are shown at y-axis and time at x-axis. We divide the time started from 0 seconds to infinity at a-axis in equal sized time buckets of duration 20ms. Results show that how many packets experienced how much delay in the network. For example, how many packets received in first 20ms next 20ms and so on. Fig. 34 shows the latency of ZigBee MAC when there are one PAN Coordinator and 5 source nodes. Fig. 35 shows the latency of GTSon and GTSon modes of proposed MAC mechanism separately when there are one PAN Coordinator and 5 source nodes and Fig. 36 shows the latency of proposed adaptive MAC for the same number of nodes.

Fig. 37, Fig. 38 and Fig. 39 show the latency of ZigBee MAC, GTSon and GTSoff modes of proposed MAC mechanism and Proposed adaptive MAC mechanism receptively when there is one PAN coordinator and 10 source nodes in the network.

Similarly Fig. 40, Fig. 41 and Fig. 42 show the latency

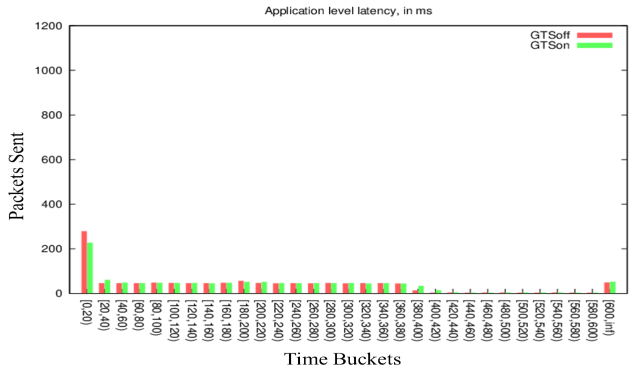

Fig. 34. Application Level Latency(ms) of GTSon and GTSoff Modes ZigBee MAC When 1 PAN Coordinator and 5 Source Nodes

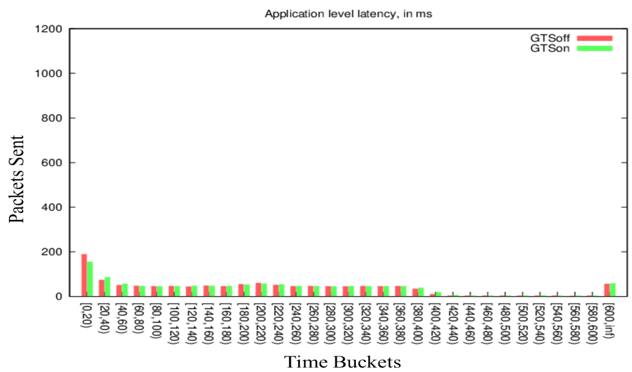

Fig. 35. Application Level Latency(ms) of GTSon and GTSoff Modes of proposed MAC mechanism When 1 PAN Coordinator and 5 Source Nodse

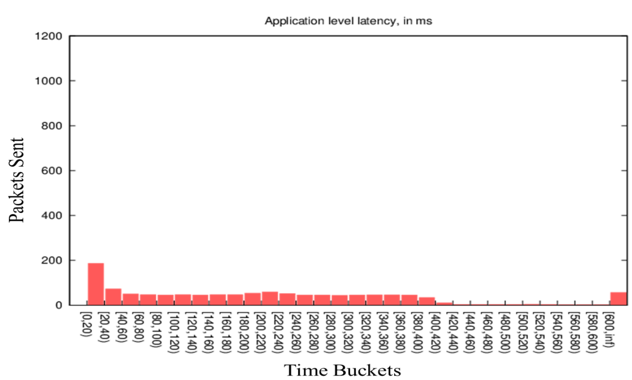

Fig. 36. Application Level Latency(ms) of Proposed Adaptive MAC When 1 PAN Coordinator and 5 Source Nodes

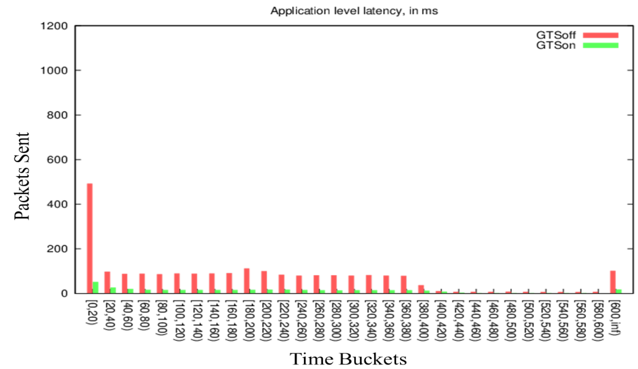

Fig. 37. Application Level Latency(ms) of Standard ZigBee MAC When 1 PAN Coordinator and 10 Source Nodes

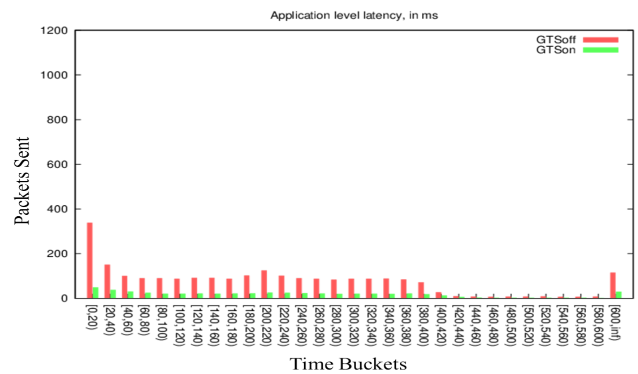

Fig. 38. Application Level Latency(ms) of GTSon and GTSoff Modes of proposed MAC mechanism When 1 PAN Coordinator and 10 Source Nodes

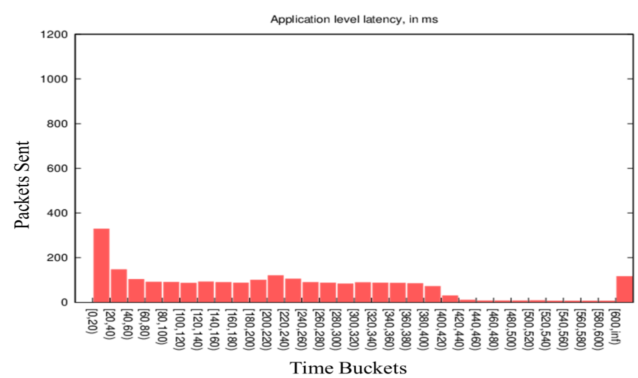

Fig. 39. Application Level Latency(ms) of Proposed Adaptive MAC When 1 PAN Coordinator and 10 Source Nodes

of ZigBee MAC, GTSon and GTSoff modes of proposed MAC mechanism and proposed adaptive MAC mechanism receptively when there is one PAN coordinator and 15 source nodes in the network.

And Fig. 43, Fig. 44 and Fig. 45 show the latency of ZigBee MAC, GTSon and GTSoff modes of proposed MAC mechanism and Proposed adaptive MAC receptively when there is on PAN coordinator and 30 nodes in the network.

Although proposed MAC mechanism shows a significant improvement in goodput, packet delivery ratio, packet loss and energy efficiency as compared to ZigBee MAC but the simulation results of application level latency show that there is still need to improve the MAC in order to minimize the latency in the network. Proposed MAC contributes very less to minimize the latency in the network. There can be multiple reasons for this issue such as PAN coordinator has to do some extra processing for efficiency GTS allocation to the nodes. When proposed MAC mechanism works in full adaptive MAC, it has to adapt itself according to the traffic such as emergency and normal traffic. This can be a reason for proposed MAC mechanism to not contribute much for reducing the latency.

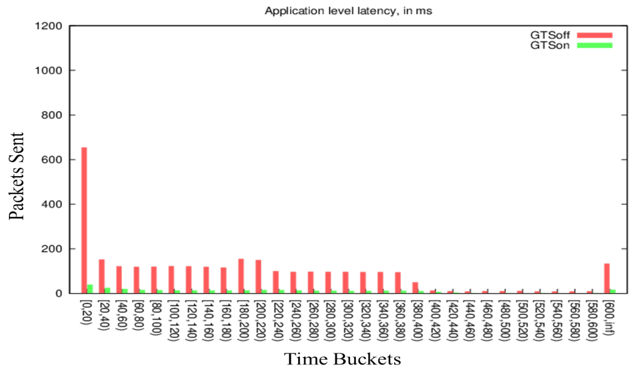

Fig. 40. Application Level Latency(ms) of Standard ZigBee MAC When 1 PAN Coordinator and 15 Source Nodes

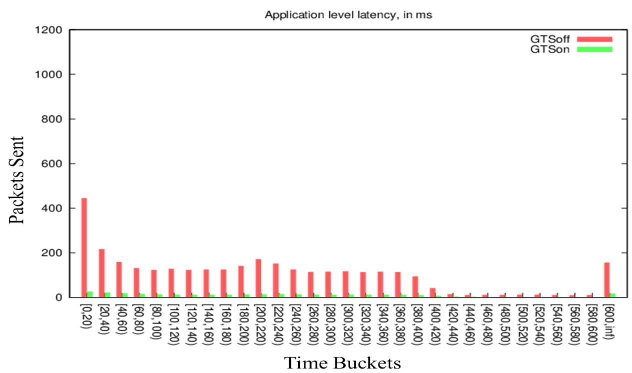

Fig. 41. Application Level Latency(ms) of GTSon and GTSoff Modes of proposed MAC mechanism When 1 PAN Coordinator and 15 Source Nodes

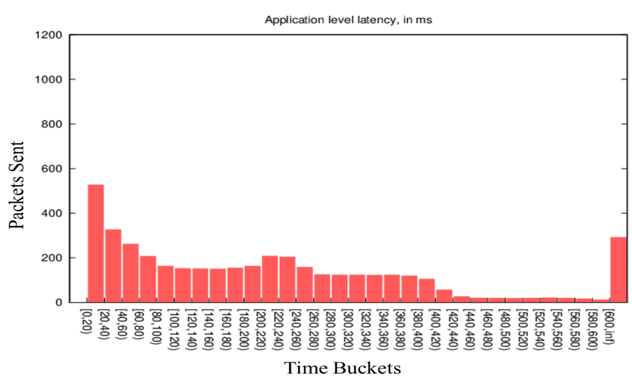

Fig. 42. Application Level Latency(ms) of Proposed Adaptive MAC When 1 PAN Coordinator and 30 Source Nodes

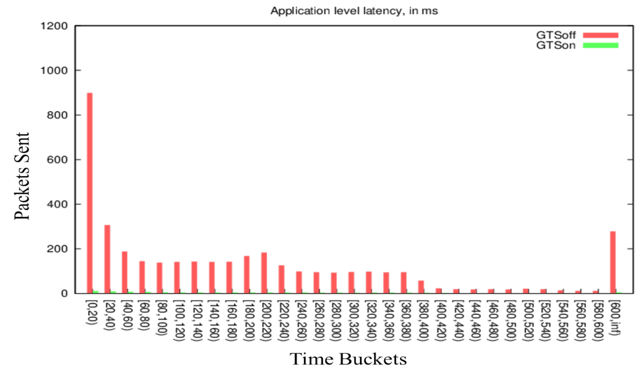

Fig. 43. Application Level Latency(ms) of Standard ZigBee MAC When 1 PAN Coordinator and 30 Source Nodes

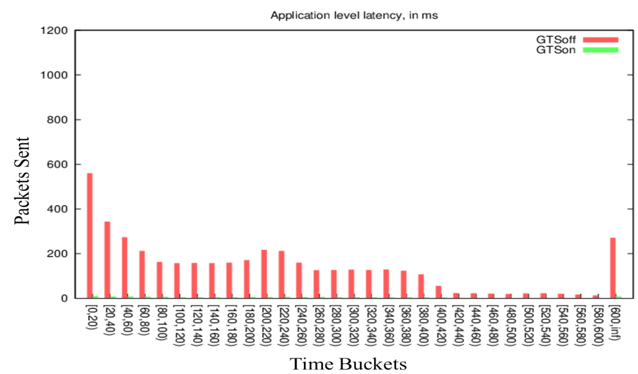

Fig. 44. Application Level Latency(ms) of GTSon and GTSoff Modes of proposed MAC mechanism When 1 PAN Coordinator and 30 Source Nodes

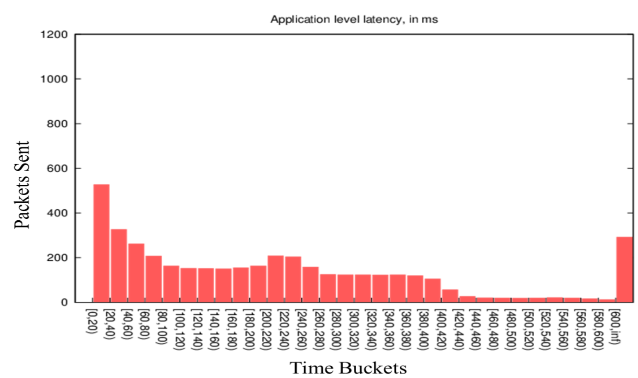

Fig. 45. Application Level Latency(ms) of Proposed Adaptive MAC When 1 PAN Coordinator and 15 Source Nodes

In the next section we discuss the outcomes of our proposed Scheme and future work.

B. Discussion and Future Work

In this paper we proposed some enhancements in the ZigBee MAC to make it best suitable for medical body area networks. We compare the results of the proposed MAC mechanism with ZigBee, and show that proposed MAC mechanism performs better than ZigBee MAC in term of reliability and energy efficiency. We compare the reliability of both MACs by comparing the results of goodput, packet delivery ratio and MAC packet breakdown. In order to compare the energy efficiency of both MACs we calculate the number of retransmissions and duplicate packets of both MACs and compare it with each other. Although proposed MAC mechanism shows better performance as compared to ZigBee MAC but there are still some issues which need to be addressed. If we see the results of the MAC packet breakdown in Fig. 31, Fig. 32 and Fig. 33 transmission failure due to acknowledgment loss is still an issue. It is necessary to resolve this issue to improve the reliability in medical body area network. It will also help to improve the energy efficiency of network by reducing the number of retransmissions. The GTS allocation scheme also needs some improvements and there is a need to put some more efforts to make more flexible. Performance of GTS allocation mechanism can be improved, but introducing some fairness policy among the nodes. We can also specify priorities of different nodes depending on the nature of vital signs data which they are monitoring. Another possible enhancement is reliabilitiy of GTS request and reply messages. Because in case of not getting the guaranteed time slot, the node has to wait until next superframe which can introduce extra delay in packet transmission and can also introduce packet drop due to buffer overflow. There is also a need to propose some mechanism to reduce the latency to improve the network performance.

VI. Conclusion

In this paper we discuss different applications and requirements of medical body area network. We also give an overview of ZigBee MAC and highlight its limitations for medical body area network. We propose a reliable and energy efficient MAC mechanism for medical body area network for patient's monitoring in hospitals. Our results show that proposed MAC mechanism has better performance compared to ZigBee MAC. We also highlight some limitations of ZigBee MAC which are still present in proposed MAC mechanism as future directions.

VII. Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," *Computer networks*, vol. 38, no. 4, pp. 393–422, 2002.

[2] M. R. Ceballos, J. L. Gorricho, O. Palma Gamboa, M. K. Huerta, D. Rivas, and M. Erazo Rodas, "Fuzzy system of irrigation applied to the growth of habanero pepper (capsicum chinense jacq.) under protected conditions in yucatan, mexico," *International Journal of Distributed Sensor Networks*, vol. 2015, 2015.

[3] M. S. Islam, "Heartbeat biometrics for remote authentication using sensor embedded computing devices," *International Journal of Distributed Sensor Networks*, 2015.

[4] R. A. Haraty, M. Dimishkieh, and M. Masud, "An enhanced k-means clustering algorithm for pattern discovery in healthcare data," *International Journal of Distributed Sensor Networks*, 2015.

[5] M. Hoda, Y. Hoda, A. Alamri, B. Hafidh, and A. E. Saddik, "A novel study on natural robotic rehabilitation exergames using the unaffected arm of stroke patients," *International Journal of Distributed Sensor Networks*, 2015.

[6] A. Dandashi, S. Saad, A. G. Karkar, Z. Barhoumi, J. Al-Jaam, and A. El Saddik, "Enhancing the cognitive and learning skills of children with intellectual disability through physical activity and edutainment games," *International Journal of Distributed Sensor Networks*, 2015.

[7] A. Rahman *et al.*, "Multisensor serious game-based therapy environment for hemiplegic patients," *International Journal of Distributed Sensor Networks*, 2014.

[8] T. Arampatzis, J. Lygeros, and S. Manesis, "A survey of applications of wireless sensors and wireless sensor networks," in *Intelligent Control, 2005. Proceedings of the 2005 IEEE International Symposium on, Mediterrean Conference on Control and Automation*. IEEE, 2005, pp. 719–724.

[9] C. Wei, Q. Xin, W. H. Chung, S.-y. Liu, H.-y. Tam, and S. Ho, "Real-time train wheel condition monitoring by fiber bragg grating sensors," *International Journal of Distributed Sensor Networks*, vol. 2012, 2011.

[10] A. Wahid and D. Kim, "An energy efficient localization-free routing protocol for underwater wireless sensor networks," *International journal of distributed sensor networks*, vol. 2012, 2012.

[11] G. Manes, G. Collodi, R. Fusco, L. Gelpi, and A. Manes, "A wireless sensor network for precise volatile organic compound monitoring," *International Journal of Distributed Sensor Networks*, vol. 2012, 2012.

[12] Y.-g. Ha, H. Kim, and Y.-c. Byun, "Energy-efficient fire monitoring over cluster-based wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 2012, 2012.

[13] A. Willig, J. Hauer, N. Karowski, H. Baldus, and A. Huebner, "The angel wsn architecture," in *Electronics, Circuits and Systems, 2007. ICECS 2007. 14th IEEE International Conference on*. IEEE, 2007, pp. 633–636.

[14] B. Zhou, C. Hu, H. Wang, R. Guo, and M.-H. Meng, "A wireless sensor network for pervasive medical supervision," in *Integration Technology, 2007. ICIT'07. IEEE International Conference on*. IEEE, 2007, pp. 740–744.

[15] A. Asif and I. A. Sumra, "Applications of wireless body area network (wban): A survey," 2017.

[16] I. Ha, "Technologies and research trends in wireless body area networks for healthcare: A systematic literature review," *International Journal of Distributed Sensor Networks*, vol. 501, p. 573538, 2015.

[17] M. Kumar and M. Dave, "Mac protocols in body area network-a survey," in *Internet of Things: Novel Advances and Envisioned Applications*. Springer, 2017, pp. 87–107.

[18] C. Wang, Q. Wang, and S. Shi, "A distributed wireless body area network for medical supervision," in *Instrumentation and Measurement Technology Conference (I2MTC), 2012 IEEE International*. IEEE, 2012, pp. 2612–2616.

[19] D. W. Curtis, E. J. Pino, J. M. Bailey, E. I. Shih, J. Waterman, S. A. Vinterbo, T. O. Stair, J. V. Guttag, R. A. Greenes, and L. Ohno-Machado, "Smartan integrated wireless system for monitoring unattended patients," *Journal of the American Medical Informatics Association*, vol. 15, no. 1, pp. 44–53, 2008.

[20] A. Boulis, D. Smith, D. Miniutti, L. Libman, and Y. Tselishchev, "Challenges in body area networks for healthcare: The mac," *Communications Magazine, IEEE*, vol. 50, no. 5, pp. 100–106, 2012.

[21] "Ieee std 802.15. 4."

[22] M. Fatima, A. K. Kiani, and A. Baig, "Medical body area network, architectural design and challenges: A survey," in *Wireless Sensor Networks for Developing Countries*. Springer, 2013, pp. 60–72.

[23] M. Salayma, A. Al-Dubai, I. Romdhani, and Y. Nasser, "Wireless body area network (wban): A survey on reliability, fault tolerance, and technologies coexistence," *ACM Computing Surveys (CSUR)*, vol. 50, no. 1, p. 3, 2017.

[24] Y.-K. Huang, A.-C. Pang, and T.-W. Kuo, "Aga: Adaptive gts allocation with low latency and fairness considerations for ieee 802.15. 4," in *Communications, 2006. ICC'06. IEEE International Conference on*, vol. 9. IEEE, 2006, pp. 3929–3934.

[25] L. Cheng, A. G. Bourgeois, and X. Zhang, "A new gts allocation scheme for ieee 802.15. 4 networks with improved bandwidth utilization," in *Communications and Information Technologies, 2007. ISCIT'07. International Symposium on*. IEEE, 2007, pp. 1143–1148.

[26] Y.-G. Hong, H.-J. Kim, H.-D. Park, and D.-H. Kim, "Adaptive gts allocation scheme to support qos and multiple devices in 802.15. 4," in *Advanced Communication Technology, 2009. ICACT 2009. 11th International Conference on*, vol. 3. IEEE, 2009, pp. 1697–1702.

[27] B. Shrestha, E. Hossain, S. Camorlinga, R. Krishnamoorthy, and D. Niyato, "An optimization-based gts allocation scheme for ieee 802.15. 4 mac with application to wireless body-area sensor networks," in *Communications (ICC), 2010 IEEE International Conference on*. IEEE, 2010, pp. 1–6.

[28] H. W. Cho, S. J. Bae, and M. Y. Chung, "Utilization-aware dynamic gts allocation scheme in ieee 802.15. 4," in *Communications (APCC), 2010 16th Asia-Pacific Conference on*. IEEE, 2010, pp. 210–214.

[29] B. Shrestha, E. Hossain, and S. Camorlinga, "A markov model for ieee 802.15. 4 mac with gts transmissions and heterogeneous traffic in non-saturation mode," in *Communication Systems (ICCS), 2010 IEEE International Conference on*. IEEE, 2010, pp. 56–61.

[30] D.-T. Huynh, T. Q. Nhat, and D. D. Van, "Energy optimization in wireless body area network based on zigbee," in *Proceedings of the 2016 International Conference on Intelligent Information Processing*. ACM, 2016, p. 2.

[31] B. Shrestha, E. Hossain, and S. Camorlinga, "Ieee 802.15. 4 mac with gts transmission for heterogeneous devices with application to wheelchair body-area sensor networks," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 15, no. 5, pp. 767–777, 2011.

[32] N. T. Le, S. Choi, and Y. M. Jang, "A new qos resource allocation scheme using gts for wpans," *Wireless Personal Communications*, vol. 67, no. 1, pp. 25–45, 2012.

[33] C.-L. Ho, C.-H. Lin, W.-S. Hwang, and S.-M. Chung, "Dynamic gts allocation scheme in ieee 802.15. 4 by multi-factor," in *Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), 2012 Eighth International Conference on*. IEEE, 2012, pp. 457–460.

[34] Z. Yan, B. Liu, and C. W. Chen, "Qos-driven scheduling approach using optimal slot allocation for wireless body area networks," in *e-Health Networking, Applications and Services (Healthcom), 2012 IEEE 14th International Conference on*. IEEE, 2012, pp. 267–272.

[35] M. A. Huq, E. Dutkiewicz, G. Fang, R. P. Liu, and R. Vesilo, "Meb mac: Improved channel access scheme for medical emergency traffic in wban," in *Communications and Information Technologies (ISCIT), 2012 International Symposium on*. IEEE, 2012, pp. 371–376.

[36] H. Li, C. Chen, W. Yu, B. Yang, and X. Guan, "Supersa: Superframe design based slot allocation of wireless body area networks for healthcare systems," in *Wireless Communications & Signal Processing (WCSP), 2012 International Conference on*. IEEE, 2012, pp. 1–6.

[37] J. Shuai, W. Zou, and Z. Zhou, "Priority-based adaptive timeslot allocation scheme for wireless body area network," in *Communications and Information Technologies (ISCIT), 2013 13th International Symposium on*. IEEE, 2013, pp. 609–614.

[38] R. Kong, C. Chen, W. Yu, B. Yang, and X. Guan, "Data priority based slot allocation for wireless body area networks," in *Wireless Communications & Signal Processing (WCSP), 2013 International Conference on*. IEEE, 2013, pp. 1–6.

[39] T. Paso, J. Makela, and J. Iinatti, "Enhancing the ieee 802.15. 4 mac with dynamic gts allocation for medical applications," in *Wireless Personal Multimedia Communications (WPMC), 2011 14th International Symposium on*. IEEE, 2011, pp. 1–5.

[40] P. H. Ghare, A. Kothari, and A. G. Keskar, "Modification of superframe structure of 802.15. 4 mac for body area networks," in *Communication Systems and Networks (COMSNETS), 2011 Third International Conference on*. IEEE, 2011, pp. 1–4.

[41] M. Maman and L. Ouvry, "Batmac: an adaptive tdma mac for body area networks performed with a space-time dependent channel model," in *Medical Information & Communication Technology (ISMICT), 2011 5th International Symposium on*. IEEE, 2011, pp. 1–5.

[42] M. Di Francesco, G. Anastasi, M. Conti, S. K. Das, and V. Neri, "An adaptive algorithm for dynamic tuning of mac parameters in ieee 802.15. 4/zigbee sensor networks," in *Pervasive Computing and Communications Workshops (PERCOM Workshops), 2010 8th IEEE International Conference on*. IEEE, 2010, pp. 400–405.

[43] S. Brienza, D. De Guglielmo, G. Anastasi, M. Conti, and V. Neri, "Strategies for optimal mac parameter setting in ieee 802.15. 4 wireless sensor networks: A performance comparison," in *Computers and Communications (ISCC), 2013 IEEE Symposium on*. IEEE, 2013, pp. 000 898–000 903.

[44] M. Di Francesco, G. Anastasi, M. Conti, S. K. Das, and V. Neri, "Reliability and energy-efficiency inieee 802.15. 4/zigbee sensor networks: An adaptive and cross-layer approach," *Selected Areas in Communications, IEEE Journal on*, vol. 29, no. 8, pp. 1508–1524, 2011.

[45] P. Park, P. Di Marco, P. Soldati, C. Fischione, and K. H. Johansson, "A generalized markov chain model for effective analysis of slotted ieee 802.15. 4," in *Mobile Adhoc and Sensor Systems, 2009. MASS'09. IEEE 6th International Conference on*. IEEE, 2009, pp. 130–139.

[46] S. Xie, K. S. Low, and E. Gunawan, "An adaptive tuning algorithm for ieee 802.15. 4-based network control system," in *Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2014 IEEE Ninth International Conference on*. IEEE, 2014, pp. 1–6.

Towards Evaluating Web Spam Threats and Countermeasures

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***Abstract*—Web spam is a deceiving technique that aims to get high ranks for the retrieved web pages at the top Search Engine Result Pages (SERPs). This paper provides an evaluation for the web spam threats and countermeasures. It is started by presenting the different types of web spam threats that aim to deceive the users with incorrect information, distribute phishing and propagate malware. Then, presenting a detailed description for the proposed anti web spam tools, systems and countermeasures, and conducting a comparison between them. The results indicate that online real time tools are highly recommended solutions against web spam threats.**

***Keywords*—SEO; web spam threats; phishing; malware; web attacks**

I. Introduction

Nowadays, enormous amounts of queries are performed by many users on the search engines; with intentions like solving a problem, answering a question, finding information, or just for an entertainment. Regardless the query types, users want high-quality results and prefer the relevant ones that are displayed at the top of Search Engine Result Pages (SERPs). The retrieved web pages mainly are handled by ranking algorithms and the retrieved results are called organic results. In the contrast to the organic results, poor quality, and irrelevant information also are retrieved. Retrieving irrelevant results (web spam) makes search engines less credible and users become more annoyable [1].

Web spam is a fraud practice that imposes search engines to fetch web pages that are considered meaningless and do not meet the users needs. It is a fraud method because it is based on cheating and deceiving search engines, users, and webmasters from the real content. Web spam includes several types such as content web spam, link web-spam, cloaking, and doorway pages [2]. Conversely, Search Engine Optimization (SEO) is a legal way that is used to achieve high ranks for the retrieved web pages which are convenient to the user's queries. It is a type of Search Engine Marketing (SEM) models. SEO is considered a worthy business, some of the leading optimizers and SEO corporations regularly spend more than $20,000 per month for continuing in optimization [3].

The study presents the current web spam types, threats and related attacks that mislead the users with irrelevant information or hurt their devices by redirecting them to malicious links or phishing web pages. It provides a comprehensive description of several existence countermeasures and anti web spam systems. Finally, the study compares them to recommend the best appropriate solutions.

The paper is organized as follow: Section II briefly presents related studies of web spam types. Section III presents the main web spam threats. Section IV shows the Anti Web spam tools, systems, and countermeasures. Section V presents the conclusion of the study.

II. Web Spam

Web spam includes various types such as content-based, link-based, opinion based, and cloaking. Many studies explored different spam techniques and proposed several solutions to handle web spamming techniques.

- content web spam: In content web spam, the actual contents of the web pages are altered using different techniques. Typically, search engines are based on the TF-IDF algorithm of information retrieval for evaluation and ranking the retrieved web pages. Term Frequency measure (TF) computes the frequency of terms inside the documents, while the Inverse Document Frequency (IDF) is the proportion of the overall number of documents to the number of documents that hold the term. Spammers seek to raise TF of terms by exploiting the impairments of these models. Keywords stuffing in the main HTML elements, including $< title >< /title >, < meta/ >, < body >< /body >, and < a >< /a >$ tags is considered the most common technique that is used by spammers. The technique is based on packing the web page contents with many irrelevant and meaningless terms for raising the possibility of retrieving those pages at SERPs [4]. The various types of web content spam are surveyed by [5].
- Link web spam: it is categorized to in-link and out-link types [5]. Regarding the in-link web spam, the spammers raise the rank of the target pages by increasing the number of incoming links using different techniques such as link farm [6] and accessible pages [7]. Whereas, the out-link web spam is a trivial technique in which, spammers own their pages; therefore they can insert and modify any component of their pages. Also, they can easily reduplicate the whole web catalogue such as DMOZ and Yahoo! Directory and speedily conduct a large collection of trustworthy links [8].
- Opinion spam: It is imitation reviews which are written by fraudsters, which disturb customers and organizations to reach the actual results about the products. Hence, these reviews must be discovered

and removed in order to deny the possible tricky customers. An opinion spam survey is presented by [9].

- Cloaking: It is dedicated to fake web browsers and search engine through disguise the web page or a portion of the page which is not discovered using the visual examination. It can be applied legitimately to produce improving-suited pages for the index of a search engine, for example by giving a content without ads or navigational assistance. It can also be abused to expose users contents that are unrelated to the indexed contents [10].

III. Web Spam Threats

Web spam can be described as a real threat that publishes fake information which misleads the users for inaccurate results. In addition, web-spam is considered a source for phishing, malware and spam messages [7], [11]. Web attacks take a place when exploiting the vulnerabilities by attackers who grant means to malicious users to break the system's protection mechanisms. Usually attackers try to take advantages, acquire private information and system resources. There are several types of web attacks such as phishing and malware.

- Phishing: is a illegal technique to steal sensitive information such as user-names and passwords from the naive people. Phishers fabricate the web pages by creating duplicate pages from the genuine ones. It can be driven by transmitting an e-mail that looks to be sent from a committed organization to users by phishers. The phishers deceive the users by motivating them to submit their sensitive information through clicking on a phishing link that could be received by e-mail. Also, phishing can be found in blogs, forums, or file sharing [12].
- Malware: is a harmful software that targets computers and aims to hurt the users devices such as: computer viruses, worms, Trojan horses, spyware and adware [13].

Attackers employ wide-range techniques for phishing and malware dissemination in web spam pages such as setting a link in a barcode that navigates users to malicious (phishing or malware) web pages [14], [15]. Another technique is setting up a Trojan through a malicious email attachment or ads, which give the attacker the ability to exploit vulnerabilities and acquire important information [16].

IV. Anti Web Spam Tools, Systems and Countermeasures

Discovering the web spam is considered as important issue for the web society and takes more attention for the researchers from many fields. Several attempts have been established to combat the problem of web spam. Some of the proposed methods which are developed to discover the web spam are presented as follow:

A. Spam detection using machine learning technique

Machine learning techniques are based on developing programs that can learn from experience and discover knowledge from data. Machine Learning techniques are mainly categorized into supervised and unsupervised learning [17]. Several machine learning techniques include Bayesian network, Neural networks, Support vector machine, and Decision tree have been adopted to combat the different types of spams.

The researchers in [18] proposed a web Spam detection system called SAAD based on analyzing a set of web page content features to detect the spam. They applied many classification algorithms and the best detection results were obtained by a C4.5 classifier. The study was conducted on two common web spam datasets, webb Spam Corpus which includes 350,000 varied spam pages and WEBSPAM-UK2006/7 which includes more than 100 million Web pages.

The study of [19] introduced a Dual-Margin Multi-Class Hypersphere Support Vector Machine (DMMH- SVM) classifier for automatically categorizing web spam by type. Also, they proposed new cloaking-based spam features that help to obtain high web spam detection accuracy, precision, and recall percentages. The experiments were conducted on WEBSPAM-UK2007, ClueWeb09, and ECML/PKDD10. The experimental results showed that DMMH-SVM performed better accuracy than existing algorithms with new cloaking features.

The researchers in [20] conducted a comparative study on a WebSpam UK2007 dataset to evaluate the efficiency of various machine learning classifiers. These classifiers were Decision Tree, Naive Bayes, Random Forest, and RBF Network. They applied 10- fold cross-validation in order to evaluate their experiments and used F-measure scores as the evaluation metric. Their results showed that the Random Forest classifier obtained the highest F-measure value for detecting content and link spam.

The study of [21] was conducted based on a PU-learning algorithm that learned from a very few positive instances and unlabeled dataset. The study was carried on a dataset that had 800 positive opinion reviews. The obtained accuracy was 78.12% with F-score 76.67 using the k-NN classifier.

Table I summarizes the evaluations and limitations for anti web-spam machine learning techniques.

B. Spam detection using graph-based technique

This technique recognizes the web as a directed graph, the vertices represent the web pages and the links among web pages represent the edges. Web takes the style of bowtie shape and is arranged to five components based on the characteristics of links. Characteristics of the graph have been used in the discovery of spam.

The researchers in [22] introduced a new method through combining weight properties in order to improve the web spam detection algorithms. Weight properties are the influences of one web node to another web node. They altered the existing Web spam detection algorithms with their proposed method. For the performances evaluation, their experiments are carried on a large well-known Web spam dataset WEBSPAMUK2007. The performance of the altered algorithms performed better

TABLE I. COMPARISON OF THE ANTI WEB SPAM MACHINE LEARNING TECHNIQUES

System/Paper	Threat Detection			Evaluation	Limitation
	Web Spam	Phishing	Malware		
SAAD/ [18]	✓	—	✓	effective by improvement of 15% in the worst case and 27% in the best case	Real web browsers are not embedded with it, therefore, it cannot detect the actual risky web pages
DMMH- SVM/ [19]	✓	—	—	effective of categorizing web spam with higher accuracy, precision and recall than the state-of-art frameworks	All types of web spam cannot be categorized
[20]	✓	—	—	Random Forest is the most effective classifiers with higher F-measure among all features	All types of web spam cannot be categorized
[21]	✓	—	—	effective in discovering opinion spam with 78.12% accuracy	Unlabeled data cannot be handled

than the existing algorithms up to 30.5% enhancement at the host level and 6.11% enhancement at the page level.

The study of [23] proposed a framework that spread both trust and distrust web pages by assigning scores which were T-Rank for the trust web pages and D-Rank for the untrustworthiness. In the proposed framework, the spread of T-Rank/D-Rank was determined by the targets current possibility of being trustworthy/untrustworthy. Thus a page spread more trust/distrust to a trustworthy/untrustworthy neighbor than to an untrustworthy/trustworthy neighbor. They utilized T-Rank scores to recognize spam rank reduction and D-Rank scores to finish spam detection. The proposed Trust-DistrustRank (TDR) algorithm rebounded to TrustRank and Anti-TrustRank when the punishment factor was adjusted to 1 and 0, respectively. Also, TDR beat the cons of both TrustRank and Anti-TrustRank. The Experimental results showed that TDR performed better than other semi-automatic anti-spam algorithms for both spam rank reduction and spam detection. Table II presents the evaluations and limitations for anti web-spam graph-based techniques.

C. Natural Language Processing Technique

Natural Language Processing is dedicated to the investigation of text data of the web page. Language Analysis is conducted at two levels which are semantic level and syntactic level with intent to establish several assumptions. Commonly, the TF-IDF algorithm is applied in information retrieval and text mining. TF-IDF measures the importance of a word to a document in a corpus. The importance improves proportionally to the number of times in which a term occurs in the document but is neutralized by the frequency of the word in the corpus.

The researchers in [24] proposed a Bag-Of-Spam-Words (BOSW) technique for web spam detection. In the proposed method, they illustrated each document as a vector of certain words that were chosen from a spam corpus. They performed different feature selection techniques on a dataset that is conducted based on the Persian host and applied many classification algorithms to classify the Persian websites. Their results showed that employing the BOSW technique with the SVM classifier achieved the best performance in discovering Persian spam websites.

The study of [25] proposed a method to determine the spam pages using content, link-based, and integrate both content and link-based techniques. For the content based method, the researchers utilized the term density and the linguistic features using Part of Speech (POS) ratio test to identify the spam pages. While in the link-based method, they applied collaborative discovering through calculating personalized page ranking for all web pages to identify the spam pages and non-spam pages. The study was conducted for identifying the spam and non-spam pages by integrating the content and link-based techniques. Their study is conducted using the WEBSPAM-UK2006 dataset and the results of the proposed approach achieved 75.2% F-measure. Also, the results showed that the proposed approach outperformed the four spam detection techniques that were compared to their approach. Table III reports the evaluations and limitations for anti web-spam natural language processing techniques.

D. Anti Phishing Technique

Classical security tools such as anti-virus measures are not able to protect against all cyber-attacks. Most of the serious security issues take place due to humans unwitting mistakes, errors, culture, and knowledge which are not considered completely by existing security paradigms. The improvement of current cyber-security paradigms to conduct better user consciousness, counsel, and restraint in cybercrime will be needed [26]. Several systems were proposed to face the problem of phishing.

The study of [27] introduced a method using the associative classification that is called Multi-label Classifier based Associative Classification (MCAC). They characterized the features that identify the phishing websites, and provided a survey of the intelligent strategies adopted to deal with the phishing attack. The experimental results showed that associative classification and MCAC can discover the phishing websites and extract new rules.

The researchers in [28] developed an open-source plugin for the Chrome browser which is called AuntieTuna. The novel technique can automatically create personalized lists of candidate sites and check whether the sites are browsed by users. They utilized the cryptographic hashing of each pages that are viewed as Document Object Model (DOM), giving a zero false positive measure and classifying more than half of discovered Phishing pages. The importance of AuntieTuna can be shown when providing warnings on phishing pages before users expose their sensitive information.

Both [14] and [29] studies showed that several tagging technologies like barcodes can be used to launch phishing and malware attacks. The mechanism depends on tricking the users and connect them with a spam (or irrelevant content), where users can be easily under threats by just scanning these

TABLE II. SUMMARY OF THE ANTI WEB SPAM GRAPH-BASED TECHNIQUES

System/Paper	Threat Detection			Evaluation	Limitation
	Web Spam	Phishing	Malware		
[22]	✓	—	—	improve the baseline algorithm by 30% in discovering the Web spam for WEBSPAM-UK 2007 dataset	There is not a consideration for the bidirectional links between spam and obscure pages
TDR/ [23]	✓	—	—	perform better than the preceding anti-spam algorithms for both spam reduction and spam detection	It is not incorporated in the refinements of TrustRank and Anti-TrustRank like link variable and link credibility

TABLE III. COMPARISON OF THE ANTI WEB SPAM NATURAL LANGUAGE PROCESSING TECHNIQUES

System/Paper	Threat Detection			Evaluation	Limitation
	Web Spam	Phishing	Malware		
BOSW/ [24]	✓	—	—	effective by improving the detection of spam and non-spam in Persian websites	not consider the content-based and link-based features together that help in discovering spam in Persian websites
[25]	✓	—	—	effective in discovering the web spam with 75.2% F-measure	It is not considered the bidirectional links between spam and obscure pages

barcodes. Both studies proposed solutions based on applying digital signatures to authenticate barcodes, and protect users from phishing and malware attacks.

The researchers in [30] introduced a new technique based on the auto-updated white-list of legitimate sites accessed by the different user for defending against the phishing attacks. The proposed technique was characterized by fast access time and high discovery rate. The main idea of the proposed technique is warning the users from revealing sensitive information, when they open websites that are not listed in the whitelist. Moreover, the proposed technique examins the legitimacy of a web page based on the hyperlink features. The experimental results showed that the proposed technique was very efficient for defending against phishing attacks and it had 86.02% true positive rate while less than 1.48% false negative rate. Furthermore, the proposed technique was able to discover different types of phishing attacks including Domain Name System (DNS) poisoning, embedded objects, and zero-hour attack.

The study of [31] proposed a FeedPhish application to discover phishing attacks including zero-day and phishing sites that are hosted on settled domains. When the users access to a fraud website, the application analyzes the users' behavior. Then it automates the fake identity that is submitted by online users before they are submitting their real identity. If the login to the web page is done successfully, then the web page is categorized as phishing otherwise it tested with more filters. If the fake site succeeds through all filters then the website is categorized as a legitimate site. The experimental results showed that the proposed application gained a true positive rate of 97.61%, a true negative rate of 94.37% and total accuracy of 96.38%.

The researchers in [32] showed a novel technique which was called Phishing-Alarm, to discover phishing attacks based on the features that are arduous to shuffle by attackers. They introduced an algorithm that counts the distrust ratings of web pages using the similarity of obvious features among the web pages. They employed the Cascading Style Sheet (CSS) as the ground to count the visual similarity of each page component. The main rating method was used was based on weighted page-element similarity. They prototyped their technique in the Chrome browser. The proposed system was evaluated on real-world websites and the results showed the effectiveness of the proposed technique. Table IV reports the evaluations and limitations for anti phishing techniques.

E. Real Time Systems and Online Tools

This section presents a comparison between three main free existing real-time and online tools; PhishTank [33], Search Engine SPAM Detector [34] and Google Safe Browser [35] that are widely used in different applications. These tools are used to provide highly recommended level of security against web spam threats such as irrelevant content, phishing, and malware distribution.

- PhishTank: is a free collaborative web service (open API) that was developed for detecting phishing web pages. PhishTank considers the users voting regarding suspected phishing web pages through community-based phish verification system [33]. PhishTank is widely adopted by several browsers and other software such as Opera, Mozilla, Yahoo! and Kaspersky.
- Search Engine SPAM Detector: is a free web spam detector online tool that aims to analyze web pages through extracting web spam features [34]. This tool is mainly depending on three main groups of spam techniques; keyword stuffing, spam (doorway) farms and hidden text. The main limitation of SPAM Detector tool that cannot detect Javascript tricks for increasing the web pages rank on SERPs [34].
- Google Safe Browser: is simple, flexible and easy to use Google web service, which allows users to check suspected web pages against possible threats such as phishing, malware or unwanted applications. Google Safe Browsing uses Google techniques to detect dangerous web pages by checking Google blacklists for unsafe web pages [35]. Table V summarizes the evaluations and limitations for anti web-spam real-time systems and online tools.

V. CONCLUSION

Web spam is an illegal method to increase the rank for the web pages to appear at the top SERPs. Web spam is considered the main source for distributing phishing, malware

TABLE IV. SUMMARY OF THE ANTI PHISHING TECHNIQUES

System/Paper	Threat Detection			Evaluation	Limitation
	Web Spam	Phishing	Malware		
MCAC/ [27]	—	✓	—	effective with 94% accuracy of defining the phishy websites	It is not considered the content-based features that help in understanding the behavior of the attackers
AuntieTuna/ [28]	✓	✓	—	effective with 58.8% sensitivity and 100% specificity	—
[30]	—	✓	✓	effective in discovering phishy web pages based on the hyperlink information with 86.02% true positive rate and 1.48% false negative rate	It is not considered the content-based features that help in understanding the behavior of the attackers
FeedPhish/ [31]	—	✓	—	effective in discovering phishy websites with 96.38% accuracy	It is not addressed the Single Sign-On phishing websites
Phishing-Alarm/ [32]	—	✓	—	effective in discovery the phishy websites with 100% precision rate and 97.92% recall rate	—

TABLE V. COMPARISON OF THE ANTI WEB SPAM REAL TIME SYSTEMS AND ONLINE TOOLS

System/Paper	Threat Detection			Evaluation	Limitation
	Web Spam	Phishing	Malware		
PhishTank [33]	—	✓	—	Highly recommended solution against phishing attacks	It can not detect other web attacks
Search Engine SPAM Detector [34]	✓	—	—	Highly recommended real time solution against web spam URLs	It can not detect web spam Javascript tricks and can not detect Arabic web spam (which mainly used other spam features)
Google Safe Browsing [35]	—	✓	✓	Highly recommended solution against suspected web pages	—

and irrelevant content. The study highlights the web spam threats and summarized several web spam filtering/preventing approaches. The outperformed of comparing several tools and schemes indicates that online real-time tools are highly recommended solutions against web spam threats.

REFERENCES

[1] F. A. Zaghoul, O. Rababah, and H. Fakhouri, "Website Search Engine Optimization: Geographical and Cultural Point of View," in *Computer Modelling and Simulation (UKSim), 2014 UKSim-AMSS 16th International Conference on*. IEEE, 2014, pp. 452–455.

[2] Z. Gyongyi and H. Garcia-Molina, "Web Spam Taxonomy," in *First international workshop on adversarial information retrieval on the web (AIRWeb 2005)*, 2005.

[3] R. A. Malaga, "Search Engine Optimizationblack and White Hat Approaches," *Advances in Computers*, vol. 78, pp. 1–39, 2010.

[4] A. Ntoulas, M. Najork, M. Manasse, and D. Fetterly, "Detecting Spam Web Pages Through Content Analysis," in *Proceedings of the 15th international conference on World Wide Web*. ACM, 2006, pp. 83–92.

[5] N. Spirin and J. Han, "Survey on Web Spam Detection: Principles and Algorithms," *ACM SIGKDD Explorations Newsletter*, vol. 13, no. 2, pp. 50–64, 2012.

[6] B. Wu and B. D. Davison, "Identifying Link Farm Spam Pages," in *Special interest tracks and posters of the 14th international conference on World Wide Web*. ACM, 2005, pp. 820–829.

[7] M. Erdélyi, A. Garzó, and A. A. Benczúr, "Web Spam Classification: a Few Features Worth More," in *Proceedings of the 2011 Joint WICOW/AIRWeb Workshop on Web Quality*. ACM, 2011, pp. 27–34.

[8] J. M. Kleinberg, "Authoritative Sources in a Hyperlinked Environment," *Journal of the ACM (JACM)*, vol. 46, no. 5, pp. 604–632, 1999.

[9] A. Heydari, M. ali Tavakoli, N. Salim, and Z. Heydari, "Detection of Review Spam: A Survey," *Expert Systems with Applications*, vol. 42, no. 7, pp. 3634–3642, 2015.

[10] A. Chandra and M. Suaib, "A Survey on Web Spam and Spam 2.0," *International Journal of Advanced Computer Research*, vol. 4, no. 2, p. 634, 2014.

[11] G. Canfora and C. A. Visaggio, "A Set of Features to Detect Web Security Threats," *Journal of Computer Virology and Hacking Techniques*, vol. 12, no. 4, pp. 243–261, 2016.

[12] M. Kaytan and D. Hanbay, "Effective Classification of Phishing Web Pages Based on New Rules by Using Extreme Learning Machines," 2017.

[13] A. Malhotra and K. Bajaj, "A Survey on Various Malware Detection Techniques on Mobile Platform," *Int J Comput Appl*, vol. 139, no. 5, pp. 15–20, 2016.

[14] F. Razzak, "Spamming the Internet of Things: A Possibility and its Probable Solution," *Procedia computer science*, vol. 10, pp. 658–665, 2012.

[15] R. Focardi, F. L. Luccio, and H. A. Wahsheh, "Security Threats and Solutions for Two-Dimensional Barcodes: A Comparative Study," in *Computer and Network Security Essentials*. Springer, 2018, pp. 207–219.

[16] B. Gupta, A. Tewari, A. K. Jain, and D. P. Agrawal, "Fighting Against Phishing Attacks: State of the Art and Future Challenges," *Neural Computing and Applications*, vol. 28, no. 12, pp. 3629–3654, 2017.

[17] J. Brownlee, "Supervised and Unsupervised Machine Learning Algorithms," https://machinelearningmastery.com/supervised-and-unsupervised-machine-learning-algorithms/, 2016.

[18] V. M. Prieto, M. Álvarez, R. López-García, and F. Cacheda, "Analysis and Detection of Web Spam by Means of Web Content," in *Information Retrieval Facility Conference*. Springer, 2012, pp. 43–57.

[19] S. Kumar, X. Gao, I. Welch, and M. Mansoori, "A Machine Learning Based Web Spam Filtering Approach," in *Advanced Information Networking and Applications (AINA), 2016 IEEE 30th International Conference on*. IEEE, 2016, pp. 973–980.

[20] M. Iqbal, M. M. Abid, U. Waheed, and S. H. Alam Kazmi, "Classification of Malicious Web Pages Through a j48 Decision Tree, anaïve bayes, a RBF Network and a Random Forest Classifier for Web Spam Detection," *International Journal of u- and e- Service, Science and Technology (ijunesst)*, vol. 10, no. 4, pp. 51–72, 2017.

[21] R. Narayan, J. K. Rout, and S. K. Jena, "Review Spam Detection Using Semi-supervised Technique," in *Progress in Intelligent Computing Techniques: Theory, Practice, and Applications*. Springer, 2018, pp. 281–286.

[22] K. L. Goh, R. K. Patchmuthu, and A. K. Singh, "Link-based Web Spam Detection Using Weight Properties," *Journal of Intelligent Information Systems*, vol. 43, no. 1, pp. 129–145, 2014.

[23] X. Zhang, Y. Wang, N. Mou, and W. Liang, "Propagating both Trust and Distrust with Target Differentiation for Combating Link-based Web Spam," *ACM Transactions on the Web (TWEB)*, vol. 8, no. 3, p. 15, 2014.

[24] E. Rabbani and A. Shakery, "Analyzing Content-based Heuristics for Persian Web Spam Detection," *International Journal of Information & Communication Technology Research*, vol. 6, no. 3, pp. 25–39, 2014.

[25] R. K. Roul, S. R. Asthana, M. Shah, and D. Parikh, "Detecting Spam Web Pages Using Content and Link-based Techniques: A Combined Approach," *Sadhana*, vol. 41, no. 2, pp. 193–202, 2016.

[26] A. M. Shabut, K. Lwin, and M. Hossain, "Cyber Attacks, Countermeasures, and Protection Schemes A State of the Art Survey," in *Software, Knowledge, Information Management and Applications (SKIMA), 2016 10th International Conference on*. IEEE, 2016, pp. 37–44.

[27] N. Abdelhamid, A. Ayesh, and F. Thabtah, "Phishing Detection Based Associative Classification Data Mining," *Expert Systems with Applications*, vol. 41, no. 13, pp. 5948–5959, 2014.

[28] C. Ardi and J. Heidemann, "Auntietuna: Personalized Content-based Phishing Detection," in *NDSS Usable Security Workshop (USEC)*, 2016.

[29] R. Focardi, F. L. Luccio, and H. A. Wahsheh, "Usable Cryptographic QR Codes," in *2018 IEEE International Conference on Industrial Technology (ICIT)*. IEEE, 2018, pp. 1664–1669.

[30] A. K. Jain and B. Gupta, "A Novel Approach to Protect Against Phishing Attacks at Client Side Using Auto-updated White-list," *EURASIP Journal on Information Security*, vol. 2016, no. 1, p. 9, 2016.

[31] R. Srinivasa Rao and A. R. Pais, "Detecting Phishing Websites Using Automation of Human Behavior," in *Proceedings of the 3rd ACM Workshop on Cyber-Physical System Security*. ACM, 2017, pp. 33–42.

[32] J. Mao, W. Tian, P. Li, T. Wei, and Z. Liang, "Phishing-Alarm: Robust and Efficient Phishing Detection via Page Component Similarity," *IEEE Access*, vol. 5, pp. 17 020–17 030, 2017.

[33] PhishTank, "Phishing Detection," https://www.phishtank.com/, 2015.

[34] "Search Engine SPAM Detector," 2018, http://tool.motoricerca.info/spam-detector/.

[35] "Google Safe Browser," 2018, https://safebrowsing.google.com.

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Data Modeling Guidelines for NoSQL Document-Store Databases

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***Abstract*—Good database design is key to high data availability and consistency in traditional databases, and numerous techniques exist to abet designers in modeling schemas appropriately. These schemas are strictly enforced by traditional database engines. However, with the emergence of schema-free databases (NoSQL) coupled with voluminous and highly diversified datasets (big data), such aid becomes even more important as schemas in NoSQL are enforced by application developers, which requires a high level of competence. Precisely, existing modeling techniques and guides used in traditional databases are insufficient for big-data storage settings. As a synthesis, new modeling guidelines for NoSQL document-store databases are posed. These guidelines cut across both logical and physical stages of database designs. Each is developed based on solid empirical insights, yet they are prepared to be intuitive to developers and practitioners. To realize this goal, we employ an exploratory approach to the investigation of techniques, empirical methods and expert consultations. We analyze how industry experts prioritize requirements and analyze the relationships between datasets on the one hand and error prospects and awareness on the other hand. Few proprietary guidelines were extracted from a heuristic evaluation of 5 NoSQL databases. In this regard, the proposed guidelines have great potential to function as an imperative instrument of knowledge transfer from academia to NoSQL database modeling practices.**

Keywords*—Big Data; NoSQL; Logical and Physical Design; Data Modeling; Modeling Guidelines; Document-Stores; Model Quality

I. Introduction

With the rise in data sizes, types and rates of generation, i.e., big data, traditional datastores have become less capable for many reasons, such as structural rigidity and untimely response due to high access latency [1], [2], [3], [4], [5]. This unacceptable performance has led to a reevaluation of how such data can be efficiently managed in a new generation of applications where performance and availability are paramount [5], [6]. As a result, NoSQL (Not Only SQL) databases were introduced to augment the features of Traditional Databases (TD) with new concepts such as schema flexibility, scalability, high performance, partition tolerance, and other new extended features [7]. The schemas of such databases are enforced by client-side application developers rather than database engines, as in the case of TD [2], [8].

Consequently, several giant organizations, such as Google, Facebook, and Amazon, have adopted NoSQL technology for data management and storage [5]. However, the inherent complexity and unpredictable nature of todays data [9], along with the low competence level of data modelers [3], [10], [11], developer autonomy [1], [12] and inadequate modeling guidelines [13], have posed numerous challenges in NoSQL schema best-practice implementation. This has increasingly led to erroneous database modeling and designs [1], [14], [15], [16], [17], which defeats the notion of robustness in NoSQL databases and results in the production of low-performance, non-secure and less-durable systems.

For example, consider the security aspect of NoSQL document-oriented databases. The databases offer a query language or an Application Program Interface (API) that has the ability to retrieve the contents of any document in a collection. These APIs, although they provide flexibility in data access across heterogeneous platforms, can be used as breaking points by hackers when incorrectly implemented [18], [19]. Recently, Flexcoin, a United States bank, was attacked, and more than a half-million USD was lost [20]. In addition, an airport was completely shut down due to a system failure [21] in the UK, resulting in several flight cancelations. These tragic events were strongly attributed to improper database design, as discussed in Section 3. However, some of the latest reported security breaches are as follows: 1) schema: because of its flexibility, mere record insertion can automatically create a new schema within a collection, 2) queries: unsafe queries can be created via string concatenation, and 3) JavaScript (JS): the clause of db.eval(), $where takes in JS functions as parameters [18]. Such types of issues are what drew the attention of researchers to provide viable and substantial solutions. However, many of the solutions come in as testing tools for already developed databases [4], [22], [23] or are proprietary [10], [17], [24], [25], which opposes our understanding that the solutions should come at the earliest stage of design (data modeling). Clearly, there is a need for a standard guide in practice.

As such, a set of NoSQL modeling guidelines for the logical and physical design of document-store databases is proposed. In these guidelines, all possible relationships are retrieved, analyzed, categorized and prioritized. The resulting guidelines are expected to serve as an important tool of knowledge for beginners, intermediates or even advanced NoSQL database developers. For the actualization of this goal, we employ an exploratory approach for the investigation of existing works, empirical methods and expert consultations. We analyze how industry experts prioritize the guidelines and analyze the relationships between datasets on the one hand and error prospects and awareness on the other hand. Few proprietary guidelines were extracted and harmonized from a heuristic evaluation of 5 different existing NoSQL databases. In this regard, the proposed guidelines have great potential to function as an imperative instrument of knowledge transfer from academia to NoSQL database modeling practices.

The remainder of this paper is structured as follows. Section II reviews and analyzes existing works. Section III puts forward the proposed guidelines and their application scenarios. Section IV prioritizes guidelines in 3 different categories. Section V discusses the findings (limitations and potentials). Finally, Section VI concludes and highlights the future focus.

II. Related Works

The origin of Data Modeling (DM) in databases can be traced back to the mid-20th century as a technique for structuring and organizing data [33]. The exercise is astonishingly similar to construction designs where walls are planned, flows are optimized, and materials are chosen based on the type of utility that it will accommodate and the level of interaction needed between sections [34]. DM gained the attention of researchers in the field of information systems and data visualizations in the 1970s (see [35], [36]). In the late 1990s, a Unified Modeling Language (UML) [34] was introduced to consolidate the data modeling symbols and notations invented by [35], [36] into one standardized language, all for the purpose of simplifying data visualization and modeling in relational databases.

Now, with the emergence of unstructured, voluminous and complex datasets, i.e., big data, requirement to have more flexible and higher-performance databases have become essential [27], [28], [33], [37], which has given rise to the concept of NoSQL databases. The high flexibility of NoSQL databases makes data modeling even more challenging, as schemas are written and enforced by the client-side application developers rather than database engines, as in the case of RDBMS [12], [38], [26], [29]. This raises the question of competence, which may lead to the production of high- or low-quality models [10], [12]. A recent report by [20] shows how a low level of competence in NoSQL data modeling cost a United States-based company called Flexcoin a half-million US dollars. A hacker was able to make several transactions before the account-balance-document was updated (low consistency). In another case, an airport was completely shut down as a result of a major IT system failure in London [21], for which the experts assigned the blame to the poor back-end system design. These are officially reported instances, while several other cases, such as those discussed in [39], [40], do exist.

To mitigate these challenges, experts shared their experiences on the most common questions asked by the client-side application developers online. Some of these questions are (i) how to model one-to-N relationships in document databases, (ii) how to know when to reference instead of embedding a document, and (iii) whether document databases allow Entity Relationship modeling at all. In an attempt to address these and similar questions, experts highlighted the necessity of having a standardized modeling guide for these powerful data stores [10], [12], [17], [30]. This is partly because many of the questions keep reappearing repeatedly on multiple platforms or even the same platform.

In the words of William (Lead Technical Engineer at MongoDB) [10], guidance is strongly required for MongoDB developers, upon which few guidelines were produced to ease the modeling process. Moreover, Ryan CrawCuor and David Makogon [17] created a comprehensive presentation on how to model data in JSON. In addition, eBay [24] and Netflix [25] produced some guidelines for schema design in Cassandra. However, these guidelines, though comprehensive, are complex and designed for the referenced databases only, i.e., they are proprietary. Consequently, straightforward and more general guidelines are needed in practice.

In [8] and [12], reuse of existing modeling expertise (from RDBMS) is allowed to minimize the high level of competence required to model NoSQL databases. This was achieved using Idef1X (a standard data-modeling language) and Formal Concept Analysis (FCA). However, an experiment conducted by [13] evidently showed the limitation of the existing modeling expertise when applied to new-generation complex datasets (big data). Clearly, NoSQL databases need a different modeling approach to efficiently manage big data due to its diverse characteristics [32].

In [1], a cost-based approach for schema recommendation is proposed with the aim of replacing the rules of thumb currently followed by less competent NoSQL database designers. In this approach, the expected performance of the target application is estimated, upon which a candidate schema is recommended. The approach made schema modeling more stable and secure than before. However, more stages are added to the design processes, such as data analysis, application of the tool to propose schema, and then translation of the schema into real application. Moreover, the approach is applicable to column family databases only. In addition, the tool focuses only on the expected performance of candidate schema, despite the fact that NoSQL schema design is largely driven by the nature of the target data [16]. Alternately, an interactive, schema-on-read approach was proposed in [41] for finding multidimensional structures in document stores. [42] proposed a data migration architecture that migrates data from SQL to NoSQL document-stores while taking into account the data models of both the two categories of databases. Although these approaches yielded relatively good findings, more generic, simple, and data-driven guidance prepared for at least one category of NoSQL databases [12], [31], [32] is still needed for practitioners.

The heterogeneity of todays systems, data complexity growth, and lack of modeling expertise have been stated as motivations of the aforementioned works. These claims have been confirmed by error-rate reports [20], [21], [39], [40] in real-world of NoSQL-driven projects. Undoubtedly, there is a need for well-founded guidelines in practice. The following section presents the proposed guidelines, which were synthesized from empirical research and professional involvements.

III. Proposed Guidelines

In this section, the proposed guidelines which were synthesized from empirical work are introduced. The section is divided into four subsections. In Section 3.1 an example model from university social media networking system is described which was used for this research. Section 3.2 highlights, in summary, the empirical research upon which the proposed guidelines are built. Section 3.3 presents the guidelines and their respective explanations. Section 3.4 shows how the proposed guidelines can improve the model presented in Section 3.1.

A. An Example Model

To illustrate the proposed guidelines, a running example shown in Fig. 1 was used. The model describes entities and their connections of a university social media networking system which was developed by the university programmers. The modeling was done without considering the proposed guidelines and, as will be seen later, will improve when the proposed guidelines are applied.

The model shown in Fig. 1 follows the Entity Relationship Diagram (ERD) notations and symbols proposed by [35] and [36] which are the most popular relational database modeling technique in both the academia and industry.

Although a Unified Modeling Language (UML) [43] was introduce to standardize approaches and notations, the model in Fig. 1 adopted few fundamental symbols and notations from [35], [36], [43] for demonstration purposes. Rectangle, arrows, and curly and square brackets were used to show, conceptually, the activity flow. Generally, in ERD, rectangles are used to indicate entities while arrows correspond to data flows or connections between the entities. Moreover, notations such as curly and square brackets were used to indicate attribute and arrays of keys respectively.

The given model in Fig. 1 roughly describes a user entity and user-dependent entities. A user has direct entities such as contact info, basic info, friends and family, messages, and education and work. Each of these entities has other sub-entities which, as the tree expands; many entities repeatedly appear in different parent entities. For example, likers and commenters entities contain the same list of people as in friends & family entity. Furthermore, the list of people in friends and family entity are also the system users who are recorded in the User entity. Now, these repetitions might improve data availability but at the expense of consistency or speed during inserts, updates or deletes. This will be further explained later when the model in Fig. 1 is improved using our guidelines.

B. Empirical Research Background

The research background upon which the proposed guidelines are defined is described in this section. The widely acceptance and adoption of ERD model in relational databases is connected with its ease of comprehension and application onto structured datasets. In prior research, we thoroughly investigated the new generation datasets (big data) while taking into account the connection between NoSQL databases and the factors leading to their comprehension and proper modeling. Factors such as understanding, error probability, and ambiguity are experimented as well as other factors that motivated the guidelines propositions. The findings are summarized as follow.

- Understanding relates to the degree to which datasets and system requirements can be easily understood. Its a strong basis on which data is classified, categorized and modeled. In an experiment reported in [13] we introduced new cardinality notations and relationship styles for NoSQL databases. From our engagement with programmers regarding the new notations and

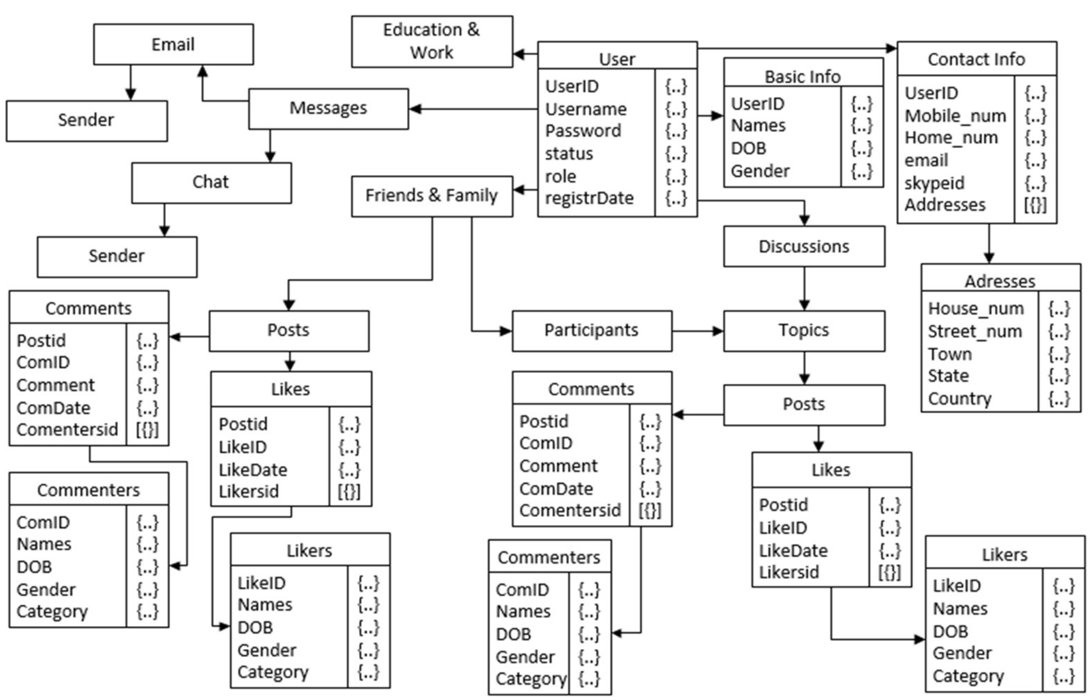

Fig. 1. A section of social media database model.

styles, we found a negative correlation with understanding how the new notations should be best implemented.

- Error probability in our case refers to the extent a programmer is able to classify datasets based on the new notations and styles without introducing errors. In a different experiment we have modeled the new notations using MongoDB database [44] while focusing on availability and consistency as the measurement factors. The results of this experiment trace error probability back to lack of understanding of data sets, knowledge of modeling, and expertise. We found that, modeling expertise and datasets complexity are the most important drivers to error probability in NoSQL database modeling.
- Ambiguity in relationships between datasets and system/business requirements are an important road block to the understanding NoSQL database design structure. As such, it was observed during our experiment that, the notations (*1:1*, etc.) used in relational databases have been in practice for decades which shows the level of knowledge of SQL modeling notations among practitioners; therefore, similar grammatical representation was adopted and extended for the new NoSQL notations (*1:F*, etc.) [13]. Out of 14 postgraduate students from University Technology PETRONAS, 12 students said that using similar notations will lessen the ambiguity as the focus would be on datasets analysis rather than introducing entirely new notations.
- Styles Application Scheduling (SAS) captures the awareness of most appropriate time to implement any of the modeling style like embedding, referencing or bucketing when modeling NoSQL database. We conducted an experiment on each of the modeling styles and found that, even though they are less ambiguously introduced, knowledge of when to apply which modeling style is still missing.
- Guidelines extraction from a heuristic evaluation of five different NoSQL databases [45]. We extracted the available modeling guidelines written by the technical team of databases such as MongoDB, Couchbase, Google Cloud Datastore, CouchDB, and MarkLogic. The extracted guidelines were harmonized and generalized for document-store databases.
- Expert consultations from three different SME companies across the globe were involved. In total, 9 different industry experts were requested to critically scrutinize and make recommendations on the proposed guidelines. The experts consisted of one independent programmer from Sweden, one researcher from Spain, two from Software Development Company (SDC) in Malaysia, two from Software Development Committee (SDC) Ahmadu Bello University Nigeria and three postgraduate students from Universiti Teknologi PETRONAS, Malaysia. 2919

Based on these six empirical insights into NoSQL relationship modeling, we define the proposed guidelines as presented in the next section.

C. The Guidelines

The proposed guidelines provide a set of recommendations on how to develop NoSQL document-store databases, each of which builds on empirical research [13], [45] summarized in the previous section. Modeling NoSQL databases has noticeably become more challenging as data increases in volume, variety and velocity, i.e. big data [10], [12], [17], [22]. The aim of these guidelines is to ease data modeling process by improving developers skills towards modeling document-store databases. This is hoped to maximize data retrieval and storage efficiency, minimize erroneous modeling, and reduce the time taken to model database, as well as improve data security. Hence, it is important to note that, the proposed guidelines build on insight which might be described differently using a different approach.

For better understanding and quick mapping, the proposed guidelines were categorized into four different categories as illustrated in Fig 2. This includes embedding, referencing, bucketing and general. In each of the categories, there is at least one important note which should be taken into account.

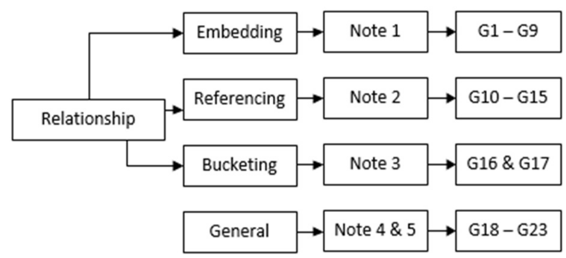

Fig. 2. Categorization of guidelines

At first, the notes as presented in Fig 2 are elaborated, which were followed by the proposed guidelines.

Note 1: Characteristically, embedding provides better read performance when retrieving data from document-store databases. However, when writing data to database, it can be exceedingly slower, unlike referencing which uses the concept of writing data horizontally into smaller files.

Note 2: Typically referencing provides better write performance. However reading data may require more round trips to the server.

Note 3: Bucketing enhances data retrieval by partitioning document with large contents into smaller affordable sizes.

Note 4: Normalizing data may help to save some space, but with the current advancement of technology, space is not a problem anymore.

Note 5: Finally, understand the data access patterns, the nature of the data to be used in the application, the rate of updates on a particular field, and the cardinality relationships between entities. Such information shapes the design and modeling structure of document-store databases.

The proposed guidelines are as follows. They adhere to the categorizations as depicted in Fig. 2. In the beginning, embedding is put forward.

1) Embedding: This section presents the first set of the proposed guidelines (G1 — G9) which aim to answer questions related to embedding (i.e. insertion of one document into another).

G1: Embed sub documents unless forced otherwise: For better system performance in terms of saving and retrieving speed, try to always embed child documents except when it is necessary to do otherwise. With embedding, there is no need to perform a separate query to retrieve the embedded documents [7].

G2: Use array concept when embedding: It is recommended to use array of embedded documents when modeling few relationships [10], [17].

G3: Define array upper bound in parent document: Avoid the use of unlimited array of ObjectID references in the many side of the relationship if it contains a few thousands of documents [17].

G4: Embed records which are managed together: when records are queried, operated and updated together, they should be embedded [13].

G5: Embed dependent documents: dependency is one of the key indicators to embed a document [17]. For example, order details are solely dependent to the order itself; thus they should be kept together.

G6: Embed one-to-one (explained in [13]) relationships: when modeling one-to-one relationship, embedding style should be applied.

G7: Group data with same volatility: data should be grouped based on the rate to which it changes [13]. For example, persons bio-data and status of several social media accounts. The volatility of social media status is higher than the bio-data which does not change quite often like email address or does not even change at all, explicitly, date of birth.

G8: Two-way embedding is preferred when *N* size is close to the *M* size in *N:M* relationship (presented in [13]): in *N:M* relationship, try establish a relationship balance by predicting the maximum number of *N* and maximum number of *M* [7], [13]. Two-way embedding is preferred when the *N* size is close to the *M* size.

G9: One-way embedding is preferred if theres a huge gap in size between *N* to *M*: if gap is for example 3 in N side and 300,000 in *M* side, then one-way embedding should be considered [13].

2) Referencing: Referencing can be explained as a process of connecting two or more documents together using a unique identifier [13]. The following guidelines (G10 G15) aim to answer questions related to referencing.

G10: Reference highly volatile documents: high volatility of document gives a good signal to reference a document instead of embedding. For example, lets consider a post made on a social media (Fig. 1), the likes tag changes so often; thus unbound it from the main document so that the main document is not always accessed each time likes button is hit.

G11: Reference standalone entities: avoid embedding a child document/object if it will be at one time accessed alone. Documents, when embedded, cannot be retrieved alone as a single entity without retrieving the main entity [10].

G12: Use array of references for the many side of the relationship: when a relationship is one-to-many as in [13] or a document is a standalone document, array of references are best recommended.

G13: Parent referencing is recommended for large quantity of documents: for instance, when the many side of a relationship is squillion (introduced in [13]), parent-referencing is preferred.

G14: Do not embed sub-documents if they are many: a key entity with many other sub-entities should adopt referencing rather than embedding [13]. This will minimize high-cardinality arrays [41].

G15: Index all documents for better performance: If documents are indexed correctly and projection spacefarers like the relationship styles discussed in [13] are used, the applications level joins are nothing to be worried about.

3) Bucketing: Bucketing refers to splitting of documents into smaller manageable sizes. It balances between the rigidity of embedding and flexibility of referencing [13].

G16: Combine embedding and referencing if necessary: embedding and referencing can be merged together and work perfectly [10]. For example, consider a product advert on Amazon website, there is the product information, the price which may change, and a list of comments and likes. This advert actually combines reasons to embed as well as to reference, thus merging the two techniques together can be the best practice in this case.

G17: Bucket documents with large content: to split a document into discreet batches such as days, months, hour, quantity etc, bucketing should be considered [13]. For example, the squillions (introduced in [13]) side of the relationship can be divided into 500 records per display as the case of pagination.

4) General: There are few guidelines that do not fall into any of the earlier discussed categories (embedding, referencing and bucketing). Such guidelines are grouped and presented as follows.

G18: Denormalize document when read/write frequency is very low: denormalize document only if it is not updated regularly. So, access frequency prediction should guide the decision to denormalize any entity.

G19: Denormalize two connected documents for semi-combined retrievals: Sometimes two documents are connected, but only one is to be retrieved and few fields from the second document, denormalization can help here [13]. For example, when retrieving a presentations session, a speakers name would need to be displayed as well but not all the speakers details, so, the second document (speaker) is denormalized to get only the name of the presenter and attach it to session document.

G20: Use tags implementation style for data transfer: if information is not sensitive, packaging it within tags like in XML document is recommended [46].

G21: Use directory hierarchies if security is a priority: apply role based authorization to each of the directories for access protection [19]. A user can have the privilege to access one directory or a collection of directories, depending on the users role.

G22: Use documents collections implementation style for better read/write performance: this is the same as G21, but with addition of better read/write performance.

G23: Use Non-visible metadata for data transfer between nodes or servers: in many cases, APIs dont have security mechanisms embedded in them [47]. So, encoding sensitive information before transfer and decoding upon arrival is strongly recommended. This will improve data security on the air.

TABLE I. OVERVIEW OF THE PROPOSED GUIDELINES

Gl	Embed sub-documents unless forced otherwise
G2	Use array concept when embedding
G3	Define array upper bound in parent document
G4	Embed records which are managed together
G5	Embed dependent documents
G6	Embed one-to-one relationships
G7	Group data with same volatility
GS	Two-way embedding is preferred when N size is close to the M size in N:M relationship
G9	One-way embedding is preferred if there's hug gap in size between N to M
G10	Reference highly volatile document
G11	Reference standalone entities
G12	Use array of references for the many side of the relationship
G13	Parent referencing is recommended for large quantity of entities
G14	Do not embed sub-documents if they are many
G15	Index all documents for better performance
G16	Combine embedding and referencing if necessary
G17	Bucket documents with large content
G18	Denormalize document when read write frequency is very low
G19	Denormalize two connected documents for semi-combined re-trievals
G20	Use tags implementation style for data transfer
G21	Use directory hierarchies if security is a priority
G22	Use document collections implementation style
G23	Use Non-visible metadata for data transfer between nodes or server

The following section explains the application of the aforementioned guidelines.

D. Application

To demonstrate the proposed guideline, we will show how the original social media model (Fig. 1) can be transformed into a more stable model. In Fig. 3, we marked and labeled some areas of improvement on the same model using guideline identifies. A transformed model is presented as in Fig. 4 which results from the application of the proposed guidelines. The application of each of these guidelines is explained as follows.

In the original model, some modeling problems were identified such as too much redundancy of information which of cause leads to inconsistencies among entities. For example, there exists an entity of user which contains some information about users, this entity is fully repeated in places like "family & friends", "commenters", "likers" etc. in different branches of the model. The problem with this approach is that, updating a single attribute for instance will require updating all documents with the same attribute. Now, in a situation where an attribute changes so frequently and the affected documents are many, more serious issues like inconsistency, temporary insecurity (for access authorization) and performance deterioration may arise. Such events motivated many guidelines such as **G1** which recommends the embedment of all documents or **G6** which recommends embedding of a single document. To maintain the availability provided by duplicating users data even when its embedded into "User" entity, **G17** came in to take the few rarely changed attributes from the main document to the areas where they are accessed quite often. However, as "User" entity is bucketed, referencing became required (**G11**). Similarly, higher volatile documents like "Discussions" and "Posts" were bucketed from "User" entity and grouped based on the rate to which they change (**G7**) which allows write/update operations without necessarily accessing the parent documents. Also, **G11** was considered for independent access of "Discussions" and "Posts" since they may be accessed alone in most cases.

While referencing related documents, **G2** was used, which states the use of array concept when referencing documents using their IDs especially in the M (many) side of the relationship (**G12**), besides, upper bound was defined for any array of IDs (**G3**). But in a situation of a large number of entities like "comments", the spirit of parent referencing (**G13**) was followed.

By referring to the original model, since the write frequency is very high in the entities of "comments" and "likes", embedding was avoided (**G14**), instead we denormalized "commenters" and "likers" entities (**G19**) and reference each of them (**G10**) such that embedding and referencing can be combined (**G16**) using only the commenters name and ID, leading to achieving both availability and consistency at the same time. The rationale behind this is that, only commenters or likers name is often required for each comment or like. Therefore, for high availability, only the name of a user should be denormalized and for the consistency during updates, array of IDs can be used for more round trips.

On the section of "User" entity again, Basic Info" and "Contact Info" are not only dependent to "User" entity but they are also managed together. Since such information has low read/write frequencies (**G18**), putting them together based on their collectivity in management (**G4**) or based on their dependencies on one another (**G5**) will significantly minimize the number of round trips to the server for a single update. Given that, the predicted records for all the three entities ("Basic Info", "contact info" and "User") are almost at same level, two-way embedding is best recommended (**G8**) to permit connection from either directions. But in the case of "Posts"

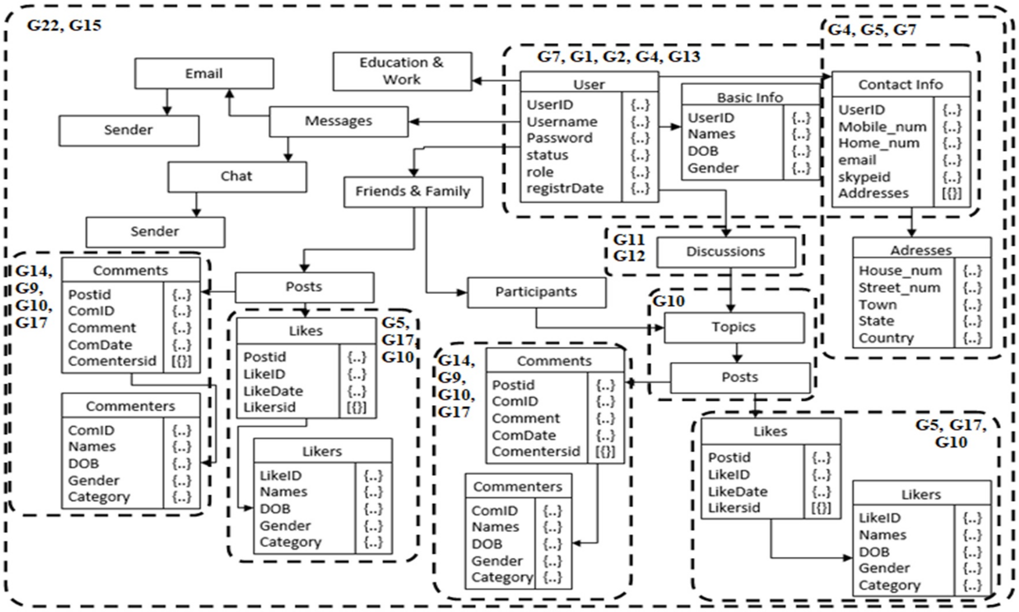

Fig. 3. A section of social media database including markers

and "Likes", One-way embedding is most preferred (**G9**) since the number of "likes" can be more than a million for a particular post.

In view of the fact that, performance is usually a priority requirement, indexing all documents (**G15**) is strongly recommended. Also, considering the node balance challenge posed by hierarchical data modeling style, document collection implementation style (**G22**) is maintained for many reasons such as horizontal schema flexibility as database scales up and down.

Although it is not frequently used, interfacing possibilities (data exchange) with other applications is an important aspect to consider right from modeling stage to avoid using proprietary data export format, **G20** proposes the use of tags formatting style such as XML which is open source and can be formatted (**G23**) and read by almost all programming languages. In many cases, web-services are allowed to determine everything including using special characters; this flexibility creates security vulnerabilities such as NoSQL injections via restful APIs. Such high expectations of security breaches motivated the use of hierarchical data modeling (**G21**) which ease the application of role based authorization on each node

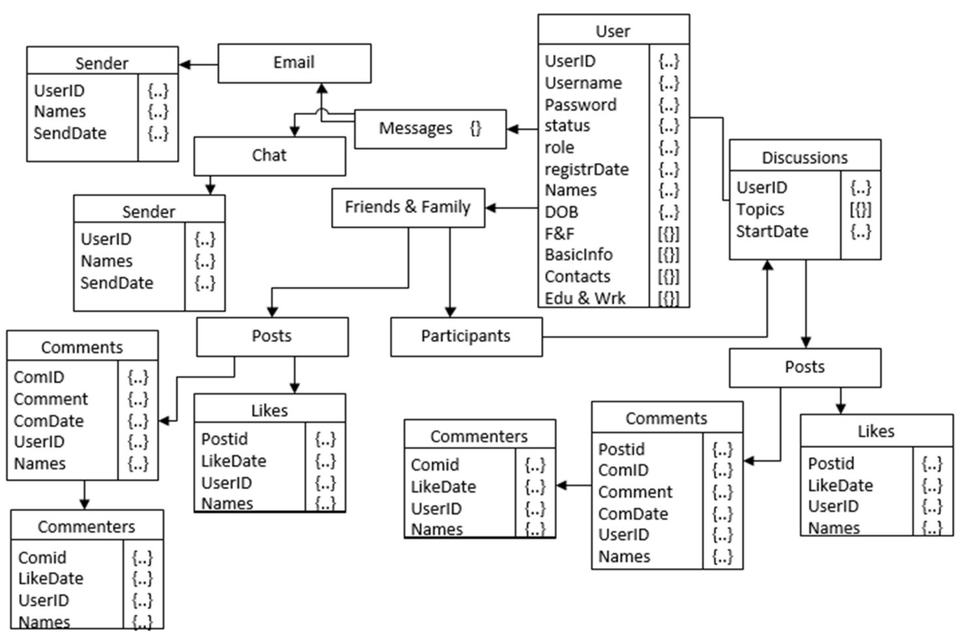

Fig. 4. The optimized model

of the tree, or **G22** which clusters documents into collection of documents at different stages.

It is important to note that not all the guidelines are applicable to the original model, some guidelines such as **G20** - **G23** were exemplified in a more generic way. This is because the original model did not interface with other models or applications. Also, the overall number of entities has been reduced from 24 in the original model to 17 in the transformed model as a result of prioritizing guidelines such as **G1**, **G4**, **G5**, **G7** etc. In summary, the original model is restructured and transformed to less redundant model with high availability and consistency without changing the model behavior.

IV. Prioritizing Guidelines

In the preceding section, we illustrated how each element of the proposed guidelines can be applied on a real datasets. However, in a situation where two or more guidelines are applicable, the modeler needs to be guided towards taking the most appropriate direction based on system requirements. For instance, while embedding dependent documents **(G7)** increases read/write performance, requirement to access document independently may necessitate referencing standalone entities **(G11)** or bucketing the frequently accessed entities **(G15)** into affordable elements. This is because, embedded child document cannot be retrieved alone without retrieving the parent document [32]. This situation is explained in the previous section, which clearly demanded more sensible priorities when applying the proposed guidelines.

Its important to note that, in as much as we tried to simplify the guidelines; their diverse nature significantly increases the challenge of resolving conflicts between them. For a given model, many conflicting guidelines can be applicable in one section, and many sections can adopt one guideline.

The scope of this paper does not include a more comprehensive prioritization which is theoretically motivated and empirically validated. Nevertheless, we have taken the following approach to arrive at some guidance on guideline application prioritization. At first, a presentation of the proposed guidelines was made to experts in Universiti Teknologi PETRONAS, Malaysia which led to comprehensive refinement of the guidelines. Secondly, SQL and NoSQL professionals in our network were contacted to take part in reviewing, analyzing and prioritizing the guidelines based on their expert opinions, this include five experts from Malaysia one from Sweden, one from Spain, and two from Nigeria. A total of nine professionals with an average modeling experience of 4 years complied with our request and assisted in refining the guidelines and prioritizing their application under different circumstances.

Each of the professionals contacted, receives a verbal or written presentation of the proposed guidelines from the researchers. After that, all professionals were asked to individually review each guideline and add or remove to/from the list. Next, each professional was also asked to rank the refined proposed guidelines with respect to three different categories, namely, availability (read operation), consistency (write and update operations) and cardinality notations using a scale of 1-23. For this scale, the ranking begins from 1 which indicates a perception of being the highest relative potential, while rank of 23 in the scale indicates the lowest relative potential. This inquiry guided the researchers to infer a priority scheme which can resolve conflicts among rival guidelines.

While ranking the guidelines, all participating experts were allowed to give equal rank to more than one guideline. However, for each participant, a constraint of a total number of 276 (= 1 + 2 + 3 + 4 + 23) assigned ranks was expected.

These assigned ranks were accumulated per guideline leading to results as presented in Table II. It can be seen from this table that, **G6** is considered to have the highest potential to improve data availability, as it has total rank scores of 12.

While, **G21** is deliberated to have the least potential to improve data availability with an average score of 202. The total scores of the remaining guidelines fall between these extremes.

On the other hand, since availability is not always a priority of all systems [4], the prioritization also considered an important database concept which is consistency in replicated, connected or dependent data. As such, another set of priority

TABLE II. Prioritizing Guidelines based on Availability (Read Operations)

No	Description	Total Scores (Rank)	Priority Level
G6	Embed one-to-one relationships	12	1
G1	Embed sub-documents unless forced otherwise	16	2
G17	Bucket documents with large content	30	3
G15	Index all documents for better performance	34	4
G2	Use array concept when embedding	52	5
G7	Group data with same volatility	54	6
G11	Reference standalone entities	67	7
G9	One-way embedding is preferred if there's hug gap in size between N to M	69	8
G3	Define array upper bound in parent document	6	9
G19	Denormalize two connected documents for semi-combined retrievals	92	10
G5	Embed dependent documents	97	11
G4	Embed records which are managed together	106	12
G22	Use document collections implementation style	123	13
G8	Two-way embedding is preferred when N size is close to the M size in N:M	I26	14
G12	Use array of references for the many side of the relationship	129	I5
G10	Reference highly volatile document	141	16
G13	Parent referencing is recommended for large quantity of entities	I57	17
G14	Do not embed sub-documents if they are many	161	18
G18	Denormalize document when read write frequency is very low	168	19
G23	Use Non-visible metadata for data transfer between nodes or server	186	20
G16	Combine embedding and referencing if necessary	I87	21
G20	Use tags implementation Style for data transfer	199	22
G21	Use directory hierarchies if security is a priority	202	23

TABLE III. PRIORITIZING GUIDELINES BASED ON CONSISTENCY (WRITE & UPDATE OPERATIONS)

No	Description	Total Scores (Rank)	Prioritv Level
G1	Embed sub-documents unless forced otherwise	17	1
G6	Embed one-to-one relationships	25	2
G4	Embed records which are managed together	28	3
G5	Embed dependent documents	35	4
G7	Group data with same volatility	50	5
G18	Denormalize document when read write frequency is way low	70	6
G10	Reference highly volatile document	79	7
G11	Reference standalone entities	91	8
G14	Do not embed sub-documents if they are many	93	9
G12	Use array of references for the many side of the relationship	95	10
G8	Two-way embedding is preferred when N size is close to the M size in X:M	99	11
G15	Index all documents for better performance	101	12
G3	Define array upper bound in parent document	103	13
G9	One-way embedding is preferred if there's hug gap in size between N to M	118	14
G13	Parent referencing is recommended for iarge quantity of entities	125	15
G16	Combine embedding and referencing if necessary	136	16
G2	Use array concept when embedding	138	17
G21	Use director.' hierarchies if security is a priority	152	18
G19	Denormalize two connected documents for semi-combined retrievals	169	19
G23	Use Non-visible metadata for data transfer between nodes or server	173	20
G22	Use document collections implementation style	190	21
G20	Use tags implementation style for data transfer	196	22
G17	Bucket documents with large content	201	23

list was debated; results of which is shown in Table III. This table suggests that, in consistency, **G1** has the highest potential to improve consistency among different clusters, documents or datasets as it has an accumulated score of 17 ranks. In contrast, **G17** is considered to have the lowest potential to do so with an accumulated score of 201 ranks. The remaining guidelines fall between the two extremes.

In addition to prioritizing guidelines for availability and consistency, cardinality can also be considered as an important factor for the categorization of the proposed guidelines. Thereafter, prioritize their application in each of the categories. To do so, the new generation cardinalities proposed by [13] were considered. These cardinalities have the potential to categorize complex datasets in seven different relationships such as one-to-one (*1:1*), one-to-few (*1:F*) etc. In line with this, our study reveals that, more than one guideline can be in the same priority level for a single cardinality as shown in Fig. 5.

In each of the cardinalities (in Fig. 5), guidelines are prioritize on a scale of seven (priority levels 1 — 7) which are color coded (light gray to dark gray). As it was mentioned before, professionals were allowed to allocate the same rank to more than one guideline, therefore, many guidelines were given the same level in the same category which indicates their potential equality in improving design performance.

In general, the suggested use of these rankings in three different categories (availability, consistency and cardinalities) is

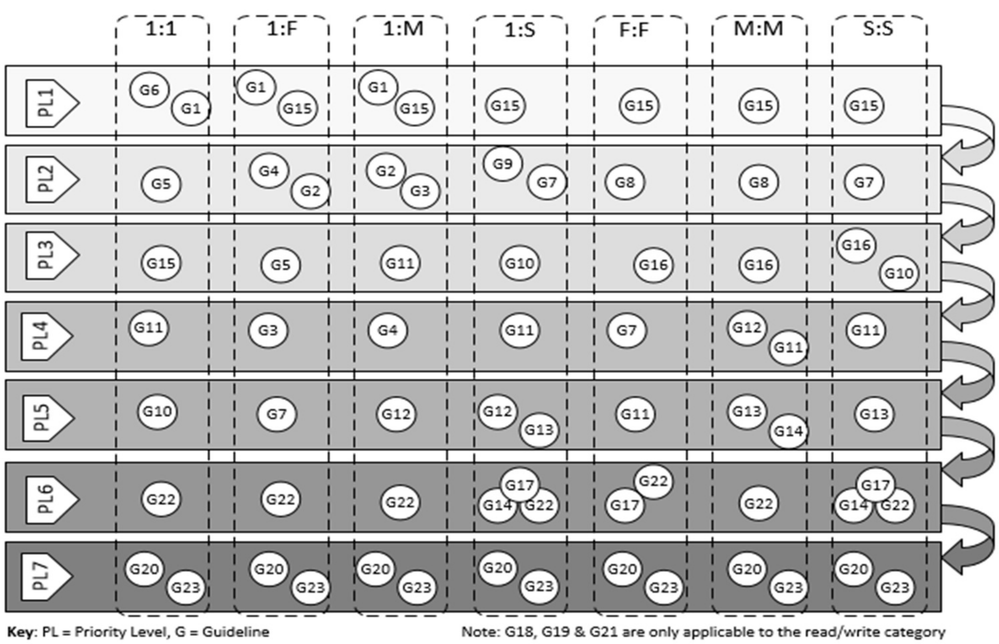

Fig. 5. Guideline Prioritization Based on Cardinalities

that guidelines with higher positions should be favored over the guidelines with lower positions or conflicting guidelines. For instance, while referencing standalone entities **(G11)** increases data availability for independent or round-trip queries, requirement to have high consistency may necessitate combining **G7** and **G15**. This means that, in the case of security access, authorization across cluster can be controlled (consistency) and the solo records within the main document can be bucketed into a different smaller document for independent retrieval (availability). In other words, the application of **G7** can interfere with the impact of applying **G11** or **G15** because it appears higher, but when categorized (availability, consistency and cardinalities), their levels of application changes based on the requirement.

It is worth mentioning that most of the elements in the presented guidelines were broadly reorganized by the experts as they have used some of them in their NoSQL modeling process already which led to better understanding on how best they can be prioritized.

V. Discussion

In this section, the proposed guidelines are investigated regarding two different aspects. First, some limitations of the proposed guidelines are discussed. Thereafter, several aspects of their potentials are elaborated.

A. Limitations

While the proposed guidelines are stronger in their foundation and more generalized than many existing proprietary guidelines, some limitations must be noted. The first limitation relates to the development of the proposed guidelines and their validity: the fundamental principles and the empirical insights that ground the introduction of said guidelines would have been more thorough and evolving if the number of professionals involved was greater than nine. However, the scarcity of NoSQL modelers (expert-level) made it difficult to find the typically used number of professionals. This is because NoSQL databases are new and used to manage new-generation datasets (big data), and they thus have not yet matured in academia and industry.

The second limitation is that the proposed guidelines assume that all modelers have basic SQL modeling skills. This means that the symbols, notations and terminologies proposed by [35] and [36] are prerequisite skills for the effective use of the proposed guidelines. People with no database modeling background may find it challenging to start modeling with the proposed guidelines. However, in the world of diversification, such individuals should also be considered in a more automated manner where a modeler answers a few questions and a suitable model is automatically produced, subject to an experts analysis. This will minimize errors in modeling, thereby producing more stable NoSQL models.

The third limitation relates to the guideline prioritization described in Section 4. The ranking was derived from a number of presentations and expert scorings. Although this could be seen as needing wider expert coverage, it also raises questions such as what other alternative ranking roots are available, for instance, through experimentation. Nevertheless, it seems less attractive at this stage to focus on producing very perfect guidance on how best the proposed guidelines can be prioritized and applied. This is why we have high expectations that the proposed guidelines will be further extended in the near future to cover more application scenarios, as professional have already inspired us with a few guidelines to be considered in the future.

B. Potential

This section continues to discuss the potential of the proposed guidelines beyond their detailed explanations (see Section 3.3) and application (see Section 3.4). The first modeling guidelines prepared to guide data modelers for NoSQL document-store databases, coupled with the increase in complexity of todays data (big data), greatly increase the potential to widely accept and adopt the proposed guidelines in both industry for practice and academia for learning.

On the technical side, two potential aspects are identified. First, the proposed guidelines can be the basis of *automating the modeling process from scratch*, which may not require more technical background. Second, if a model already exists, improvement might be required, as shown in Fig. 4, which resulted from applying the guidelines in Fig. 3. Instead of manually transforming the model using the proposed guidelines, the process can be intelligently automated to identify errors and mark them such that *existing models can be automatically transformed*. Solutions or approaches like these will require further in-depth and formal research on both aspects, as well as potentially more.

The proposed guidelines also point to more potentials for the *competence analysis* of modelers. This might be achieved by measuring the structures of the produced models, which might be based on some assumptions, such as to what extent the proposed guidelines considered the model requirements. Modelers with high levels of competence are likely to detect any model that deviates from the proposed guidelines. In an experiment that involved designing a complete mini-NoSQL-based system, a model was repeatedly redesigned for improvements as a result of a low level of competence, which can be associated with the lack of basic skills [1]. In this manner, the proposed model offers easier methods with simple language to identify difficulties associated with complex datasets as well as the best methods to relate the entities.

VI. Conclusion and Future Work

In this paper, the mismatch between proprietary recommendations for NoSQL document-store modeling and technical insight into NoSQL modeling practice are addressed. Prior empirical research and expert suggestions were consolidated, which led to the derivation of the proposed guidelines. Contrary to proprietary guidelines, our guidelines were built from a strong research foundation, which was practically motivated, empirically derived and conceptually validated. In contrast to the existing research on database modeling, our guidelines were made specifically for document-store NoSQL databases with simple and straightforward explanations. In this manner, the proposed guidelines addressed the practical modeling problems that are being faced by many modelers in industry. This fact among others was emphasized by the low competence level of casual NoSQL modelers [32], [10] and the high rates of errors, repetition and insecurity [19], [20].

In addition to these virtues, the proposed guidelines also revealed some limitations to reflect upon. More significantly, although the guidelines were prioritized based on three identified categories (availability, consistency and cardinalities), we believe that, as big data and NoSQL mature, several other categories will be harnessed, which may call for re-prioritization to suit new categories. Furthermore, humans (who are naturally prone to errors) are, to a large extent, involved in the application of the proposed guidelines, and as such, several automations are required to minimize possible human error, thereby producing more stable models. Such solutions are slotted into our future research schedule.

In addition to the future focuses mentioned earlier, the applicability and usability of the proposed guidelines are another important aspect. While considering other usability test approaches, such as that in [48], where the applicability of SEUAL quality was assessed, the proposed guidelines might be subjected to similar usability assessment in the future, particularly the use of a standard survey, which may result in further improvement of the proposed guidelines.

Finally, with high optimism, the proposed guidelines have great potential to function as an imperative instrument of knowledge transfer from academia to NoSQL database modeling practices, which may bridge the two disconnected communities (academia and industry) with respect to NoSQL database modeling.

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References

[1] Micheal J. Mior, K. Salem, A. Aboulnaga, and R. Liu, NoSE: Schema design for NoSQL applications, IEEE Trans. Knowl. Data Eng. From 2016 IEEE 32nd Int. Conf. Data Eng. ICDE 2016, vol. 4347, no. c, pp. 181192, 2016.

[2] H. Zhang, G. Chen, B. C. Ooi, K. L. Tan, and M. Zhang, In-Memory Big Data Management and Processing: A Survey, IEEE Trans. Knowl. Data Eng., vol. 27, no. 7, pp. 19201948, 2015.

[3] G. C. Everest, Stages of Data Modeling Conceptual vs . Logical vs . Physical Stages of Data Modeling, in Carlson School of Management University of Minnesota, Presentation to DAMA, Minnesota, 2016, pp. 130.

[4] M. T. Gonzalez-Aparicio, M. Younas, J. Tuya, and R. Casado, A New Model for Testing CRUD Operations in a NoSQL Database, in 2016 IEEE 30th International Conference on Advanced Information Networking and Applications (AINA), 2016, vol. 6, pp. 7986.

[5] IBM, Why NoSQL? Your database options in the new non-relational world, Couchbase, no. March, p. 6, 2014.

[6] J. Bhogal and I. Choksi, Handling Big Data Using NoSQL, in Proceedings - IEEE 29th International Conference on Advanced Information Networking and Applications Workshops, WAINA 2015, 2015, pp. 393398.

[7] MongoDB, How a Database Can Make Your Organization Faster, Better, Leaner, MongoDB White Pap., no. October, p. 16, 2016.

[8] V. Jovanovic and S. Benson, Aggregate Data Modeling Style, Proc. South. Assoc. Inf. Syst. Conf. Savannah, GA, USA March 8th9th, pp. 7075, 2013.

[9] H. He and E. A. Garcia, Learning from imbalanced data, IEEE Trans. Knowl. Data Eng., vol. 21, no. 9, pp. 12631284, 2009.

[10] Z. William, 6 Rules of Thumb for MongoDB Schema Design, MongoDB, 2014. [Online]. Available: https://www.mongodb.com/blog/post/6-rules-of-thumb-for-mongodb-schema-design-part-1. [Accessed: 23-Jan-2017].

[11] X. Wu, X. Zhu, G. Q. Wu, and W. Ding, Data mining with big data, IEEE Trans. Knowl. Data Eng., vol. 26, no. 1, pp. 97107, 2014.

[12] V. Varga, K. T. Jnosi, and B. Klmn, Conceptual Design of Document NoSQL Database with Formal Concept Analysis, Acta Polytech. Hungarica, vol. 13, no. 2, pp. 229248, 2016.

[13] A. A. Imam, S. Basri, R. Ahmad, N. Abdulaziz, and M. T. Gonzlez-aparicio, New Cardinality Notations and Styles for Modeling NoSQL Document-stores Databases, in IEEE Region 10 Conference (TENCON), Penang, Malaysia, 2017, p. 6.

[14] A. Ron, A. Shulman-Peleg, and A. Puzanov, Analysis and Mitigation of NoSQL Injections, IEEE Secur. Priv., vol. 14, no. 2, pp. 3039, 2016.

[15] M. Obijaju, NoSQL NoSecurity Security issues with NoSQL Database, Perficient: Data and Analytics Blog, 2015. [Online]. Available: http://blogs.perficient.com/dataanalytics/2015/06/22/nosql-nosecuity-security-issues-with-nosql-database/. [Accessed: 21-Sep-2016].

[16] M. J. Mior, Automated schema design for NoSQL databases, Proc. 2014 SIGMOD PhD Symp. - SIGMOD14 PhD Symp., pp. 4145, 2014.

[17] R. CrawCuor and D. Makogon, Modeling Data in Document Databases. United States: Developer Experience & Document DB, 2016.

[18] M. Chow, Abusing NoSQL Databases, Proceedings of DEF CON 21 Hacking Conference. 2013.

[19] L. Okman, N. Gal-Oz, Y. Gonen, E. Gudes, and J. Abramov, Security issues in NoSQL databases, in Proc. 10th IEEE Int. Conf. on Trust, Security and Privacy in Computing and Communications, TrustCom 2011, 8th IEEE Int. Conf. on Embedded Software and Systems, ICESS 2011, 6th Int. Conf. on FCST 2011, 2011, pp. 541547.

[20] E. G. Sirer, NoSQL Meets Bitcoin and Brings Down Two Exchanges: The Story of Flexcoin and Poloniex, Hacking, Distributed, 2014. [Online]. Available: http://hackingdistributed.com/2014/04/06/another-one-bites-the-dust-flexcoin/. [Accessed: 31-Jul-2017].

[21] J. FORTIN and A. Cruz, System Failure at British Airways Shuts Down Flights Out of London, The New York Times, 2017. [Online]. Available: https://www.nytimes.com/2017/05/27/world/europe/british-airways-flights-heathrow-and-gatwick-airports-.html. [RAccessed: 01-Aug-2017].

[22] W. Naheman, Review ofNoSQL Databases and Performance Testing on HBase, 2013 Int. Conf. Mechatron. Sci. Electr. Eng. Comput., pp. 23042309, 2013.

[23] C. O. Truica, F. Radulescu, A. Boicea, and I. Bucur, Performance evaluation for CRUD operations in asynchronously replicated document oriented database, in Proceedings - 2015 20th International Conference on Control Systems and Computer Science, CSCS 2015, 2015, pp. 191196.

[24] J. Patel, Cassandra data modeling best practices, part 1, ebaytech-blog, 2012. [Online]. Available: http://ebaytechblog.com/?p=1308. [Accessed: 02-Aug-2017].

[25] N. Korla, Cassandra data modeling - practical considerations @ Netflix, Netflix, 2013. [Online]. Available: http://www.slideshare.net/nkorla1share/cass-summit-3. [Accessed: 02-Aug-2017].

[26] N. Jatana, S. Puri, and M. Ahuja, A Survey and Comparison of Relational and Non-Relational Database, Int. J. , vol. 1, no. 6, pp. 15, 2012.

[27] C. JMTauro, A. S, and S. A.B, Comparative Study of the New Generation, Agile, Scalable, High Performance NOSQL Databases, Int. J. Comput. Appl., vol. 48, no. 20, pp. 14, 2012.

[28] R. April, NoSQL Technologies: Embrace NoSQL as a relational Guy Column Family Store, DBCouncil, 2016. [Online]. Available: https://dbcouncil.net/category/nosql-technologies/. [Accessed: 21-Apr-2017].

[29] S. Visigenic, ODBC 2.0 Programmers Manual, Version 2. United States: TimesTen Performance Software, 2000.

[30] G. Matthias, Knowledge Base of Relational and NoSQL Database Management Systems: DB-Engines Ranking per database model category, DB-Engines, 2017. [Online]. Available: https://db-engines.com/en/ranking_categories. [Accessed: 21-Apr-2017].

[31] Gartner and M. Fowler, The NoSQL Generation: Embracing the Document Model, MarkLogic Corp. Hype Cycle Big Data, no. May, 2014.

[32] P. Atzeni, Data Modelling in the NoSQL world: A contradiction?, Int. Conf. Comput. Syst. Technol. - CompSysTech16, no. June, pp. 2324, 2016.

[33] P. Lake and P. Crowther, A History of Databases: Concise guide to databases: a practical introduction, Springer-Verlag London, vol. 17, no. 1, p. 307, 2013.

[34] K. Dembczy, Evolution of Database Systems, Intell. Decis. Support Syst. Lab. Pozna_n Univ. Technol. Pol., vol. 16, p. 139, 2015.

[35] P. P.-S. Chen, The Entity-Relationship Unified View of Data Model-Toward a, ACM Trans. Database Syst., vol. 1, no. 1, pp. 936, 1976.

[36] G. C. Everest, Basic Data Structure Models Explained with a Common Example, in In Proc. Fifth Texas Conference on Computing Systems, 9176, pp. 1819.

[37] J. Han, E. Haihong, G. Le, and J. Du, Survey on NoSQL database, Proc. - 2011 6th Int. Conf. Pervasive Comput. Appl. ICPCA 2011, pp. 363366, 2011.

[38] T. A. Alhaj, M. M. Taha, and F. M. Alim, Synchronization Wireless Algorithm Based on Message Digest (SWAMD) For Mobile Device Database, 2013 Int. Conf. Comput. Electr. Electron. Eng. Synchronization, pp. 259262, 2013.

[39] K. Storm, How I stole roughly 100 BTC from an exchange and how I could have stolen more!, reddit, 2014. [Online]. Available: https://www.reddit.com/r/Bitcoin/comments/1wtbiu/how_i_s tole_roughly_100_btc_from_an_exchange_and. [Accessed: 02-Aug-2017].

[40] G. Khan, Why you should never, ever, ever use documet-store databases like MongoDB, reddit, 2015. [Online]. Available: https://www.reddit.com/r/programming/comments/3dvzsl/w hy_you_should_never_ever_ever_use_mongodb. [Accessed: 02-Aug-2017].

[41] M. L. Chouder, S. Rizzi, and R. Chalal, Enabling Self-Service BI on Document Stores, Work. Proceed- c ings EDBT/ICDT 2017 Jt. Conf. Venice, Italy, 2017.

[42] M. Mughees, DATA MIGRATION FROM STANDARD SQL TO NoSQL, 2013.

[43] T. Halpin, UML data models from an ORM perspective: Part 1 - 10, J. Concept. Model. 8, no. August, pp. 17, 1999.

[44] V. Abramova and J. Bernardino, NoSQL databases: MongoDB vs cassandra, Proc. Int. C* Conf. Comput. Sci. Softw. Eng. ACM 2013, pp. 1422, 2013.

[45] M. Gelbmann, DB-Engines Ranking of Document Stores, DB-Engines, 2017. [Online]. Available: https://db-engines.com/en/ranking/document+store. [Accessed: 21-Feb-2017].

[46] A. P. George Papamarkos, Lucas Zamboulis, XML Databases. School of Computer Science and Information Systems, Birkbeck College, University of London, 2013.

[47] A. Ron, A. Shulman-Peleg, and E. Bronshtein, No SQL, No Injection? Examining NoSQL Security, arXiv Prepr. arXiv1506.04082, 2015.

[48] D. L. Moody, S. Guttorm, T. Brasethvik, and A. S. lvberg, Evaluating the Quality of Process Models: Empirical Testing of a Quality Framework, in S. Spaccapietra, S.T. March, Y. Kambayashi (Eds.), Conceptual Modeling ER 2002, 21st International Conference on Conceptual Modeling, Tampere, Finland, October 711, Proceedings, Lecture Notes in Computer Science, Vol. 2503, Springer, 2002, pp. 380396.

A Routing Calculus with Distance Vector Routing Updates

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***Abstract*—We propose a routing calculus in a process algebraic framework to implement dynamic updates of routing table using distance vector routing. This calculus is an extension of an existing routing calculus $\mathbf{DR}_\pi^\omega$ where routing tables are fixed except when new nodes are created in which case the routing tables are appended with relevant entries. The main objective of implementing dynamic routing updates is to demonstrate the formal modeling of distributed networks which is closer to the networks in practice. We justify our calculus by showing its reduction equivalence with its specification $\mathbf{D}_\pi$ (distributed π-calculus) after abstracting away the unnecessary details from our calculus which in fact is one of the implementations of $\mathbf{D}_\pi$. We nomenclate our calculus with routing table updates as $\mathbf{DR}_\pi^\varphi$.**

Keywords*—Routing Calculi; Routing Protocols; Well Formed Configuration; Reduction Semantics

I. Introduction

In recent years, developments in formal modeling of distributed networks in a process algebraic framework through process calculi has marked profound work [1], [2] [3], [4], [5], [6], [7], [8], [9], [10], [11], [12]. The extended version of Asynchronous Distributed π-calculus (AD$_\pi$) named as routing calculi DR$_\pi^\omega$ was one of the significant developments towards modeling the distributed computer network using an active component named router and considering the path of a communication between the communicating nodes where a routing table is a dynamic entity in a typical distributed network.

DR$_\pi^\omega$ consists of a network of routers of fixed topology. The processes reside in a located site called nodes which are directly connected to some specific router. Any two processes at nodes can communicate through the routers. The routers find the path over the network between the communicating processes. The processes communicate via this path.

A system in DR$_\pi^\omega$, looks like $\Gamma_c \triangleright S$. Here S can be of the form $\langle R\rangle[\![n[P]]\!]$ where P is a process that resides under node n connected at the same or a different node to some router R. The communication between the processes takes place through routers. Each process is located at some particular node which in turn resides at some particular router. The routers determine the particular path along the router connectivity through which the communicated values are forwarded. In this language, the routing table is updated only when a new node is created which limits dynamic updates of the table.

We present a new calculi DR$_\pi^\varphi$ which is a direct adoption of routing calculus DR$_\pi^\omega$ [10] with a modified feature of routing table updates which is dynamic in DR$_\pi^\varphi$ unlike DR$_\pi^\omega$. We have abstracted away few details from DR$_\pi^\omega$ to demonstrate the power of new calculi in more simple way. These features can be adopted to DR$_\pi^\varphi$ without much amendments to it. We describe a method for routing table updates with the help of implementation of distance vector routing method [13], [14], [15], [16] which uses the Bellman-Ford algorithm [17], [18], [19], [20] to compute the shortest route. In this calculi, the routing tables are periodically exchanged with their neighbors and with this updated entries new routes are found. We abstract away the details of new routes calculation methods by incorporating function δ in our semantics rule. Further to maintain the consistency in the calculi a clock $t_{k'}$ is introduced so that the routing table exchange and thereafter update calculation are done at discrete time. The condition in well formed configuration ensure that the calculi remains consistent in term of self looping of message propagation, path guarantee etc. This calculi presents more realistic picture of distributed networks with routers and therefore is closer to the real implementation.

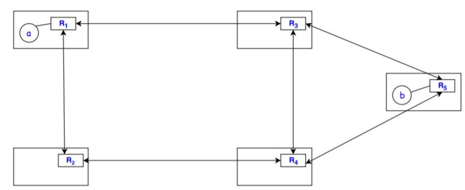

Fig. 1. A simple distributed with routers and nodes

In DR$_\pi^\varphi$, a system is represented by $\langle R^{t_{k'}}\rangle[\![n[P]]\!]$ where a process P is located at node n. The node n is directly connected to the router R at global clock $t = t_{k'}$. The system is accompanied with the router connectivity Γ_c. Hence, the configuration paves the way to reductions. A configuration $\Gamma_c \triangleright S$ comprises of router connectivity Γ_c and system S.

In the following sections the paper is organized as follows:

The syntax , structural equivalence and reduction semantics of DR$_\pi^\varphi$ are described in Section 2, 3 and 4 respectively. We have explained an example to illustrate the reduction rules more clearly in Section 5. We require certain conditions on well formed configuration for the consistent behavior of the reduction semantics in Section 6. We describe the equivalence between DR$_\pi^\varphi$ and D$_\pi$ in Section 7. The conclusion is in Section 8.

II. Syntax

We will use $v, v_1, v_2, u, u_1 \ldots$. to represents values which may be a simple value or a name or a variable. For simplicity in the language we don't use tuples as values. Therefore $u, v, \ldots$.. are singleton names or simple values i.e. integers, boolean etc. We use meta variables $a, b, c, \ldots$ to range over channel names $\complement$ or node names N. In the description of the language $n, m, \ldots$ are used to range over node names N and we use $R, R_1, R_2, \ldots$ to range over set of router names $\Re$ at global time $t_k, t_{k+1}, t_{k+2}, \ldots$. The variables $h, l, \ldots$ range over integers to represent the cost of communication.

Further, we assume that sets of node names, router names and channel names are disjoint from each other. More formally

$$\Re \cap \complement \cap N = \Phi$$

There exists three main syntactic categories in the language that are Nodes , Systems, and Processes. We described the syntax of $\mathrm{DR}_{\pi}^{\varphi}$ in Fig. 1. We have given the descriptions of these syntactic categories in the following sub-sections.

A. System

In Fig. 2, we described a system as $\langle R^{t_{k'}} \rangle [\![M]\!]$ where R being a router at global clock $t_{k'}$ and M is a another syntactic category named as nodes that are directly connected to R. $S \mid T$ represents two parallel systems and $[R] M_{sg}^{h}(n, m, v@c)$ is a message at router R. This message is used to propagate the value v from one router to another during communication between some process at source node n to another process at destination node m. The value propagated by the message is represented by $v@c$ to deliver value v to the specified channel c of the destination process. Here the integer h indicates the number of hops(routers), the message has already travelled across the path towards its destination and ε is the identity.

B. Node

In Fig. 2, the nodes are named processes $n[P]$ where n is the name of a node and P is a process term in it. $M \mid N$ describes usual concurrency between nodes M and N at any router. As an example, in a system $\langle R^{t_{k'}} \rangle [\![M \mid N]\!]$ the nodes M and N are running in parallel at router R at global clock $t_{k'}$. 0 is the identity.

C. Process terms

The process terms are very similar to the terms in [1], [5]. These process terms are described in Fig. 2.

III. Structural Equivalence

We introduce a formal relation between the system terms in $\mathrm{DR}_{\pi}^{\varphi}$ called structural equivalence which is represented by the notation $\equiv$ to this relation, they are same computational entity. This is defined in [1], [5]. We describe the definition of structural equivalence is separated for all syntactic categories. Nevertheless, the node equivalence inherits process equivalence and system equivalences inherits by node equivalence. For example, the terms $\langle R^{t_{k'}} \rangle [\![M_1 \mid M_2]\!]$ and $\langle R^{t_{k'}} \rangle [\![M_2 \mid M_1]\!]$, instinctively represent the same systems where the nodes M_1 and M_2 at router R run in parallel at global clock $t_{k'}$ and the order of their composition really does not matter. These are defined in Fig. 2, 3, 4, 5 and 6.

S, T **::=**	**Systems**
$\langle R^{t_{k'}} \rangle [\![M]\!]$	Router at global clock
$S \mid T$	Concurrency
$[R] M_{sg}^{h}(n, m, v@c)$	Messages
ε	Identity
M, N **::=**	**Nodes**
$n[P]$	Named processes
$M \mid N$	Concurrency
0	Identity
T, U **::=**	**Process Terms**
$c?(x)P$	Input
$m!(v@c)$	Output
if $v_1 = v_2$ then P else Q	Matching
$P \mid Q$	Concurrency
$*P$	Recursive
$stop$	Termination

Fig. 2. Syntax Of $\mathrm{DR}_{\pi}^{\varphi}$

(SE-COM)	$P \mid Q \equiv Q \mid P$
(SE-ASSOC)	$(P \mid Q) \mid R \equiv P \mid (Q \mid R)$
(SE-ID)	$P \mid id \equiv P$

Fig. 3. Structural Equivalence(Standard) for $\mathrm{DR}_{\pi}^{\varphi}$

(SE-P-STANDARD)	standard axioms
(SE-P-Recursion)	$*P \equiv P \mid *P$

Fig. 4. Structural Equivalence(Processes) for $\mathrm{DR}_{\pi}^{\varphi}$

(SE-N-STANDARD)	standard axioms
(SE-N-STOP)	$m[stop] \equiv 0$
(SE-N-INHERITANCE)	$\dfrac{P \equiv Q}{m[P] \equiv m[P]}$

Fig. 5. Structural Equivalence(Nodes) $\mathrm{DR}_{\pi}^{\varphi}$

(SE-S-STANDARD)	standard axioms
(SE-S-INHERITANCE)	$\dfrac{N \equiv S}{\langle R^{t_{k'}} \rangle [\![N]\!] \equiv \langle R^{t_{k'}} \rangle [\![S]\!]}$

Fig. 6. Structural Equivalence(Systems) for $\mathrm{DR}_{\pi}^{\varphi}$

IV. Reduction Semantics

The reduction semantics are defined on configurations $\Gamma_c \triangleright S$. The configuration reduction step is defined as $\Gamma_c \triangleright S \longrightarrow^{h} \Gamma_c \triangleright S'$ where the cost of reduction [3], [4] is h and a system S reduces S'. These reduction rules for $\mathrm{DR}_{\pi}^{\varphi}$ are given in Fig. 7 and directly inherited from [8], [10]. The Rule (R-OUT) is for delivery. For example, let us take the configuration $\Gamma_c \triangleright \langle R^{t_{k'}} \rangle [\![n[m!(v@c)$
$|P]|N]\!]$ where a process $m!(v@c)|P$ at source node n at router R at a global clock $t_{k'}$ outputs a value v at channel c which is located at some process at destination node m. This reduction rule generates a propagation message $[R] M_{sg}^{0}(n, m, v@c)$ in parallel with the system $\langle R^{t_{k'}} \rangle [\![n[P]|N]\!]$ resulting in a configu-

ration $\Gamma_c \rhd [R]\, M^0_{sg}\,(n,m,v@c)\,|\langle R^{t_{k'}}\rangle[\![n[P]|N]\!]$. The message with subscript 0 indicates that it has been generated at router R and has not hopped to any other router yet. The term $(n,m,v@c)$ in the message represents the source node name n where a process outputs a value and destination node m where the value v is to be delivered on channel c to a waiting process.

The propagation of the message from one router to another router towards the destination node is done using reduction rule (R-MSG-FWD) in Fig. 7 . Let us consider the reduction rule (R-MSG-FWD). In this reduction rule a configuration of the form $\Gamma_c \rhd [R_1]M^h_{sg}\,(n,m,v@c)\,|\langle {R_2}^{t_{k'}}\rangle[\![N]\!]|S$ reduced to $\Gamma_c \rhd [R_2]M^{h+1}_{sg}\,(n,m,v@c)\,|\langle {R_2}^{t_{k'}}\rangle[\![N]\!]|S$. There are two premises the first $(R_1,R_2) \in \Gamma_c$ means that the routers R_1 and R_2 are directly connected or R_2 is a neighbor of R_1. The second one, $\langle {R_1}^{t_{k'}}\rangle(m) = R_2$ means that m belongs to the domain of the routing table at R_1 at global clock $t_{k'}$ and the function $\langle {R_1}^{t_{k'}}\rangle$ returns R_2 as the next hop towards the destination node m.

In the reduction rule (R-COMM) in Fig. 7, a configuration $\Gamma_c \rhd\ [R]M^h_{sg}\,(n,m,v@c)|\,\langle R^{t_{k'}}\rangle[\![m[c?(x)P|Q]|N]\!]$ does a reduction to $\Gamma_c \rhd \langle R^{t_{k'}}\rangle[\![m[P\{v/x\}|Q]|N]\!]$. Here note that cost of reduction is h as the message has hopped h routers from source node n to destination node m. However it is not necessary that for every hop the global clock count increases by an interval.

we describe the reduction rule (R-TABLE-UPDATE) in Fig. 7 which uses a new special notation $(\longleftrightarrow)$ to depict the exchange of routing tables at global clock $t = t_{k'}$. This notion $(\longleftrightarrow)$ adds a novelty to this calculus as this will not only exchange the routing table between the connecting routers but also update tables (using distance vector routing methods [13], [14], [15], [16] dynamically with the help of synchronization of the global clock. Here we define reduction semantics for updating table dynamically, may or may not at global clock $t_{k'}$. In this reduction rule a configuration of the form $\langle {R_1}^{t_{k'+1}}\rangle[M]|S$ reduces to $\langle {R'_1}^{t_{k'+1}}\rangle[M]|S$. There are six premises, the first $(R_1,R_2) \in \Gamma_c$ means that the routers R_1 and R_2 are directly connected or R_2 is a neighbor of R_1 at global clock $t = t_{k'}$. The second and third, $\Gamma_c \rhd \langle {R_1}^{t_{k'}}\rangle[M]|\ S$ and $\langle {R_2}^{t_{k'}}\rangle[N]|T$ are well formed which mean that the well formedness is preserved under reductions. The fourth, $\langle {R_1}^{t_{k'}}\rangle[M]|S \longleftrightarrow \langle {R_2}^{t_{k'}}\rangle[N]|T$ means that the routing table between the connecting routers is exchanged. The fifth and sixth, $\delta\langle {R_1}^{t_{k'+1}}\rangle = \langle {R'_1}^{t_{k'+1}}\rangle$ and $\delta\langle {R_2}^{t_{k'+1}}\rangle = \langle {R'_2}^{t_{k'+1}}\rangle$ mean that routing tables (using distance vector routing methods) are updated dynamically with the help of synchronization of the global clock $t_{k'}$.

The rules (R-MATCH) and (R-MISMATCH) are tests for values. Here the initial cost of these reductions is also zero. The compositional rules are defined in the rule (R-CONTX) in Fig. 7 and are preserved under the static operator |. The other reduction rule (R-STRUCT) in Fig. 7 defines well formed configuration reduction upto system structural equivalence.

Now we will demonstrate these rules with the help of an example. This example also shows the exclusive feature of this particular language regarding the novel rule is implemented for routing table updates.

V. EXAMPLE

In Fig. 1, let us assume that a system S is defined as $S_1|S_2|S_3|S_4|S_5$ where

(R-OUT)
$$\Gamma_c \rhd \langle R^{t_{k'}}\rangle[\![n[m!\,(v@c)\,|P]|N]\!] \rightarrow$$
$$\Gamma_c \rhd [R]\,M^0_{sg}\,(n,m,v@c)\,|\langle R^{t_{k'}}\rangle[\![n[P]|N]\!]$$

(R-COMM)
$$\frac{\langle R^{t_{k'}}\rangle(m) = R}{\begin{array}{c}\Gamma_c \rhd\ [R]M^h_{sg}\,(n,m,v@c)|\,\langle R^{t_{k'}}\rangle[\![m[c?(x)P|Q]|N]\!] \longrightarrow \\ \Gamma_c \rhd \langle R^{t_{k'}}\rangle[\![m[P\{v/x\}|Q]|N]\!]\end{array}}$$

(R-MSG-FWD)
$$\frac{\begin{array}{c}(R_1,R_2) \in \Gamma_c \\ \langle {R_1}^{t_{k'}}\rangle(m) = R_2\end{array}}{\begin{array}{c}\Gamma_c \rhd [R_1]M^h_{sg}\,(n,m,v@c)\,|\langle {R_2}^{t_{k'}}[\![N]\!]|S \longrightarrow \\ \Gamma_c \rhd [R_2]M^{h+1}_{sg}\,(n,m,v@c)\,|\langle {R_2}^{t_{k'}}[\![N]\!]|S\end{array}}$$

(R-MATCH)
$$\Gamma_c \rhd \langle R^{t_{k'}}\rangle[\![n[\text{ if } \ v=v \ \text{ then } P \text{ else } Q]]\!] \longrightarrow \Gamma_c \rhd \langle R^{t_{k'}}\rangle[\![n[P]]\!]$$

(R-MISMATCH)
$$\Gamma_c \rhd \langle R^{t_{k'}}\rangle[\![n[\text{ if } v_1 \neq v_2 \text{ then } P \text{ else } Q]]\!] \longrightarrow \Gamma_c \rhd \langle R^{t_{k'}}\rangle[\![n[Q]]\!]$$

(R-TABLE-UPDATE)
$$\frac{\begin{array}{c}(R_1,R_2) \in \Gamma_c,\ t = t_{k'} \\ \Gamma_c \rhd \langle {R_1}^{t_{k'}}\rangle[M]|\ S \text{ is wff} \\ \Gamma_c \rhd \langle {R_2}^{t_{k'}}\rangle[N]|T \text{ is wff} \\ \langle {R_1}^{t_{k'}}\rangle[M]|S \longleftrightarrow \langle {R_2}^{t_{k'}}\rangle[N]|T \\ \delta\langle {R_1}^{t_{k'+1}}\rangle = \langle {R'_1}^{t_{k'+1}}\rangle \\ \delta\langle {R_2}^{t_{k'+1}}\rangle = \langle {R'_2}^{t_{k'+1}}\rangle\end{array}}{\begin{array}{c}\Gamma_c \rhd \langle {R_1}^{t_{k'+1}}\rangle[M]|S \longrightarrow \Gamma_c \rhd \langle {R'_1}^{t_{k'+1}}\rangle[M]|S \\ \Gamma_c \rhd \langle {R_2}^{t_{k'+1}}\rangle[N]|T \longrightarrow \Gamma_c \rhd \langle {R'_2}^{t_{k'+1}}\rangle[N]|T\end{array}}$$

(R-STRUCT)
$$\frac{S \equiv S', \Gamma_c \rhd S' \longrightarrow \Gamma_c \rhd R', R' \equiv R}{\Gamma_c \rhd S \longrightarrow \Gamma_c \rhd R}$$

(R-CONTX)
$$\frac{\Gamma_c \rhd S_1 \longrightarrow \Gamma_c \rhd S'_1}{\begin{array}{c}\Gamma_c \rhd S_1 \mid S_2 \longrightarrow \Gamma_c \rhd S'_1 \mid S_2 \\ \Gamma_c \rhd S_2 \mid S_1 \longrightarrow \Gamma_c \rhd S_2 \mid S'_1\end{array}}$$

Fig. 7. Reduction Semantics for DR^{φ}_{π}

$$\begin{array}{c}S_1 \equiv \langle R_1^{t_k}\rangle[\![P|N_1]\!] \\ S_1 \equiv \langle R_2^{t_k}\rangle[\![N_2]\!] \\ S_3 \equiv \langle R_3^{t_k}\rangle[\![N_3]\!] \\ S_4 \equiv \langle R_4^{t_k}\rangle[\![N_4]\!] \\ S_5 \equiv \langle R_5^{t_k}\rangle[\![Q|N_5]\!]\end{array}$$

Where $P \equiv a[b!\langle v@c\rangle]$ and $Q \equiv b[c?(x)R]$
The router connectivity Γ_c is defined as $\{(R_1,R_2),(R_1,R_3),(R_2,R_4),(R_3,R_4),(R_3,R_5),(R_5,R_4)\}$.

The configuration $\Gamma_c \rhd S_1|S_2|S_3|S_4|S_5$ does a reduction using the rule (R-OUT) where the process $b!\langle v@c\rangle$ at node a generates a message at global clock $t_{k'}$ where $t_{k'} = t_k, t_{k+1}, t_{k+2}, \ldots..$ The configuration reduces to another configuration of the form

$$\Gamma_c \rhd [R_1]\, M^0_{sg}\,(a,b,v@c)\,|\langle R_1^{t_k}\rangle [\![N_1]\!]|S_2|S_3|S_4|S_5$$

In the Fig. 1, R_1 is directly connected to R_2 and R_3. we know that $(R_1,R_2) \in \Gamma_c$ and $(R_1,R_3) \in \Gamma_c$. Similarly we know that $(R_2,R_4) \in \Gamma_c$, $(R_3,R_4) \in \Gamma_c$, $(R_4,R_5) \in \Gamma_c$, $(R_5,R_3) \in \Gamma_c$.

All the routing table will share its routing table with adjacent router. Now by using rule(R-TABLE-UPDATE), we get

$$\begin{gathered}\Gamma_c \rhd \langle R_1^{t_k}\rangle [\![P|N_1]\!] \text{ is wff}\\ \Gamma_c \rhd \langle R_2^{t_k}\rangle [\![N_2]\!] \text{ is wff}\\ \Gamma_c \rhd \langle R_3^{t_k}\rangle [\![N_3]\!] \text{ is wff}\\ \Gamma_c \rhd \langle R_4^{t_k}\rangle [\![N_4]\!] \text{ is wff}\\ \Gamma_c \rhd \langle R_5^{t_k}\rangle [\![Q|N_5]\!] \text{ is wff}\end{gathered}$$

All the systems are well formed which are defined in definition 1. Now all the routing tables shall be exchanged with each other at a global clock t_k.

$$\begin{gathered}\langle R_1^{t_k}\rangle [\![P|N_1]\!] \longleftrightarrow \langle R_2^{t_k}\rangle [\![N_2]\!]\\ \langle R_1^{t_k}\rangle [\![P|N_1]\!] \longleftrightarrow \langle R_3^{t_k}\rangle [\![N_3]\!]\\ \langle R_2^{t_k}\rangle [\![N_2]\!] \longleftrightarrow \langle R_4^{t_k}\rangle [\![N_4]\!]\\ \langle R_3^{t_k}\rangle [\![N_3]\!] \longleftrightarrow \langle R_4^{t_k}\rangle [\![N_4]\!]\\ \langle R_3^{t_k}\rangle [\![N_3]\!] \longleftrightarrow \langle R_5^{t_k}\rangle [\![Q|N_5]\!]\\ \langle R_4^{t_k}\rangle [\![N_4]\!] \longleftrightarrow \langle R_5^{t_k}\rangle [\![Q|N_5]\!]\\ \langle R_5^{t_k}\rangle [\![Q|N_5]\!] \longleftrightarrow \langle R_3^{t_k}\rangle [\![N_3]\!]\end{gathered}$$

Now route checks update for new information then routers will be calculated using Bellman-Ford algorithm and metric is updated, new entries are stored in the routing table. Thus routers will exchange routing information at t_{k+1}.

$$\begin{gathered}\delta\langle R_1{}^{t_{k+1}}\rangle = \langle R_1{}^{t_{k+1}}\rangle\\ \delta\langle R_2{}^{t_{k+1}}\rangle = \langle R_2'{}^{t_{k+1}}\rangle\\ \delta\langle R_3{}^{t_{k+1}}\rangle = \langle R_3'{}^{t_{k+1}}\rangle\\ \delta\langle R_4{}^{t_{k+1}}\rangle = \langle R_4{}^{t_{k+1}}\rangle\\ \delta\langle R_5{}^{t_{k+1}}\rangle = \langle R_5'{}^{t_{k+1}}\rangle\end{gathered}$$

In this way $\langle R_2{}^{t_{k+1}}\rangle$, $\langle R_3{}^{t_{k+1}}\rangle$ and $\langle R_5{}^{t_{k+1}}\rangle$ are updated and new routing tables are $\langle R_2'{}^{t_{k+1}}\rangle$, $\langle R_3'{}^{t_{k+1}}\rangle$ and $\langle R_5{}^{t'_{k+1}}\rangle$ respectively at global clock t_{k+1}.

Now the message hops towards the destination node b, the router table $\langle R_1{}^{t_{k+1}}\rangle$ may return either the adjacent router R_2 or the adjacent router R_3 as next hop on the communication path to node b at router R_5. This may be formally expressed as $\langle R_1{}^{t_{k+1}}\rangle(b) = R_2$ and $\langle R_1{}^{t_{k+1}}\rangle(b) = R_3$.

The communication path is chosen by distance vector approach (shortest path). Suppose the routing table $\langle R_1{}^{t_{k+1}}\rangle$ returns R_3 as the next hop for reaching b. This essentially means that R_3 is on the path towards b which is hosted at router R_5. Formally $\langle R_1{}^{t_{k+1}}\rangle(b) = R_3$ and also we know that $(R_1,R_3) \in \Gamma_c$. Therefore with an application of rule (R-MSG-FWD) the message $[R_1]M^0_{sg}(a,b,v@c)$ hops at R_3. So the configuration

$$\begin{gathered}\Gamma_c \rhd [R_1]\, M^0_{sg}\,(a,b,v@c)\,|\langle R_1^{t_{k+1}}\rangle [\![P|N_1]\!]|\langle R_2'{}^{t_{k+1}}\rangle [\![N_2]\!]|\\ \langle R_3'{}^{t_{k+1}}\rangle [\![N_3]\!]|\langle R_4{}^{t_{k+1}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+1}}\rangle [\![Q|N_5]\!]\end{gathered}$$

reduces to

$$\begin{gathered}\Gamma_c \rhd [R_3]\, M^1_{sg}\,(a,b,v@c)\,|\langle R_1^{t_{k+1}}\rangle [\![P|N_1]\!]|\langle R_2'{}^{t_{k+1}}\rangle [\![N_2]\!]|\\ \langle R_3'{}^{t_{k+1}}\rangle [\![N_3]\!]|\langle R_4{}^{t_{k+1}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+1}}\rangle [\![Q|N_5]\!]\end{gathered}$$

Further suppose $\langle R_3'{}^{t_{k+1}}\rangle(b) = R_4$ and the message $[R_3]M^1_{sg}(a,b,v@c)$ is propagated to R_4. Since $(R_3,R_4) \in \Gamma_c$. Therefore again using the rule (R-MSG-FWD) the configuration

$$\begin{gathered}\Gamma_c \rhd [R_3]\, M^1_{sg}\,(a,b,v@c)\,|\langle R_1^{t_{k+1}}\rangle [\![P|N_1]\!]|\langle R_2'{}^{t_{k+1}}\rangle [\![N_2]\!]|\\ \langle R_3'{}^{t_{k+1}}\rangle [\![N_3]\!]|\langle R_4{}^{t_{k+1}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+1}}\rangle [\![Q|N_5]\!]\end{gathered}$$

reduces to

$$\begin{gathered}\Gamma_c \rhd [R_4]\, M^2_{sg}\,(a,b,v@c)\,|\langle R_1{}^{t_{k+1}}\rangle [\![P|N_1]\!]|\langle R_2'{}^{t_{k+1}}\rangle [\![N_2]\!]|\\ \langle R_3'{}^{t_{k+1}}\rangle [\![N_3]\!]|\langle R_4{}^{t_{k+1}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+1}}\rangle [\![Q|N_5]\!]\end{gathered}$$

Similarly again all the tables are updated with new entries with an application of rule (R-TABLE-UPDATE) at global clock t_{k+2}. Further suppose $\langle R_4'{}^{t_{k+2}}\rangle(b) = R_5$ and message $[R_4]M^2_{sg}(a,b,v@c)$ is propagated to R_5. Since $(R_4,R_5) \in \Gamma_c$. Therefore again using the rule (R-MSG-FWD) the configuration

$$\begin{gathered}\Gamma_c \rhd [R_4]\, M^2_{sg}\,(a,b,v@c)\,|\langle R_1'{}^{t_{k+2}}\rangle [\![P|N_1]\!]|\langle R_2''^{t_{k+2}}\rangle [\![N_2]\!]|\\ \langle R_3''^{t_{k+2}}\rangle [\![N_3]\!]|\langle R_4'{}^{t_{k+2}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+2}}\rangle [\![Q|N_5]\!]\end{gathered}$$

reduces to

$$\begin{gathered}\Gamma_c \rhd [R_5]\, M^3_{sg}\,(a,b,v@c)\,|\langle R_1'{}^{t_{k+2}}\rangle [\![P|N_1]\!]|\langle R_2''^{t_{k+2}}\rangle [\![N_2]\!]|\\ \langle R_3''^{t_{k+2}}\rangle [\![N_3]\!]|\langle R_4'{}^{t_{k+2}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+2}}\rangle [\![Q|N_5]\!]\end{gathered}$$

Because $\langle R_5'{}^{t_{k+2}}\rangle(b) = R_5$, the value v is delivered to the waiting process at b using the rule (R-COMM). Therefore the configuration

$$\begin{gathered}\Gamma_c \rhd [R_5]\, M^3_{sg}\,(a,b,v@c)\,|\langle R_1'{}^{t_{k+2}}\rangle [\![P|N_1]\!]|\langle R_2''^{t_{k+2}}\rangle [\![N_2]\!]|\\ \langle R_3''^{t_{k+2}}\rangle [\![N_3]\!]|\langle R_4'{}^{t_{k+2}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+2}}\rangle [\![b[c?(x)R]|N_5]\!]\end{gathered}$$

reduces to

$$\begin{gathered}\Gamma_c \rhd \langle R_1'{}^{t_{k+2}}\rangle [\![P|N_1]\!]|\langle R_2''^{t_{k+2}}\rangle [\![N_2]\!]|\langle R_3''^{t_{k+2}}\rangle [\![N_3]\!]|\\ \langle R_4'{}^{t_{k+2}}\rangle [\![N_4]\!]|\langle R_5'{}^{t_{k+2}}\rangle [\![b[R\{v/x\}]|N_5]\!]\end{gathered}$$

Similarly all the tables are updated with new entries by rule (R-TABLE-UPDATE) at every global clock $t_{k'}$ where $t_{k'} = t_k, t_{k+1}, t_{k+2}......$ Thus all the routers in a path of communication between R_1 and R_5 are updated dynamically. This method of routing table update is known as distance vector routing updates.

Previously the path for communication from a to b is via $R_1 \rightsquigarrow R_3 \rightsquigarrow R_5$ where the value propagating message hops two routers before delivering the value at the destination process which means paths are fixed. But now path are changed and new path for communication from a to b via $R_1 \rightsquigarrow R_3 \rightsquigarrow R_4 \rightsquigarrow R_5$. Due to this all the routing tables are updated dynamically. Therefore paths are also changed and this ensures the best optimal path. This is more closer to the real distributed network.

VI. WELL FORMED CONFIGURATIONS

We define a set of conditions on well formed configurations and prove them in DR_π^φ. The well formedness is preserved under reductions. The conditions on well formed configurations are explained in definition 1 and DR_π^φ is ensured by the reduction semantics.

In definition 1, the concept of well formed configurations in DR_π^φ is inherited from [8] and the reduction rule (6) and (7) are used to illustrate that when (R-COMM) and (R-MSG-FWD) occurs, reduction rule (R-TABLE-UPDATE) is prohibited for given network and vice- versa. These configuration rules will prevent looping and congestion in the network. Hence it will reduce inconsistency in the network.

Definition 1: well formed configuration A configuration is called well formed if it satisfies the following conditions:

1) $\Gamma_c \triangleright \varepsilon$ is a well formed system.
2) If $\Gamma_c \triangleright \langle R^{t_{k'}} \rangle [\![N]\!] \mid S$ is well formed at a global clock if
   a) $\Gamma_c \triangleright S$ is well formed where S contains no message at R.
   b) $\langle R^{t_{k'}} \rangle$ does not occur in S. (Uniqueness of router name R)
   c) $\forall \in \mathrm{fn}(N)$ such that $m \in NN$ where NN is the set of node names, if $\langle R^{t_{k'}} \rangle(m) = R$ then $\forall\ \langle R_1^{t_{k'}} \rangle \in S, \langle R_1^{t_{k'}} \rangle(m) \neq R_1$. (Uniqueness of node name m)
3) If $\Gamma_c \triangleright \langle R^{t_{k'}} \rangle [\![N]\!] \mid S$ is well formed at a global clock $t = t_{k'}, t_{k'+1}, ..$then $\Gamma_c \triangleright \langle R^{t_{k'+1}} \rangle [\![N]\!] \mid S$ is also well formed.
4) $\Gamma_c \triangleright [R]\, M_{sg}^h(n,m,v@c) \mid S$ is a well formed if
   a) $\Gamma_c \triangleright S$ is well formed and $S \equiv \langle R^{t_{k'}} \rangle [\![N]\!] \mid S'$ for some S'
   b) There exists a path $P(R',R) = R' \rightsquigarrow R'' \rightsquigarrow .....R$ for some $R', R'', ...$ such that $\langle R'^{t_{k'}} \rangle(n) = R'$ and $\langle R''^{t_{k'}} \rangle(m) = R''.....$ where $h = \mid \rho(R',R) \mid -1$
5) In any well formed configuration $\Gamma_c \triangleright S$, for every pair of nodes n and m such that $\langle {R_i}^{t_{k'}} \rangle(n) = R_i$ and$\langle {R_j}^{t_{k'}} \rangle(m) = R_j$ at any global clock $t = t_{k'}$ where $(R_i, R_j) \in S$, there exists a unique path $R_i \rightsquigarrow R_j$ such that $\langle\ {R_i}^{t_{k'}} \rangle(m) = R',\ \langle\ R'^{t_{k'+1}}\ \rangle(m) = R'', ...R'^{t_{k'+p}} \rangle(m) = R_j$
6) $\Gamma_c \triangleright S$ is well formed iff
   a) If $\Gamma_c \triangleright S \longrightarrow^h \Gamma_c \triangleright S'$ is using rule (R-COMM) then $\Gamma_c \triangleright S \not\longrightarrow {}^h\Gamma_c \triangleright S'$ will not be used rule (R-TABLE-UPDATE).
   b) If $\Gamma_c \triangleright S \longrightarrow^h \Gamma_c \triangleright S'$ is using rule (R-MSG-FWD) then $\Gamma_c \triangleright S \not\longrightarrow {}^h\Gamma_c \triangleright S'$ will not be used rule (R-TABLE-UPDATE).
7) $\Gamma_c \triangleright S$ is well formed iff
   a) If $\Gamma_c \triangleright S \longrightarrow^h \Gamma_c \triangleright S'$ is using rule (R-TABLE-UPDATE) then $\Gamma_c \triangleright S \not\longrightarrow {}^h\Gamma_c \triangleright S'$ will not be used either rule (R-COMM) or rule (R-MSG-FWD) .
   b) If $\Gamma_c \triangleright S \longrightarrow^h \Gamma_c \triangleright S'$ is using rule (R-TABLE-UPDATE) then $\Gamma_c \triangleright S \not\longrightarrow {}^h\Gamma_c \triangleright S'$ will not be used rule (R-COMM) and rule (R-MSG-FWD) .

Lemma.1. Suppose $S \equiv T$ then $\Gamma_c \triangleright S$ is well formed iff $\Gamma_c \triangleright T$ is well formed.

*Proof.***(OUTLINE)** By induction on definition of $\equiv$.

Theorem 1. *If* $\Gamma_c \triangleright S$ is well formed configuration and $\Gamma_c \triangleright S \longrightarrow^h \Gamma_c \triangleright S'$ then $\Gamma_c \triangleright S'$ is also well formed.

Proof. **(OUTLINE)** By rule induction on inference of $\Gamma_c \triangleright S \longrightarrow^h \Gamma_c \triangleright S'$ then $\Gamma_c \triangleright S'$. It is easy to prove that each inference of $\Gamma_c \triangleright S'$, using the reduction rules in Fig. 7, satisfies all the properties of a well formed configuration.

VII. EQUIVALENCE BETWEEN DR_π^φ AND D_π

We proved that whenever a D_π [2] system does a reduction there exists a corresponding well formed configuration in DR_π^φ which can do a number of reductions such that the residual are equivalent upto structural equivalence after ϕ abstraction of the residual system in DR_π^φ. Similarly for the converse, we proved that whenever a well formed configuration in DR_π^φ does a reduction there exists a corresponding D_π system which either does nothing or does a reduction where residuals of both D_π and DR_π^φ systems are matched upto structural equivalence. Since D_π is a specification for DR_π^φ therefore we have shown that DR_π^φ conforms to its specification. Our model is also closer to real distributed networks.

we define a function to abstract away the details of routers and paths from a DR_π^φ term state theorems about the equivalence of DR_π^φ with D_π.

Definition 2: We define a function $\phi : LSY \rightarrow HSY$, where LSY and HSY are sets of DR_π^φ system terms and D_π systems respectively, as follows:

$$\begin{aligned}
\phi\,(\varepsilon) &= nil\\
\phi\,(\langle R^{t_{k'}} \rangle [\![N]\!]) &= N\\
\phi\left([R]M_{sg}^h(n,m,v@c)\right) &= n[m!\langle v@c \rangle]\\
\phi\,(S|T) &= \phi\,(S)\,|\,\phi\,(T)
\end{aligned}$$

Proposition 1. For any system term L in DR_π^φ such that $\phi(L) = H$ and $H \equiv H'$ implies that there exists some system term L' in DR_π^φ such that $\phi(L') = H'$ and $L \equiv L'$.

Proof. We shall prove it by induction on various forms L can take and syntactic analysis of L such that $\phi(L) = H$ and $H \equiv H'$.

1) Let us take a case when a system L, in DR_π^φ, is of the form
$$L \equiv \langle {R_1}^{t_{k'}} \rangle [\![n[m!\langle v@c \rangle|P]|N]\!]$$
By using ϕ definition, we get
$$\phi(L) = n[m!\langle v@c \rangle|P]|N$$
$$H \equiv n[m!\langle v@c \rangle|P]|N$$
Therefore when we write $\phi(L) = H$ for some term L in DR_π^φ and a D_π system H , we can rearrange the terms in a D_π systems H', by using various axioms of structural equivalence (SE-COM) and (SE-ID). Since
$$H' \equiv N|n[m!\langle v@c \rangle|P]$$
or
$$H' \equiv n[m!\langle v@c \rangle|P]|N|e$$
Therefore $H \equiv H'$. When a system term L', in DR_π^φ, is of the form
$$L' \equiv \langle {R_1}^{t_{k'}} \rangle [\![N|n[m!\langle v@c \rangle|P]]\!]$$

Further by definition of ϕ we get,

$$\phi(L') = N|n[m!\langle v@c\rangle|P]\ H' \equiv N|n[m!\langle v@c\rangle|P]$$

By using axiom (SE-COM), we get

$$H' \equiv n[m!\langle v@c\rangle|P]|N \equiv H$$

Now it is clear that, the relation $=$ in the definition ϕ is much stronger than $\equiv$ i.e. ϕ is closed upto $\equiv$. Therefore, by definition of $\equiv$ given in Figure 3 it can be easily verified that $\phi(L') = H'$ and $L \equiv L'$.

2) Let us take another case when a system L, in DR_π^φ, is of the form

$$L \equiv [R_1]M^0_{sg}(n,m,v@c)\,|\langle R_2{}^{t_{k'}}[\![N]\!]|M$$

By using ϕ definition on L, we get

$$\phi(L) = n[m!\langle v@c\rangle|P]|N|M$$
$$H \equiv n[m!\langle v@c\rangle|P]|N|M$$

Therefore when we write $\phi(L) = H$, for some term L in DR_π^φ and D_π system H, we can rearrange the terms in a D_π systems H', by using various axioms of structural equivalence (SE-COM),(SE-ASSOC) and (SE-ID). Since H' is take various forms like,

$$H' \equiv n[m!\langle v@c\rangle|P]|M|N$$
or
$$H' \equiv M|N|n[m!\langle v@c\rangle|P]$$
or
$$H' \equiv n[m!\langle v@c\rangle|P]|N|M|e$$

All the form of H' is structurally equivalent to H, by using various axioms of structural equivalence. Since H'

Now we take system term L' in DR_π^φ, is the form of

$$L' \equiv \langle R_2{}^{t_{k'}}[\![N]\!]|M|[R_1]M^0_{sg}(n,m,v@c)$$

Further by definition of ϕ we get,

$$\phi(L') = N||M|n[m!\langle v@c\rangle|P]$$
$$H' \equiv N||M|n[m!\langle v@c\rangle|P]$$

By using rule (SE-COM), we get

$$H' \equiv n[m!\langle v@c\rangle|P]|N|M \equiv H$$

Therefore $\phi(L') = H'$ and $L \equiv L'$.

Similarly other cases can be proved.

Proposition 2. For any system term L in DR_π^φ $L \equiv L'$ implies $\phi(L) \equiv \phi(L')$.

Proof. This can be proved by induction on the definition of L and $\equiv$ as defined in Figure 2 and . By applying function ϕ above proposition can be derived fairly straightforward.

Lemma.2. In a D_π system H_1 does a reduction $H_1 \longrightarrow H_2$ and $\phi(L_1) = H_1'$ such that $H_1' \equiv H_1$ where L_1 is a system term over a well formed configuration $\Gamma_c \rhd L_1$ in DR_π^φ, then $\Gamma_c \rhd L_1 \longrightarrow \Gamma_c \rhd L_2$ for some h such that $\phi(L_2) = H_2'$ where $H_2' \equiv H_2$.

Proof. We shall prove it by rule induction on the inference of a D_π system reduction $H_1 \longrightarrow H_2$ and syntactic analysis of L_1 such that $\phi(L_1) = H_1'$ where $H_1' \equiv H_1$. There are various possibilities and we we will take each of them as follows:

1) Let us take a case where a D_π system H_1 is the form $l_1[c?(x)P$
$|\ M]\ |\ l_2[l_1!\langle v@c\rangle\ |N]$. Suppose the D_π system H_1 does a reduction to

$$l_1[P\{v/x\}|M]\ |\ l_2[N]$$

By using the rule (R-H-COMM) where

$$H_2 \equiv l_1[P\{v/x\}|M]\ |\ l_2[N]$$

A system term L_1 in DR_π^φ, such that $\phi(L_1) = H_1'$ can take various forms. We shall examine each of them as follows:

a) We take the case where L_1 is structurally equivalent to

$$\langle R_1^{t_{k'}}\rangle[\![l_1[c?(x)P\mid M]]\!]\mid\langle R_2^{t_{k'}}\rangle[\![l_2[l_1!\langle v@c\rangle\ |N]]\!]$$

for some R_1 and R_2. We can clearly see that

$$\phi(L_1) = l_1[c?(x)P\ |\ M]\ |\ l_2[l_1!\langle v@c\rangle\ |N]$$

where

$$l_1[c?(x)P\ |\ M]\ |\ l_2[l_1!\langle v@c\rangle\ |N] \equiv H_1 \text{ s.t. } H_1' \equiv H_1$$

We know that $\Gamma_c \rhd L_1$ is a well formed system and therefore L_1 does a following reduction using rule (R-OUT) to become

$$[R]M^0_{sg}(l_2,l_1,v@c)\ |\ \langle R_2^{t_{k'}}\rangle[\![l_2[N]]\!]\ |\ \langle R_1^{t_{k'}}\rangle[\![l_1[c?(x)P\ |\ M]]\!]$$

We use various standard axioms of structural equivalence rules and by definition of ϕ we know that

$$\phi(L_2) = l_2[l_1!\langle v@c\rangle]\ |\ l_2[N]\ |\ l_1[c?(x)P\ |\ M]$$

where

$$H_2' \equiv l_2[l_1!\langle v@c\rangle]\ |\ l_2[N]\ |\ l_1[c?(x)P\ |\ M]$$

By using axiom (R-H-COM),we get

$$H_2' \equiv l_2[l_1!\langle v@c\rangle]\ |\ l_1[c?(x)P\ |\ M]|\ l_2[N]$$

By using axiom (R-H-COMM),we get

$$H_2' \equiv l_1[P\{v/x\}|M]\ |\ l_2[N] \equiv H_2$$

Further as we know that $\Gamma_c \rhd L_1$ is a well formed system and therefore according to the condition of well formed configuration $R_2 \rightsquigarrow R_1$ where $\langle R_2^{t_{k'}}\rangle(l_2) = R_2$ and $\langle R_1^{t_{k'}}\rangle(l_1) = R_1$. Let us assume that $\langle R_2^{t_{k'}}\rangle(l_2) = R_3$ for some R_3 such that $(R_2,R_3) \in \Gamma_c$. A reduction is done using rule (R-MSG-FWD)

$$[R_2]M^0_{sg}(l_2,l_1,v@c)\ |\ \langle R_2^{t_{k'}}\rangle[\![l_2[N]]\!]\ |\ \langle R_1^{t_{k'}}\rangle[\![l_1[c?(x)P\ |\ M]]\!]$$

does a reduction to

$$[R_3]M^1_{sg}(l_2,l_1,v@c)\ |\ \langle R_2^{t_{k'}}\rangle[\![l_2[N]]\!]\ |\ \langle R_1^{t_{k'}}\rangle[\![l_1[c?(x)P\ |\ M]]\!]$$

where

$$\phi(L_2) = l_2[l_1!\langle v@c\rangle]\ |\ l_2[N]\ |\ l_1[c?(x)P\ |\ M]$$

and

$$H_2' \equiv l_2[l_1!\langle v@c\rangle]\ |\ l_2[N]\ |\ l_1[c?(x)P\ |\ M]$$

By using axiom (S-MONOID-COM), we get

$$H_2' \equiv l_2[l_1!\langle v@c\rangle]\ |\ l_1[c?(x)P\ |\ M]\ |\ l_2[N]$$

By using axiom (R-H-COMM), we get

$$H_2' \equiv l_1[P\{v/x\}|M]\ |\ l_2[N] \equiv H_2$$

By using rule (R-COMM), after reduction directly gives the form of H_2.

b) We can take another possibility of the form that a system L_1 in DR_π^φ can take. In a D_π system H_1 is the form $l_1[c?(x)P\ |\ M]\ |\ l_2[l_1!\langle v@c\rangle\ |N]$. It is possible that M and N contain several output process terms. Theses output terms will have equivalent messages terms at L_1 which are originated at nodes l_1 and l_2 to carry arbitrary values to some channel at various nodes. Therefore L_1 may contain several messages which may be equivalent to one of the output terms in M or N after ϕ abstraction.

2) We will now consider another possibility when a D_π system H_1 is the form
$$n[\text{ if } v = v \text{ then } P \text{ else } Q]$$
and does a reduction using (R-H-MATCH), we get
$$n[\text{ if } v = v \text{ then } P \text{ else } Q] \rightarrow n[P]$$
where $n[P] \equiv H_2$
In one possibility a system term L_1, in $\mathrm{DR}^{\varphi}_{\pi}$, can take a form
$$\langle R^{t_{k'}} \rangle [\![n[\text{ if } v = v \text{ then } P \text{ else } Q]]\!] \equiv L_1$$
for some R such that
$$\phi(L_1) = n[\text{ if } v = v \text{ then } P \text{ else } Q]$$
with an application of rule (R-MATCH) in a well formed configuration $\Gamma_c \rhd L_1$ can do a reduction to
$$\Gamma_c \rhd \langle R^{t_{k'}} \rangle [\![n[P]]\!]$$
Here $L_2 \equiv \langle R^{t_{k'}} \rangle [\![n[P]]\!]$. Further with an application of the function ϕ on L_2 we can get
$$\phi(L_1) = n[P] \equiv H'_2$$

3) We will now consider another possibility when a D_π system H_1 is the form
$$n[\text{ if } v_1 = v_2 \text{ then } P \text{ else } Q]$$
and does a reduction using (R-H-MISMATCH), we get
$$n[\text{ if } v = v \text{ then } P \text{ else } Q] \rightarrow n[Q]$$
where $n[Q] \equiv H_2$
In one possibility a system term L_1, in $\mathrm{DR}^{\varphi}_{\pi}$, can take a form
$$\langle R^{t_{k'}} \rangle [\![n[\text{ if } v_1 = v_2 \text{ then } P \text{ else } Q]]\!] \equiv L_1$$
for some R such that
$$\phi(L_1) = n[\text{ if } v_1 = v_2 \text{ then } P \text{ else } Q]$$
with an application of rule (R-MISMATCH) in a well formed configuration $\Gamma_c \rhd L_1$ can do a reduction to
$$\Gamma_c \rhd \langle R^{t_{k'}} \rangle [\![n[Q]]\!]$$
Here $L_2 \equiv \langle R^{t_{k'}} \rangle [\![n[Q]]\!]$. Further with an application of the function ϕ on L_2 we can get
$$\phi(L_1) = n[Q] \equiv H'_2$$

4) Now we consider the cases of compositional reduction of a D_π system. Let us assume that a D_π system H_1 is of the form $P_1 \mid P_2$. An application of the rule (R-H-CONTX) reduces H_1 to $P'_1 \mid P_2$. Let us assume that a system term in $\mathrm{DR}^{\varphi}_{\pi}$, is of the form $L_1 \mid L_2$ such that $\phi(L_1) = P_1$ and $\phi(L_2) = P_2$. We also assume that a configurations $\Gamma_c \rhd L_1 \mid L_2$ and $\Gamma_c \rhd L_1$ are well formed configurations. By induction we can say that $\Gamma_c \rhd L_1 \longrightarrow \Gamma_c \rhd L'_1$ such that $\phi(L'_1) = P''_1$ for some h, $P''_1 \equiv P'_1$. Therefore using the rule (R-CONTX), we can conclude that $\Gamma_c \rhd L_1 \mid L_2 \longrightarrow \Gamma_c \rhd L'_1 \mid L_2$. We know that $\phi(L'_1 \mid L_2) = \phi(L'_1) \mid \phi(L_2)$. Since $\phi(L_2) = P_2$ and $\phi(L'_1) = P''_1$ therefore $\phi(L'_1 \mid L_2) = P''_1 \mid P_2$. Further we already know that $P''_1 \equiv P'_1$ therefore from the axioms of structural equivalence , we can conclude that $P'_1 \mid P_2 \equiv H_2$.
Same as H_1 is the form of $P_2 \mid P_1$. We can proved similarly.

5) Let us now consider the last case when a D_π system H_1 does a reduction to H_2 using the rule (R-H-STRUCT) because $H'_1 \longrightarrow H'_2$ where $H_1 \equiv H'_1$ and $H_2 \equiv H'_2$. Let us assume that for a system L_1 in $\mathrm{DR}^{\varphi}_{\pi}$, $\phi(L_1) = H_1$. We also assume that $\Gamma_c \rhd L_1$ is a well formed configuration. Since $H_1 \equiv H'_1$ therefore using proposition 1. we can say that there exists a L'_1 such that $\phi(L'_1) = H'_1$ and $L \equiv L'$. Further using lemma.1. We know that $\Gamma_c \rhd L'_1$ is a well formed. Now by induction we can say $H'_1 \longrightarrow H'_2$ implies $\Gamma_c \rhd L'_1 \longrightarrow \Gamma_c \rhd L''_1$ for some L''_1 and h such that $\phi(L''_1) = H''_2$ for some H''_2 such that $H''_2 \equiv H'_2$. We already know that $L_1 \equiv L'_1$ therefore with an application of rule (R-STRUCT). We can say that $\Gamma_c \rhd L_1 \xrightarrow{*} \Gamma_c \rhd L''_1$. We know that $\phi(L''_1) = H''_2$ and since $H''_2 \equiv H'_2$, $H'_2 \equiv H_2$ therefore $H''_2 \equiv H_2$

Lemma.3. In $\mathrm{DR}^{\varphi}_{\pi}$, if a well formed configuration $\Gamma_c \rhd L_1$ does a reduction $\Gamma_c \rhd L_1 \longrightarrow \Gamma_c \rhd L_2$ and $\phi(L_1) = H_1$ where H_1 is a D_π system then either there exists a D_π system H_2 such that $H_1 \longrightarrow H_2$ and $\phi(L_2) \equiv H_2$ or $\phi(L_2) \equiv H_1$.

Proof. By induction on the inference of reduction $\Gamma_c \rhd L_1 \longrightarrow \Gamma_c \rhd L_1$ of well formed configurations in $\mathrm{DR}^{\varphi}_{\pi}$ and syntactic analysis of $\phi(L_1) = H_1$. There are various possibilities and we we will take each of them as follows:

1) Let us take a case when a system L_1, in $\mathrm{DR}^{\varphi}_{\pi}$, is of the form $\langle R^{t_{k'}} \rangle [\![n[m!(v@c)|P]|N]\!]$. A well formed configuration $\Gamma_c \rhd L_1$ does a reduction to
$$\Gamma_c \rhd [R]\, M^0_{sg}(n, m, v@c)\, \langle R^{t_{k'}} \rangle [\![n[P]|N]\!]$$
using rule (R-OUT) in fig. 7, Let a D_π system H_1 is of the form $n[m!(v@c)|P]|N$ and by definition of ϕ we know that
$$\phi(L_1) = \phi(\langle R^{t_{k'}} \rangle [\![n[m!(v@c)|P]|N]\!]) = n[m!(v@c)|P]|N$$
Further by definition of ϕ we know that
$$\phi(L_2) = \phi([R]\, M^0_{sg}(n, m, v@c)\, \langle R^{t_{k'}} \rangle [\![n[P]|N]\!]) = n[m!(v@c)|P]|N$$
now by an application of axiom (S-H-MERGE), We can conclude that
$$n[m!(v@c)|P]|N \equiv H_1$$

2) In another case we consider that a system term L_1, in $\mathrm{DR}^{\varphi}_{\pi}$, is of the form $[R_1]M^h_{sg}(n, m, v@c)|\langle R_2{}^{t_{k'}} [\![N]\!] |S$. We consider a case when using the rule (R-MSG-FWD), the well formed configuration $\Gamma_c \rhd L_1$ does a reduction to $\Gamma_c \rhd [R_2]M^{h+1}_{sg}$ $(n, m, v@c)|\langle R_2{}^{t_{k'}} [\![N]\!] |S$. Let a D_π system H_1 be of the form $n[m!\langle v@c\rangle]|N|S$ where $\phi(L_1) = H_1$. Clearly
$$\phi(L_1) = \phi([R_1]M^h_{sg}(n, m, v@c)|\langle R_2{}^{t_{k'}} [\![N]\!] |S)$$
$$\phi(L_1) = n[m!\langle v@c\rangle]|N|S \equiv H_1$$
Further by definition of ϕ we know that
$$\phi(L_2) = \phi([R_2]M^{h+1}_{sg}(n, m, v@c)|\langle R_2{}^{t_{k'}} [\![N]\!] |S)$$
$$\phi(L_2) = n[m!\langle v@c\rangle]|N|S \equiv H_1$$

3) Now let us take a case when a system L_1, in $\mathrm{DR}^{\varphi}_{\pi}$, is of the form

$[R]M^h_{sg}(n,m,v@c)|\langle R^{t_{k'}}\rangle[\![m[c?(x)P|Q]|N]\!]$. The well formed configuration $\Gamma_c \triangleright L_1$ does a reduction using the rule (R-COMM) to another well formed configuration $\Gamma_c \triangleright \langle R^{t_{k'}}\rangle[\![m[P\{v/x\}|Q]|N]\!]$. Let us assume that $L_2 = R^{t_{k'}}\rangle[\![m[P\{v/x\}|Q]|N]\!]$. Clearly

$$\phi(L_1) = n[m!\langle v@c\rangle]\,|m[P\{v/x\}|Q]|N$$

By using the rule (R-H-COMM), The D_π system $n[m!\langle v@c\rangle]\,|m[P\{v/x\}|Q]|N$ can reduce to $m[P\{v/x\}|Q]|n[\varepsilon]|N$ which is structurally equivalent to $m[P\{v/x\}|Q]|N \equiv H_1$. We know that $\phi(L_2) = m[P\{v/x\}|Q]|N \equiv H_1$

4) Now we take another case where a system term L_1, in DR^φ_π, is of the form either $\Gamma_c \triangleright \langle {R_1}^{t_{k'+1}}\rangle[M]|S$ or $\Gamma_c \triangleright \langle {R_2}^{t_{k'+1}}\rangle[N]|T$. We can take one form $\Gamma_c \triangleright \langle {R_1}^{t_{k'+1}}\rangle[M]|S$. The well formed configuration $\Gamma_c \triangleright L_1$ reduces using the rule (R-TABLE-UPDATE) to another well formed configuration $\Gamma_c \triangleright \langle {R'_1}^{t_{k'+1}}\rangle[M]|S$ and by definition of ϕ we know that

$$\phi(L_1) = M|S \equiv H_1$$
$$\phi(L_2) = M|S \equiv H_1$$

5) Now we take another case where a system term L_1, in DR^φ_π, is of the form $\Gamma_c \triangleright \langle R^{t_{k'}}\rangle[\![n[\text{ if } v = v \text{ then } P \text{ else } Q]]\!]$. The well formed configuration $\Gamma_c \triangleright L_1$ reduces using the rule (R-MATCH) to another well formed configuration $\Gamma_c \triangleright \langle R^{t_{k'}}\rangle[\![n[P]]\!]$ and by definition of ϕ we know that

$$\phi(L_1) = n[\text{ if } v = v \text{ then } P \text{ else } Q]$$
$$\phi(L_1) = n[P] \equiv H_1 \quad \text{where value is true then result is } P$$
$$\phi(L_2) = n[P] \equiv H_1$$

6) Now we take another case where a system term L_1, in DR^φ_π, is of the form $\Gamma_c \triangleright \langle R^{t_{k'}}\rangle[\![n[\text{ if } v_1 \neq v_2 \text{ then } P \text{ else } Q]]\!]$. The well formed configuration $\Gamma_c \triangleright L_1$ reduces using the rule (R-MISMATCH) to another well formed configuration $\Gamma_c \triangleright \langle R^{t_{k'}}\rangle[\![n[Q]]\!]$ and by definition of ϕ we know that

$$\phi(L_1) = n[\text{ if } v_1 \neq v_2 \text{ then } P \text{ else } Q] = n[Q] \equiv H_1$$
$$\phi(L_1) = n[Q] \equiv H_1$$

7) Now let us take compositional cases. First suppose a system in in DR^φ_π, is of the form $L_1 \mid L_2$ and a D_π system is of the form $H_1 \mid H_2$ where $\phi(L_1) = H_1$ and $\phi(L_2) = H_2$. By definition of the ϕ we can clearly see that $\phi(L_1 \mid L_2) = H_1 \mid H_2$. Now take the case when the well formed configuration in DR^φ_π, $\Gamma_c \triangleright L_1 \mid L_2$ does a reduction using the rule (R-CONTX) to another well formed configuration $\Gamma_c \triangleright L'_1 \mid L_2$, the well formed configuration $\Gamma_c \triangleright L_1$ does a reduction to $\Gamma_c \triangleright L_1 \longrightarrow \Gamma_c \triangleright L'_1$ for some h. By induction we know that
   a) either $H_1 \longrightarrow H'_1$ such that $\phi(L'_1) = H'_1$
   b) or $\phi(L'_1) = H_1$

   From the reduction rule reduction rule (R-H-CONTX), the D_π system $H_1 \mid H_2$ can reduce to $H'_1 \mid H_2$. We already know that either $\phi(L'_1) = H'_1$ or $\phi(L'_1) = H_1$, therefore by definition of ϕ we know that, either $\phi(L'_1 \mid L_2) \equiv H'_1 \mid H_2$ or $\phi(L'_1 \mid L_2) \equiv H_1 \mid H_2$. The other case in rule (R-CONTX) is exactly similar.

8) let us take second compositional case where a well formed configuration in DR^φ_π, $\Gamma_c \triangleright L_1$ does a reduction to $\Gamma_c \triangleright L_2$ using the rule (R-STRUCT)because

$$\Gamma_c \triangleright L'_1 \longrightarrow \Gamma_c \triangleright L'_2$$

for some h where $L_1 \equiv L'_1$ and $L_2 \equiv L'_2$. Let us assume that a D_π system H_1 is such that $\phi(L_1) = H_1$. As $L_1 \equiv L'_1$ therefore from proposition 2, we know that $\phi(L_1) \equiv \phi(L'_1)$. Now by induction we know that $\Gamma_c \triangleright H_1 \longrightarrow \Gamma_c \triangleright H_2$ for some h the D_π system term H_2 such that either $\phi(L'_2) \equiv H_2$ or $\phi(L'_2) \equiv H_1$. Since it is known that $L_2 \equiv L'_2$ and using proposition 2 we know that $\phi(L'_2) \equiv \phi(L_2)$ therefore either $\phi(L_2) \equiv H_2$ or $\phi(L_2) \equiv H_1$.

Theorem 2. In DR^φ_π, if a well formed configuration $\Gamma_c \triangleright L_1$ does a reduction $\Gamma_c \triangleright L_1 \longrightarrow \Gamma_c \triangleright L_2$ and $\phi(L_1) = H_1$ where H_1 is a D_π system if and only if either there exists a D_π system H_2 such that $H_1 \longrightarrow H_2$ and $\phi(L_2) \equiv H_2$ or $\phi(L_2) \equiv H_1$.

*Proof.***(OUTLINE)** By using lemma.2 and lemma.3.

VIII. Conclusion

We described the syntax and reduction semantics for the calculus DR^φ_π that gives a realistic model of distributed network with incorporation of dynamic updation in routing table. We have explained an example to demonstrate reduction rules and also demonstrate that how routing table is updated across the network by using distance vector routing updates. This equivalence has been proved with the well known distributed π-calculus, D_π after abstracting away the unnecessary details from DR^φ_π. Now we have proved that both DR^φ_π and D_π systems are reduction equivalent after abstracting away the details of routers and paths from DR^φ_π.

This calculus implemented routing table updates via distance vector routing methods and included the exclusive feature of this particular calculus with a novel notation ($\longleftrightarrow$) to depict the exchange of routing tables at global time $t = t_{k'}$. Thus all the routing tables are updated dynamically due to this paths are also changed and ensure the best optimal path. This is more close to the actual real distributed network.

In DR^φ_π, the δ function used in the calculus is abstract function which does not allow a real value in the network. Also the calculus does not support dynamic node creation which can be a possible future work for further research. In this paper, we have shown that specification coincides its implementation in our next work will justify the calculus using bisimulation based proof technique.

References

[1] R. Milner., *Communicating and mobile systems: The π -Calculus*. Cambridge University Press, 1999.

[2] M. Gaur., "A routing calculus for distributed computing." *In Elena Troubitsyna, editor, Proceedings of Doctoral Symposium held in conjunction with Formal Methods 2008,Turku Centre for Computer Science General Publication*, vol. 48, pp. 23–32., May 2008.

[3] M. Gaur, "A routing calculus: Towards formalising the cost of computation in a distributed computer network," PhD, Informatics, University of Sussex, U.K., December 2008.

[4] M. Gaur and M. Hennessy, ". counting the cost in the picalculus (extended abstract)." *Electronic Notes in Theoretical Computer Science (ENTCS)*, pp. 229:117–129, 2009.

[5] M. Hennessy., *A distributed Pi-Calculus.* Cambridge University Press, 2007.

[6] D. Sangiorgi and DavidWalker., *The π -Calculus: A theory of Mobile Processes.* Cambridge University Press, 2001.

[7] J. Parrow., *An Introduction to the π -Calculus*, Dep. Teleinformatics,Royal Institue of Technology,Stockholm.

[8] M. Gaur, S. J. Gay, and I. Mackie, "A routing calculus with flooding updates," in *Proceedings of the 11th International Conference on Distributed Computing and Internet Technology - Volume 8956*, ser. ICDCIT 2015. New York, NY, USA: Springer-Verlag New York, Inc., 2015, pp. 181–186. [Online]. Available: http://dx.doi.org/10.1007/978-3-319-14977-6_12

[9] R. Milner, *Communicating and mobile systems: The Pi Calculus*. Cambridge: Cambridge University Press, 1999.

[10] M. Gaur., "A routing caculus towards formalising the cost of computation in a distributed computer netwok," Ph.D. dissertation, University of Sussex, 2008.

[11] U. Montanari and M. Sammartino, "Network-conscious π-calculus - A model of pastry," *Electr. Notes Theor. Comput. Sci.*, vol. 312, pp. 3–17, 2015. [Online]. Available: https://doi.org/10.1016/j.entcs.2015.04.002

[12] R. D. Nicola, G. L. Ferrari, and R. Pugliese, "Klaim: a kernel language for agents interaction and mobility," *IEEE Transactions on Software Engineering*, 1998.

[13] L. Tang and Q. Liu, "A survey on distance vector routing protocols," *CoRR*, vol. abs/1111.1514, 2011. [Online]. Available: http://arxiv.org/abs/1111.1514

[14] J. J. Garcia-Luna-Aceves, "A unified approach to loop-free routing using distance vectors or link states," *SIGCOMM Comput. Commun. Rev.*, vol. 19, no. 4, pp. 212–223, Aug. 1989. [Online]. Available: http://doi.acm.org/10.1145/75247.75268

[15] M. K. Marina and S. R. Das, "Ad hoc on-demand multipath distance vector routing," *SIGMOBILE Mob. Comput. Commun. Rev.*, vol. 6, no. 3, pp. 92–93, Jun. 2002. [Online]. Available: http://doi.acm.org/10.1145/581291.581305

[16] I. Vukotic and S. Scepanovic, "Description of distance vector routing protocols using mathematical means," 01 2013.

[17] A. S. Tanenbaum., *Computer Networks.*, 4th ed. Upper Saddle River,New Jersey,: Pearson Education, Inc.,, 2003.

[18] C. Cheng, R. Riley, S. P. R. Kumar, and J. J. Garcia-Luna-Aceves, "A loop-free extended bellman-ford routing protocol without bouncing effect," in *Symposium Proceedings on Communications Architectures &Amp; Protocols*, ser. SIGCOMM '89. New York, NY, USA: ACM, 1989, pp. 224–236. [Online]. Available: http://doi.acm.org/10.1145/75246.75269

[19] D. Walden, "The bellman-ford algorithm and "distributed bellman-ford," 01 2008.

[20] K. R. Hutson, T. L. Schlosser, and D. R. Shier, "On the distributed bellman-ford algorithm and the looping problem," vol. 19, pp. 542–551, 11 2007.

TokenSign: Using Revocable Fingerprint Biotokens and Secret Sharing Scheme as Electronic Signature

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***Abstract*—Electronic signature is a quick and convenient tool, used for legal documents and payments since business practices revolutionized from traditional paper-based to computer-based systems. The growing use of electronic signature means they are used in many applications daily, both in government and private organizations such as financial services, where an electronic signature is taken from group of people at once to cash checks or perform a transaction approval. However, non-repudiation and authentication issues remain highlighted concerns for electronic signature. To overcome these obstacles, we propose a TokenSign system that uses revocable fingerprints biotokens with Secret Sharing as electronic signature. TokenSign maintains two layers of security. First, TokenSign scheme transforms and encrypts a user fingerprint data. Second, TokenSign embeds a shared secret inside the encrypted fingerprints. Then, TokenSign Scheme distributes all shares of electronic signatures over multiple clouds. During the matching/signing process, TokenSign utilizes threading to do parallel matching for the fingerprints in its secure encrypted form without decrypting the data. Finally, TokenSign scheme applies Secret Sharing scheme to compute the shared secret, producing an electronic signature. As a result, our experiments show that TokenSign scheme achieves comparable accuracy and improves performance comparing to the two baselines.**

Keywords*—*Signature; Fingerprint; Electronic; Security

I. Introduction

Electronic signature affords many benefits for individuals and organizations regarding signing documents or filing and electronic payment. Online document signing has been used in many applications daily, either in governments or private organizations [1]. These services have obvious advantages such as speeding up the work process and allowing for high production [2]. Electronic payment, such as Apple pay, Samsung pay, etc., is considered the most growing technology in financial services and has impacted the business revolution and increase the online e-commerce [3]. The growth of electronic payment has many reasons behind it. For an organization, it is a trusted, easy, fast and convenient way to receive payment from customers; for an individual, it provides convenience in that customers do not need to carry cash for shopping. Therefore, these huge benefits attract many technology companies and researchers to invent more and more tools/applications for financial services [4].

While electronic signature provides a great verity of advantages, the non-repudiation and authentication issues remain a research challenge. Because a signature is not performed face-to-face, there is a concern about non-repudiation issues in electronic signature when one party denies his/her signature [5]. Regarding electronic payment system, according to Abrazhevich et al [6], there are some limitations in electronic payment systems such as usability, security, and trust. Kahn et al [7] shed light on the effect of theft incidents on online banking and how it could limit the electronic payment systems. On the other hand, authentication issues remain a research challenge in electronic signature and electronic payment. The invention [8] implemented an authentication method of electronic signature by generating a digital work fingerprint and a representation file which were transmitted to the client to be signed. In terms of electronic payment authentication, Kalakota et al [9] describes the fraud against e-commerce which increase the cyberattacks. Thus, electronic payment needs authentication methods that are secure and reliable [9]. Biometrics have been suggested as a replacement for the traditional username/password in electronic payment [10]. Biometrics provide a unique identity which enhance the security and build trust to a greater degree [11]. However, despite the biometrics advantages, there are some concerns regarding privacy and security, especially if biometric data get compromised [12].

To address the privacy and security issues, particularly the non-repudiation and authentication of electronic signature, we propose the TokenSign scheme. TokenSign is a new electronic signature for legal documents and financial services using a fingerprint as a signature. Fingerprints are suggested as each is unique; no two people share the same fingerprint pattern. TokenSign scheme utilizes the revocable fingerprint biotokens (Biotope) [13], Bipartite token [14], and the secret-sharing scheme [15] while performing an electronic signature online for legal documents and financial services. Particularly, our aim is designing, implementing, and evaluating a TokenSign system. Then comparing our system with the approaches used in the underlying algorithm wherein the biometric data (i.e. fingerprint) is not encrypted for matching. TokenSign utilizes the revocable fingerprint biotokens (Biotope) [13] to perform matching in secure encryption form without decrypting biometric data (i.e. fingerprint), using shares to separately protect the shared secret (transaction reference numbers/user ID) to perform electronic signature for legal documents and financial services. During the enrollment process, TokenSign transforms the biometric data (i.e. fingerprint) into encrypted data using the revocable fingerprint biotokens (Biotope) [13]. Then, TokenSign embeds a shared secret (i.e. reference numbers/user ID) inside the encrypted fingerprint data using Bipartite token [14] and secret sharing scheme [15]. During the matching/signing process, TokenSign matches the fingerprint data in encoded mode, which provides confidentiality and non-repudiation. TokenSign also provides authentication when the threshold shares of secret (i.e. reference numbers/user ID) return a valid secret (token). In sum, this combination of the two layers of security ensure no attacks are successful against the fingerprint data nor the embedded shared data inside the fingerprint data.

The remainder of this paper is organized as follows: First, we describe the previous literature review in section II. The objectives of TokenSign are discussed in section III. In section IV, we present the proposed TokenSign algorithm. We describe the experimental design in section V. While in section VI, we discuss and evaluate the experimental results. Finally, we conclude the paper in section VII.

II. Background

A. Non-Repudiation

Non-repudiation is a situation where an action cannot be denied from both parties (sender and receiver). In the other word, non-repudiation is the ability to prove something happen between two parties, especially in electronic signature for legal document or financial transactions. McCullagh et al [5] discusses the non-repudiation concerns of electronic signature when a signature is not performed face-to-face. Also, they addressed the legal and crypto meaning of non-repudiation and model law for trusted system. McCullagh et al [5] concluded that the electronic signature can be secure and trusted if it is equivalent to paper-based environment. In terms of electronic payment system, Abrazhevich et al [6] outlines the important role of electronic payment system in the future and addresses the limitations such as usability, security, and trust. They concluded their study with recommended design for electronic payment system which has better insight of a users perspective. Kahn et al [7] focus on the effect of theft incidents on online banking. In particular, their study analyzed the difference between two types of identity theft with payment security assessments to capture the effect of safety on payment [7].

B. Authentication

Authentication here is to prove that the person who is performing the electronic signature is the right person. The authentication issue is not a new research problem; in fact, it has been studied deeply. The invention [8] outlines their authentication method where the client received digital work fingerprint and a representation file to sign, while in electronic payment authentication, Kalakota et al [9] describes the fraud in e-commerce. These frauds increase the cyberattacks against electronic payments. To have more efficient tool for authentication in electronic payment, Clodfelter et al [10] suggests biometrics. Kaleist et al [11] outlines that biometric as a unique identity in order to enhance the security and trust for electronic payment.

C. Security and Privacy

Even though biometrics data (i.e. fingerprints) afford a wide variety of advantages such as non-repudiation and authentication, the privacy and security of biometrics data itself is the main concern [12]. Biometrics data considered a very sensitive and has been targeted for many attacks, including the adversary attack and the intrinsic failure [13] [12]. Also, biometric data is vulnerable for doppelganger attacks and biometric dilemma [13] [16]. To protect biometrics data from such attacks, many approaches proposed in the literature. Some of these schemes use encryption methods to provide security and privacy for biometric [17]. These approaches are vulnerable for attacks in the matching process when the biometric data needs to be decrypted for matching [12] [18]. On the other hand, template protection approaches have been introduced to secure the biometrics data. These template approaches are classified into four distinct categories: non-invertible transform [19], salting [20], key generating biometrics cryptosystems [21] [22], and key binding biometrics cryptosystems [23] [24].

III. TokenSign Objectives

The main goal of TokenSign scheme is to introduce a new electronic signature by considering the fingerprint a signature to replace the common handwriting signature. In this section we explore the objectives of TokenSign in non-repudiation, authentication, security, and privacy.

A. Non-Repudiation and Authentication

TokenSign scheme provides non-repudiation and authentication by using Biometric data (fingerprint), the revocable fingerprint biotokens (Biotope) [13], Bipartite token [14], and Secret Sharing Scheme [15]. Any time a user wants to perform a signature, a user must provide his/her fingerprint data. In this case, a user cannot deny his/her signature. From the point of view of a government or other organization, the biometric data is a highly acceptable tool for authentication as they can verify who signed, meaning the signer is the right/authenticated user. TokenSign scheme utilizes Secret Sharing Scheme [15] to authenticate the biometric data (fingerprint) belongs to the same person, providing another layer of authentication. To achieve this goal, TokenSign schemes hide a secret inside an encrypted fingerprint data. In the matching/signing process, this secret must be released and computed to match the secret on record.

B. Security and Privacy

TokenSign scheme provides security and privacy for the biometric (fingerprint) by utilizing the revocable fingerprint biotokens (Biotope) [13] and Bipartite token [14]. In this case, TokenSign scheme does not use the biometric data (fingerprint) raw data, providing more security and privacy for the fingerprint data. Moreover, all fingerprint data stored in TokenSign system are revocable biotokens, meaning they can be revoked at any time by a user or its organization. In addition, TokenSign scheme hides a time stamp for each biotoken; this time stamp gives more security by indicating how long a biotoken has been in use. That means each biotoken can be valid only for a time period as specified by organizations. For usability, TokenSign scheme can create new biotokens for expired biotokens without taking the fingerprint raw data again from users.

IV. Design of TokenSign Scheme Algorithm

In our design, we present the architecture of TokenSign scheme in enrollment and matching/signing process. The TokenSign scheme consist of two protocols: single protocol and group protocol. Single protocol is used to perform a signature for one person while group protocol is used to perform a signature for a group of people.

Plain Text			Encrypted			share of *secret* (User ID)
k	j	θ_{kj}	d_{kj}	β_1	β_2	

Fig. 1. The layout of the pair table data store in the cloud. Each row of the pair table data contains of d_{k_j}, β_1, β_2, k, j, θ_{kj} combined with share of secret of the user ID.

Plain Text			Encrypted			share of *secret* (transaction number)
k	j	θ_{kj}	d_{kj}	β_1	β_2	

Fig. 2. The layout of the pair table data store in the cloud. Each row of the pair table data contains of d_{k_j}, β_1, β_2, k, j, θ_{kj} combined with share of secret of the transaction number.

A. Enrollment Process

TokenSign scheme algorithm has two protocols: single signature and group signature. Single signature is used for one user while group signature is used for multiple users. Algorithm 1 and 2 explain the details of TokenSign process.

First to occur in single signature protocol, TokenSign scheme takes multiple gallery fingerprint images (N) from each user to extract the minutia points files. Second, TokenSign scheme creates a gallery pair table, as in the NIST Bozorth Matcher Algroithm [25], for each minutia points file. Third, TokenSign scheme uses the revocable fingerprint biotokens (Biotope) [13] to encrypt the gallery pair table. Then TokenSign scheme takes the user ID and applies Secret Sharing Scheme [15] in order to split the user ID into multiple shares equal to the number of a users images (N) while determining the threshold number to recover the user ID where N is always greater than or equal to K. Finally, TokenSign scheme uses a Bipartite token [14] to hide each share of secret (the user ID) inside the encrypted fingerprint data (i.e. pair table). Figure 1 shows the structure of single signature protocol.

Data: Gallery fingerprint image g_i, Where i=1,2,3,...,n
Result: Encrypted gallery fingerprint (pair-table t_i)
for (*each gallery fingerprint impression* g_i) {
  extract minutia points m_i from fingerprint image g_i;
  compute minutia file mf_i from minutia points m_i;
  create the gallery pair table t_i from the minutia file mf_i;
  encrypt the gallery pair table t_i using Biotope [13];
  create a secret and determine all shares and the threshold using SSS [15] ;
  hide a secret inside the encrypted gallery pair-table t_i using Bipartite [14] ;
  upload the encrypted gallery fingerprint (pair-table t_i) over multiple clouds;

Algorithm 1: Algorithm of enrollment operation of TokenSign for single and group protocols. For single protocol, the algorithm creates a secret (user ID) and hides it inside one user fingerprint data. While in group protocol, the algorithm creates a secret (transaction number as a random) and hides it inside multiple users fingerprint data.

In group signature protocol, the same steps are followed, but with minor modification to how they are executed. First, TokenSign scheme takes gallery fingerprint images from group of users (N fingerprints from N users) to extract the minutia points files. Then, TokenSign scheme creates a secret (transaction number) for all users in a group and applies Secret Sharing Scheme [15] in order to split this secret into multiple shares equal to all users in a group while determine the threshold number (K) to recover the secret key back, where N is always greater than or equal to K. Finally, TokenSign scheme using Bipartite token [14] to hide each share of the secret inside each encrypted fingerprint data of each user in a group. Figure 2 shows the structure of group signature protocol.

Data: Probe fingerprint image p_i where i=1,2,3,...,n
Result: Electronic Signature (Print the secret (transaction number/user ID) and (time/data)
for (*each probe fingerprint impression* p_i) {
  extract minutia points m_i from fingerprint image p_i;
  compute minutia file mf_i from minutia points m_i;
  construct the probe pair-table t_i from the minutia file mf_i;
  encrypt the probe pair-table t_i using Biotope [13];
for (*all encrypted probe pair-table* t_i) {
  match each encrypted probe pair-table t_i in parallel against all encrypted gallery pair-table t_i ;
  if *match == true* **then**
    release the threshold secret hidden inside all encrypted gallery pair-table t_i;
    compute the threshold secret using SSS [15] ;
  if *threshold secret shares in gallery == right secret* **then**
    confirm the two fingerprints (probe and gallery) belongs to the same person;
    perform the electronic signature by printing the user ID/transaction number;

Algorithm 2: Algorithm of matching/signing operation of TokenSign for single and group protocols. For single protocol, the algorithm matches one user probe fingerprint data against his/her all gallery fingerprint data and releases the threshold shared secret (user ID). Meanwhile, in group protocol, the algorithm matches multiple users probe fingerprint data against their all gallery fingerprint data and releases the threshold shared secret (transaction number shared by the group). For both protocols, the TokenSign algorithms print the secret number and time/data.

B. Matching Process

In the matching/signing process, TokenSign scheme will follow the same steps in enrollment process to construct an encrypted probe pair table. In the single signature, TokenSign scheme matches the encrypted probe pair table against the threshold of the encrypted gallery pair tables for one user fingerprint data in parallel. The matching/signing process performs in encrypted space. If the matching is successful, TokenSign scheme computes the secret (Shared users ID) from the threshold shares by applying the Sharing Secret Scheme [15]. Then, the TokenSign scheme can perform the single signature for a user by printing user ID, time, and date. In the group signature, TokenSign scheme matches a group encrypted probe pair tables against the threshold of group encrypted gallery pair tables in parallel. The matching process performs in encrypted space. If the matching is successful, TokenSign scheme computes the secret (shared secret/transaction number) from the threshold shares by applying the Sharing Secret Scheme [15]. Then the TokenSign scheme can perform the group signature for group of users by printing the secret (transaction number), time and, date.

V. Experimental Design

The main objective of our experiment is to compare three systems: TokenSign (group protocol) scheme against two baselines named the revocable fingerprint biotokens (Biotope) [13] and our design baseline called TokenSign (single protocol). We conduct the experiment using threading for parallel matching and using C++ and Python as the programming languages. We use the Amazon cloud to do our experiment. We use the dataset (FV C2002Db2 a) [26] and upload all encrypted gallery fingerprint data into Amazon AWS S3 using Python Amazon S3 API. For storage, we use Paris, N. Virginia, London, N. California, Sydney, Ireland, Ohio, and Tokyo. During the matching process, we transfer our executable files using FileZilla to Amazon EC2 servers. Then we use the Python boto library to connect Amazon S3 with Amazon EC2 instance. Finally, we match in parallel between probe encrypted fingerprint against gallery encrypted fingerprint. The result of this experiment is the average of twenty runs.

A. Baseline Setup

We use two baselines in our experiment: TokenSign (single protocol) scheme and the revocable fingerprint biotokens (Biotope) [13]. For the Biotope [13] baseline, we implement and conduct our experiment in the Amazon cloud instead of local storage. By conducting our scheme in the cloud, we have a fair experiment. For the second baseline, we design our baseline similar to our scheme (TokenSign for group protocol). In this baseline (TokenSign for single protocol), we match a single user against his/her encrypted fingerprints data in the cloud in parallel, calculate the time cost, and compare it to our scheme (TokenSign for group protocol).

B. TokenSign (Group Protocol) Setup

For the TokenSign (group protocol), our designed is similar to baseline (TokenSign for single protocol). In our scheme (TokenSign for group protocol), we matched multiple of users against their encrypted fingerprint data in the cloud in parallel and calculated the time cost and compared it to both baselines.

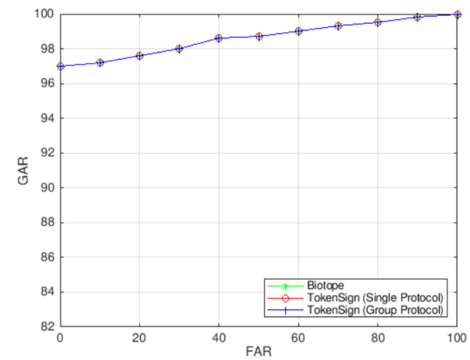

Fig. 3. The ROC curve comparing TokenSign and baseline scheme accuracy.

TABLE I. The Comparison of the Two Algorithms (TokenSign and Biotope [13])

P-value	TokenSign (Single protol)	TokenSign (Group Protocol)
Biotope	2.10E-16	2.10E-16

VI. Experiment Evaluation

In this experiment, the main goal is to prove that TokenSign maintains compatible accuracy while increasing the matching speed. To prove this claim, we conducted two experiments: accuracy evaluation and speed evaluation. When then evaluate if the TokenSign achieves its goal in increasing speed and compatible accuracy. Lastly, we conclude if the result support or reject the hypothesis claim.

A. Accuracy Evaluation

In this section, we evaluated TokenSign (Group Protocol) against the revocable fingerprint biotokens (Biotope) [13] and our designed baseline TokenSign (Single Protocol). We ran the experiment and evaluated the genuine acceptance rate (GAR) and the false acceptance rate (FAR) to prove our scheme maintained compatible accuracy comparing to both baselines. Figure 3 shows that TokenSign (Group Protocol) scheme achieved promising results when compared to both baselines where GRA is equal to 97 while FAR is equal to zero. Thus, this result support our hypothesis claim. Figure 3 shows the ROC curve comparing TokenSign scheme with both baselines.

B. Speed Evaluation

In the speed evaluation, we evaluated TokenSign (Group Protocol) with the revocable fingerprint biotokens (Biotope) [13] and our designed baseline TokenSign (Single Protocol). We ran the experiment of identification (1:N) in parallel to prove our scheme maintained increased speed when compared to both baselines. For the statistical test, the null hypothesis Ho is that the time for the baseline is less than or equal to TokenSign (Group Protocol). Table I illustrates the p-values from the ANOVA F-test, which rejects the null hypothesis of 20 runs, using a one-way ANOVA test. Table II and Figure 4 show the increased speed results when TokenSign scheme is compared with Biotope baseline.

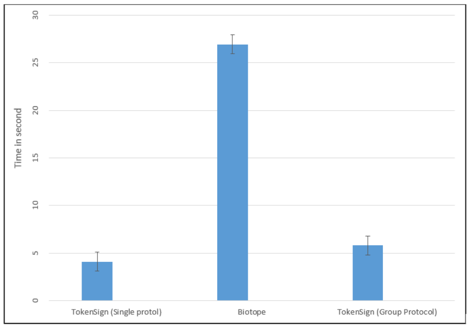

Fig. 4. The average matching time (with the error bars represent the standard deviation) comparing the two algorithms (TokenSign and Biotope [13])

TABLE II. THE AVERAGE MATCHING TIME AND STANDARD DEVIATION OF THE TWO ALGORITHMS (TOKENSIGN AND BIOTOPE [13])

	Biotope	TokenSign (Single protol)	TokenSign (Group Protocol)
AVE	26.93	4.09	5.81
STD	0.307	0.209	0.202

VII. CONCLUSION

This paper represents the design, implementation, and evaluation of a TokenSign system, comparing it with the approaches used in underlying algorithm. TokenSign is a new electronic signature for legal documents and financial services that uses a fingerprint as a signature. TokenSign shows a significant improvement in performance besides providing non-repudiation, authentication, security, and privacy. Our experiments show that applying Bipartite token algorithm and secret sharing scheme to underling algorithm of electronic signature was statistically faster and accurate comparing to the two baselines. In addition, TokenSign scheme utilizes cloud computing to process and compute big data like biometrics data of electronic signature to provide scalability. Future work is to use different fingerprint matcher algorithm for electronic signature and deploy these electronic signature systems on smart devices platforms.

REFERENCES

[1] M. J. Moon, "The evolution of e-government among municipalities: Rhetoric or reality?" *Public Administration Review*, vol. 62, no. 4, pp. 424–433, 2002.

[2] T. Anderson, L. Peterson, S. Shenker, and J. Turner, "Overcoming the internet impasse through virtualization," *Computer*, vol. 38, no. 4, pp. 34–41, April 2005.

[3] O. Ogbanufe and D. J. Kim, "Comparing fingerprint-based biometrics authentication versus traditional authentication methods for e-payment," *Decision Support Systems*, vol. 106, pp. 1 – 14, 2018.

[4] J. Bughin, M. Chui, and J. Manyika, "Clouds, big data, and smart assets: Ten tech-enabled business trends to watch," p. 7586, 2010.

[5] A. McCullagh and W. Caelli, "Non-repudiation in the digital environment," *First Monday*, vol. 5, no. 8, 2000.

[6] D. Abrazhevich, "Electronic payment systems: a user-centered perspective and interaction design," 2004.

[7] C. Kahn and J. Linares Zegarra, "Identity theft and consumer payment choice: Does security really matter?" *Journal of Financial Services Research*, vol. 50, no. 1, pp. 121–159, 8 2016.

[8] R. Daouphars, J.-M. Desperrier, and L. Fourni, "Electronic signature authentication," Jun 2014.

[9] R. Kalakota and A. B. Whinston, *Electronic Commerce: A Manager's Guide*. Boston, MA, USA: Addison-Wesley Longman Publishing Co., Inc., 1997.

[10] R. Clodfelter, "Biometric technology in retailing: Will consumers accept fingerprint authentication?" *Journal of Retailing and Consumer Services*, vol. 17, no. 3, pp. 181 – 188, 2010, new Technologies and Retailing: Trends and Directions.

[11] V. F. K. Ph.D., "Building technologically based online trust: Can the biometrics industry deliver the online trust silver bullet?" *Information Systems Management*, vol. 24, no. 4, pp. 319–329, 2007.

[12] A. K. Jain, K. Nandakumar, and A. Nagar, "Biometric template security," *EURASIP J. Adv. Signal Process*, vol. 2008, pp. 113:1–113:17, Jan. 2008.

[13] T. E. Boult, W. J. Scheirer, and R. Woodworth, "Revocable fingerprint biotokens: accuracy and security analysis," in *2007 IEEE Conference on Computer Vision and Pattern Recognition*, June 2007, pp. 1–8.

[14] W. J. Scheirer and T. E. Boult, "Bipartite biotokens: Definition, implementation, and analysis," in *Advances in Biometrics*, M. Tistarelli and M. S. Nixon, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009, pp. 775–785.

[15] A. Shamir, "How to share a secret," *Commun. ACM*, vol. 22, no. 11, pp. 612–613, Nov. 1979.

[16] W. J. Scheirer, B. Bishop, and T. E. Boult, "Beyond pki: The biocryptographic key infrastructure," in *The IEEE International Workshop on Information Forensics and Security (WIFS)*, December 2010.

[17] [Online]. Available: http://www.griaulebiometrics.com/enus/ biometric-framework

[18] W. J. Scheirer and T. E. Boult, "Cracking fuzzy vaults and biometric encryption," in *2007 Biometrics Symposium*, Sept 2007, pp. 1–6.

[19] N. K. Ratha, S. Chikkerur, J. H. Connell, and R. M. Bolle, "Generating cancelable fingerprint templates," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 29, no. 4, pp. 561–572, Apr. 2007. [Online]. Available: http://dx.doi.org/10.1109/TPAMI.2007.1004

[20] A. B. J. Teoh, A. Goh, and D. C. L. Ngo, "Random multispace quantization as an analytic mechanism for biohashing of biometric and random identity inputs," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 28, no. 12, pp. 1892–1901, Dec 2006.

[21] Y.-J. Chang, W. Zhang, and T. Chen, "Biometrics-based cryptographic key generation," pp. 2203–2206 Vol.3, June 2004.

[22] C. Vielhauer, R. Steinmetz, and A. Mayerhofer, "Biometric hash based on statistical features of online signatures," pp. 123–126 vol.1, 2002.

[23] A. Juels and M. Wattenberg, "A fuzzy commitment scheme," in *Proceedings of the 6th ACM Conference on Computer and Communications Security*, ser. CCS '99. New York, NY, USA: ACM, 1999, pp. 28–36. [Online]. Available: http://doi.acm.org/10.1145/319709.319714

[24] K. Nandakumar, A. Nagar, and A. K. Jain, *Hardening Fingerprint Fuzzy Vault Using Password*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 927–937.

[25] C. I. Watson, M. D. Garris, E. Tabassi, C. L. Wilson, R. M. McCabe, S. Janet, and K. Ko, "User's guide to non-export controlled distribution of nist biometric image software," 2004.

[26] D. Maltoni, D. Maio, A. K. Jain, and S. Prabhakar, "Handbook of fingerprint recognition," 2009.

KNN and ANN-based Recognition of Handwritten Pashto Letters using Zoning Features

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***Abstract*—This paper presents an intelligent recognition system for handwritten Pashto letters. However, handwritten character recognition is challenging due to the variations in shape and style. In addition to that, these characters naturally vary among individuals. The identification becomes even daunting due to the lack of standard datasets comprising of inscribed Pashto letters. In this work, we have designed a database of moderate size, which encompasses a total of 4488 images, stemming from 102 distinguishing samples for each of the 44 letters in Pashto. Furthermore, the recognition framework extracts zoning features followed by K-Nearest Neighbour (KNN) and Neural Network (NN) for classifying individual letters. Based on the evaluation, the proposed system achieves an overall classification accuracy of approximately 70.05% by using KNN, while an accuracy of 72% through NN at the cost of an increased computation time.**

***Keywords*—KNN; deep neural network; OCR; zoning technique; Pashto; character recognition; classification**

I. Introduction

In this modern technological and digital age, optical character recognition (OCR) systems play a vital role in machine learning and automatic recognition problems. OCR is a section of the software tool that converts printed text and images to machine-readable form and enables the device to recognize images or text like humans. OCR systems are commercially available for separate languages, which include Chinese, English, Japanese, and others. However, limited OCR-based systems are available for cursive languages such as Persian and Arabic and are not highly robust. To the best of our knowledge, commercial OCRs do not exist for carved Pashto letters recognition except in research labs.

Handwritten letters recognition is a daunting task mainly because of variations in writing styles of different users. Handwritten letters recognition can be done either offline or online. Online character recognition is simpler and easier to implement due to the temporal-based information such as velocity, time, number of strokes, and direction for writing. Besides, the trace of the pen is a few pixels wide, so thinning techniques are not viable here. On the other hand, the implementation of an offline recognition system implementation is even laborious due to high variations in writing and font styles of different users.

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Pashto is a major language of Pashtun tribe in Pakistan and the official language of Afghanistan. In census of 2007 2009, it was estimated that about 40 60 millions of people around the world are native speakers of this language.

Pashto letters can be shaped into six different formats, which make the recognition process challenging. Furthermore, the count of character dots and occurrence of these dots that varies between letters make the problem challenging.

Research shows the use of high-level features based on the structural information of letters. An OCR-based system using deep learning network model that incorporates Bi- and Multi-dimensional short-term memory for printed Pashto text recognition has been suggested [1].

A web-based survey shows that Pashto script contains a considerable number of unique ligature [2]. Such ligature poses challenges on the implementation of an OCR-based system for identifying carved Pashto letters. As printed letters contain a constant shape/style and font size; thus, the said technique fails due to higher variations in style and font in case of inscribed letters. Riaz et al. [3] has presented the development of an OCR system for cursive Pashto script using scale invariant feature transform and principle component analysis. This work presents a system for handwritten Pashto letters recognition, which has the following key contributions:

- Designed and developed a medium-sized database of 4488 (102 samples for each letter) for further research work.
- Provided a baseline result for the identification of inscribed Pashto letters using KNN and deep Neural Network and zoning features.
- Evaluated and provided comprehensive results through the proposed system for handwritten Pashto letters recognition, which may help the researchers to further explore this area.

The proposed approach is efficient, simple, and cost-effective. This paper is divided in seven sections: Section II explains the related work. Section III captures the background information about the classifiers and feature extraction algorithm used in this research work. Section IV delineates the methodology. Section V discusses about the feature extraction, which is very important in the area of pattern recognition and machine learning while section VI demonstrates the experimental results followed by the conclusions and future work in Section VII.

II. Related Work

Pashto, Persian, Urdu, and Arabic are sister languages. Several diverse approaches are suggested by different researchers for developing an OCR system for these languages. However, Pashto script contains 44 letters, greater than Arabic script which are 28 though comprehensive, Persian script comprising of 32 letters, and Urdu script encompassing 38 letters. Pashto language encapsulates all the letters from the Urdu script with additional seven letters. This additional seven letters in Pashto makes the traditional OCRs incapable to recognize handwritten Pashto letters. Some of the closely related work on the prescribed languages is mentioned below.

Abdullah et al. [4] presented an OCR system for Arabic handwriting recognition based on Neural Network classifier for classifying an IFN—ENIT dataset. Ahmad et al. [5] presented a novel approach of gated bidirectional long short term memory (GBLSTM) for recognition of printed Urdu Nastaliq text, which is a special form of Neural Network based on ligature information of the printed text. Ahmed et al. [6] used a one dimensional BLSTM for handwritten Urdu letter recognition where a medium size database for handwritten Urdu letters collected from 500 people was developed.

Alotaibi et al. [7] suggested an algorithm to develop an OCR that can check the originality and similarity of online Quranic contents where Quranic text is a combination of diacritics and letters. For diacritic detection, they used region-based algorithms and projection method is used for letter detection. The results of the similarity indices are compared with standard Mushaf Al Madina benchmark. Boufenar et al. [8] presented the concept of supervised learning technique named Artificial immune system based on zoning technique for isolated carved Arabic letters recognition. Jameel and Kumar [9] suggested the use of B spline curves as a feature extractor for offline Urdu character recognition. Naz et al. [10] [11] presented the use of multi-dimensional recurrent Neural Network based on statistical features for Urdu Nastaliq text recognition. Rabi et al. [12] performed a survey on different OCR systems for handwritten cursive Arabic and Latin script recognition where it was concluded that the results of contextual sub character of Hidden Markov Models were proven with high accuracy for handwritten Latin and Arabic script recognition.

Rouini et al. [13] presented the use of dynamic random forest classifier based on surf descriptor feature extraction technique. Sahlol et al. [14] inspected different classifiers Genetic algorithm (GA), Particl Swam optimization (PSO), Grey Wolf optimization (GWO), and BAT algorithms (BAT) for handwritten Arabic characters recognition. After testing each algorithm, it was concluded that GWO provides prominent results for handwritten Arabic characters recognition. As Sindhi language is a super set of Arabic language, Shaikh et al. [15] developed an OCR system for text recognition using an approach based on segmentation.

M. Kumar et al. [16] presented a comprehensive survey of Indic and non-Indic scripts on letters and numeral recognition. Zayene et al. [17] presented a novel approach for Arabic video text recognition using recurrent Neural network. This system suggests a segmentation free method mainly based on a multi-dimensional version of long short term memory combined with a connectionist temporal classification layer. Veershetty et al. [18] suggested the concept of an optical character recognition (OCR) system for handwritten script recognition based on KNN, SVM, and linear discriminant analysis (LDA) classifiers. For feature extraction, they used a technique based on Radon and wavelet transform, and words were extracted using morphological dilation methods.

Malviya et al. [19] carried out a comparative study of various feature extractions techniques named Zernike moments, projection histogram, zoning methods, template machine, and chain coding technique and classification algorithms such as SVM and Artificial Neural Network (ANN) have been discussed. Some vital parameters are selected based on sample size, data types, and accuracy. Bhunia et al. [20] presented a novel approach for word level Indic-script recognition using character level data in input stage. This approach uses a multimodal Neural Network that accepts both offline and online data as an input to explore the information of both online and offline modality for text/script recognition. This multi-modal fusion scheme combines the data of both offline and online data, which indeed a real scenario of data being fed to the network. The validity of this system was tested for English and six Indian scripts. Obaidullah et al. [21] carried out a comprehensive survey for the development of an OCR system for Indic script recognition in multi-script document images. Multiple pre-processing techniques, feature extraction techniques, and classifiers used in script recognition were discussed.

The literature review shows that a little work is available on the development of an OCR system for the recognition of printed Pashto letters; however, there is no OCR system developed for automatic recognition of handwritten Pashto letters. All the above mentioned algorithms perform well for the specified languages but fail in recognizing the handwritten Pashto letters owing to the extra number of letters in the character set. In this paper, we present a robust OCR system for the recognition of handwritten Pashto letters having the key benefits mentioned above.

III. Background Study

This section describes the detail of the character modeling for Pashto script, classification techniques followed by KNN, and Neural Network classifiers.

A. Pashto

Pashto is the language of Pashtuns, often pronounced as Pakhto/Pukhto/Pushto and is the official language of Afghanistan and a major language of Pashtun clan in Pakistan. In Persian literature, it is known as Afghani while in Urdu or Hindi literature, it is known as Pathani. Pashto has two major dialects namely soft dialect and hard dialect. Both of these dialects are phonologically differ from each other. The soft dialect is called southern while the hard dialect is known as northern. In soft dialect i-e., southern, Pushto is spelled as Pashto while in hard dialect i-e., in northern, it is spelled as Pukhto or Pakhto. The word Pashto is followed as a representation for both hard and soft dialects. The Kandahari form of

Pashto Character Set

Name	Alphabet	Name	Alphabet	Name	Alphabet
Alif	ا	Re	ر	Qa'uf	ق
Be	ب	Rhe	ړ	Ka'f	ک
Pe	پ	Ze	ز	Ga'f	ګ
The	ت	Jey	ژ	Laam	ل
Te	ټ	Ghey	ږ	Meem	م
Se	ث	Seen	س	Noon	ن
Jeem	ج	Sheen	ش	Rnoon	ڼ
Zeem	ځ	Heen	ښ	Wow	و
Che	چ	Swa'd	ص	Kha	ه
Seem	څ	Dwa'd	ض	Yee	ي
Hey	ح	Thwe	ط	Yey	ې
Khe	خ	Zwe	ظ	Ye	ی
Dhaal	د	Ain	ع	Yay	ۍ
Daal	ډ	Ghain	غ	Yai	ئ
Zaal	ذ	Fey	ف		

Fig. 1: Pashto characters dataset.

TABLE I: Urdu Specific Letters Representation in Pashto Script

Urdu Letter	Pashto equivalent
ٹ	ټ
ڈ	ډ
ڑ	ړ
گ	ګ
ے	ی

Pashto dialect, also known as Pata Khazana, is considered as standard spelling system for Pashto script.

Pashto script consists of 44 letters shown in Fig. 1. The Name represents letter name while Alphabet represents letters shape in isolated form. It has borrowed all the letters from Persian script, i.e., 32 letters that has further borrowed the entire letter set, i.e., 28 letters from Arabic script. That is why Pashto is known as a modified pattern of Perso-Arabic characters. Urdu script adopts all 32 letters from Persian script with 6 additional letters. Pashto script encapsulates all the Urdu characters with minor change in these 6 special characters for Urdu script as shown in Table I. It encompasses additional 7 characters, especially to Pashto script forming a dataset of 44 characters as shown in Table II. In order to make a word in Pashto script, two or more than two isolated letters are combined to form a word. While defining a word, a letter shape changes w.r.t its position (start, middle or end) in the word as shown in the Table III. Both Naksh and Nastaliq is followed for Pashto script writing; however, Naksh is considered as standard writing style for Pashto script.

TABLE II: Pashto Specific Letters

7 Special Pashto characters						
ځ	څ	ډ	ښ	ي	ې	ئ

TABLE III: Change in Letters Shape W.R.T. its Position in Word

Isolated Letter	Contextual form		
	Start	Middle	End
و	و	ـو	ـو
ظ	ظ	ـظـ	ـظ

B. K-Nearest Neighbor (KNN)

KNN is a supervised learning tool used in regression and classification problems. In training phase, KNN uses multi-dimensional feature vector space that assigns a class label to each training sample. Many researchers have suggested the use of KNN classifier in text/digits recognition and classification such as Hazra et al [22] who presented the concept of KNN classifier for both handwritten and printed letters recognition in English language based on sophisticated feature extractor technique.

For online handwritten, Gujarati character recognition Naik et al. [23] suggested the use of SVM with polynomial, linear, and RBF kernel, KNN with variant values of K and multi-layer perception (MLPs) for stroke classification based on hybrid feature set. Selamat et al. [24] suggested the use of hybrid KNN algorithms for web paged base Arabic language identification and classification. They carried out the results based on SVM, back propagation neural network, KNN, and hybrid KNN. Zhang et al. [25] presented the use of KNN for visual category recognition based on text, color, and particularly shape in a homogeneous framework. Hasan [26] presented the concept of KNN classifier for Arabic(Indian) digits recognition using multi-dimensional features, which consist of discrete cosine transform (DCT) and projection methods.

KNN generates classification results by storing all the available cases and stratify new classes based on a similarity measure (distance functions). Pashto contains 44 letters in its character set so there are 44 classes to be classified. In short, it is a multi-class recognition problem. Fig. 2 represents a basic multi-class KNN model. In Fig. 2 class1, class2, and class3 represent 3 different classes. In our case, it contains 44 classes as there are 44 letters in Pashto character dataset.

C. Neural Network (NN)

NN has performed a vital role in the recognition and classification problems. Inspired from human nervous system, ANN is composed of layered architecture—input, hidden, and output layer. It contains a network of neurons connected through weighted connections that accepts input, performs processing, and produce detailed patterns. Machine learning (ML) has been widely used in a varitey of applications. ML has been used in scheduling tasks in real time through cloud computing in the form of genetic algorithms [27]. Another

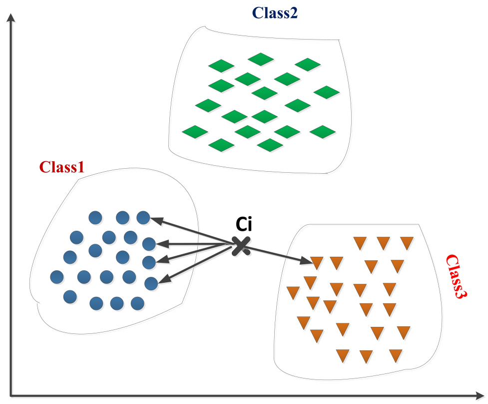

Fig. 2: Basic multi-class KNN basic model.

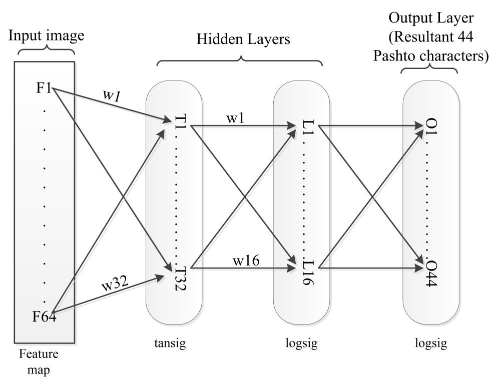

Fig. 3: Neural Network for handwritten Pashto character recognition.

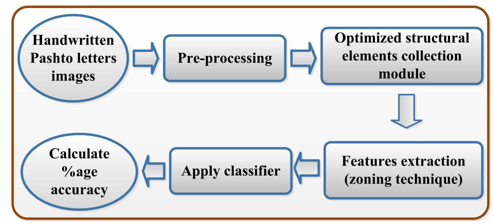

Fig. 4: The proposed Pahsto handwritten letter recognition system.

Fig. 5: First 23 handwritten Pashto characters.

study shows the use of ML models in genomics [28]. The goal is to detect variations and errors in Genomics datasets that entail higher variations. Decision trees and tabu search have been utilized in order to learn the dispatching rules for smart scheduling [29]. To explore the active learning, exponential gradient exploration has been studied [30].

Owing to NN's high identification and recognition abilities especially in text recognition problems, multiple researchers have suggested the use of this model, some of which are mentioned here. Jameel et al. [31] carried a review paper on Urdu character recognition using NN. In this paper, they suggested the use of B-Spline curves as a feature extractor technique for Urdu characters recognition. Zhang et al. [32] presented the use of recurrent NN for drawing and recognition purposes of Chinese language. Patel et al. [33] suggested the use of ANN for handwritten character recognition based on discrete wavelet transform as a feature extractor technique, which is based on accurate level of multi-resolution technique. A basis NN diagram for HPLR system is shown in Fig. 3. In this research work, a NN classifier is selected with two hidden layers and one input and output layer. A feature map of 16 distinct values based on zoning technique are fed at input layer and the expected results are calculated at the output layer.

IV. The Proposed Methodology

The proposed OCR system for the recognition of handwritten Pashto letters is divided into three main steps as shown in Fig. 4.

- Database development for the handwritten Pashto letters.
- Feature selection/extraction.
- Classification and recognition using KNN and NN classifiers.

A. *Database development for the handwritten Pashto letters*

A medium size handwritten character database of 4488 characters (contains 102 samples for each letter) is developed by collecting handwritten samples from different individuals. These samples are collected on an A4 size paper divided into 6 columns for collecting a letter variant samples from same person. These samples are further scanned into computer readable format as shown in as shown in Fig. 5 and Fig. 6.

1) Letters Extraction: The letters are extracted in order to create a database. A few extracted letters are shown in

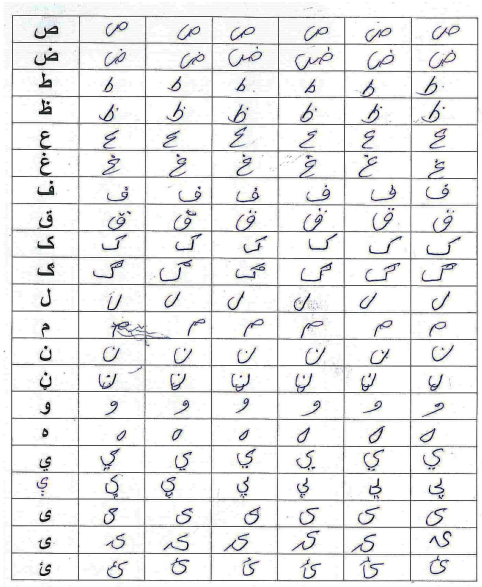

Fig. 6: Remaining 21 handwritten Pashto characters.

TABLE IV: A Table with Handwritten Sliced Pashto Characters

(a)

(b)

(c)

(d)

Table IV. All these extracted letters are resized into a fixed size of 44×44. This fixed size of the character helps in generating a uniform sized feature vector.

Each extracted letter in Table IV is hugely affected with dark spots i.e., noise, which is removed using thresholding. During the data collection phase, the handwritten character position varies in the 64×64 region/box. The reason is that letters can be written on top, left, right, and bottom of the box varying from person to person. We have centralized all the letters. Post-thresholding and centralizing results are captured in Table V.

V. Feature Extraction

Selecting an astute, informative and independent feature is a crucial step for effective classification. This paper presents the concept of zoning method as a feature extractor technique for the recognition of handwritten Pashto letters.

A. Zoning Technique

This research work uses a 4×4 static grid to extract each letter features as shown in Fig. 7. By applying this zoning

TABLE V: A Table with Thresholded and Centralized Results on Sliced Characters

(a) Befor thresholding

(b) After thresholding

(c) Centralized

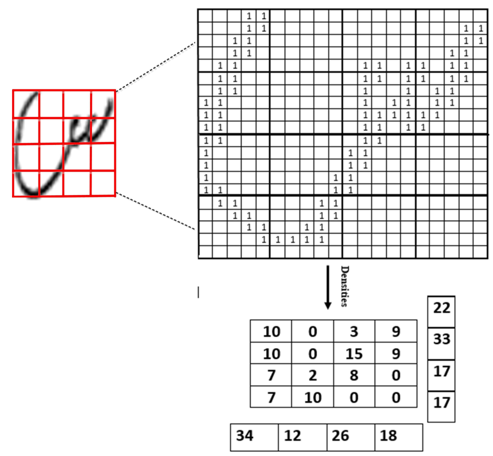

Fig. 7: Zoning feature extraction.

grid, it superimposes the pattern/character image and divides it into 16 equal zones. In each zone, the density of the letter is extracted that represents the ratio of the black pixels forming the letter on the total size of zone [34]. In this way, a feature map for all 4488 letters is obtained for classification.

After applying this technique a feature vector of 16 real values formed for each sample because we focuses on zones not on the number of pixels.

VI. Results

This section summarizes the results obtained after applying KNN and NN classifiers to handwritten Pashto letters for classification/recognition.

A. Classification Accuracy of K-Nearest Neighbours

The results of the KNN classifier for Pashto script recognition are shown in Fig. 8. The results are carried out using KNN classifier based on zoning features. The total image features for the Pashto letters is divided into a ratio of (2:1) for training and testing phases. The databases consists 102 samples for each Pashto letter. Thus, 68 letters features are selected for training phase and the remaining 34 letters features are selected for testing phase. An overall accuracy of about 70.05% is obtained for KNN, lesser than ANN, which is 72%.

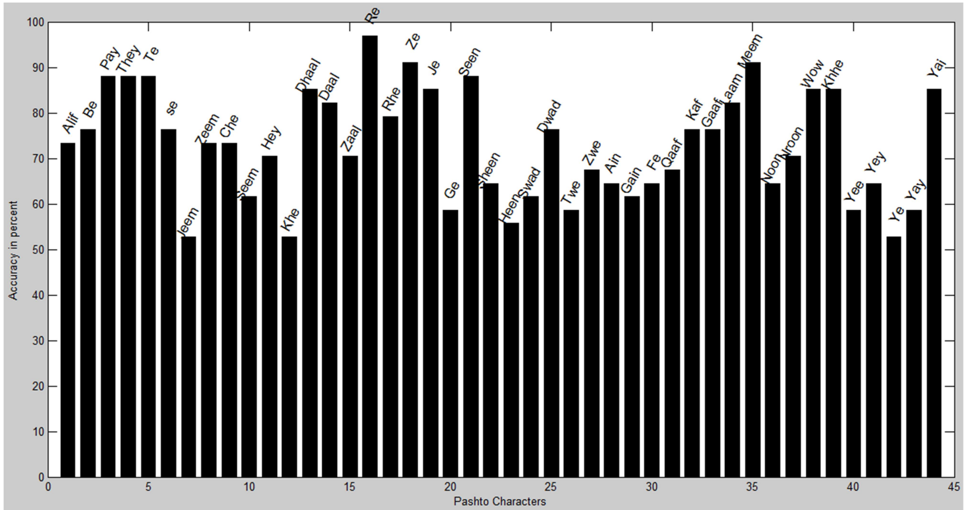

Fig. 8: KNN classifier accuracy results for HPLR system.

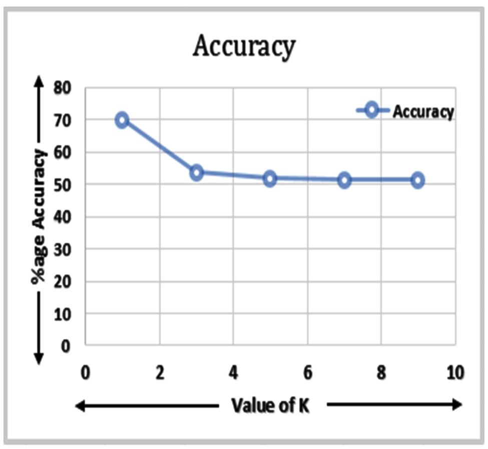

Fig. 9: KNN accuracy results for different values of K.

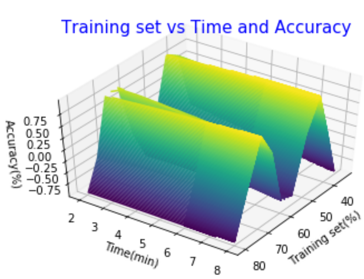

Fig. 10: NN results of HPLR system.

The accuracy of the KNN classifier is tested for different nearest neighbor values of K and it was detected that accuracy varies when the value of K increases, as the occurrence of other class features causes miss-classification. Fig. 9 represents the accuracy results drawn for varying values of K. High accuracy of KNN classifier is noted for the value of K equals to 1, because of high values of K causes the occurrence of other class features that cause miss-classification.

B. Classification Accuracy of Neural Network Classifier

The feature map is divided into 2:1 for training and test data. NN classifier achieves an accuracy of about 72 % better than KNN classifier. Fig. 10 represents the overall result of NN classifier for Pashto letter recognition problem.

The efficiency of the classifier is tested for different size of training and test samples vs. time. The data is split into (training, test) sets of of (35%, 65%), (40%, 60%), (45%, 55%), (50%, 50%), (55%, 45%), (60%, 40%), (65%, 35%), (70%, 30%), (75%,25%), and (80%, 20%). The corresponding time and accuracy results are generated in Fig. 10. Where it is explained that when there is an increase in the training size, accuracy of the system increases. However, increasing the training size adversely affects the simulation time. A higher accuracy rate of 72% is carried out for 80% of training and 20% of test set.

Furthermore, the NN results based on varying epoch size for different training and test sets are also shown in Fig. 11. It is evident that as the number of epoch increases for given training and test sets, accuracy of the system increases. The mean square error error rate and gradient in the shape for handwritten Pashto letters is shown in Fig. 12.

VII. Conclusions and Future work

In this paper, an OCR system for automatic recognition of Pashto letters is developed by using KNN and NN classifiers based on zoning feature extractor technique. Experimental results show an accuracy of 70.07% for KNN while 72% for NN. Contributions include the provision of handwritten Pashto letters database as a resource for future research work and the experimental results, which will provide a baseline accuracy for future models tested on the data.

In future, we aim to extend and evaluate our technique for a larger database of Pashto script using an increasing number

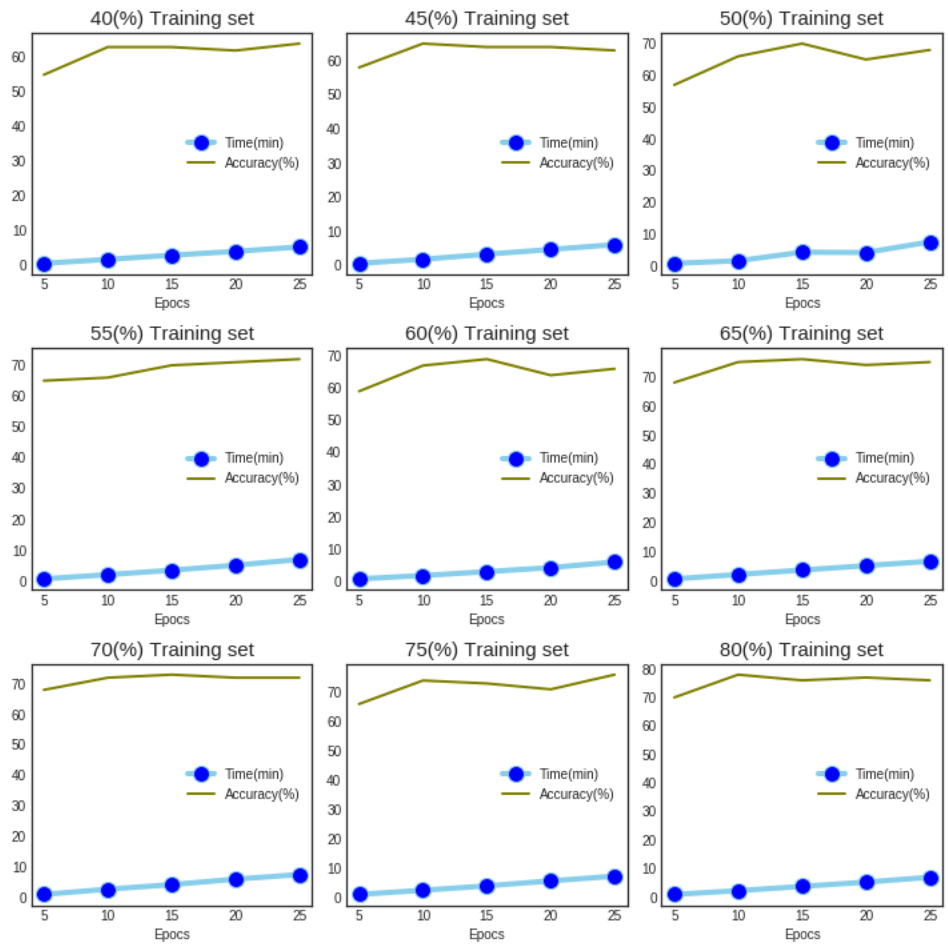

Fig. 11: NN classifier accuracy and time results for varying training and test sets.

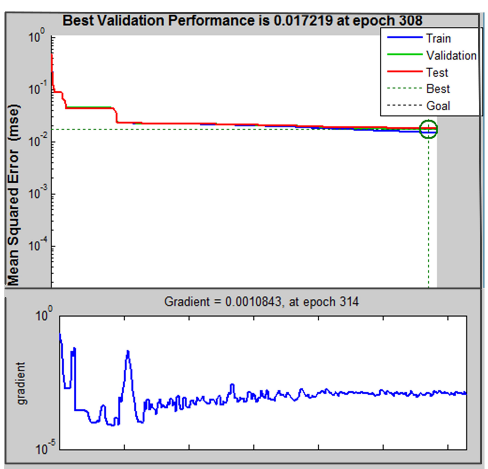

Fig. 12: MSE and gradient results of HPLR system.

of hidden layers coupled with different feature extractor techniques to achieve a higher accuracy. Furthermore, our goal is to extend the proposed model for the connected letters.

REFERENCES

[1] R. Ahmad, M. Z. Afzal, S. F. Rashid, M. Liwicki, A. Dengel, and T. Breuel, "Recognizable units in pashto language for ocr," in *Document Analysis and Recognition (ICDAR), 2015 13th International Conference on*. IEEE, Conference Proceedings, pp. 1246–1250.

[2] R. Ahmad, M. Z. Afzal, S. F. Rashid, M. Liwicki, T. Breuel, and A. Dengel, "Kpti: Katib's pashto text imagebase and deep learning benchmark," in *Frontiers in Handwriting Recognition (ICFHR), 2016 15th International Conference on*. IEEE, Conference Proceedings, pp. 453–458.

[3] R. Ahmad, S. Naz, M. Z. Afzal, S. H. Amin, and T. Breuel, "Robust optical recognition of cursive pashto script using scale, rotation and location invariant approach," *PloS one*, vol. 10, no. 9, p. e0133648, 2015.

[4] A. Abdullah, B. Agal, C. Alharthi, and D. Alrashidi, "Arabic handwriting recognition using neural network classifier," *Journal of Fundamental and Applied Sciences*, vol. 10, no. 4S, pp. 208–212, 2018.

[5] I. Ahmad, X. Wang, Y. hao Mao, G. Liu, H. Ahmad, and R. Ullah, "Ligature based urdu nastaleeq sentence recognition using gated bidirectional long short term memory," *Cluster Computing*, pp. 1–12, 2017.

[6] S. B. Ahmed, S. Naz, S. Swati, and M. I. Razzak, "Handwritten urdu character recognition using one-dimensional blstm classifier," *Neural Computing and Applications*, pp. 1–9, 2017.

[7] F. Alotaibi, M. T. Abdullah, R. B. H. Abdullah, R. W. B. O. Rahmat, I. A. T. Hashem, and A. K. Sangaiah, "Optical character recognition for quranic image similarity matching," *IEEE Access*, vol. 6, pp. 554–562, 2018.

[8] C. Boufenar, M. Batouche, and M. Schoenauer, "An artificial immune system for offline isolated handwritten arabic character recognition," *Evolving Systems*, vol. 9, no. 1, pp. 25–41, 2018.

[9] M. Jameel and S. Kumar, "Offline recognition of handwritten urdu characters using b spline curves: A survey," *International Journal of Computer Applications*, vol. 157, no. 1, 2017.

[10] S. Naz, A. I. Umar, R. Ahmad, S. B. Ahmed, S. H. Shirazi, and M. I. Razzak, "Urdu nastaliq text recognition system based on multi-dimensional recurrent neural network and statistical features," *Neural Computing and Applications*, vol. 28, no. 2, pp. 219–231, 2017.

[11] S. Naz, A. I. Umar, S. B. Ahmed, R. Ahmad, S. H. Shirazi, M. I. Razzak, and A. Zaman, "Pak. j. statist. 2018 vol. 34 (1), 47-53 statistical features extraction for character recognition using recurrent neural network," *Pak. J. Statist*, vol. 34, no. 1, pp. 47–53, 2018.

[12] M. Rabi, M. Amrouch, and Z. Mahani, "A survey of contextual handwritten recognition systems based hmms for cursive arabic and latin script," *International Journal of Computer Applications*, vol. 160, no. 2, 2017.

[13] K. Rouini, K. Jayech, and M. A. Mahjoub, "Off-line arabic handwriting recognition using dynamic random forests," 2017.

[14] A. T. Sahlol, M. Elhoseny, E. Elhariri, and A. E. Hassanien, "Arabic handwritten characters recognition system, towards improving its accuracy," in *Intelligent Techniques in Control, Optimization and Signal Processing (INCOS), 2017 IEEE International Conference*. IEEE, Conference Proceedings, pp. 1–7.

[15] N. A. Shaikh, Z. A. Shaikh, and G. Ali, "Segmentation of arabic text into characters for recognition," in *International Multi Topic Conference*. Springer, Conference Proceedings, pp. 11–18.

[16] M. Kumar, M. Jindal, R. Sharma, and S. R. Jindal, "Character and numeral recognition for non-indic and indic scripts: a survey," *Artificial Intelligence Review*, pp. 1–27, 2018.

[17] O. Zayene, S. M. Touj, J. Hennebert, R. Ingold, and N. E. B. Amara, "Multi-dimensional long short-term memory networks for artificial arabic text recognition in news video," *IET Computer Vision*, 2018.

[18] C. Veershetty, R. Pardeshi, M. Hangarge, and C. Dhawale, *Radon and Wavelet Transforms for Handwritten Script Identification*. Springer, 2018, pp. 755–765.

[19] P. Malviya and M. Ingle, "Feature extraction and classification techniques in character recognition systemsa comparative study," in *Proceedings of International Conference on Recent Advancement on Computer and Communication*. Springer, Conference Proceedings, pp. 527–538.

[20] A. K. Bhunia, S. Mukherjee, A. Sain, A. Bhattacharyya, A. K. Bhunia, P. P. Roy, and U. Pal, "Indic handwritten script identification using offline-online multimodal deep network," *arXiv preprint arXiv:1802.08568*, 2018.

[21] S. M. Obaidullah, K. Santosh, N. Das, C. Halder, and K. Roy, "Handwritten indic script identification in multi-script document images: A survey," *International Journal of Pattern Recognition and Artificial Intelligence*, 2018.

[22] T. K. Hazra, D. P. Singh, and N. Daga, "Optical character recognition using knn on custom image dataset," in *Industrial Automation and Electromechanical Engineering Conference (IEMECON), 2017 8th Annual*. IEEE, Conference Proceedings, pp. 110–114.

[23] V. A. Naik and A. A. Desai, "Online handwritten gujarati character recognition using svm, mlp, and k-nn," in *Computing, Communication and Networking Technologies (ICCCNT), 2017 8th International Conference on*. IEEE, Conference Proceedings, pp. 1–6.

[24] A. Selamat, I. M. I. Subroto, and C.-C. Ng, "Arabic script web page language identification using hybrid-knn method," *International Journal of Computational Intelligence and Applications*, vol. 8, no. 03, pp. 315–343, 2009.

[25] H. Zhang, A. C. Berg, M. Maire, and J. Malik, "Svm-knn: Discriminative nearest neighbor classification for visual category recognition," in *2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'06)*, vol. 2, June 2006, pp. 2126–2136.

[26] A. K. A. Hassan, "Arabic (indian) handwritten digits recognition using multi feature and knn classifier," *Journal of University of Babylon*, vol. 26, no. 4, pp. 10–17, 2018.

[27] A. Mahmood and S. A. Khan, "Hard real-time task scheduling in cloud computing using an adaptive genetic algorithm," *Computers*, vol. 6, no. 2, p. 15, 2017.

[28] M. Krachunov, M. Nisheva, and D. Vassilev, "Application of machine learning models in error and variant detection in high-variation genomics datasets," *Computers*, vol. 6, no. 4, p. 29, 2017.

[29] A. Shahzad and N. Mebarki, "Learning dispatching rules for scheduling: A synergistic view comprising decision trees, tabu search and simulation," *Computers*, vol. 5, no. 1, p. 3, 2016.

[30] D. Bouneffouf, "Exponentiated gradient exploration for active learning," *Computers*, vol. 5, no. 1, p. 1, 2016.

[31] M. Jameel, S. Kumar, and A. Karim, "A review on recognition of handwritten urdu characters using neural networks," *International Journal*, vol. 8, no. 9, 2017.

[32] X.-Y. Zhang, F. Yin, Y.-M. Zhang, C.-L. Liu, and Y. Bengio, "Drawing and recognizing chinese characters with recurrent neural network," *IEEE transactions on pattern analysis and machine intelligence*, 2017.

[33] D. Patel, T. Som, and M. Singh, *Wavelet-Based Recognition of Handwritten Characters Using Artificial Neural Network*. IGI Global, 2017, pp. 1043–1060.

[34] S. Nebti and A. Boukerram, "Handwritten characters recognition based on nature-inspired computing and neuro-evolution," *Applied intelligence*, vol. 38, no. 2, pp. 146–159, 2013.

Towards Secure IoT Communication with Smart Contracts in a Blockchain Infrastructure

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Abstract—**The Internet of Things (IoT) is undergoing rapid growth in the IT industry, but, it continues to be associated with several security and privacy concerns as a result of its massive scale, decentralised topology, and resource-constrained devices. Blockchain (BC), a distributed ledger technology used in cryptocurrency has attracted significant attention in the realm of IoT security and privacy. However, adopting BC to IoT is not straightforward in most cases, due to overheads and delays caused by BC operations. In this paper, we apply a BC technology known as Hyperledgder Fabric, to an IoT network. This technology introduces an execute-order technique for transactions that separates the transaction execution from consensus, resulting in increased efficiency. We demonstrate that our proposed IoT-BC architecture is sufficiently secure with regard to fundamental security goals i.e., confidentiality, integrity, and availability. Finally, the simulation results are highlighted that shows the performance overheads associated with our approach are as minimal as those associated with the Hyperledger Fabric framework and negligible in terms of security and privacy.**

Keywords*—*IoT; Blockchain Authorization; Hyperledger Fabric; BC; Blockchain Integrity

I. Introduction

The Internet of Things is undergoing exponential growth as everything is increasingly connected via the internet. According to the Gartner research report that predicts the future of IoT, there were almost 7 billion devices connected via smart technology in 2017, and this is set to approach 20 billion by 2020 [1]. Some areas that apply this technology in daily life include automatic vehicles, home appliances, smart grid stations, health care applications, the retail sector, industrial supply chains and logistics management, security and surveillance, transportation and general industrial control systems [2] [3]. These all comprise a smart infrastructure supported by heterogeneous entities including web servers, end users, smartphones and cloud resources, that function with and without human interaction, selecting and providing information to the end users.

Millions of sensors and actuators are used in smart-environments to control and monitor lighting and heating systems, elevators, and cameras. Apart from this, Industrial control systems composed of numerous sub-systems, such as Supervisory control and data acquisition (SCADA), distributed control systems (DCS), other smaller systems, including programmable logic controllers (PLCs), remote terminal units (RTUs), and others involved in running an industrial operation [4]. These systems are composed of various interconnected sensing devices, and their heterogeneous nature and swiftly developing technology results in security and privacy risks that pose a major challenge to the IoT community.

With the widespread adoption and advancement of this technology, IoT devices face numerous security problems in terms of hardware, software and network communications. Increased communication between IoT devices involves large amounts of critical data and privacy-sensitive information that are increasingly vulnerable: a recent DDoS attack known as *mirai* [5] affected millions of IoT devices. Several approaches have been proposed to optimise security and privacy [6][7] [8], but due to the IoTs rapid expansion at a massive scale, no consensus has been reached regarding the optimal solution, and several questions remain.

In IoT systems, the majority of communication between devices is facilitated through client/server architecture or centralised architecture, through which authentication and identification, and other security measures, are processed by a central authority. The first major issue in these centralised systems, where everyone is reliant on a central authority, is the possibility of a single point of failure. Second, all connected devices must communicate via the internet regardless of the distance between them, thus leading to command processing overhead. Additionally, the current approach to IoT security involves high maintenance costs in terms of central cloud servers and other network equipment. In short, to migrate the current IoT centralised architecture to a decentralised approach some fundamental capabilities are required:

- peer-to-peer communication,
- distributed file sharing
- autonomous device communication, and
- efficiency and security.

The above requirements are conveniently available in a newly introduced Blockchain (BC) technology known as Hyperledger Fabric [9]. BC is a shared and replicated ledger that offers immutability, consensus, and finality. Although there are several other BC technologies, BC such as that adopted by Bitcoin, but Fabric reduces computation cycles and provides scalability, identity management, and privacy, which is of the utmost importance in the IoT paradigm. The cryptographic algorithms used in BC ensure superior security and privacy for device data and IoT is increasingly adopting BC technology. As far as BCs applicability to IoT is concerned, it records the transaction histories of smart devices in an immutable manner, thus eliminating the need for a central authority. For messaging exchange between IoT-devices a smart contract is used for successful agreement between all parties. The most promising feature of BC, with regard to its application in IoT, is the possibility of maintaining a transaction record across all devices, thus and thus make a distributed and trustless ledger.

Generally, all currently adopted approaches are highly centralised and thus unable to manage the IoT environment at the current scale. BC technology has the potential to overcome the scalability and security issues associated with IoT through decentralisation. This papers contribution is twofold: To implement Hyperledger Fabric in a smart-IoT environment to assess the validity of the communicating devices whether normal or malicious i.e., to assure users of the integrity of the data from a particular device. Another important issue is that the IoT network is growing very rapidly as predicted, and cannot, as such, be efficiently and securely managed by the current centralised mechanisms. In this study, we implemented IoT-based architecture in tandem with BC (Hyperledger Fabric). We tested our scheme in a smart home-based scenario, however, it will be applicable in other contexts, including smart cities and smart industries.

The remainder of this paper is organized as follows: Section II presents some background information concerning BC, smart contracts and Hyperledger Fabric. In section III, we detail the need for security in IoT with a review of the literature. Section IV presents our proposed architecture in detail. Section V includes the experiment results and some discussion of the findings. Finally, in section VI we conclude and propose potential future directions.

II. Background

A. Block-Chain

Blockchain (BC) is initially adopted by a very well-known crypto-currencies called bitcoin [10]. BC record the transactions across many computers and store in a decentralised way and thus form a immutable digital distributed ledger. This ledger is distributed among all the nodes in the network and every one have the copy of all the transactions record. Blockchain is composed of two kinds of record: blocks & transactions. Every transaction is recorded in the form of blocks and these blocks are then organized into a linear sequences and form a merkle tree. Every block in BC contains a hash of the previous block. New transactions are initially process by *miners* which are further append to end of the chain and cannot be modified or remove by anyone, once accepted. Initially the BC is started with the first block called genesis or initial block. After then each transaction is validated stored in the form of block. Every block contains the hash to the preceding block and changes to the previous block would produced different hash-code and thus visible to all member in BC immediately. Therefore, the block-chains are considered to be tamper-proof ledger. Figure 1 shows a sample block chain.

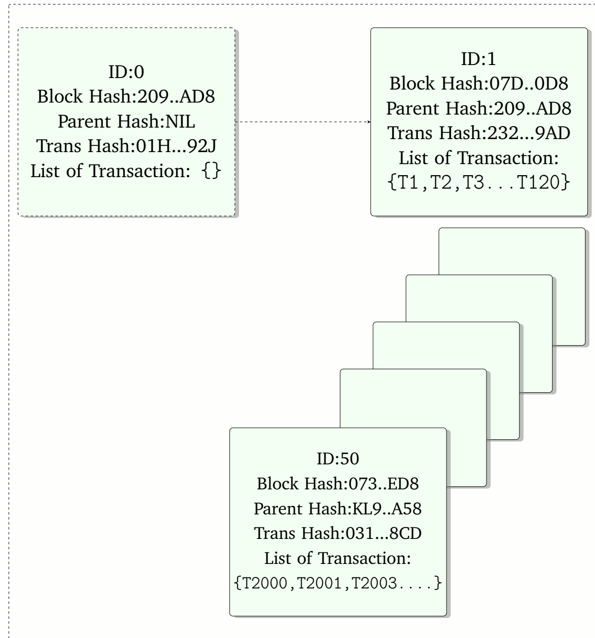

Fig. 1. A sample Blockchain

1) BlockChain and IOT: Authors in [11] put efforts on the case of expanding IoT-devices to a decentralised way in order to be sustainable. From manufacturers perspective, current centralised mechanisms needed a high maintenance cost in case of distribution of software updates to a billion number of nodes in IOT. On the consumer's end, trust on devices is merely a big challenge where someone needs a transparent security. In short, these issues cannot be tackle without a trust-less and peer-to-peer architecture that can distribute data in a secure and transparent way. In [12], authors argue that in current arising security problems with IOT, BlockChain provides a better an elegant solution.

B. Smart Contracts

Smart Contracts [13] also called crypto-contract are a computer program that are used to transfer/monitor assets or digital currencies among parties under certain rules. It does not only determine the conditions and penalties but can also enforce those policies/agreements. These smart contracts are stored on block-chains and BC is an ideal technology to store these contracts because of its immutability and security. Whenever a transaction is suppose to happen, smart-contract determine where the transaction should be transfer/returned or from where the transaction was actually originated.

C. Hyper-Ledger Fabric

Hyper-ledger fabric [9] is recently proposed by IBM team and considers it as an open-source blockchain platform and a truly scalable system for distributed applications running on a large-scale network. The main reasons behind this proposal is to cope with the limitations found in the other permissioned BlockChain architectures. Unlike all the other BC technologies that rely on order-execute paradigm while doing some kind of transactions, *fabric* introduces execute-order paradigm where transactions executed at the first stage before reaching to their final order. Some of limitations that fabric overcome are as follows:

- Performance overhead: The order-execute method is widely acceptable because of its simplicity, but it execute transactions sequentially on all peers in the network which may cause a performance overhead. A smart-contract with infinite loop may launch a DoS attack, which can severely degrade the performance on blockchain. This issue is resolve with fabric by execute the transaction first and then order the transaction over the BC. One of important benefit of execution at first is to be efficient and avoid DOS attack by denying the unvalidated transactions before ordering.
- Confidentiality: As discussed earlier that the design of other BC technologies runs the smart contracts on all the peers. However, in many scenarios of permissioned BCs, requires *confidentiality* i.e. to restrict the ledger state or transaction data. In Fabric the execution of smart-contract restricted to a number of trusted peers (endorsers) that give assurance to the outcomes of execution.

The transactions flow in Fabric comprises three different phases: Execution, ordering and validation.

- Execution Phase: In this first phase, the node in BC signs and send the transaction-proposal for execution to endorser(s) (designated peers). The information of endorsers are defined in the endorsement policy already. The endorsers is suppose to simulate the transaction with respect to the operations specified on the chaincode. After this simulation, each endorsers generate two values i.e. *writeset* value that contains the state-update information and *readset* defining the version of transaction-proposal simulation. Finally, the endorser(s) signs and send the message now called *endorsement(s)* that composed of readset and writeset, to the client. The client receive the message and wait until they satisfy the chain-code endorsement policy. In particular, all the endorser(s) need to produce the same execution result. After this, the client may proceed to make a transaction and pass it to the ordering phase.
- Ordering Phase: Upon adequate endorsement on transaction-proposal, client assembles the *transaction* and send it to the ordering service. This transaction consists of all the parameters including chain-code information, transaction metadata and set of endorsements. The ordering service organize total order of transactions per channel (sub-network) that has been submitted. Furthermore, the ordering service combine multiple transaction and arrange it into *blocks* and form a blocks that improves the overall throughput of broadcast protocol. As it is known that there are a huge numbers of peers in BC, only few of them are supposed to implement ordering service. Finally, the ordering service also include the access control policies to check the clients whether it can receive block or not.
- Validation Phase: When the ordering service sends the block to the peer, it will enter to validation phase for further checking that is done by three sequential steps. (1) Endorsement policy evaluation occurs, if it is not satisfied then the transaction disregarded and marked it as invalid. (2) To check read-write conflict by comparing the key version to the current ledger state if it is not matched then marked invalid and disregarded. (3) Finally, the ledger update phase run and append the block to the block-chain.

III. Security in IoT

In the past decade, Internet of Things provides an automation and smartness in our daily lives. Due to the rapid advancement and deployment of IoT in the current infrastructure leads to many security and privacy requirements. S.Sicari et al. [14] outline the current problems in the existing IoT and analyze to the most relevant solutions. The key security requirements are confidentiality, authentication and access control. The author discussed various scheme of confidentiality and authentication in context of Wireless sensors networks (WSN), but because of heterogeneity and low power consumption in IoT several questions arises that are:

- Are the WSN easily adaptable to IoT with it heterogeneous nature of devices and different applications.
- Which communication layer is responsible for authentication process.
- How to ensure the integrity and privacy of end-to-end devices in order to prevent from malicious attacks.

Furthermore, access control that deals with user-access policies and usage control in the wide area network such as RBAC, DAC, MAC and their extensions. In context of IoT we needed to deal with streaming of data, Unlike traditional DBMS, where we deal with the discrete form of data. The problem arises here is the that the access control mechanism on data stream need more computation and hence lead to performance issue. Several solutions related to access control with data stream are discussed by the author and found the main challenges lying in it. Some issues are:

- How to ensure that the things could be recognized by the system where user is not available.
- How to manage with large volume of data stream in a standard recognized way.

A. Privacy & Trust in IoT

Keeping in mind the versatility of IoT in various areas that are: Smart-Homes, Smart-Cities, Smart-Health care, Traffic Control, smart parking system and so on. For all these scenarios, everyone need their protections for his personal information related to their movement from one place to another and communication with different other peoples. Author in [15] investigated a survey study on all approaches in context of privacy in IoT and find a wide gap of research that need to be addressed before deployment in the current IoT paradigm. The next important factor of security is satisfaction of trust between parties while communication. This satisfaction is basically reflected to the issues of identity management and access control mechanisms. In addition, they put an overview of trust management in IoT and discuss some past researches related to it. But all of them lacks a fully dynamic and distributed approach that can be suitable for the upcoming scale of IoT. Furthermore, most important missing item and a great challenge is a well-definition of trust agreement which needs to be a common language.

B. Literature study

David Airehrour [16] did a thorough study on the security and privacy while routing in internet of things. On security in IOT they find out the privacy preservation as a key issue because of heterogeneity in devices over the network. Due to limited battery capacity in most of IOT devices, several devices are not capable to end with the complete process of cryptography and authentication and argued for a robust secure authentication system. In general they classified the threats into two main groups:

1) *General Security threats in IoT network*: It includes the traditional threats present in network such as DDOS, Man-in-the-middle attack etc. However, considering the scalability and massiveness of IoT networks along with their complexities & heterogeneity, these traditional system attacks become more bigger challenge in IOT environment.
2) *Threats specific to IoT security:* These threats are related to the interconnection between IOT devices. For example sensitive data & record retrieving of a heart or brain patient, smart meter reading and forest-reading. Reading of such sensitive data may be compromised while communicating over the IoT network or may be results in malicious transmission to other nodes for misuse.

Furthermore, this survey study highlighted the routing protocols i.e. (6LowPAN and RPL) and their lack-ness in regards of security and privacy. Finally, the author deliver some key considerations for the researchers in order to design secure routing protocols for IOT. Some of recommendations are: secure routing establishment, self-stabilization, location privacy and so on. In conclusion this whole study has revealed that the current routing mechanisms and its standards are insecure for IoT.

Yuichi Kawamoto et al. [17] puts his efforts on location based authentication scheme in IoT. In this proposed architecture, they used ambient information for uniqueness by collecting the data from IOT-nodes at certain place & time. In his case the ambient information doesn't bound to use the key-elements such as SSID (service set identifier) and RSS (received signal strength) for the freshness of data. Such kind of authentication methods are more useful in scenarios like confidential information floating in military area or other secret meetings which is limited to some users. The important factor in this work is the unique information collected from different nodes that is further used to authenticate the devices over network. Thus, it is needed to collect real-time data as much as possible from many points in order to accomplish an accuracy in authentication. The two metric for authentication are as follows:

- *Freshness of Data*: As it is known that the data and location of nodes is continuously changes at interval of time, thus it is need to collect the real-time-data in order to ensure the accuracy.
- *Density of data collection*: The amount of data collected from huge number of point will lead to accuracy in the system. However, such gathering of information from massive points could decrease the real-time performance of system.

To uncover the optimal solutions for accuracy and efficiency, it is needed to evaluate both these metrics for different occasions. The main limitations and open research holes of this work are: (a) Real-time performance degradation in case of data collection for huge number of nodes. (b) More characteristics features added to ambient information could resolve the real-time collection as well as accuracy.

Qinlong et al. [18] addressing the issues of security and privacy in Fog computing. Basically, fog computing access the benefits of both the cloud and IoT paradigms. Similarly the security concerns (confidentiality & access control) with this kind of computing is also similar to Cloud and IoT. This proposed work is based on ABE-attribute based encryption and ABS (attribute based signature) which are the types of cryptographic techniques. ABE process features an access control policies over vast majority of attributes for user to perform decryption that can provide confidentiality and access control of data.

Current ABE-based solutions cannot have the capacity to authenticate custom (some) users to update the encrypted data. Thus, to update the cipher-data one should prove his validity by public key management to cloud service provider (CSP). However, it would create much burden on CSP in order to maintain a key-list for identification. To cope with this issue, ABS (attribute based signature) is used to provide help to CSP in regards of user validity. For the above reasons, the authors uses the combination of ABE & ABS for fine-grained access control in Fog computing paradigm. In the first step, user data is encrypted with access and update policies and then fused the data to cloud servers via fog nodes. Afterwards, those users whose attributes satisfy the required access policies are capable to decrypt the encrypted data. For this purpose, CSP is designated to check the signature in order to ensure the data integrity by verifying the user policies. The contribution of this research in terms of security analysis are to ensure Data confidentiality, to provide authentication, fine-grained access control mechanism and collusion resistance.

Michael et al. [19] proposed a platform for transactive IoT blockchain applications with repeatable testing (PlaTIBART) that combines actor patterns with custom DSL (domain specific language) and test network management tool. DSL defines the roles that different clients in our network have, based on the actor pattern. The advantage of DSL model is to implement a correct-by-construction design means, that allows the verification stage on the model, to check the internal consistency before any deployment is attempted e.g to prevent inconsistencies: two clients requesting the same port on the same host.

PLaTIBART uses Ethereum as its BC implementation, i.e DSL has Ethereum-specific required setting such as ChainID and GasLimit etc. Future implementation will be refactor these requirements on other BC platforms, i.e. Hyperledger, formal Verification of internal-consistency of a configuration file and a means of defining incremental adjustments to a test network by DSL.

IoT in context of security and privacy is a very challenging because of its low constraints and resources capabilities of the heterogeneity among them. Moreover, these devices retrieve, store and share huge amounts of data from our personal (smart-home) to industry level, and thus attracting the community to a significant privacy concern. In [20] the authors declares different zones for privacy in order to classify diverse kinds of data. Each of the zone is associated with context based policy checking technique, that is checked by Home-Security-Hub before accepting to join or re-join data from device. However, they do not consider the case of bypassing the hub and access the device directly.

A research efforts proposed in [21] that relies of safe answers or aggregations of data in which the user can send only a small data as much possible to the third party or service provider. For ensuring privacy their technique add noise to the data in the smart-home environment, but this noisy data could lead to inaccurate and harmful services.

A study in [22] have been done regarding that the household devices are more prone to attacks by users devices such as smartphones. As per perception that the router or gateway should offer security perimeter that can prevent from internet attacks. Authors shows a demonstration on attacks that penetrate the smart home network by a smart-phone applications. Such kind of attacks could be able to modifies firewall and allow the external user to directly attack the smart-device. Thus, it is concluded that routers and firewall at the home-end are consider as poor protection against internet attacks and figure out the need of extra security features on IoT devices.

Currently the CSIRO team proposed a new approach of integrating Blockchain with IoT [23]. In his initial efforts they use smart-home technology in order to realize that how blockchain can be deployed to IoT. The blockchain is specifically use to provide an access control mechanisms of smart-devices transactions located at smart-home. This research provides some extra security features by introducing BC technology in IoT, however it lacks the concept of consensus algorithm that every mainstream BC technology must have. Moreover, this technique cannot provide a generalize form of Block-Chain solution to IoT use cases.

In the light of above discussion, there is no technique that leverage the standard Block Chain implementation for scale-IOT environment. We argue that this research is the first step towards a generalize BC solution for the emerging IoT area. For better understanding we consider smart-home at this time as a use-case. In the next section, we will discuss our proposed IoT-Fabric architecture.

IV. Proposed Solution

In the current literature of IoT security and privacy several kinds of security and privacy mechanisms have been proposed. All of these mechanisms rely on centralised approach so-called client/server paradigm. Using this approach, all the devices in IoT network are identified and authenticated through a central point or server. But this centralised way supports today small-scale IoT network and will not capable to respond in the growing IoT system in the near future. Due to this rapid growth in IoT, existing solutions are very expensive in terms of high maintenance cost and infrastructure related to central cloud servers and other networking equipments.

Decentralised mechanisms in IoT infrastructure would remove several issues discussed above i.e. allowing peer-to-peer communications between IoT nodes will significantly reduce the cost of installation and maintenance. It will also distribute the storage and computation load over the entire IoT network that can achieve efficiency and prevention from a single point of failure. We realize and implement Hyper-ledger Fabric: A Block-Chain technology in our proposed solution. The benefit of adopting BC in our research is three-fold: Decentralised or distributed, Permission-based and all-secure. In this paper, we use smart-phone case study in order to exemplify our proposed architecture. However it is pluggable and well-suited in other IoT case scenarios.

A. Hyper-Ledger Fabric based IoT architecture

As discussed above that we consider a smart-home based scenario for better understanding. In a typical smart-home, user is connected to certain number of IoT devices i.e. IP camera, thermo-state, smart-phone, smart-bulb and several other sensors. The architecture shown in Figure 2 includes the components namely the smart-home, Hyper-ledger fabric interface and Block-chain Peers / Orderers. Smart-homes has equipped with a number of different smart-IoT devices. Every device can share, store and update their transaction data. The Fabric interface is used to provide distributed ledger where each transaction from IoT devices is store in the sequence and thus output in Blocks. Smart-contracts defines the policies where every transaction is checked against a set of pre-defined policies. Finally, the consensus algorithm make an arc over the entire transactional flow, that can provide the generation of agreements on the order and to verify the correctness of blocks.

1) Initialization: Initialization of the network is the first step that needs before the transactions are made. All the smart-devices in smart-home need to store the device information in smart-contract. Information in smart-contract might consist of every device information and its endorsement policies according to our defined policy structure in application interface.

2) Handling Transaction in Smart-home: In a smart-IoT environment, communication between devices is either directly or with other external resources i.e. cloud. Each smart-device requests some other device that can serve some services e.g. if a smart-bulb needs data from the motion sensor to start automatically in case if someone get to entrance of home. For such direct communication between devices a shared-key is used, in order to achieve user control over every transactions inside smart-home. Smart-contract has list of all devices in a particular environment that can share data by using secure shared key.

3) Transactional Flow in Fabric: A *Hyperledger-fabric* consists of nodes or peers that constitute the network of Blockchain. As fabric architecture is permissioned, so every node or device participate using their identity provided by membership service provider (MSP). The flow of transactions in fabric are complete in three different phases i.e. execution, ordering and validation. In execution phase, a client (smart-home device) send a signed transaction proposal to one or more endorsers in the network. The endorsers (cf. Fig 2)are specific peers that are defined in our smart-contract / chain-code via endorsement policy. After execution and get enough endorsements on proposal, client then assembles the transaction and submit to the ordering phase where all the transactions are properly placed in order. Moreover, the ordering phase also turned multiple transactions into blocks and also ensure that blocks on one channel are correctly ordered. Finally, the validation phase checks the validity of transaction sequentially as discussed in background section.

In our proposed architecture illustrated in Figure 2, we deploy smart-home based scenario on the Fabric architecture. The benefit of adopting Fabric is that, it totally separate consensus procedure from execution and validation which we need for efficient and scalable IoT environment. The transaction proposal begins from the smart-device to fabric interface where it first passed through our defined endorsement policy in smart-contract develop in Go language. The endorser peers recognizes and give decision on the transaction from a particular device and proceed for making transactions i.e store, access and monitor data. In the next step, as we discussed earlier that the ordering phase automatically broadcasts the endorsements in order to establish consensus and is responsible to make all the transactions in an orderly fashion and finally formed the shapes of Blocks. Finally validation phase runs and checks certain evaluation to prove that the transaction is valid or invalid.

Considers a smart-home based transaction (Figure 2) where a device send transaction data for storage on Blockchain e.g. *store* transaction. The device first needs to prove his identity by matching the information defined in smart-contract. By receiving the device request or proposal the smart-contract identify the device and proceed for further procedure. After the device authenticated, it may send the data i.e. temperature data, along with the previous parameters (ID) for placement the transactions in order and store them to hash chain-sequence of block. The other possible types of transactions are *monitor* and *access* transactions. Such transactions are commonly initiated by user or simply smart-home owner in this case where he is far and need to access / monitor some data.

Furthermore, *channel* as depicted in 2 is used to connect two different zones i.e more than one smart-home. However, at this time we are focusing on single home and multiple case scenario are out of scope in this research. In addition, we integrate our proposed architecture with an open-source distributed ledger known as IOTA [24], that is specifically designed to power the upcoming future of IoT. It is known that per-missioned BC's like the one we used as a private BC for IoT network is although efficient but in a limited nodes. As the nodes increases in the IoT network the permissioned model of BC's degrades performance and hardly to scale-up in environment. As it is known that *fabric* is pluggable architecture for in regards of consensus algorithms. For this purpose, the proposed architecture in this research is easy to integrate with DAG (Directed Acyclic Graph) for acquiring both side benefits i.e. Fabric for Efficiency & DAG for scalability. DAG is recently adopted in IOTA a public BC having no mining fee, designed for IoT network. For more details regarding IOTA & DAG we refer the reader to [25].

V. Results and Discussion

In this section, we detail our analysis on security, privacy and performance overhead in the smart-home use case. Before going to results and analysis section we discuss some reasons behind choosing Fabric in our proposed architecture. Hyperledger Fabric proposed by IBM [9] has gain a lot of attention from market. Some of reasons behind choosing Fabric for our proposed IoT architecture are as follows:

1) Generalized BC: As discuss earlier, an industry big players are supporting Fabric and make several solutions for it. Keeping this in mind, we argue that our proposed solution will be easily adaptable by other use cases in IoT and becomes a standardized BlockChain technology for IoT-applications.
2) Execute-order: Previous BC technologies relies on order-execute architecture where mining of transactions degrade performance. Fabric introduces execute-order where consensus phase is separated from execution, which ultimately improve performance. For IoT, performance is a key challenge and Fabric mitigate this issue comparing to other BCs.

A. Security Analysis

The three main requirement for robust security design in every case are mainly: Confidentiality, integrity and Availability or simply (CIA) [26]. Confidentially stated that only authorized entity must be granted access. Integrity makes sure that the data is not changed or modified at the receiving end and Availability means that the service or data to the user is available when someone has needed. All of these requirements are addressed in our proposed architecture. Table I analyze that how our proposed solution could achieved the mainstream security requirements.

TABLE I. Security Evaluation

Security Requirements	Solution Provided
Confidentiality	Matching ID in Smart Contract
Integrity	Hashing Mechanism
Authorization	Endorsement Policy checking

Further, we need to analyze the famous attack known as DDOS (Distributed Denial of Service Attack) where an attacker uses several malicious or previous infected IoT-devices and attack some particular target device. A number of attacks have been discussed in [26] that can exploit the IoT-network in the form of DDOS attack. Our architecture is somehow provides a hierarchical prevention from such kinds of attacks. At the first level, attacker cannot gain access to these smart devices because these devices are generally not accessible physically. For instance, if attacker got access and supposed to infect the device, the second level of our security defense is that, each outgoing transaction has to be identified by our endorsement policy. Thus any transaction or traffic that constitute the DDOS attack would be rejected and cannot exit from the smart-home.

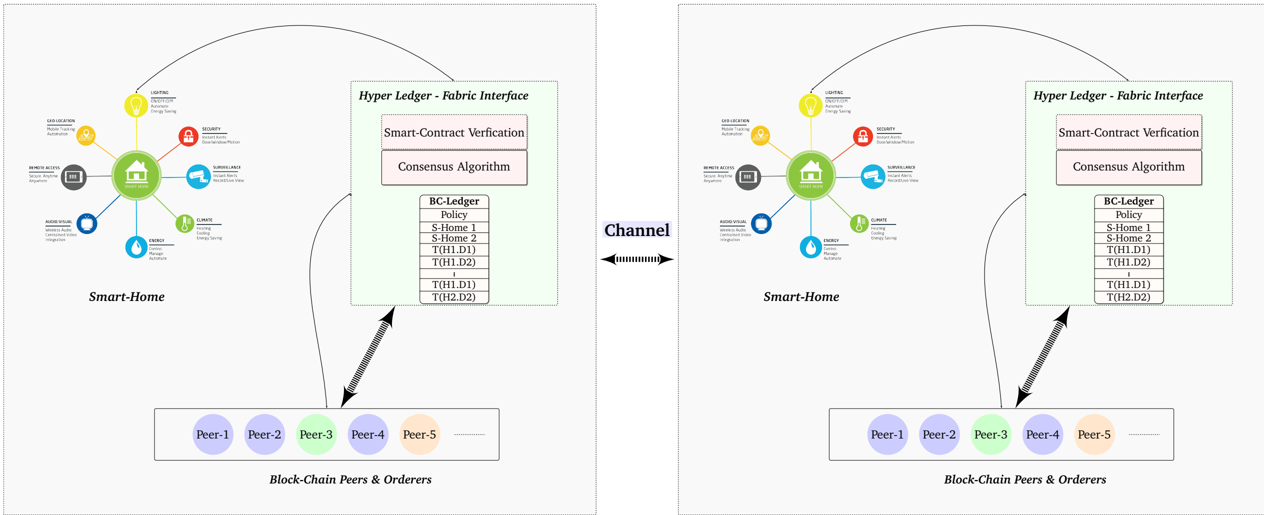

Fig. 2. Proposed IoT Block Chain Architecture

B. Performance Evaluation

IoT with Block-Chain integration acquire extra computational overhead on the smart-devices in terms of packet communication, time overhead and Energy consumption. However, these low overhead somehow have no bigger impact and significantly increase security and privacy. For communication between devices IPV6 over (LoWPAN) is used in our smart-home devices because it is well-suited for low-resource devices in IoT. Secondly, Fabric is a complex architecture and the performance is depends on various parameters such as choice of distributed applications, transaction size, ordering services, consensus algorithm and network topology etc. Therefore, an in-depth performance analysis is not possible in this phase of research. This research is focusing on a standardize Block-Chain application for the growing need of IoT.

However, the evaluation done in Fabric architecture [9] rely on crypto-currencies and is not directly applicable to our solution. To provide an evaluation for our use-case we simulate two type of transactions in a smart-home setting i.e. store and access. A store transaction means that a smart-device would like to store a transaction data on Fabric i.e. temperature sensor data, and access transaction is used to invoke some data. In our simulation we analyze two types of experiments that are:

1) Block Size Analysis: Recall that transactions are combined and shaped into form of blocks. So the size of block is key factor that impact the overall throughput and latency. We ran simulation of block size varying 0.2MB to 4.5MB. Figure 3 show throughput measured at peers and Figure 4 illustrate end-to-end latency impacted by block sizes. We observe in our case that the block size of 2 to 2.5MB is significant in terms of throughput. However, the latency get worse as expected with increase in block size, but in this particular case we assume that roughly about 450 to 500 (ms) is acceptable.

2) Transaction Size: We also investigate the number of transactions per block. Specifically, 1MB block contains 230 store and 350 access transactions. The sizes calculated are 3.00KB for store and 4.20KB for access transactions. In general, the transaction sizes in Fabric are larger because they also carry the certificate information for approval.

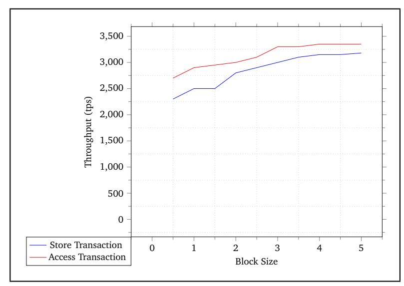

Fig. 3. Impact of Block Size on Throughput

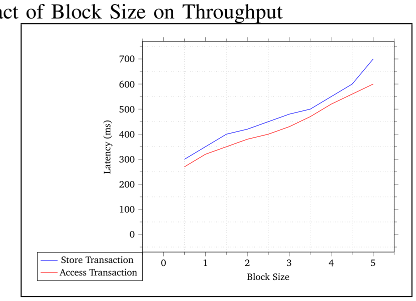

Fig. 4. Impact of Block Size on end-to-end Latency

3) Transaction Payload Size Analysis: This experiment measures the latencies at different transactions payload sizes. Transaction payload is actually the size of data that is going to passed in a smart contract upon invoking. Table II shows the comparative transaction payload analysis of Proposed IoT-BC and QUORAM-BC [27]. QUORAM is also a permissioned public BC and based on Ethereum. As it is known that Ethereum [28] uses mining for consensus which is slow as compared to Fabric, and thus, not suitable for IOT environment. In QUORAM, they selected 32KB size for transaction payload, therefore we also considered the same size for comparison. The results show that the latencies increases with the increment of 10KB in payload size. The total increase in transaction latency in QUORAM 25.23%, while in our technique the value is approximately 22.45%.

TABLE II. LATENCY WITH VARIABLE TRANSACTION SIZES

	Latencies (s) Transaction Payload	
Payload Size (KB)	Proposed BC	Quoram BC [27]
1	0.225	0.325
10	0.280	0.383
20	0.320	0.384
30	0.330	0.407

VI. CONCLUSION AND FUTURE WORK

Security and privacy in IoT is extremely important these days and gain a considerable attention from research and industry. Current security models for IoT are not suitable anymore due to rapid-scale, high maintenance cost of equipments, performance overhead and energy consumption. To cope with these problems, we proposed a new approach of implementing IoT Application on Fabric-BC. Hyper-ledger Fabric introduces a novel framework in BC that separate the execution phase from consensus and implement policy-based endorsements. Our representative case-study through out research was smart-home. We presented solution for main-stream security requirements. We also discussed performance overhead of some transactions and found no extra overhead by our application interface developed on top of Fabric for IoT. Furthermore, a comparison has been done with QUORAM-BC which shows that our architecture is more efficient, specifically for IoT networks. Future work will include applications of our framework to other IoT domains, in-depth overhead analysis and integration with IOTA implementation.

REFERENCES

[1] "Internet of Things," http://www.gartner.com/newsroom/id/3165317, 2017, [Online; accessed 08-April-2017].

[2] N. Shahid and S. Aneja, "Internet of things: Vision, application areas and research challenges," in *I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC), 2017 International Conference on*. IEEE, 2017, pp. 583–587.

[3] I. Lee and K. Lee, "The internet of things (iot): Applications, investments, and challenges for enterprises," *Business Horizons*, vol. 58, no. 4, pp. 431–440, 2015.

[4] K. Stouffer, V. Pillitteri, S. Lightman, M. Abrams, and A. Hahn, "Guide to Industrial Control Systems (ICS) Security," 2015. [Online]. Available: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-82r2.pdf

[5] "Mirai Attack," https://www.corero.com/resources/ddos-attack-types/mirai-botnet-ddos-attack.html, 2017, [Online; accessed 01-Jan-2018].

[6] O. O. Bamasag and K. Youcef-Toumi, "Towards Continuous Authentication in Internet of Things Based on Secret Sharing Scheme," *Proceedings of the WESS'15: Workshop on Embedded Systems Security*, pp. 1:1—-1:8, 2015. [Online]. Available: http://doi.acm.org/10.1145/2818362.2818363

[7] H. Daojing, Y. Gao, S. Chan, C. Chem, and J. Bu, "An Enhanced Two-factor User Authentication Scheme in Wireless Sensor Networks," *Ad Hoc & Sensor Wireless Networks*, vol. 10, no. 4, pp. 361–371, 2010.

[8] V. Sivaraman, H. H. Gharakheili, A. Vishwanath, R. Boreli, and O. Mehani, "Network-level security and privacy control for smart-home iot devices," in *Wireless and Mobile Computing, Networking and Communications (WiMob), 2015 IEEE 11th International Conference on*. IEEE, 2015, pp. 163–167.

[9] E. Androulaki, A. Barger, V. Bortnikov, C. Cachin, K. Christidis, A. De Caro, D. Enyeart, C. Ferris, G. Laventman, Y. Manevich, S. Muralidharan, C. Murthy, B. Nguyen, M. Sethi, G. Singh, K. Smith, A. Sorniotti, C. Stathakopoulou, M. Vukolić, S. W. Cocco, and J. Yellick, "Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains," 2018. [Online]. Available: http://arxiv.org/abs/1801.10228%0Ahttp://dx.doi.org/10.1145/3190508.3190538

[10] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system," 2008.

[11] P. Brody and V. Pureswaran, "Device democracy: Saving the future of the internet of things," *IBM, September*, 2014.

[12] K. Christidis and M. Devetsikiotis, "Blockchains and Smart Contracts for the Internet of Things," *IEEE Access*, vol. 4, pp. 2292–2303, 2016.

[13] "Smart Contracts," http://searchcompliance.techtarget.com/definition/smart-contract, 2017, [Online; accessed 4-Dec-2017].

[14] D. Miorandi, S. Sicari, F. De Pellegrini, and I. Chlamtac, "Internet of things: Vision, applications and research challenges," *Ad hoc networks*, vol. 10, no. 7, pp. 1497–1516, 2012.

[15] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," *Computer networks*, vol. 54, no. 15, pp. 2787–2805, 2010.

[16] D. Airehrour, J. Gutierrez, and S. K. Ray, "Secure routing for internet of things: A survey," *Journal of Network and Computer Applications*, vol. 66, pp. 198–213, 2016.

[17] Y. Kawamoto, H. Nishiyama, N. Kato, Y. Shimizu, A. Takahara, and T. Jiang, "Effectively collecting data for the location-based authentication in Internet of things," *IEEE Systems Journal*, vol. PP, no. 99, pp. 1–9, 2015.

[18] Q. Huang, Y. Yang, and L. Wang, "Secure Data Access Control with Ciphertext Update and Computation Outsourcing in Fog Computing for Internet of Things," *IEEE Access*, vol. 5, pp. 1–1, 2017. [Online]. Available: http://ieeexplore.ieee.org/document/7981322/

[19] M. A. Walker, A. Dubey, A. Laszka, and D. C. Schmidt, "PlaTIBART: a Platform for Transactive IoT Blockchain Applications with Repeatable Testing," 2017. [Online]. Available: http://arxiv.org/abs/1709.09612

[20] A. Arabo, I. Brown, and F. El-Moussa, "Privacy in the age of mobility and smart devices in smart homes," in *Privacy, Security, Risk and Trust (PASSAT), 2012 International Conference on and 2012 International Confernece on Social Computing (SocialCom)*. IEEE, 2012, pp. 819–826.

[21] Y.-A. de Montjoye, E. Shmueli, S. S. Wang, and A. S. Pentland, "openpds: Protecting the privacy of metadata through safeanswers," *PloS one*, vol. 9, no. 7, p. e98790, 2014.

[22] V. Sivaraman, D. Chan, D. Earl, and R. Boreli, "Smart-phones attacking smart-homes," in *Proceedings of the 9th ACM Conference on Security & Privacy in Wireless and Mobile Networks*. ACM, 2016, pp. 195–200.

[23] A. Dorri, S. S. Kanhere, and R. Jurdak, "Blockchain in internet of things: Challenges and Solutions," *arXiv:1608.05187 [cs]*, 2016. [Online]. Available: http://arxiv.org/abs/1608.05187%5Cnhttp://www.arxiv.org/pdf/1608.05187.pdf

[24] "IOTA," https://www.iota.org/get-started/what-is-iota, 2018, [Online; accessed 24-June-2018].

[25] A. Baliga, I. Subhod, P. Kamat, and S. Chatterjee, "Performance Evaluation of the Quorum Blockchain Platform."

[26] N. Komninos, E. Philippou, and A. Pitsillides, "Survey in smart grid and smart home security: Issues, challenges and countermeasures," *IEEE Communications Surveys & Tutorials*, vol. 16, no. 4, pp. 1933–1954, 2014.

[27] A. Baliga, I. Subhod, P. Kamat, and S. Chatterjee, "Performance Evaluation of the Quorum Blockchain Platform."

[28] G. Wood, "Ethereum: A secure decentralised generalised transaction ledger," *Ethereum project yellow paper*, vol. 151, pp. 1–32, 2014.

A Spin / Promela Application for Model checking UML Sequence Diagrams

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***Abstract*—UML sequence diagrams usually represent the behavior of systems execution. Automated verification of UML sequence diagrams' correctness is necessary because they can model critical algorithmic behaviors of information systems. UML sequence diagrams applications are often on the requirement and design phases of the software development process, and their correctness guarantees the accurate and transparent implementation of software products. The primary goal of this article is to review and improve the translation of basic and complex UML sequence diagrams into Spin / Promela code taking into account behavioral properties and elements of combined fragments of UML sequence diagrams for synchronous and asynchronous messages. This article also redefines a previous proposal for a transition system for UML sequence diagrams by specifying Linear Temporal Logic (LTL) formulas to verify the model correctness. We present an application example of our modeling proposal on a modified version of a traditional case study by using UML sequence diagrams to translate it into Promela code to verify their properties and correctness.**

***Keywords*—Spin / Promela; UML Sequence Diagrams; Fault Tolerance; LTL formulas; Combined Fragment**

I. Introduction

Developing computerized systems requires the use of modeling languages like UML to identify and characterize the systems structural and behavioral elements along with their properties [1] [2]. Namely for behavior modeling, UML offers use cases, sequences and state diagrams [3].

UML use case diagrams are usual at the beginning of the software development process [1] [2] [3]. UML sequence diagrams are useful to identify participant objects in use case scenarios and how those objects interact each other during the use case execution process. Usually participant objects in UML sequence diagrams modeled scenarios are part of the system's classes and respect their properties and communication methods [1] [2] [3].

UML state diagrams and UML sequence diagrams are usual in the design stage of the software development process. Even though UML state diagrams can represent states, state transitions, and events for those state changes either of individual objects or an instance of the complete system, those models do not give details about objects involved in the state changes (UML state diagrams do not represent interactions among objects in the system). On the other hand, UML sequence diagrams model the execution of systems by representing each communication (message) among their participant objects. UML sequence diagrams traditionally model only one execution scenario of the model system (a representative and critical execution situation) because multiple scenarios exist. Taking into consideration the model of algorithmic interactions by combined fragments of UML 2.0 sequence diagrams and the use of gates to represent modular behavior, without a doubt UML sequence diagrams are usable for modeling all of the interactions within a system.

Each model of an entirely consistent computerized system should be consistent (valid) with the user requirements as well as with each other valid product [4]. Using that base idea and assuming consistent previous models, this article describes steps to reach consistent UML sequence diagrams for a software system.

A system model is formally consistent with the user requirements if those requirements can be written and verified as correct LTL (Linear Temporal Logic) formulas [5] [6] [7] [8]. Thus, it is relevant to consider that Promela language [7] [9] allows verifying the correctness of LTL formulas.

Each model of an entirely consistent computerized system should be consistent (valid) with the user requirements as well as with each other valid product [4]. For that base idea and valid models for the system's requirements, this article describes steps to reach consistent and valid UML sequence diagrams for a software system.

Formally talking, a system model is consistent with the user requirements if those requirements are writeable and verifiable as correct LTL formulas [6] [7]. Thus, it is relevant to consider that Promela language [7] [9] allows verifying the correctness of LTL formulas.

Taking into account current references about the correctness verification of UML sequence diagrams [6] [10] [11] with the common application of the model checker Spin / Promela and other formal tools [12] [13], the main goals of this article are to improve previous concerning the representation in Promela code of UML sequence diagrams [12] [10] and to give the necessary steps for establishing LTL formulas to verify properties of execution scenarios for the modeled system.

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This article promotes the use of UML sequence diagrams for modeling system behavior. This article uses a modified version of an existing case study [10] [11] for translating UML sequence diagrams into Promela code just to show improvements in the translation algorithm and highlight new considerations for the system transition states in the specification of LTL formulas to verify the consistency and correctness of systems' models. This article takes into account synchronous and asynchronous messages in the translation process, as well as additional details for the modeling and consideration of combined fragments of UML sequence diagrams. Thus, the correctness of a UML 2.0 sequence diagram for our case study is completely valid.

This article organizes as follows: Section 2 describes the main characteristics of UML sequence diagrams and describes a case study modeling its execution using a UML sequence diagram. Section 3 presents algorithms to translate UML sequence diagrams into Promela code with their application to the case study. Section 4 describes how to define a state transition system for UML sequence diagrams to specify LTL formulas of the modeled system for their correctness verification. In this section LTL formulas of the case study are obtained as well. Finally, section 5 indicates the pros and cons of this proposal along with future works and conclusions for this study.

II. UML Sequence Diagrams

In object-oriented software development, after defining actors and use cases for the application, a common task is to model and analyze the behavior or execution of use cases. Likewise, after establishing the main structural elements of the system, that is, classes and their components (attributes and methods), a traditional modeling task is to know the behavior and interaction of participant objects of those classes on critical scenarios to analyze behavioral characteristics of the participants. UML sequence diagrams permit describing system scenarios and understanding how their participant objects interact and react to special conditions over time [1] [3]. Participant elements, named or unnamed blocks, interact and communicate using synchronous or asynchronous messages (open and solid arrows, respectively).

UML sequence diagrams allow establishing combined fragments to support concurrent and parallel behavior, alternative and optional behavior, cycles, and exceptions [1] [2] [3]. Even though, there may be a high number of system scenarios, modeling critical scenarios of a system along with their participant instances is a relevant task for verifying a correct system execution.

Concerning the works of [2] and [3], UML sequence diagrams show collaborative behavior among participant objects, but sequence diagrams are not adequate to define the complete behavior and details for a particular object. For behavioral modeling of a single object, applying UML state diagram is more convenient. Even though UML state diagrams allow modeling the whole system behavior (the system as an object), to deduce all participant objects for each state change is neither simple nor direct. UML sequence diagrams allow modeling particular scenarios of the system execution, modularizing algorithmic behavior (combined fragments), and mixing behavioral scenarios (combined fragments and gates). A complete system behavior model is reachable.

As a practical application, this article models a modified version of a traditional case study [10] [11], the ATM system, to show new considerations to translate UML sequence diagrams into Promela code: to define guards of the associated state transition system to consistently specify LTL formulas for their correctness verification, and to be able to reach a correctness verification of the complete model.

Figure 1 shows the UML sequence diagrams for a scenario of the case study for interactions among anonymous instances of the classes User, ATM, and Bank. A user first inserts his / her card in the ATM (InsertCard() message); then, the ATM in parallel (combined fragment par), first, communicates with the Bank to validate the card status; and, second, asks for and receives the user introduced PIN. Two possible results exist regarding the card status (combined fragment alt): 1. if the card status is OK (Cardok = true), ATM asks for and receive the PIN validation; 2. if the card is not valid (Cardok = false), then the card is ejected. Two possible results exist concerning the PIN validation (combined fragment alt): 1. if the PIN were not valid, the card is ejected; 2. if the PIN were valid, the user can proceed to operate with its bank account using the ATM. A combined fragment alt exists to proceed with a bank transaction: 1. if the card or PIN were not valid, then the card is ejected; 2. if the card and the PIN were valid, then the User provides his account and the desired bank operation for the ATM to proceed. Assuming only 2 operations exist in the ATM (CashAdvance and ejectCard), the last combined fragment alt contains a combined fragment loop concerning the operation selection that iterates as long as the chosen operation is not ejectCard. For CashAdvance, the User indicates the required quantity of cash, then the ATM checks the ATM card balance and delivers its status. After, because BalanceOk = true or BalanceOk = false, there is an alt combined fragment to indicate either t pick the cash or insufficient money. Following this combined fragment alt, inside the loop the User can choose a new operation in the ATM. Finally, after finishing the loop, the card is ejected.

III. Algorithm to Translate a UML Sequence Diagram into Promela Code

In general, each participant of a UML sequence diagram is a process in Promela (Process or Protocol Meta Language). Basically, for two instances A and B in a UML sequence diagram, when A sends a message to B, either that corresponds to a signal or to a request of a method of B [14]. Modeling this situation in Promela, because Promela supports sending and receiving messages between processes by channels, A is the sender and B is the receiver of the message in a channel with the same name as the original message in the UML sequence diagram. Furthermore, when A needs return values, B sends them using an additional channel, $R_{OriginalName}$, including its output parameters.

It is entirely relevant to consider the synchronization nature of each message (synchronous or asynchronous), because in Promela the size of a channel allows determining that channels behavior [9]. A channel with size =1 represents an asynchronous channel while a channel with size = 0 represents a rendezvous communication or synchronous channel.

It is entirely relevant to consider the synchronization nature of each message (synchronous or asynchronous), because

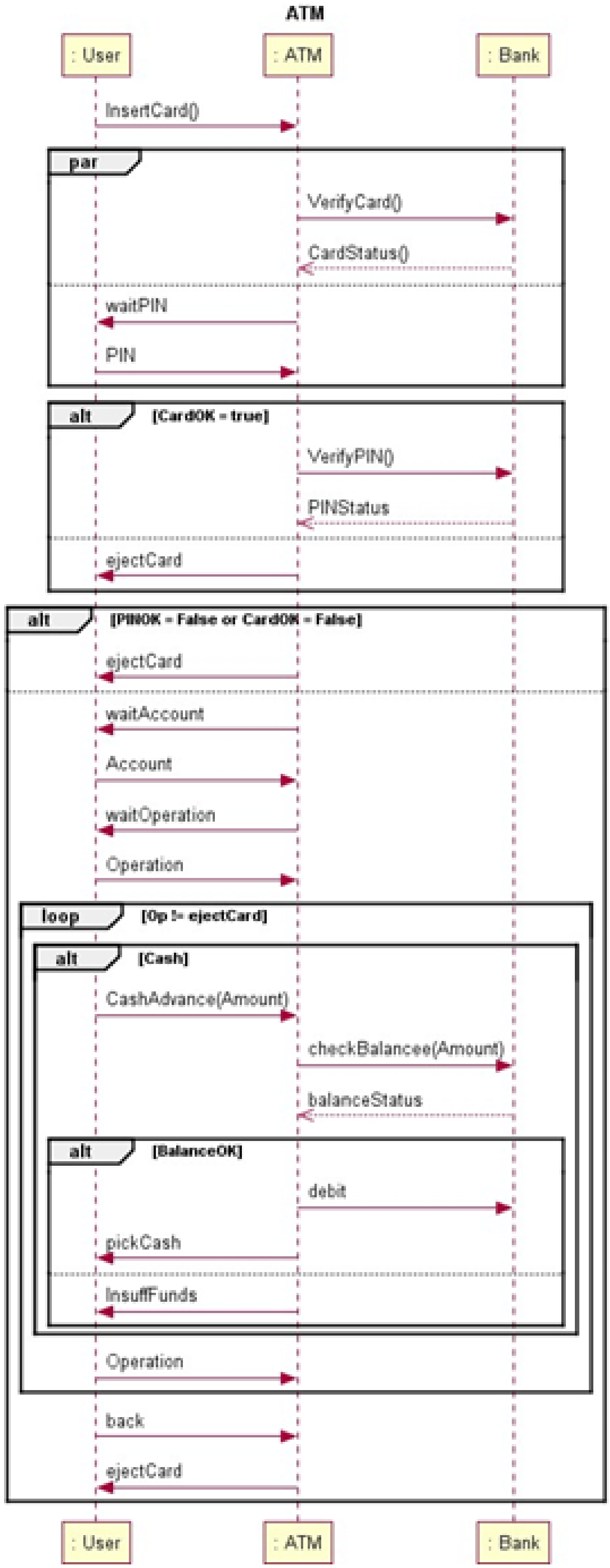

Fig. 1. UML Sequence Diagram for a Scenario of the ATM System.

in Promela the size of a channel allows determining that channels behavior [7]. A channel with size =1 represents an asynchronous channel while a channel with size = 0 represents a rendezvous communication or synchronous channel.

Furthermore, each synchronous message implies that the sender of the message has to wait until getting informed about a complete reception of the message. Thus, the sender needs to receive a reception confirmation to continue its work. Usually, each synchronous message in UML sequence diagrams requires a return value. This situation was solved in the classic UML by the use of return messages, but this situation is implicit in UML 2.0, that is, a return message is not necessary. For example, for the first message in the case study which is synchronous, there is an associated return value which should be known by the User, status of the card (CardOK), to continue in this scenario. One solution is to represent these required values as global variables in Promela, but global variables are visible for all the system processes, so messages are not directly required for communicating. A different solution for those synchronous messages which require a return value is to include an asynchronous channel to return those required values. This option claims for establishing communication because to see the result of any synchronous operation, a return message (R Message) is necessary. Nevertheless, as we later review, global variables are used for sharing elements among the main process and sub-processes. Thus, in the case study, to know the card status, there should be a return message in the first section of the combined fragment par, after ATM receives that information from the Bank, but this action is part of a section of the combined fragment par, and the process User communicates in a different section as well. So, this particular scenario includes a return message to know the card status as well as a global shared variable for the process User and its sub-processes User1 and User2. This modeling idea represents an essential element not considered by previous articles about this topic.

Moreover, a situation exists for which the use of asynchronous messages is typical: when a participant sends a message to itself. The simplest solution to represent the previous case in Promela is using an asynchronous channel of buffer size 1 to send and receive the message.

Through defining a channel in Promela, one can determine a message and its parameter. Besides, we define a symbolic name Parameters by using mtype. The main goal of this symbolic type is to support messages without parameters like signals in UML sequence diagrams. Thus, in Promela code the name of a message is represented by a channel name which also includes the type of the original parameters of the message with an additional parameter mtype for the symbolic name Parameters.

Promela uses special symbols for communication by sending and receiving values through channels, symbols ? and ! respectively. Therefore, so far there is an algorithm for translating a simple UML sequence diagram without combined fragments into Promela:

- Defining a symbolic name for the parameters.
- Identifying the synchronization nature of messages by creating buffer channels of size 0 for synchronous messages, and buffer channels of size 1 for asynchronous messages. These channels represent messages of the UML sequence diagram using the same name as those messages. If a synchronous message requires of returns values, a new synchronous channel R MessageName is defined along with the type of its return values. When a channel is defined, it has the same name as the original message and has a parameter mtype along with the original kind of message parameters.
- Defining a process for each participant in the UML sequence diagram, and assuring that each process sends and receives messages in the same order as in the sequence diagram.
- Defining an init process that runs the defined process associated with the UML sequence diagram participants.

After establishing the main step of a basic algorithm for translating simple UML sequence diagrams into Promela code, it is time to define a complete algorithm for that translation and thus be able to verify properties of the modeled scenario. After getting an algorithm with the established purpose, we will apply it to the model of the case study in Figure 1 for its translation into Promela code. To proceed, it is necessary to review the translation of the UML sequence diagram combined fragments into Promela code. Consequently, following the structure of the case study, we review first the translation of combined fragment par and apply it to the first part of the case study. Second, we review the translation of combined fragment alt and also apply it to the second combined fragment of the case study. In the translation of the alt combined fragment into Promela code, because the combined fragment opt is a reduced version of alt and both share the same logic, the translation into Promela code of the combined fragment opt is also reviewed. Finally, we detail the translation of the combined fragment loop and apply it for translating the remaining part of the case study by using the already reviewed combined fragments translation into Promela solutions. The code of Figures 4, 5, 6, 7 and 8 in the Appendix present a translation into Promela code for the complete case study of Figure 1.

A. Combined Fragment par into Promela

UML sequence diagrams allow modeling parallel interactions among processes which are so useful for modeling distributed and parallel scenarios. Assuming that different objects can communicate in parallel, this combined fragment is relevant for modeling parallel scenarios in which there are multiple sources and multiple targets, or only one source and multiple targets.

First, for a combined fragment par with multiple sources and destinations without communication interference. That is a simple situation for modeling in Promela because we can model each sender and receiver as different processes not using the same communication channels, that is, each couple or pair of processes in communication do not interfere with the communication of other couples. However, this situation is not directly simple for only one source and multiple destinations which is a common occurrence as in the case study of this article.

Second, for translating a combined fragment par into Promela code in which there is only one sender process and multiple target processes, the sender executes in parallel some sub-processes depending on the required number of parallel processes. This set of sub-processes sends messages and receives messages in parallel, and has coordinated access to the primary sender process properties. In that sense, each property of the primary sender process is a shared resource for the set of sub-processes, and each property has a token for guaranteeing exclusive access when that is required. Therefore, these shared properties and their tokens are global variables in Promela code for modeled scenarios. Thus, if sub-processes access different properties of the sender, those accesses are in parallel; and token variables permit exclusively obtaining a property value. Furthermore, it is relevant to distinguish between active and inactive processes in a combined fragment par. An active process in a combined fragment par sends, receives, or executes both actions in more than one division of the combined fragment.

Considering the case study combined fragment par, in the section Appendix Codes 3 and 4 show the Promela code translation for that combined fragment.

For a secure mutual exclusion, this article assumes that the properties of the sender are global variables in Promela code, and each property has a token to guarantee mutual exclusion. Also, asynchronous channels of buffer size1 models each token and each of them initially contains one stored value. Thus, when a process wants to access a shared resource, the process asks for the token, asks for a message in the associated channel, and if it were free (not used), then it has access to the resource. Note that during the combined fragment par, if a shared resource is free, there is a message on the channel. Moreover, if another sub-process wants to access to the same resource, it must wait for the token, the existence of a message in the channel, and for a sub-process that delivers the token sending a message in the associated token channel to wake up a process or sub-process that waits for the sent message. This translation that guarantees exclusive access on shared resources among multiple processes, participant objects of a UML sequence diagram translated into Promela code, is an additional improvement to previous translations of UML sequence diagrams into Promela code.

B. Combined Fragment alt into Promela

This combined fragment presents different interaction alternatives. Therefore, combined fragment alt represents a set of execution options for sending and receiving messages.

Promela allows using the conditional structure for sending messages. In that situation, each sender must include the condition associated with its actions. In the Appendix section, Code 2, Code 3, and Code 5 present the combined fragment alt use.

It is relevant to mention that a combined fragment opt behaves analog to a combined fragment alt with only one conditional division. Thus, this translation of combined fragment alt is also applicable for combined fragment opt.

Note that presenting examples with the use of messages with parameters is an additional issue not shown in previous mode ls for translating the original version of this case study [10] [11].

C. Combined Fragment loop into Promela

A combined fragment loop permits a cycle of actions when a defined guard condition is true. When that variable is false, the combined fragment loop finishes proceeding with the next action outside the loop. In each iteration of an instance of this combined fragment, there can be active and inactive participants, that is, active and inactive processes in the associated Promela code. Each active process in the Promela code presents a do cycle with a logical condition to iterate, and inactive processes only present a conditional statement to know the end of their cycle. In practice, in a Promela code of a UML sequence diagram combined fragment loop, condition variables are global because those variables are visible for active and inactive processes.

In a combined fragment loop, it is relevant to differentiate among active processes that communicate with synchronous and asynchronous messages. A sender of asynchronous messages does not wait for a confirmation of reception and continue with the iteration meanwhile the receiver can be waiting for receiving a possible previously lost message. The presence of asynchronous messages can originate faults (missed messages), and model checking reveals these situations. Since asynchronous messages are part of the nature of distributed systems [15], it is relevant to understand their nature and include forms of synchronization for processes that communicate by asynchronous messages.

Even though in a combined fragment loop, it is relevant to define a number of iterations, there exist loops for which that number is imprecise. In those scenarios, the end of the loop is not directly determined, and this situation can generate infinite cycles (a potential failure).

To illustrate the use of a combined fragment loop and its representation in Promela code, see Code 3 in the section Appendix. In iterations of a combined fragment loop there should be actions to finishing the cycle. This situation should be in any cycle, including those cycles without an exact number of iterations. The use of non-deterministic options is relevant to select values for simulating execution of system scenarios, specifically for those which include at least two potential options.

IV. LTL Formulas for Verifying the Correctness of UML Sequence Diagrams

Defining LTL formulas for UML sequence diagrams require to determine the associated state transition system (STS system). Logically, STS should represent the set of events in a UML sequence diagram (each event potentially determines a state change). Following and extending the original ideas of [8], a set of tuples including guard variables for the sending or reception of messages characterizes the states change in an STS system:

- $receive_{NameOfMessage}$: Identifies the reception of the message.
- $send_{NameOfMessage}$: Identifies the sending of the message.

- proc1 $Participant_{NameOfMessage}$: Identifies the participant source of the message.
- proc2 $Participant_{NameOfMessage}$: Identifies a participant tar

Even though state variables allow writing LTL formulas to verify properties of the modeled system execution, there are no guards that represent return values of reply messages. According to [6], return values are relevant because their change allows verifying the existence of transient and Byzantine faults. To represent reply values a new guard, variableNameOfMessage, is added to the tuple. Thus, an LTL formula for the case study, after the participant User inserts the card in the ATM (after the user sends the message $send_{InsertCard}$, the User eventually receives a message to see the card state (receiveR InsertCard), and that value is assigned to the variable CardOKR InsertCard. Therefore, with the fact that a message cannot be received if it was not sent, the associated LTL formula for the sending and reception of a reply message is CardOkR InsertCard; receiveR InsertCard. Note that this LTL formula does not verify the existence of sources and destination. Considering that execution, combined fragment divisions usually depend on guard variables, those variables are also part of the messages inside those divisions.

Figures 2 and 3 show the set of transition tuples for the ATM system. The guards of these formulas permit verifying properties of the ATM system. Taking into account the syntax and semantic of symbols for defining LTL formulas (G for always, globally; F for eventually, in the future; X for next; and U for until), we define LTL formulas using variables of the STS system to verify properties of the ATM system.

Taking into account syntax and semantic of symbols to define LTL formulas (G for always, globally; F for eventually, in the future; X for next; and U for until), it is possible to define LTL formulas using variables of the STS system are defined to verify properties of the ATM system. The following sets of formulas are verified (they do not give a counterexample):

- G($receive_{InsertCard} \wedge (\neg CardOK_{CardStatus} \vee \neg PINOK_{PINStatu}) \rightarrow \neg(proc1\_User_{waitAccount} \wedge receive_{waitAccount})$. This LTL formula establishes that always a card is inserted and either that card of the associated got it PIN are not valid; then the User will not be asked for his account. There is not a counter-example for this formula..
- $\neg(proc1\_User_{pickCash} \wedge receive_{pickCash} \cup (proc1\_Bank_{debit} \wedge rceive_{debit}))$. This LTL formula indicates that a User does not receive a message pickCash meanwhile the Bank does not receive a debit message. There is not a counter-example for this formula.
- G($(proc1\_User_{insufFund} \wedge receive_{insufFund}) \rightarrow (\neg proc1\_User_{ejectCard} \cup (proc1\_ATM_{waitOperation} \wedge send_{waitOperation}))$. This LTL formula indicates that a User that has received a message InsufFund for insufficient funds is not the main actor of the message for the eject card action until the bank does not send a message waitOperation.

V. Discussion

We implemented these proposals using Eclipse [16] along with their PlantUML [17] and Spin / Promela [18] plugins. This technique permits validating behavioral modeling of software systems using UML Sequence diagrams which is of great value to guarantee software quality products. This proposal solution performs an automated validation which is one of its great properties for applying it to model the behavior of software products in the software development process. Nevertheless, current fast-development of software approaches such as RUP and XP in the practice demand use less time for modeling and formal modeling.

This article shows the importance of UML sequence diagrams and the benefits of modeling the behavior of software systems. The use of combined fragments in UML sequence diagrams gives the capacity for modeling algorithmic behavior, and by their translation into Promela code along with the definition and correctness verification of LTL formulas, detecting algorithmic, and faults in the requirement for their correction seem possible. Simulating faults in modeled systems behavior to see their effect on the software system would permit defining and applying solutions before their occurrence.

VI. Related Works

Primarily, Mellor et al. [19] detail about executable UML models which are like code for their examination. Those models do not work on model checking.

Baresi et al. [20] present an efficient solution for modeling checking graph transformation systems. This proposal would do not entirely support the model checking of model checking of UML sequence diagrams for their UML class diagram relations.

The works [21] and [22] applies model checking on UML sequence diagrams using labels to identify combined fragments for getting an ordered code in Eclipse Java [16] using PlantUML [17] and Spin / Promela plugging [18], that is, to accept a PlantUML sequence diagram as input and generate its translation to Promela code. The use of labels is recommendable to identify combined fragments for getting an ordered code, even though those labels do not affect the execution. These works do not directly describe the translation into Promela code of UML sequence diagrams combined fragments.

The work of [23] mainly describe and exemplify the development of a relational database schema from a conceptual UML schema in the form of a UML class diagram and OCL constraints, but they do not link UML class diagrams and UML sequence diagrams.

VII. Conclusions

This article shows new considerations for translating UML sequence diagrams into Promela code expanding this process for more case studies, specifically:

- distinguishing the synchronization nature of messages;
- defining how to work with shared resources through processes and associated sub-processes;

$\{send_{InsertCard}; proc1\_User_{InsertCard}; proc2\_ATM_{InsertCard}\}$
$\{receive_{InsertCard}; proc1\_ATMInsertCard; proc2_2\_User_{InsertCard}\}$

$\{send_{VerifyCard}; proc1\_ATM_{VerifyCard}; proc2\_Bank_{VerifyCard}\}$
$\{receive_{VerifyCard}; proc1\_Bank_{VerifyCard}; proc2\_ATM_{VerifyCard}\}$
$\{send_{CardStatus}; proc1\_Bank_{CardStatus}; proc2\_ATM_{CardStatus}\}$
$\{receive_{CardStatus}; proc1\_ATM_{CardStatus}; proc2\_Bank_{CardStatus}; CardOK_{CardStatus}\}$
$\{send_{R\_InsertCard}; proc1\_ATM_{R\_InsertCard}; proc2\_User_{R\_InsertCard}\}$
$\{send_{waitPIN}; proc1\_ATM_{waitPIN}; proc2\_User_{waitPIN}\}$
$\{receive_{waitPIN}; proc1\_User_{waitPIN}; proc2\_ATM_{waitPIN}; CardOK_{CardStatus}\}$
$\{send_{PIN}; proc1\_User_{PIN}; proc2\_ATM_{PIN}\}$
$\{receive_{PIN}; proc1\_ATM_{PIN}; proc2\_User_{PIN}\}$

$\{CardOK_{CardStatus}; send_{verifyPIN}; proc1\_ATM_{verifyPIN}; proc2\_Bank_{verifyPIN}\}$
$\{CardOK_{CardStatus}; receive_{verifyPIN}; proc1\_Bank_{verifyPIN}; proc2\_ATM_{verifyPIN}\}$
$\{CardOK_{CardStatus}; send_{PINStatus}; proc1\_Bank_{PINStatus}; proc2\_ATM_{PINStatus}\}$
$\{CardOK_{CardStatus}; receive_{PINStatus}; proc1\_Bank_{PINStatus};$
$proc2\_ATM_{PINStatus}; PINOK_{PINStatus}\}$
$\{!CardOK_{CardStatus}; send_{ejectCard}; proc1\_ATM_{ejectCard}; proc2\_User_{ejectCard}\}$
$\{!CardOK_{CardStatus}; receive_{ejectCard}; proc1\_User_{ejectCard}; proc2\_ATM_{ejectCard}\}$

$\{!CardOK_{CardStatus}; !PINOK_{PINStatus}; send_{ejectCard}; proc1\_ATM_{ejectCard};$
$proc2\_User_{ejectCard}\}$
$\{!CardOK_{CardStatus}; !PINOK_{PINStatus}; receive_{ejectCard}; proc1\_User_{ejectCard};$
$proc2\_ATM_{ejectCard}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; send_{waitAccount}; proc1\_ATM_{waitAccount};$
$proc2\_User_{waitAccount}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; receive_{waitAccount}; proc1\_User_{waitAccount};$
$proc2\_ATM_{waitAccount}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; send_{Account}; proc1\_User_{Account};$
$proc2\_ATM_{Account}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; receive_{Account}; proc1\_ATM_{Account};$
$proc2\_User_{Account}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; send_{waitOperation}; proc1\_ATM_{waitOperation};$
$proc2\_User_{waitOperation}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; receive_{waitOperation}; proc1\_User_{waitOperation};$
$proc2\_ATM_{waitOperation}\}$

Fig. 2. First Part of State Transition System for ATM System.

$\{CardOK_{CardStatus}; PINOK_{PINStatus}; send_{Operation}; proc1\_User_{Operation};$
$proc2\_ATM_{Operation}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; receive_{Operation}; proc1\_ATM_{Operation};$
$proc2\_User_{Operation}; (Op = 1); Cash\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$send_{checkBalance}; proc1\_ATM_{checkBalance}; oc2\_Bank_{checkBalance}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$receive_{checkBalance}; proc1\_Bank_{checkBalance}; proc2\_ATM_{checkBalance}\}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$send_{balanceStatus}; proc1\_Bank_{balanceStatus}; proc2\_ATM_{balanceStatus}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$receive_{balanceStatus}; proc1\_ATM_{balanceStatus};$
$proc2\_Bank_{balanceStatus}; BalanceOK\}$

$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$BalanceOK; send_{debit}; proc1\_ATM_{debit}; proc2\_Bank_{debit}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$BalanceOK; receive_{debit}; proc1\_Bank_{debit}; proc2\_ATM_{debit}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$BalanceOK; send_{pickCash}; proc1\_ATM_{debit}; proc2\_User_{pickCash}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$BalanceOK; receive_{pickCash}; proc1\_User_{pickCash}; proc2\_ATM_{pickCash}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$!BalanceOK; send_{InsuffFunds}; proc1\_ATM_{InsuffFunds}; proc2\_User_{InsuffFunds}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$!BalanceOK; receive_{InsuffFunds}; proc1\_User_{InsuffFunds};$
$proc2\_ATM_{InsuffFunds}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$send_{Operation}; proc1\_User_{Operation}; proc2\_ATM_{Operation}; \}$
$\{CardOK_{CardStatus}; PINOK_{PINStatus}; (Op = 1); Cash;$
$receive_{Operation}; proc1\_ATM_{Operation}; proc2\_User_{Operation}; \}$

$\{send_{ejectCard}; proc1\_ATM_{ejectCard}; proc2\_User_{ejectCard}\}$
$\{receive_{ejectCard}; proc1\_User_{ejectCard}; proc2\_ATM_{ejectCard}\}$

Fig. 3. Second Part of State Transition System for ATM System.

- giving steps to translate the combined fragment loop regardless of their end condition; and
- translating into Promela reception and sending of messages with parameters.

The steps to define a state transition system to establish and verify LTL formulas in a Promela code for a UML sequence diagram gives a way to check the correctness of UML sequence diagram with the elements analyzed by this article. By having a general algorithm to translate UML sequence diagrams into Promela code along with knowing how to define a state transition system for UML sequence diagrams, establishing and verifying LTL formulas in the model system is a possible task. Without a doubt, this articles proposal permits verifying the correctness of UML sequence diagrams.

Promela code along with the LTL formula verification facilitates detection of faults in a diagram written in Promela, and UML sequence diagram translations into Promela code would permit their refinement. However, for complete verification of correctness about UML sequence diagrams messages syntax, the associated UML class diagrams are necessary to know their methods language.

This research proposal establishes steps for translating UML sequence diagrams into Promela code. Those steps are implementable as a software application using free tools for obtaining the Promela code and testing the UML sequence diagrams correctness.

Because this article gives the necessary steps for translating UML sequence diagrams into Promela code for the LTL formulas verification, using the mentioned steps and producing a tool with them would enable to find mistakes for their correction and producing accurate software according to the correctness of the software requirements. Even though Spin and Promela are more linked to distributed environments, this article demonstrates that is possible to use those tools in a non-distributed environment like traditional UML models.

As a future work, extending currently produced tools to support the translation into Promela code of other combined fragments of UML sequence diagrams (break, strict, ignore, consider, assert, and neg). Even though, the already reviewed combined fragments in this article are algorithmically the most relevant, our goal of producing a complete tool for correctness verification takes us to work on the way to translate these additional combined fragments. Now, there are steps to translate a UML sequence diagram in Promela code for implementing a software tool to generate Promela code on similar case studies. However, that does not guarantee the support for other UML diagram models such as class diagrams. For a complete consistency among UML class diagrams and UML sequence diagrams, UML class diagrams have to be an additional input for a refinement process. Therefore, a future goal is to produce a tool for refinement and consistency verification among UML class and sequence diagrams.

REFERENCES

[1] S. G. Akl, "Superlinear performance in real-time parallel computation," *J. Supercomput.*, vol. 29, no. 1, pp. 89–111, Jul. 2004. [Online]. Available: https://doi.org/10.1023/B:SUPE.0000022574.59906.20

[2] C. Larman, *Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development (3rd Edition)*. Upper Saddle River, NJ, USA: Prentice Hall PTR, 2004.

[3] R. Miles and K. Hamilton, *Learning UML 2.0*. O'Reilly Media, Inc., 2006.

[4] T. Pender, *UML Bible*, 1st ed. New York, NY, USA: John Wiley & Sons, Inc., 2003.

[5] M. Y. Vardi, "An automata-theoretic approach to linear temporal logic," in *Proceedings of the VIII Banff Higher Order Workshop Conference on Logics for Concurrency : Structure Versus Automata: Structure Versus Automata*. Secaucus, NJ, USA: Springer-Verlag New York, Inc., 1996, pp. 238–266. [Online]. Available: http://dl.acm.org/citation.cfm?id=239519.239527

[6] M. Usman, A. Nadeem, T.-h. Kim, and E.-s. Cho, "A survey of consistency checking techniques for uml models," in *Proceedings of the 2008 Advanced Software Engineering and Its Applications*, ser. ASEA '08. Washington, DC, USA: IEEE Computer Society, 2008, pp. 57–62. [Online]. Available: https://doi.org/10.1109/ASEA.2008.40

[7] Y. KAWAKAMI, T. YOKOGAWA, H. MIYAZAKI, S. AMASAKI, Y. SATO, and M. HAYASE, "Symbolic model checking of interactions in sequence diagrams with combined fragments by smv," vol. 4, pp. 1692–1695, 11 2010.

[8] F. U. Muram, H. Tran, and U. Zdun, "A model checking based approach for containment checking of uml sequence diagrams," in *23rd Asia-Pacific Software Engineering Conference (APSEC 2016)*, December 2016. [Online]. Available: http://eprints.cs.univie.ac.at/4830/

[9] J. Chen and S. S. Kulkarni, "Application of automated revision for UML models: A case study," in *Distributed Computing and Networking - 13th International Conference, ICDCN 2012, Hong Kong, China, January 3-6, 2012. Proceedings*, 2012, pp. 31–45. [Online]. Available: https://doi.org/10.1007/978-3-642-25959-3_3

[10] M. Ben-Ari, *Principles of the Spin Model Checker*, 1st ed.

[11] V. Lima, C. Talhi, D. Mouheb, M. Debbabi, L. Wang, and M. Pourzandi, "Formal verification and validation of uml 2.0 sequence diagrams using source and destination of messages," *Electron. Notes Theor. Comput. Sci.*, vol. 254, pp. 143–160, Oct. 2009. [Online]. Available: http://dx.doi.org/10.1016/j.entcs.2009.09.064

[12] M. Debbabi, F. Hassane, Y. Jarraya, A. Soeanu, and L. Alawneh, *Verification and Validation in Systems Engineering: Assessing UML/SysML Design Models*, 1st ed. Berlin, Heidelberg: Springer-Verlag, 2010.

[13] A. Nimiya, T. Yokogawa, H. Miyazaki, S. Amasaki, Y. Sato, and M. Hayase, "Model checking consistency of uml diagrams using alloy," vol. 71, pp. 547–550, 11 2010.

[14] C. Vidal, R. Villarroel, X. L'opez, and J. Rubio, "Una propuesta de algoritmo spin / promela para el anlisis y diagnstico de errores en diagramas de secuencia uml," *Información Tecnológica*, vol. 30, no. 1, 2019.

[15] M. A. Oubelli, N. Younsi, A. Amirat, and A. Menasria, "From uml 2.0 sequence diagrams to promela code by graph transformation using atom3," in *Proceedings of the Third International Conference on Computer Science and its Applications, CIIA*, Saida, Algeria, 2011.

[16] "Eclipse foundation: The platform for open innovation and collaboration," http://www.eclipse.org/, accessed: 2018-13-08.

[17] "Plantuml in a nutshell," http://en.plantuml.com/, accessed: 2018-13-08.

[18] "Eclipse plug-in for spin," http://matrix.uni-mb.si/en/science/tools/eclipse-plug-in-for-spin/, accessed: 2018-13-08.

[19] S. J. Mellor and M. Balcer, *Executable UML: A Foundation for Model-Driven Architectures*. Boston, MA, USA: Addison-Wesley Longman Publishing Co., Inc., 2002.

[20] L. Baresi, V. Rafe, A. T. Rahmani, and P. Spoletini, "An efficient solution for model checking graph transformation systems," *Electron. Notes Theor. Comput. Sci.*, vol. 213, no. 1, pp. 3–21, May 2008. [Online]. Available: http://dx.doi.org/10.1016/j.entcs.2008.04.071

[21] "Review of: Distributed systems: An algorithmic approach (2nd edition) by sukumar ghosh," *SIGACT News*, vol. 47, no. 4, pp. 13–14, Dec. 2016, reviewer-de Vera,Jr., Ramon. [Online]. Available: http://doi.acm.org/10.1145/3023855.3023860

[22] S. Ghosh, *Distributed Systems: An Algorithmic Approach, Second Edition*, 2nd ed. Chapman & Hall/CRC, 2014.

[23] M. Gogolla and K.-H. Doan, "Quality improvement of conceptual uml and ocl schemata through model validation and verification." in *Conceptual Modeling Perspectives*, J. Cabot, C. Gmez, O. Pastor, M.-R. Sancho, and E. Teniente, Eds. Springer, 2017, pp. 155–168. [Online]. Available: http://dblp.uni-trier.de/db/conf/birthday/olive2017.htmlGogollaD17

VIII. Appendix

```
mtype = {Parameters}

chan InsertCard   = [0] of {mtype};
chan R_InsertCard = [1] of {mtype, bit};


chan VerifyCard   = [0] of {mtype};
chan CardStatus   = [1] of {mtype, bit}
chan waitPIN      = [0] of {mtype}
chan PIN          = [1] of {mtype, byte}
chan R_PIN        = [1] of {mtype, bit}


chan VerifyPIN  = [0] of {mtype, byte}
chan PINStatus  = [1] of {mtype, bit}
chan ejectCard  = [0] of {mtype}


chan waitAccount    = [0] of {mtype}
chan Account        = [0] of {mtype, byte}
chan waitOperation  = [0] of {mtype}
chan Operation      = [0] of {mtype, byte}


chan CashAdvance    = [0] of {mtype, int}
chan checkBalance   = [0] of {mtype, int}
chan balanceStatus  = [1] of {mtype, bit}

chan debit          = [0] of {mtype, int}
chan pickCash       = [0] of {mtype}
chan InsuffFunds    = [0] of {mtype}

chan back  = [0] of {mtype}

////Shared Resource and Tokens
chan Token1 = [1] of {mtype}; char Token2 = [1] of {mtype};

//Variables shared by processes User, User1 & User2...
bit CardOK; byte PINNumber;

//Variables shared by ATM, ATM1 & ATM2...
bit CardOK_ATM; byte PINNumber_ATM;
```

Fig. 4. Case Study - Promela Code (Part I)

```
proctype User()
{ bit BalanceOK; bit PINOK; byte Op; bit Cash; byte Acc; int Amount;
    InsertCard!Parameters; //First Action...
    CombinedFragment_Par:
        Token1!Parameters; run User1();
        Token1!Parameters; run User2();
        //Wait until obtain a final result...
        Token1?Parameters; Token1?Parameters;
    CombinedFragment_Alt1:
    if
      :: (!CardOK) -> ejectCard?Parameters
      :: else          -> R_PIN(PINOK)
    fi;
    CombinedFragment_Alt2:
    if
      :: (!CardOK || !PINOK) -> ejectCard?Parameters
      :: else  -> waitAccount?Parameters;
             Acc = 1; //#Account = 1...
             Account!Parameters(Acc); waitOperation?Parameters;
             Cash = 1; Op = Cash; //Operation = CashAdvance
             Operation!Parameters(Op);
             CombinedFragment_Loop:
             do
             :: (Op == 1) ->
                    CombinedFragment_Alt3:
                        if
                        ::(Cash) -> Amount = 1000; //Money
                           CashAdvance!Parameters(Amount);
                           R_CashAdvance(BalanceOK)
                           CombinedFragment_Alt4:
                              if
                              :: (BalanceOK)->pickCash!Parameters
                              ::  else -> skip;
                              fi
                        :: else        -> skip;
                        fi;
                        if
                        :: (1) -> Op = 1; //Cash Advance
                        :: (1) -> Op = 0; //Eject Card
                        fi;
                        Operation!Parameters(Op);
            :: (Op != 1) -> break;
            od;
            back!Parameters; ejectCard?_Parameters; //Scenario End
    fi;
}
```

Fig. 5.   Case Study - Promela Code (Part II)

```
proctype ATM()
{  bit PIN_Status; byte AccATM; byte ATMOp; int Amount;
   bit  BalanceStatusATM;
   InsetCard?Parameters; //First action of ATM...
   CombinedFragment_Par:
       Token!Parameters; run ATM1();
       Token!Parameters; run ATM2();
       //Wait until obtain a final result...
       Token?Parameters; Token?Parameters;
    CombinedFragment_Alt1:
    if
    :: (CardOK) -> VerifyPIN!Parameters(PINNumberATM);
            PINStatus?Parameters(PIN_Status);
            R_PIN!Parameters(PIN_Status);
    :: else -> ejectCard!Parameters;
    fi;
    CombinedFragment_Alt2:
    if
      :: (!CardOK || !PINOK) -> ejectCard!Parameters;
      :: else -> waitAccount!Parameters;
           Account?Parameters(AccATM); waitOperation!Parameters;
           Operation?Parameters(ATMOp); //a Cash Advance
           CombinedFragment_Loop:
           do
           :: (ATMOp == 1) ->
                Cash = ATMOp;
                CombinedFragment_Alt3:
                if
                :: (Cash) -> CashAdvance?Parameters(Amount);
                  checkBalance!Parameters(Amount);
                  balanceStatus?Parameters(BalanceStatusATM);
                  CombinedFragment_Alt4:
                  if
                  :: (BalanceStatusATM) -> debit!Parameters(Amount);
                  pickCash!Parameters;
                  :: else -> InsuffFunds!Parameters;
                  fi;
                :: else        -> skip;
                fi;
                Operation?Parameters(ATMOp);
           od
       back?Parameters;
       ejectCard!Parameters;
    fi
 }
```

Fig. 6.   Case Study - Promela Code (Part III)

```
 ////Sub-Processes User1 & User2
proctype User1()
{
  CombinedFragment_Par:
    //Asking for the Token
    Token?Parameters;
    R_InsertCard?Parameters(CardOK); //Receive Status the Card status...
    //Releasing the Token
    Token!Parameters;
 }
 proctype User2()
 {
  CombinedFragment_Par:
    //Asking for the Token
    Token?Parameters;

    waitPIN?Parameters;
    PINNumber = 1; PIN!Parameters(PINNumber);

    //Releasing the Token
    Token!Parameters;
 }
 ////Sub-Processes ATM1 & ATM2
proctype ATM1()
{
CombinedFragment_Par:
  //Asking for the Token
  Token?Parameters;
  VerifyCard!Parameters();
  CardStatus?Parameters(CardOKATM);
  R_InsertCard(CardOKATM);
  //Releasing the Token
  Token!Parameters;
}
proctype ATM2()
{
CombinedFragment_Par:
  //Asking for the Token
  Token?Parameters;
  waitPIN!Parameters;
  PIN?Parameters(PINNumberATM);
  //Releasing the Token
  Token!Parameters;
}
```

Fig. 7. Case Study - Promela Code (Part IV)

```
proctype Bank()
 {
   int V; byte _PIN_; bit BalanceOKBank;

   VerifyCard?Parameters;
   if
     :: (1) -> CardStaus!Parameters(1); //Valid Card
     :: (1) -> CardStatus!Parameters(0) //Valid Card
   fi;

   CombinedFragment_Alt1:
   if
     :: (CardOK) -> VerifyPIN?Parameters(_PIN_);
             if
             :: (1) -> PINStatus!Parameters(1) //Valid PIN
             :: (1) -> PINStatus!Parameters(0) //Valid PIN
             fi;
    ::  else      -> skip;
  fi;
  CombinedFragment_Alt2:
  if
    :: (CardOK) -> checkBalance?Parameters(V);
             if
             :: (1) -> balanceStatus!Parameters(1); //Valid Balance.
             :: (1) -> balanceStatus!Parameters(0); //Not valid Balance.
             fi;
    ::  else     -> skip;
  fi;
  CombinedFragment_Alt3:
     if
       :: (CardOK) -> checkBalance?Parameters(V);
             if
             :: (1) -> BalanceOKBank = 1; balanceStatus!Parameters(BalanceOKBank);
             //Valid Balance.
             :: (1) -> BalanceOKBank = 1; balanceStatus!Parameters(BalanceOKBank);
             //Not valid Balance.
             fi;
       ::  else     -> skip;
     fi;
 }
init {run ATM(); run User(); run Bank();}
```

Fig. 8. Case Study - Promela Code (Part V)