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A year spent in artificial intelligence is enough to make one believe in God.
Alan Perlis

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Editor's Note

The International Journal of Interactive Multimedia and Artificial Intelligence provides an interdisciplinary forum in which scientists and professionals share their research results and report new advances on Artificial Intelligence tools and tools that use Artificial Intelligence with interactive multimedia techniques. The research works presented in this regular issue cover different fields of application such as medicine, industry or education, proposing solutions based on various topics of interest, as for example: neural networks, neuro-fuzzy systems, case-based reasoning systems, image retrieval, classification, feature selection, meta-heuristics, constraint satisfaction, or knowledge-based systems.

Machado Fernández and Bacallao Vidal [1] propose a method based on artificial neural networks to improve the stability of radar detectors in the identification of clutter anomalies. Sea clutter, which refers to unwanted echoes in naval radars, is modelled to simulate radars performance before site implementation, with the aim of improving their proper operation in different scenarios. The neural network solution estimates the shape parameters of the Pareto distribution used to model the phenomenon of sea clutter. Authors prove that the proposed method, with low computational costs, outperforms the classic methods based on Maximum Likelihood Estimates.

Esmaeilpour and Mohammadi [2] present a method to recognize anesthesia states with high accuracy and low cost. The system estimates the depth of anesthesia using electroencephalogram signals, wavelet transform, and an Adaptive Neuro Fuzzy Inference System (ANFIS). Authors find that the use of ANFIS improves deficiencies observed in other previous methods. Since analyzing electroencephalogram signals directly is difficult, the propose method facilitates the estimation of the depth of anesthesia for anesthesiologists to administer the adequate dosage of a specific anesthetic drug.

Next article, authored by Kushwaha and Welekar [3], describes a Content-Based Image Retrieval (CBIR) system that uses a genetic algorithm for feature selection. Features refer to color, texture, shape and other characteristics of the image, and automatically extracting these features allows searching relevant images from large databases based on features similarity. The performance of a CBIR depends much on selecting a subset of relevant features from large features sets. Authors find that the use of a genetic algorithm in a CBIR system, as well as a clustering technique, reduces the time for retrieval and improves the retrieval precision.

Hbali et al. [4] present a marker-less augmented reality application, which benefits of boosting techniques. The accuracy of a trained face detector depends on the data, algorithm and training parameters used for training. The main objective of this research is to find the best training parameters that enable an accurate detector. To achieve this, authors tune a boosting based detector, varying the training parameter values, to achieve accuracy in the detection task. The optimized detector is integrated into a 3D real time augmented reality application where the position of the face is used as a marker-less object, overcoming the difficulty of using markers in augmented reality application.

Next paper, authored by Parashar et al. [5], describes a control system and push recovery controller for humanoid robot walking. Push recovery is an ability that bipedal robots must have. Firstly, authors collect push data by pushing a robot from behind and analyze the push recovery pattern. This analysis is supported by a machine learning technique, specifically, by the clustering algorithm K-means. From that, the push recovery strategy of the robot is found out. When the robot is not stable because the zero moment point is not in a safe region, the robot learns and modifies the algorithm to sustain walking.

Devi et al. [6] review the different feature sets used to differentiate non-infected and malaria infected erythrocytes. The aim is to effectively diagnose the presence of the malaria parasite host inside the erythrocyte by means of erythrocyte feature extraction and effective classification. This would allow avoiding the analysis work done by a clinical expert, which is tedious and depends on the skill of the professional.

Choudhary and Singh [7] perform the analysis of stability and temporal information processing capability of a hybrid spiking neuron model in distributed delay framework. The approach focuses on the hardware level implementation of artificial neurons. The authors study the temporal information processing capability in terms of inter-spike-interval (ISI) distribution. The research done shows that the spiking activity of the considered neuron model is invariant when a large fluctuation input is applied. Therefore, the model is capable to handle threshold variability and noisy parameters like those caused by increase of chip temperature, which is one of the common concerns in hardware level implementation of threshold based neuron models.

Next article, authored by Amar et al. [8], proposes a solution to protect the intellectual property of 3D objects. Digital watermarking is one of the best methods for data protection and authors propose a robust and blind watermarking algorithm. This uses characteristics of the mesh geometry to embed the watermark bits into the object by slightly shifting vertex positions. Moreover, thanks to the use of a blind detection scheme, the watermarked object is perceptually indistinguishable from the original one. The paper describes experiments that validate the quality of the watermarked object and its robustness under different attacks.

Kasihmuddin et al. [9] face the constraint optimization well-known problem MAX-kSAT with a method based on combining the use of a Hopfield network and a genetic algorithm. Their experimental results show that their solution outperforms conventional methods that are based only on Hopfield networks. Moreover, the proposed framework is solid promising to be valid to evaluate other satisfiability problems.

Sad Houari and Taghezout [10] describe a novel business rules management system that aims to efficiently capitalize experts' knowledge in small and medium enterprises. The solution includes a domain ontology and a multi-agent system. Several autonomous agents collaborate and interact to achieve a common goal while each one has its specific role such as supervising, interacting with the user, caring of security or detecting inconsistencies. The system presents advantages related to other described in literature as it deals with security and automatically manages the consistency of rules introduced by the experts during the capitalization of the business rules process, treating a higher number of inconsistency cases.

Continuing with multi-agent based approaches, next paper authored by Benkaddour et al. [11] proposes a system for solving industrial diagnostic problems based on agent-based modelling with case-based reasoning, as an alternative to reasoning rules. The system specifically provides a classification of the solutions given by operators in maintenance tasks, ranking them. Besides authors study similarity measures between the target case and case sources, to select the more suitable measure that improves the case-based reasoning results.

In the field of intelligent e-learning, Bhattacharya and Nath [12] discusses about motivations and limitations of some areas such as scaffolding based e-learning, personalized e-learning, confidence based e-Learning, intelligent system and technology enhanced learning. The paper includes a review on recent works in these areas.

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Osaba and Díaz [13] present the work developed during PhD thesis of first author, related to multi-population meta-heuristics for solving vehicle routing problems. The main contribution of this thesis is a meta-heuristic called Golden-Ball, which is conceptually original, based on soccer concepts. Besides, different real-world transportation problems are modelled and treated with Golden-Ball, such as newspaper distribution, and therefore the thesis also includes formulation and treatment of these problems.

Last paper, authored by Kamble et al. [14], is an exhaustive literature review on fractal coding, specifically on those approaches based on block matching motion estimation and automata theory. Fractal compression is an image and video compression technique, which has the following benefits: high compression rate and good image quality with fast decoding time. However, it is a lossy compression technique, which means that some data is lost during the compression process, and encoding time is long. Therefore, improving encoding time remains a challenge. The paper includes performance comparison of the different existing methods and concludes with a description of future scope.

Dr. Elena Verdú

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Improved Shape Parameter Estimation in Pareto Distributed Clutter with Neural Networks

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***Abstract* — The main problem faced by naval radars is the elimination of the clutter input which is a distortion signal appearing mixed with target reflections. Recently, the Pareto distribution has been related to sea clutter measurements suggesting that it may provide a better fit than other traditional distributions. The authors propose a new method for estimating the Pareto shape parameter based on artificial neural networks. The solution achieves a precise estimation of the parameter, having a low computational cost, and outperforming the classic method which uses Maximum Likelihood Estimates (MLE). The presented scheme contributes to the development of the NATE detector for Pareto clutter, which uses the knowledge of clutter statistics for improving the stability of the detection, among other applications.**

***Keywords* — Sea Clutter, Artificial Neural Networks, Pareto Distribution, Distribution Parameter Estimation.**

I. Introduction

A radar scans the surrounding area emitting electromagnetic waves that produce echoes after being reflected on nearby objects. Echoes are then received back in the transceiver containing the objects' information [1]. Depending on the type of application, radars must ignore certain reflections and focus on others [2].

In the specific case of coastal and ocean exploration, the reflective properties of the sea surface result in the generation of unwanted echoes that may reach high magnitudes. The elimination of these echoes, known as sea clutter, is one of the main problems faced by naval radars whose objective is to detect targets like ships or low altitude aircraft [3].

The representation of clutter is one of the topics most discussed in the literature [4-10]. Clutter modeling, as it's also called, facilitates the simulation of radars' performance before site implementation. As the clutter is a random signal, its modeling falls in the field of probability distributions.

Many distributions have been used in the modeling of sea clutter. The Weibull [11], K [12], Log-Normal [13], WW [14] and KK [15] are among the most commonly employed alternatives. However, in recent years evidence have been provided suggesting that the Pareto distribution may achieve a better modeling of the phenomenon than its traditional counterparts, while having a simple mathematical formulation [16]. Consequently, a significant amount of papers have been presented in a short period of time including the Pareto distribution in radar related solutions [17-22].

Among the different components of clutter modeling, the estimation of the distribution parameters has occupied a prominent place in multiple studies [23-26]. In the specific case of the Pareto distribution, various estimators have been proposed for the shape parameter that has a remarkable influence in the quality of the detection [21, 27, 28]. Nevertheless, the Maximum Likelihood Estimator (MLE) is commonly regarded as the classical estimator [29].

The Radar Research Team from the Instituto Superior Politécnico Jose Antonio Echeverria (ISPJAE-CUJAE) has developed improved parameter estimation techniques for the Weibull and K distributions using artificial neural networks (ANN) [30, 31]. Given the similarity of the above distributions and the Pareto alternative, the authors aimed at creating a new method for estimating the Pareto shape parameter using ANN.

The neural network, which was finally designed, achieves a precise and low computational cost estimation of the Pareto shape parameter in a wide range of possible values. Its design contributes to the development of the NATE (Neural Adaptive Threshold Estimation) detector for Pareto clutter, which uses the statistical knowledge of the clutter to improve the stability of detection in different scenarios. Similarly, the precise estimation of the clutter has application in the DRACEC scheme and in identifying anomalous sea surface conditions such as fish gatherings, oil spills or shipwrecks.

The paper is structured as follows. The second section introduces the fundamentals of the Pareto distribution, and the third one presents the method used in the design and training of the neural network. The four section entitled "Results and Discussion" characterizes the performance of the solution and compares it with the classical MLE alternative. Finally, in "Conclusions and Future Research" the contributions of the paper are summarized and recommendations are given for future research lines.

II. Pareto Distribution

The Pareto distribution has been used in modeling the income of a population [32] and in several fields of engineering [27, 28, 33], including sonar [34] and radar [16, 35, 36] applications. Particularly in [16], the application of the Pareto distribution in the representation of high-resolution X-band sea clutter, observed at low grazing angles, was examined. The investigation compared the Pareto fit with the popular Log-Normal, Weibull, K, KK and WW intensity models. As a result, it was found that the Pareto distribution achieved a better fit than these traditional models.

It was also reported that the closest competitor to Pareto was the KK distribution. As the Pareto distribution is characterized by a simple PDF (Probability Density Function), the results are very promising. It is suggested that the Pareto distribution will become a natural replacement for the KK which uses between 4 and 5 parameters with a complicated PDF that includes Bessel functions.

The PDF of the Pareto distribution is given below.

$$PDF = f_X(x) = \begin{Bmatrix} 0 & x < \beta \\ \dfrac{\alpha\beta^{\alpha}}{x^{\alpha+1}} & x \geq \beta \end{Bmatrix} \quad (1)$$

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Where α is the shape parameter and β is the scale parameter [29], also referred to as location parameter or *x – minimun* value [37]. The β parameter specifies the region where the distribution have positives values which always covers the interval [β, ∞); whereas the shape parameter controls how fast the tail of the distribution drops. Figure 1 ilustrates the effect on the Pareto PDF of the parameters variation.

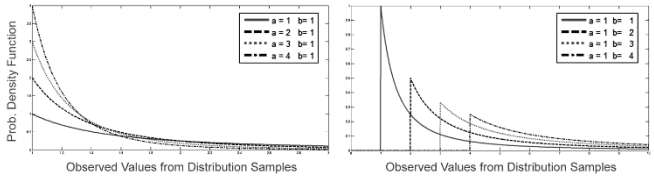

Fig. 1. Effect of the parameters variation in the Pareto PDF.

Consulting the investigations of [21, 22, 38], the authors concluded that the interval of $2 < \alpha < 10$ is the more suitable for the Pareto clutter modeling. Additional simulations verified that samples generated with $\alpha < 2$ produce high magnitude values too often and those corresponding to $\alpha > 10$ have a too short PDF tail.

III. Design and Training of the Neural Network

For the design of the neural network, the authors took as a start point the solutions given in [26, 30, 39-41] for different situations. Consequently, the initial configuration of the network internal variables was the one presented in Table 1. For the full understanding of the meaning of these parameters, the reader is referred to specialized literature [42, 43].

The configuration displayed in Table 1 was enough to achieve the desired results. Several parameters were modified looking for a better performance without obtaining virtually any gain. The only exception to this rule was the training algorithm. The best results were obtained after applying Bayesian Regularization [44] instead of Levenberg-Marquardt.

TABLE I
Configuration of the Internal Neural Network Variables

Network Variables	Choice
Network Type	Feed Forward Network (Multilayer Perceptron)
Training Function	BackPropagation (Levenberg-Marquardt)
Number of Layers	3 (Input Layer – Hidden Layer – Output Layer)
Transference or Activation Function	Hyperbolic Tangent Sigmoid (Hidden Layer), Lineal Transference Function (Output Layer)
Activation Order	Topological (Asynchronous Activation)
Error Measurement	Mean Square Error
Training Set Division	70% Training - 15% Validation - 15% Test
Samples' Presentation	Batch Training

A. Preparation of the Training Set

An essential element in the design of a neuronal estimator is the preparation of the training set. In order to execute the supervised training, a set of 16000 groups of 3000 Pareto samples each was computer-generated by changing the value of the shape parameter (α) every 10 groups. Therefore, the first group was generated with $\alpha = 2$, the group number 11 with $\alpha = 2{,}005$, the group number 21 with $\alpha = 2{,}010$, and so on until $\alpha = 10$. The Pareto scale parameter was maintained at $\beta = 0.001$ in all simulations.

The task of the neural network is to estimate the shape parameter for each of the 3000 samples groups. To present samples to the network, histograms were prepared from each group. The histograms reduced the 3000 intensity values to 50, performing therefore the feature extraction from sea clutter. The number of values in the histograms was chosen imitating what was applied in [30, 31].

So, the network had 50 inputs designed to read histograms and an output conceived to estimate the value of the α parameter. The number of neurons in the hidden layer was left to optimize by successive trials.

IV. Results and Discussion

After executing multiple trainings with ANNs, whose hidden layers contained between 5 and 50 neurons, it was concluded that the improvement by increasing the number of neurons was very low, as can be seen in Figure 2. In fact, the gain was less than a 5% in the mean absolute error when a 5 neurons ANN was replaced by a 50 neurons ANN. The mean absolute error was measured by averaging the absolute magnitude of the deviation of each parameter estimation from the exact value known a priori.

Each value from Figure 2 resulted from choosing the best network after performing 50 training with schemes containing the specified number of neurons in the hidden layer. Afterwards, the network performance was measured with a new dataset independent from the one used in the training.

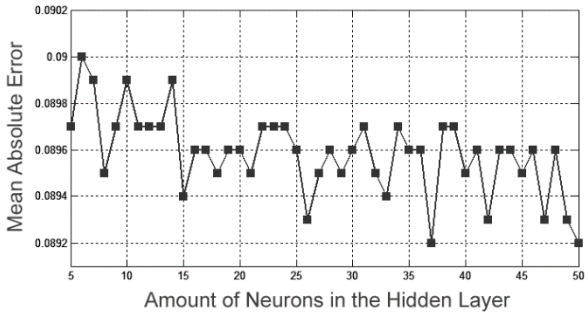

Fig. 2. Mean absolute error of ANN with different amounts of neurons in the hidden layer.

Consequently, the authors selected a network with five neurons as the final proposal. It exhibited a mean absolute error of 0,0897 and a maximum error of 0,5748. These values represent only a 1,12% and a 7,2% respectively of the search interval.

Figure 3 presents 3 graphs corresponding to the ANN's performance. Graph A shows the shape parameter estimation performed by the ANN together with the ideal estimate. Graph B shows the committed error obtained by subtracting both quantities. As can be seen, the deviation is greater for high values of the shape parameter. This is a result of the saturation of the parameter's influence in the heavy tail property of the Pareto distribution and it verifies what it was observed in [30] for the Weibull distribution. As α increases, the PDF curves will become more and more similar to each other, making more difficult the accurate estimation of the parameter.

Finally, graph C from Figure 3 presents a histogram of the committed error. As it's shown, the error exhibits a Gaussian-like behavior which is a positive feature for an estimator.

A. Comparison with the MLE Estimator

Generally, the shape parameter of clutter related distributions such as Weibull, K and Log-Normal is estimated by one of two methods: the Method of Moments (MoM) and the MLE method. In the case of the Pareto distribution, the MoM does not provide good estimates due to the long tails of the distribution and to limitations in the definition of

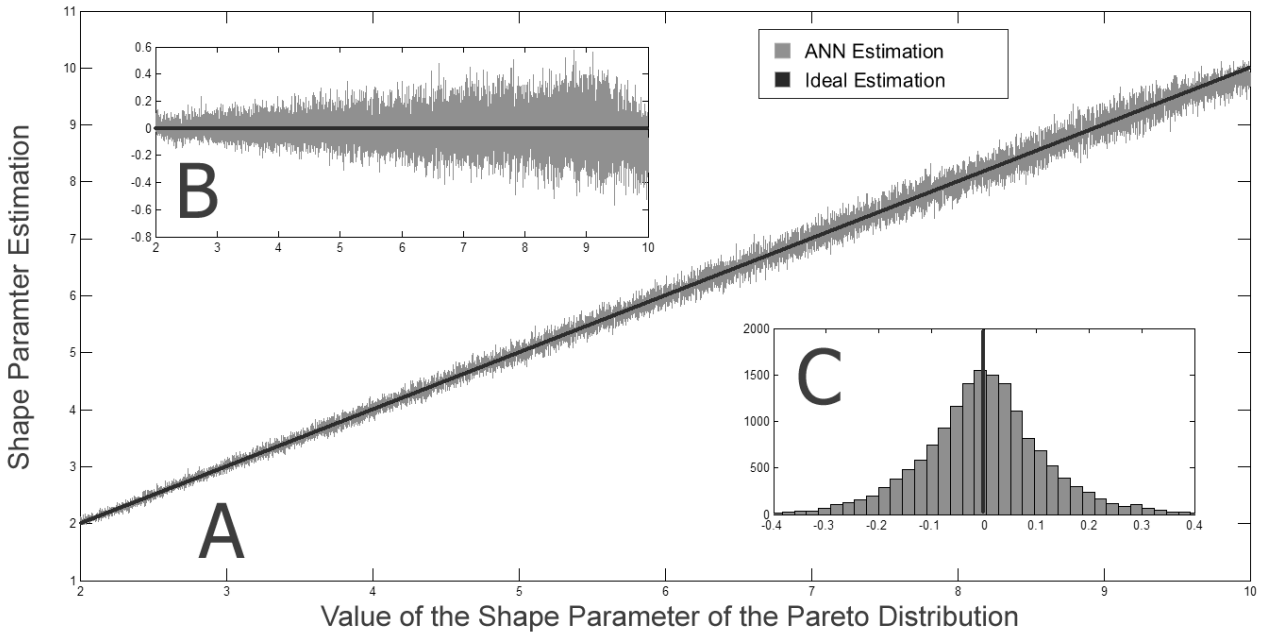

Fig. 3. Characterization of the Errors Committed by the ANN.

the moments that require a certain value of β as a condition of existence [29]. **In fact, the use of this estimator is strongly unadvised**. So, the most widely employed estimator is the MLE that uses the following expressions [29, 45]:

$$\hat{\beta} = \min\{x_1, x_2, \dots, x_n\} \quad \hat{\alpha} = \frac{n-1}{\sum_{j=1}^{n}\left[\log(x_j) - \log(\hat{\beta})\right]} \quad (2)$$

Where $\hat{\beta}$ is the estimate of the scale parameter, $\hat{\alpha}$ is the estimate of the shape parameter and x_n is the sample number n of a given set.

The authors compared the performance of the new neuronal proposed estimator with the MLE. After evaluating both schemes with a new set of 16000 groups of 3000 samples, it was concluded that the neuronal method performs the estimation with a deviation 50% inferior to the one exhibited by the MLE, both regarding the mean absolute error and the maximum error. The mean absolute error committed by the MLE was of $0{,}1689$ and the maximum error of $1{,}1077$.

Additionally, it was observed that the behavior of the estimators changed in the different estimation intervals as it's shown in Tables 2 and 3. Note that both estimators exhibit a similar performance in the $2 < \alpha < 3$ interval, where only a small gain of less than a 3% is achieved by replacing the MLE with the neuronal solution. However, as the magnitude of α increases, the gain starts to be significant, reaching a figure of 200% for the $9 < \alpha < 10$ region.

Moreover, the speed of both the MLE method and the neural solution were tested using a personal computer with an Intel Core i5-4460 CPU (3.20GHz) and 4 GBs of RAM memory. The MLE took 5,5425 seconds to complete the estimation on a set containing 16000 groups of 3000 Pareto samples, whereas the ANN consumed 1,8721 seconds (almost 3 times faster). Nevertheless, the ANN processing time can be reduced even more by placing the solution on a FPGA kit which will provide parallel processing features. Also, the time elapsed in the gathering of the histograms (94% of the 1,8721 seconds) can be further reduced by establishing a memory aware system which will only replace the older sample when receiving a new one.

In conclusion, it's safe to say that the neuronal method outperforms the MLE in the region of high magnitudes of the shape parameter; while it's able to maintain an equal or superior performance in the remainder of the estimation interval. The proposed ANN achieves an accurate and low computational cost estimation of the Pareto shape parameter. Therefore, it contributes to the design of radar detectors that guarantee a constant false alarm probability when processing clutter with statistical variations. Indeed, the neural estimation solution presented in [30] for the Weibull distribution led, together with the contribution of [46], to the creation of the W-NATE-CA-CFAR adaptive detector [47]. So, the current paper is expected to lead to the creation of the P-NATE-CA-CFAR (Pareto-Neural Adaptive Threshold Estimation-Cell Averaging-Constant False Alarm Rate) detector.

TABLE II

Mean Absolute Error in the Estimation of the Pareto Shape Parameter for Different Intervals.

Interval	MLE	ANN	Gain
$2 < \alpha < 3$	0,0380	0,0371	2,42%
$3 < \alpha < 4$	0,0542	0,0512	5,86%
$4 < \alpha < 5$	0,0777	0,0669	16%
$5 < \alpha < 6$	0,1087	0,0840	35%
$6 < \alpha < 7$	0,1594	0,0977	63%
$7 < \alpha < 8$	0,2134	0,1157	84%
$8 < \alpha < 9$	0,2990	0,1325	125%
$9 < \alpha < 10$	0,4008	0,1343	200%

TABLE III

Maximum Absolute Error in the Estimation of the Pareto Shape Parameter for Different Intervals.

Interval	MLE	ANN	Gain
$2 < \alpha < 3$	0,1966	0,1910	2,93%
$3 < \alpha < 4$	0,2326	0,2	16%
$4 < \alpha < 5$	0,3361	0,29	15%
$5 < \alpha < 6$	0,5141	0,3474	48%
$6 < \alpha < 7$	0,6358	0,4648	36%
$7 < \alpha < 8$	0,8654	0,5039	71%
$8 < \alpha < 9$	1,0054	0,5748	75%
$9 < \alpha < 10$	1,1077	0,5653	95%

At the same time, the new neural method helps improving the identification of anomalous sea surface conditions such as fish gatherings [48], oil spills [49, 50] or shipwrecks [51, 52]. These conditions cause deviations in the clutter statistics, which may be identified with a precise estimator of the shape parameter such as the one proposed.

Lastly, the presented results contribute to the development of the DRACEC method [53] that proposes an alternative detection scheme based on the moments domain. One of the major disadvantages of DRACEC is the need for the accumulation of a large number of samples for further processing. The accurate estimation of distribution parameters allows making inferences on the properties of the samples, reducing thus the volume of data to be stored.

V. Conclusions and Future Research

A new estimation technique for the Pareto shape parameter, based on artificial neural networks, was proposed. The neural method proved to be better than the classic alternative based on Maximum Likelihood Estimates mainly in the region of high magnitudes of the parameter. The neural solution provides an accurate and low computational cost estimation that can be used to improve the stability of radar detectors, in the identification of clutter anomalies and in the detection in the moments' domain.

The authors will focus next on the development of the P-NATE-CA-CFAR detector and in the FPGA implementation of the presented solution to profit from the parallel processing advantages of this platform. Additionally, the design of similar solutions applied to clutter distributions such as the KK, WW and Compound Gaussian is recommended.

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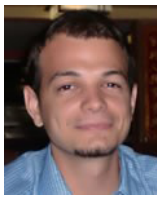

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Analyzing the EEG Signals in Order to Estimate the Depth of Anesthesia Using Wavelet and Fuzzy Neural Networks

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***Abstract* — Estimating depth of Anesthesia in patients with the objective to administer the right dosage of drug has always attracted the attention of specialists. To study Anesthesia, researchers analyze brain waves since this is the place which is directly affected by the drug. This study aimed to estimate the depth of Anesthesia using electroencephalogram (EGG) signals, wavelet transform, and adaptive Neuro Fuzzy inference system (ANFIS). ANFIS can estimate the depth of Anesthesia with high accuracy. A set of EEG signals regarding consciousness, moderate Anesthesia, deep Anesthesia, and iso-electric point were collected from the American Society of Anesthesiologists (ASA) and PhysioNet. First, the extracted features were combined using wavelet and spectral analysis after which the target features were selected. Later, the features were classified into four categories. The results obtained revealed that the accuracy of the proposed method was 98.45%. Since the visual analysis of EEG signals is difficult, the proposed method can significantly help anesthesiologists estimate the depth of Anesthesia. Further, the results showed that ANFIS could significantly increase the accuracy of Anesthesia depth estimation. Finally, the system was deemed to be advantageous since it was also capable of updating in real-time situations as well.**

***Keywords* — Anesthesia, Electroencephalogram, Wavelet, Classification, Adaptive Neuro Fuzzy Inference System.**

I. Introduction

Anesthesia results from administration of anesthetic drugs, through injection, and is characterized by sleepiness and loss of feeling of pain. Today, depth of Anesthesia is expressed as a consistent decrease in the performance of Central Nervous System (CNS) as well as decreased response to stimuli [1, 2]. Injecting an appropriate level of anesthetic drugs has always been a great concern to anesthesiologists. They seek ways to ensure patients' blood circulation and, at the same time, increase the depth of Anesthesiato ensures patients' recovery in a shorter period of time. Since the most important causes of Anesthesia lie in the brain, researchers mostly focus on analyzing the Electroencephalogram(EEG) [2,3].Recently, methods basing on EEG signals – these signals express the electrical activity of the brain and are dynamic, random, non-stop, and non-linear [4,5] – have increased the accuracy of Anesthesia depth estimation. These methods are particularly efficient for separating non-stop signals with their impedance and Anesthesia. An expert needs to visually analyze a large amount of EEG signals to extract the required information. The computer analysis of EEG signals aims at making such data extraction fast, effortless, and automatic.

Mathematical models, i.e. artificial neural networks and fuzzy systems, have an array of applications in clinical medicine – extraction of features and diagnosis of illness being only few examples. Fuzzy systems are modeling methods with wide applications in various scientific fields. They are used widely and quite efficiently in investigations targeting different biological and non-biological phenomena [6,7].

Adaptive Neuro Fuzzy Inference System (ANFIS) exploits neural network and fuzzy logic algorithms to formulate a non-linear mapping between the input and the output space. Having the linguistic strength of a fuzzy system and the numerical strength of a neural network, ANFIS has proven to be particularly efficient in modeling complex processes [6,7,8].Accordingly, the present study aimed at proposing an intelligent model to estimate depth of Anesthesia using features extracted from EEG signals. Sample features obtained from wavelet coefficients as well as the spectral analysis of EEG signals were used as parameters in this study.

II. Material and Methods

To undertake the present study, use was made of EEG signals – obtained from American Society of Anesthesiologists(ASA) – and the Sleep-EDF database of PhysioNet. The signals used included four categories namely consciousness, moderate Anesthesia, deep Anesthesia, and coma. The signals collected were in BDF, EDF, ASCII, and TEXT formats. To extract features, MATLAB R2009a, EDFBrowser, and EEGLAB applications were drawn on. Figures 1a to 1b illustrate examples of EEG signals belonging to each category respectively.

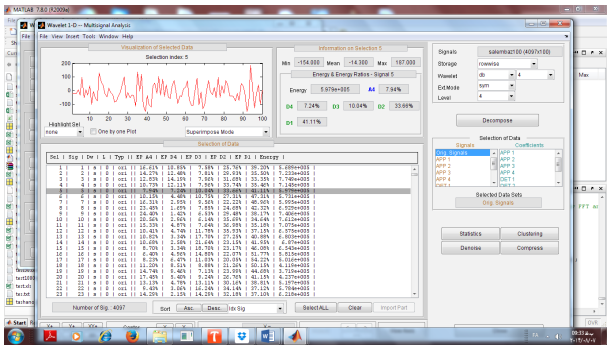

Fig. 1 a. A sample of the EEG signals in consciousness mode.

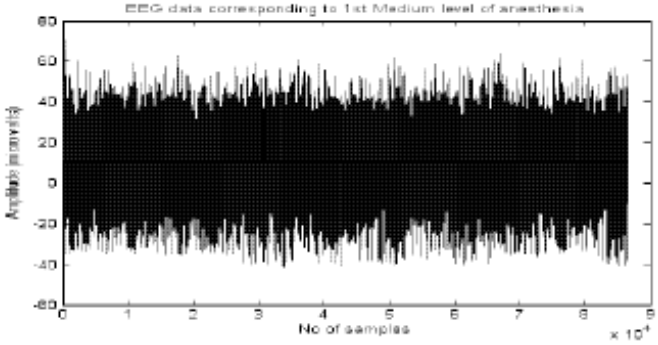

Fig. 1b. A sample of the EEG signal in the middle of Anesthesia.

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Wavelet analysis is one of the most useful methods in analyzing bio-signals, such as EEG ones [9]. For this reason Discrete Wavelet Transform (DWT) was used to extract statistical features. Wavelet transform is particularly used in extracting non-stop signals with various frequency characteristics [10]. In fact, it decomposes signals into a set of basic functions. These continuous basic functions are calculated from the application of delays, contractions, and transmissions on a unique function called wavelet model [11]. Using a Daubechies 4 (D4) wavelet transform, the collected signals are decomposed into 4 sub-bands. The frequency range was taken to be within 0 to 60 Hz and frequencies higher than 60 Hz were dismissed as noises. As shown in Figure 1c, the original signal is first passed through a High Pass Filter (HPF) and a Low Pass Filter (LPF).

Having removed other samples, the signals are decomposed into two simpler signal types. Each stage comprises two digital filters and two down-sampler filters. The output of the first HPF and LPF results in D1 component and A1 approximation. Then, the first calculated approximation, A1, is decomposed further which produces component D2 and approximation A2. In all, this procedure is repeated four times in this study. As shown in Figure 1d, D1, D2, D3, D4, and A4 are gamma sub-band, beta sub-band, alpha sub-band, theta sub-band, and delta sub-band, respectively.

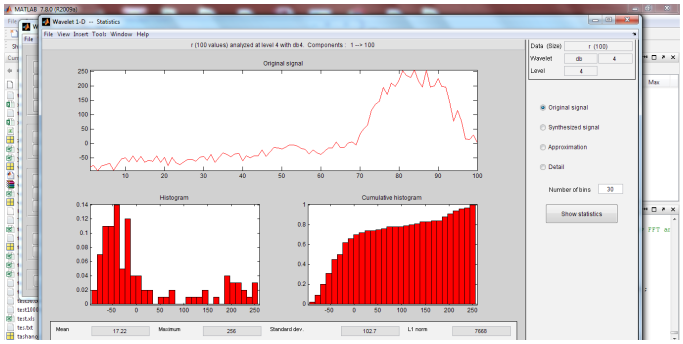

Fig. 1c. A sample of the EEG signal in a state of deep anesthesia.

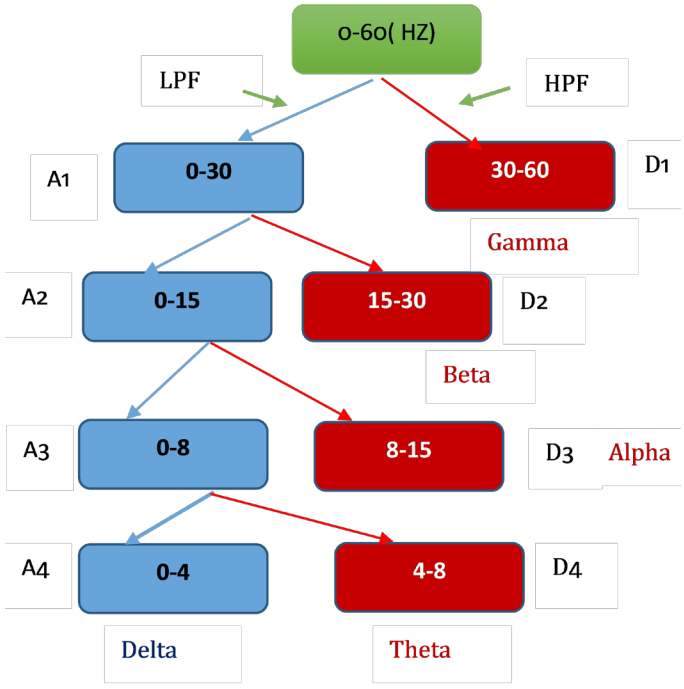

Fig. 1d. EEG signal is decomposed into sub-bands.

Since sub-bands contain more accurate information compared to the mother signal, decomposition was carried out using wavelet. Having completed this stage, the desired and optimized information and features were extracted from the sub-bands. Figures 1e and 1f show examples of decomposed signals in various levels, including consciousness and Anesthesia.

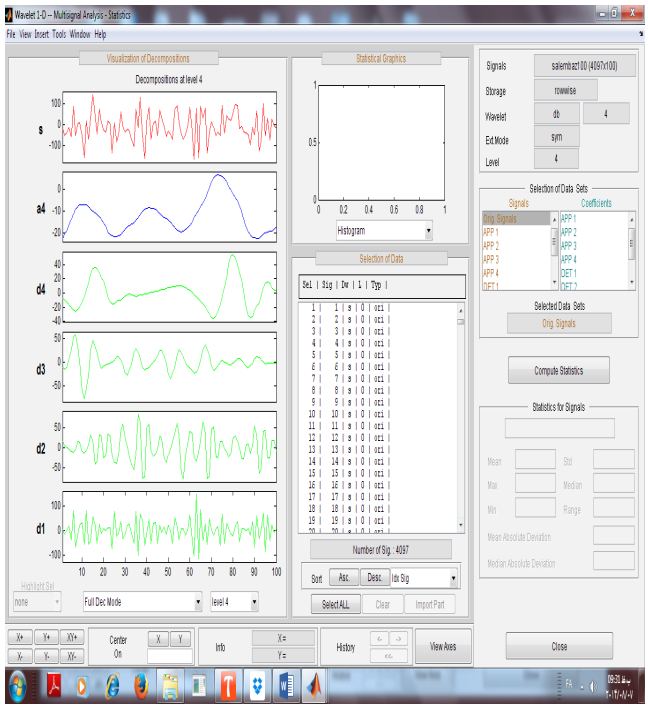

Fig. 1e. EEG signal levels in db 4to alert level 4.

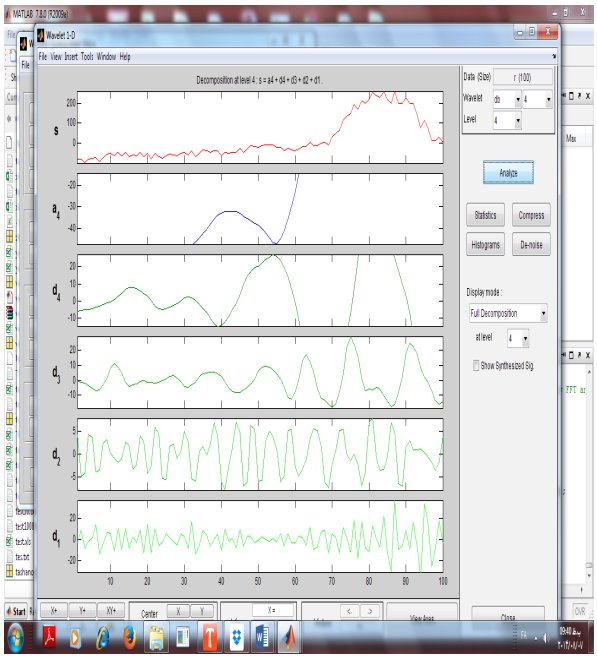

Fig. 1f. EEG signal levels in Anesthesia state to the db 4with level 4.

The target statistical features in this study included the maximum and minimum of wavelet coefficients as well as the mean and the standard deviation of each set of signals. All these features were extracted from each sub-band. Moreover, all the spectral features intended were also extracted. The calculated features included alpha and beta ratios (Eq. 2.1 & 2.2) as well as theta ratio (Eq. 2.3) denoting the depth of

Anesthesia, consciousness, and a state between alpha and beta and between moderate Anesthesia and other states, respectively[12].

$$Alpha_{ratio} = log \frac{E(30-42.5\ Hz)}{E(6-12\ Hz)} \quad (2\text{-}1)$$

$$Beta_{ratio} = log \frac{E(30-42.5\ Hz)}{E(11-21\ Hz)} \quad (2\text{-}2)$$

$$Theta_{ratio} = log \frac{E(6-12\ Hz)}{E(11-21\ Hz)} \quad (2\text{-}3)$$

Further, four features were extracted from the set of statistical and spectral features as indicated in Table 1.

TABLE I. The Extracted Features

Spectral characteristics are extracted	Statistical features extracted	Features used on this model
Alpha ratio	(MAX)	Alpha ratio
Beta ratio	(MIN)	Beta ratio
Theta ratio	(STD)	Theta ratio
Gamma ratio	Mean	STD

These features were used as input for the designed Fuzzy Inference System (FIS)[13]. In the proposed FIS, the first input, as shown in Figure 1g, comprises factors that draw a clear cut distinction between Anesthesia and the other states. Similarly, the second input, Figure 1h, represents consciousness and the other states. In the same vein, the third input, as illustrated in Figure 1i, represents moderate Anesthesia, Anesthesia, and consciousness. Finally, Figure 1j distinguishes coma from other states.

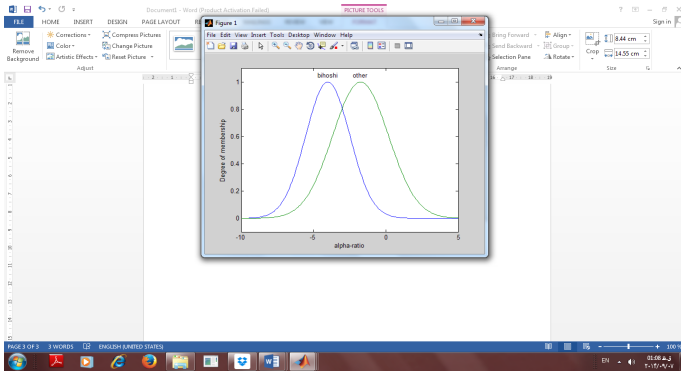

Fig. 1g. The first input in FIS.

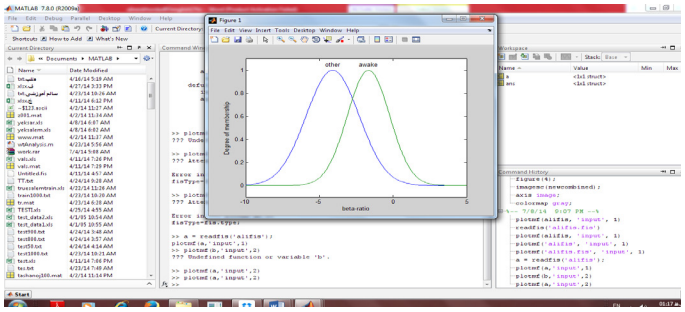

Fig. 1h. The second input in FIS.

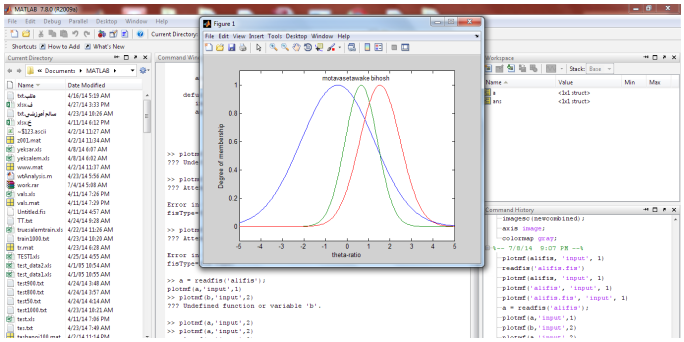

Fig. 1i. The third input in FIS.

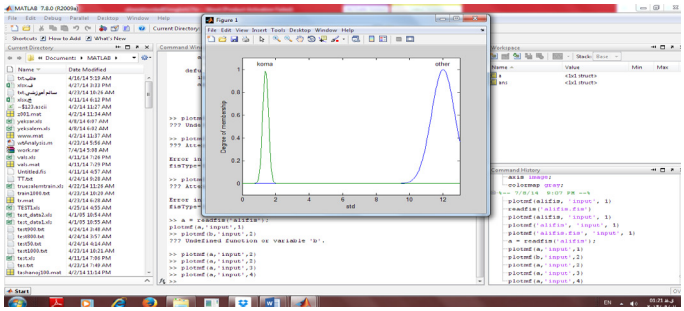

Fig. 1j. The fourth input in FIS.

In all, 24 fuzzy rules were composed regarding the four features of the input space. For the selected features and the defined target classes, an IF-THEN fuzzy rule was formulated, for each fuzzy sub-set, as follows [14,15]:

$$if\ x_1\ is\ A_1^k \quad and \ldots x_n\ is\ A_1^k \quad then\ class\ k \quad (2\text{-}4)$$

The last phase of the study dealt with designing the ANFIS that is responsible for classifying the signals into four states of consciousness, moderate Anesthesia, deep Anesthesia, and coma. Compared to other fuzzy logic-based systems, one of the advantages of ANFIS is that no conversion of certain data into fuzzy data is required [6, 16]. Moreover, parameters do not need to be initialized. In fact, first the fuzzy system is designed after which its membership functions are improved and tested using ANFIS. Finally, the trained network is used to distinguish different states of Anesthesia. All the membership functions drawn on in this system are Gaussian.

III. Results

As stated in Section 2, the final ANFIS comprised four variables which had two, two, three, and two Gaussian membership functions, respectively. Accordingly, the total number of fuzzy rules amounted to 24. In this study, 80% of the data collected was used for training and the remaining 20% was used for testing purposes. The assignment of data to train or test datasets was undertaken through simple randomization. An interesting finding in the present study was that the error rate of the model would decrease with an increase in the number of iterations.

The sensitivity rate of the proposed system was found to be 96.6%, which simply means that it can recognize the Anesthesia states in 96.6% of the cases. Further, it was observed that the system could always (100%) recognize Anesthesia accurately. Moreover, the accuracy rate of the proposed system was reported to be 98.45%.

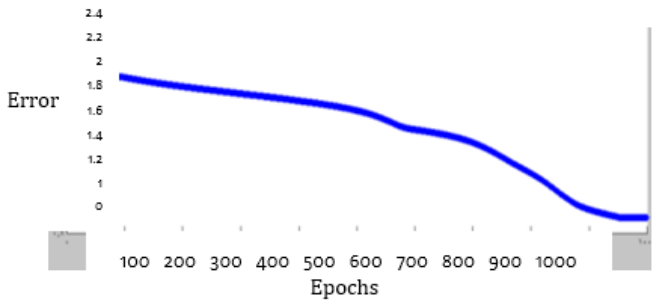

Fig. 2. The error rate of the system is negatively correlated with the number of iterations.

IV. Conclusion

The system proposed in this study is an appropriate means of extracting useful EEG signals. Wavelet analysis was used here to describe EEG signals since it facilitates the decomposition of EEG signals into sub-bands. Further, the fact that each Anesthesia state has its own specific frequency bands enables the researcher to estimate the depth of Anesthesia in each state by finding the relationship between these frequency bands. To sum up, it appears that by combining the extracted statistical features from the wavelet coefficients of EEG signals and spectral analysis, it is possible to design a system which can accurately estimate the depth of Anesthesia. The proposed system can be of great help to anesthesiologists since it can recognize the Anesthesia states with high accuracy at a lower cost.

Fig. 3. Caparison between the proposed method and others.

The comparison of the statistical results from ANFIS to those from the previous studies – including neural networks, linear discernment, and even fuzzy models – reveals that the proposed fuzzy-neural system is advantageous for two reasons: First, it can estimate the depth of consciousness with high accuracy, and second, it has improved the deficiencies of the previous systems. This was facilitated through an optimized extraction of features using wavelet transform and formulating appropriate fuzzy rules. The low error rate of RMSE calculated for the system confirms the reliability of the results.

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Feature Selection for Image Retrieval based on Genetic Algorithm

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***Abstract* — This paper describes the development and implementation of feature selection for content based image retrieval. We are working on CBIR system with new efficient technique. In this system, we use multi feature extraction such as colour, texture and shape. The three techniques are used for feature extraction such as colour moment, gray level co-occurrence matrix and edge histogram descriptor. To reduce curse of dimensionality and find best optimal features from feature set using feature selection based on genetic algorithm. These features are divided into similar image classes using clustering for fast retrieval and improve the execution time. Clustering technique is done by k-means algorithm. The experimental result shows feature selection using GA reduces the time for retrieval and also increases the retrieval precision, thus it gives better and faster results as compared to normal image retrieval system. The result also shows precision and recall of proposed approach compared to previous approach for each image class. The CBIR system is more efficient and better performs using feature selection based on Genetic Algorithm.**

***Keywords* — CBIR, Feature Extraction, Feature Selection, Genetic Algorithm, K-means Clustering, Precision and Recall.**

I. Introduction

In recent years, continuous development of multimedia technologies, storing high quality of images and digital image collection data are rapidly increasing with social networking (such as facebook, yahoo, Google, etc), storage technologies, academic website, research and development etc to upload images, videos, many possible means. With the use of internet, image capturing devices (scanner, camera, etc) and handheld devices for tremendous collection of digital images is generated every day. The intent for development of many general use of image retrieval system requires efficient searching, browsing and retrieving tools.

In current technologies the acquirement, transmission, stack away, and handling are allow in large collection of database. With the increasing in use of network and multimedia development, users are not gratified with traditional image retrieval. So in recent year, CBIR has become an area of wide interest and source of fast retrieval and exact.

Content based image retrieval is image search technique; automatically extract features (colour, texture, shape, etc) to allow searching relevant images from large image database to given input query image based on similarity in features from query image compared with feature from database. The feature extraction techniques is commonly use in CBIR. There are three feature extractions such as colour feature extraction, texture feature extraction and shape feature extraction. Each feature extraction has several techniques. Colour feature extraction is low level visual feature. The respective techniques are used in colour extraction such as colour moment, vector quantization, co-occurrence matrix, etc. Texture feature extraction is also low level visual feature. It measures look for visual patterns in images. It describes distribution of image intensity. In texture, many techniques are used like Gabor filter, Tamura features, etc. Shape feature extraction is high level visual feature. It describes surface of an object within images or particular region. It contains two methods, first is external boundary of shape; another is shape of whole region. The respective techniques are edge density (sobel, prewitt, canny,etc), moment invariant, etc.

In CBIR, the problem is which features are relevant in retrieval process that means large number of features is irrelevant. To avoid this problem, feature selection is used to reduce extraneous, excess and noisy data. The main objective of feature selection is find best feature from large feature set. To improve the performance of content based image retrieval system, feature selection which includes optimal features.

Genetic algorithm is an approach of feature selection for best optimal feature subset from large feature set. Genetic Algorithm is found on primal of evolution, natural selection and biology inheritance. Genetic algorithm is used to find optimal or best solutions to computational problem that minimizes or maximizes a particular function. Genetic algorithm works iteratively by using Genetic operators such as Selection, recombination and Mutation.The optimal feature is selected using Genetic algorithm that searches for the best feature subset corresponding to better image retrieval result.

Clustering is collection of articles which are similar between same clusters while dissimilar articles belong to other cluster. By using clustering in CBIR system is reducing the elapsed time of system. Different clustering techniques are used in CBIR such as k-means clustering, hierarchical clustering, SIFT,etc.

The rest of paper is organized as follow: in section 2 describes related work to content based image retrieval using various techniques. Section 3 presents methodology. In section 4 introduced on framework of proposed approach. The experimental result shows in section 5; and last section 6 concludes the paper.

II. Related Work

In content based image retrieval system, many techniques have been used extensively mentioned in various research papers for better performance. Lakshmi p.s et.al. [4] Performed retrieval of different input query images from the image database based on texture feature. Texture feature is extracted from image using gray level co-occurrence matrix (GLCM). They approached feature selection using genetic algorithm (GA) to improve the accuracy of content based image retrieval. The results of feature selection based on the performance measures (precision and recall) showed higher accuracy of the retrieval system can obtained in lesser computation time. P.K.Bhargavi et.al. [9] Contributes that content based image retrieval system based on the

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relevant feature. They used color coherence vector and Gabor wavelets feature extraction technique. For Feature Discrimination, it used maximum entropy method for transforming numerical features with nominal using Class Attribute Interdependence Maximization (CAIM) algorithm. They also analyzed proposed approach by optimizing it with the feature selection using Particle Swarm optimization (PSO) algorithm for extracting the near relevant features. The result showed effectiveness and efficiency of the proposed model is compared with other models using precision and recall. C.V. Rashmi et.al. [7] Views that novel image retrieval using Ant Colony Optimization and Relevance Feedback. The proposed system, feature vector of the image is extracted by calculation of color correlogram, Gabor filter and edge histogram descriptors. In their model, feature selection using ACO technique to optimize the features for speed up retrieval and similarity computation. They used support vector machine (SVM) to improve efficiency of the system by using Relevance Feedback.

Clustering is used in CBIR system, Mit Patel et.al. [7] Describes collection of features or a dataset is divided into similar image classes using clustering and classification. The clustering is done with k-means clustering, and classification is done with fuzzy rule based classification. These algorithms are based on texture and color information. In their proposed model, the result showed accuracy is increases and retrieval time is decreases. They compared with proposed model and normal model.

III. Methodology

In this section, we are introducing methods for new proposed system. As described further the new proposed system is done with three efficient techniques such as

- Three Feature extractions techniques are used for colour, shape, and texture.
- Feature selection using Genetic Algorithm. In this method, we used new fitness function
- Clustering technique

The following new approaches describe below:

A. Feature Extraction

Feature extraction is most valuable operation of CBIR system. It translates the input data into set of features. In this section, we describe three feature extraction techniques which are used in our proposed CBIR system.

1) Color Feature Extraction

Color feature extraction represents different color model such as RGB (Red, Green, and Blue), HSV (Hue, Saturation, and value), CMYK (Cyan, Magenta, yellow), etc.

Color moment represents characterized a color image. There are 3 different color moments: first order is mean, second order is standard deviation, and third order is skewness of color; are extracted from RGB and HSI color spaces to form an 18-dimensional, using the following mathematical formulation:

$$\mu_i = \frac{1}{N}\sum_{j=1}^{N} p_{ij} \quad (1)$$

$$\sigma_i = \sqrt{\left(\frac{1}{N}\sum_{j=1}^{N}(p_{ij}-\mu_i)^2\right)} \quad (2)$$

$$\theta_i = \sqrt[3]{\left(\frac{1}{N}\sum_{j=1}^{N}(p_{ij}-\mu_i)^3\right)} \quad (3)$$

where, p_{ij} is an i^{th} color channel at the j^{th} image pixel.

2) Texture Feature Extraction

Texture feature extraction describes distribution of image intensities. For texture feature extraction a gray level co-occurrence matrix is simple and most extensively used approaches to extract texture feature from an original image. There are four components of GLCM that are used to characterize the texture such as entropy, contrast, energy and homogeneity. The following formulas are given below:

$$Energy = \sum_m \sum_n x^2(m,n) \quad (4)$$

$$Entropy = \sum_m \sum_n x(m,n)\, log\ x(m,n) \quad (5)$$

$$Contrast = \sum_m (m-n)^2\, x(m,n) \quad (6)$$

$$Homogenity = \sum_m \sum_n \frac{x(m,n)}{1+|m-n|} \quad (7)$$

where, (m,n) represents number of rows and number of columns of the image x.

3) Shape Feature Extraction

Shape describes surface of an object within images or particular region. Edge histogram represents 4 directional edges. The image is subdivided into 4 x 4 sub images i.e. 16 sub blocks. For each of the sub images, compute the histogram by using 4 edge types: vertical, horizontal, 45_o and 135_o.

1	-1	1	1	√2	0	0	√2
1	-1	-1	-1	0	-√2	-√2	0

B. Feature Selection using Genetic Algorithm

Genetic algorithm is compute to find solutions to search and optimization problems. Genetic algorithm is used to find optimal or best solutions to computational problem that minimizes or maximizes a particular function. They simulate biological process of natural selection and reproduction to solve for 'fittest' solutions. This is called 'survival of fittest' used for optimization problems. The basic components to Genetic algorithms are:

1. ***Initial population of chromosomes:*** Let m be the number of features. The size of population is N. To create random population P of N number of chromosomes is given below:

   $$P = [C_1, C_2, \ldots. C_N]$$

2. ***Fitness function:*** Standard Deviation is used to evaluate the fitness of each individual population.
3. ***Selection:*** Select two parents from population according to their best fitness, which can generate new offspring. It assures that only the best fittest solutions made to generate offspring.
4. ***Recombination or Crossover:*** Recombinant the parents to form new offspring from two parents string, by copying selected bit of each parents.
5. ***Mutation:*** after the performance of crossover, mutate the new offspring from single parent. It reduces local optimum.

The block diagram of genetic algorithm is shown in below:

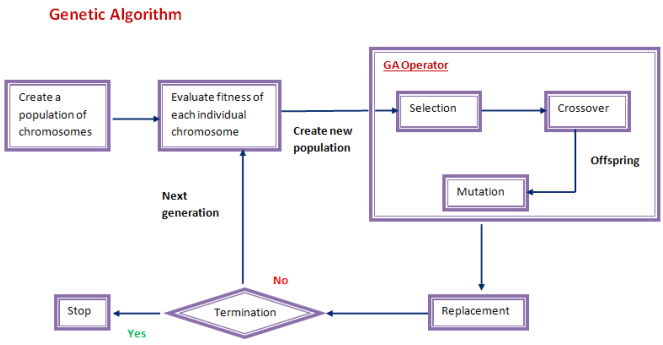

Fig. 1. Block Diagram of Genetic Algorithm.

C. Clustering

Clustering is collection of articles which are similar between same clusters while dissimilar articles belong to other cluster. In proposed system, we use k-means algorithm. We select the k-means algorithm because it manages the large number of image in cluster. In CBIR system is reducing the elapsed time of system and fast retrieval. Using k-means algorithm, the results are measure by sum of among cluster between every vector and its centroid cluster. To calculate centroid of each cluster using sum of squared error, the given formula below:

$$SSE = \sum_{i=1}^{k} \sum_{x \in c_i} dist^2(m_i, x) \quad (8)$$

IV. Proposed System

Here, we propose new CBIR system using three approaches which are described in previous section. The proposed architecture of CBIR system is shown in below:

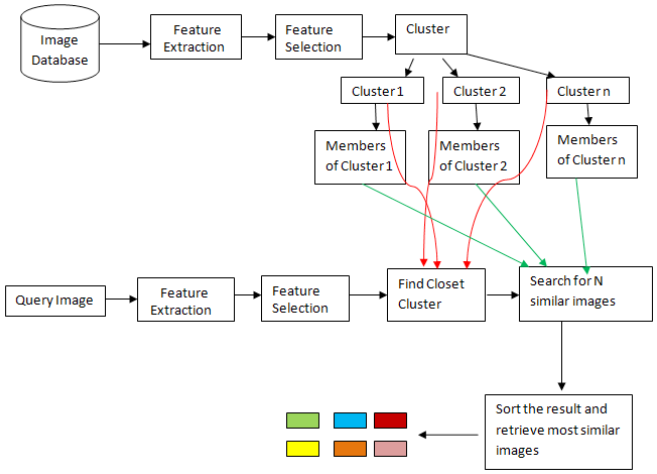

Fig. 2. Proposed Architecture of CBIR System.

The working of this system describes in step by step:

- The system will extract feature from images by using color, texture and shape automatically.
- These feature images are store in feature vector database.
- Then, we use feature selection using Genetic Algorithm that searches for the best feature subset from feature vector database.
- We use clustering which contains similar image classes. After that, system will compute distance between query image and centroid cluster to find smaller distance.
- The most similar images will retrieve and shows to the user.

V. Experimental Result and Discussion

In this section, we present a proposed CBIR system which is introduced in previous section. We are considering the new approaches which the enhancement is done. Here is first part of the expected result is present. We introduce database of image that we choose to test our system.

A. Image Database

We use image database in our evaluation is WANG database. It is subset of COREL database. It contains 1000 images in JPEG format. In this paper, 6 classes were taken and each class contains 15 images. The classes are Flowers, Bus, Architecture, Food, Elephant, and Dinosaurs.

B. Performance Measurements

In this section, we perform of the CBIR system can be evaluate in terms of precision and recall. And also compute computational time of each class.

1. **Precision:** It is defined as ratio of number of relevant images retrieved and total number of images retrieved

$$Precision = \frac{Number\ of\ relevant\ images\ retrieved}{Total\ number\ of\ images\ retrieved}$$

If precision value is 1.0 that means result images is retrieved by search was retrieved.

2. **Recall**: It is defined as ratio of number of relevant images retrieved and total number of images retrieved

$$Recall = \frac{Number\ of\ relevant\ images\ retrieved}{Total\ number\ of\ images\ retrieved\ in\ database}$$

C. Expected outcome

Here is expected outcome of each class in terms of precision, recall and computational time (s).

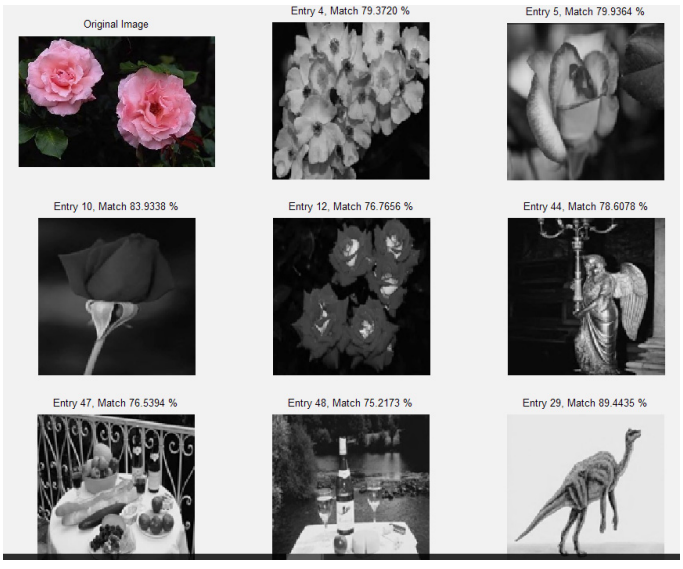

Fig. 3. Without Feature Selection Retrieved Images.

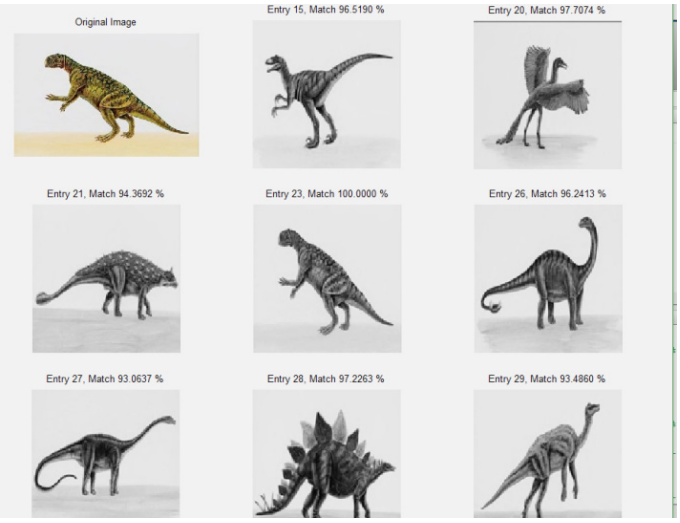

Fig. 4. Feature Selection using Genetic Algorithm based Retrieved images.

In Fig.3 shows, relevant features and irrelevant features based retrieved images without using feature selection based on Genetic algorithm in CBIR system. In Fig.4 shows, most optimal relevant images using feature selection based on Genetic algorithm.

TABLE I

COMPARATIVE ANALYSIS OF CBIR ALGORITHMS BASED ON PARAMETERS

	Without Feature Selection			Feature selection using GA		
Images	**Time(s)**	**Precision (%)**	**Recall (%)**	**Time(s)**	**Precision (%)**	**Recall (%)**
Architecture	1.94	62	40	1.89	75.8	58
Flowers	1.94	48.2	22.4	1.89	54.12	25.9
Elephant	1.90	43.2	16.8	1.77	58.9	23
Buses	1.96	46.2	27.6	1.74	59.4	35.8
Food	1.90	50.6	30.2	1.85	57.2	50.89
Dinosaurs	1.99	85	82.4	1.94	100	93.36

Table 1 shows feature selection using Genetic Algorithm is compared with without Feature Selection in terms of precision, recall, and computational time. The computational time of feature selection using GA takes less than without feature selection. The performance measure analysis is done for each image class. The highest precision value in dinosaurs contain 85% without feature selection, and after using feature selection based on GA improve precision value contain 100% in dinosaurs image. Recall values contains in the range 22-82% without using feature selection and 23-94% using feature selection based on GA.

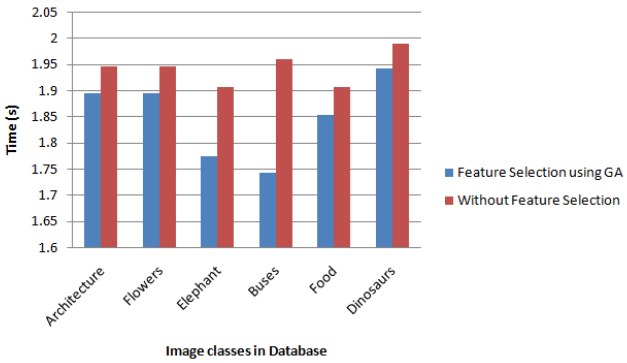

Fig. 5.a. Time (s) vs. Image classes in Database.

Figure 5.a shows computational time of each class in database. Blue indicates computational time of system by using feature selection based on GA. Red indicates computational time of system without feature selection. The bar chart shows, by using feature selection based on GA takes less time and fast retrieval. It is more efficient and better performance.

Fig. 5.b. Precision (%) vs. Image classes in Database.

Fig. 5.c. Recall (%) vs. Image classes in Database.

Figure 5.b and Figure 5.c shows, precision and recall of each image class in database. Blue indicates precision and recall of each image class without using feature selection. Red indicates precision and recall of each image class using feature selection based on Genetic Algorithm. The chart shows highest precision and recall of each image class using feature selection based on Genetic Algorithm is better than without feature selection.

TABLE II

PRECISION FOR PREVIOUS APPROACH AND PROPOSED APPROACH

	Previous Approach		Proposed Approach	
	Feature Extraction	**Feature Selection**	**Feature Extraction**	**Feature Selection**
Images	Precision (%)	Precision(%)	Precision (%)	Precision (%)
Bus	18.75	58.33	46.2	59.4
Dinosaurs	58.22	100	85	100
Elephant	41.66	51.66	43.2	58.9
Food	41.66	50	50.6	57.2
Average	**40.01**	**64.99**	**56.25**	**68.87**

TABLE III

RECALL FOR PREVIOUS APPROACH AND PROPOSED APPROACH

	Previous Approach		Proposed Approach	
	Feature Extraction	Feature Selection	Feature Extraction	Feature Selection
Images	Recall (%)	Recall(%)	Recall (%)	Recall (%)
Bus	12	28	27.6	35.8
Dinosaurs	28	48	82.4	93.36
Elephant	15.3	20	16.8	23
Food	20	23	30.2	50.89
Average	**18.825**	**32**	**39.25**	**50.76**

Table 2 and Table 3 are showing the precision and recall of Previous Approach and Proposed Approach for each Image class. The Previous approach contains Texture feature result based on feature extraction and feature selection using Genetic Algorithm; clustering is not used in this approach. The Proposed approach contains Multi Feature (Color, Texture, and Shape) result based on feature extraction and feature selection using Genetic Algorithm; clustering is used in this approach.

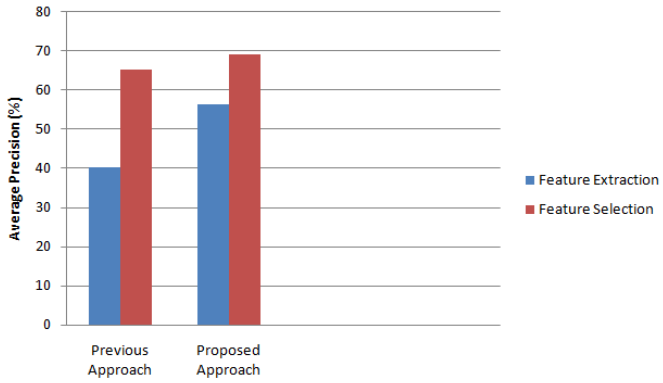

Fig. 6. Average Precision (%) for Previous and Proposed Approach.

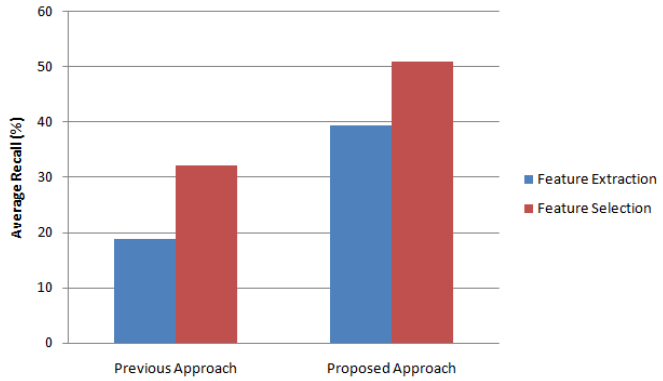

Fig. 7. Average Recall (%) for Previous and Proposed Approach.

In figure 6 and figure7 are showing Average precision and Average recall for previous and proposed approaches separately. The blue bar shows feature extraction of previous and proposed approaches; red bar shows feature extraction of previous and proposed approaches.

VI. CONCLUSION

In this paper, we introduce about the CBIR system with different techniques. Different Feature extraction techniques for colour, texture, and shape are used in CBIR system for better image retrieval. The proposed work is CBIR system based on Feature selection using genetic algorithm for best optimal features from feature set, and also use clustering for reduce elapsed time of system. The experimental result shows feature selection using Genetic Algorithm reduces the time for retrieval and also increases the retrieval precision and recall, thus it gives better and faster results as compared to normal image retrieval system. The CBIR system is more efficient and better performs using feature selection based on Genetic Algorithm. The computational time is reduced. From the result, it is clear that feature selection using Genetic Algorithm is more optimize the searching time in seconds and also shows highest precision and recall of each image class as compared with normal image retrieval system i.e. without feature selection.

In future work, we try to use feature selection based on other optimization algorithm for scale down computational time and provide better accuracy result of CBIR system. It can give better performance of CBIR system. It is also possible to improve performance of retrieval system by relevance feedback.

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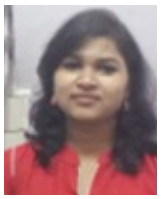

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Face Detection for Augmented Reality Application Using Boosting-based Techniques

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***Abstract* — Augmented reality has gained an increasing research interest over the few last years. Customers requirements have become more intense and more demanding, the need of the different industries to re-adapt their products and enhance them by recent advances in the computer vision and more intelligence has become a necessary. In this work we present a marker-less augmented reality application that can be used and expanded in the e-commerce industry. We take benefit of the well known boosting techniques to train and evaluate different face detectors using the multi-block local binary features. The work purpose is to select the more relevant training parameters in order to maximize the classification accuracy. Using the resulted face detector, the position of the face will serve as a marker in the proposed augmented reality.**

***Keywords* — Local Binary Pattern, Boosting, Supervised Learning, Face Detection, Augmented Reality.**

I. Introduction

Object detection and tracking is an important task for computer vision applications. With the growth of computers' power and the proliferation of high quality and low cost video cameras, industries like games, medical, media, automotive and education have gave more importance to this field of com- puter vision and started to take advantage of this technology by enhancing their products with more intelligence.

Many applications have shown an important impact on the daily human life, for example, to reduce the number of accidents on roads, vehicle manufactures have developed a clever system that detects and warns the vehicle drivers in the event of tiredness [1] [2] [3]. A small camera is placed in the cab of the vehicle, the images taken by the camera are used to measure the position of the head and rotation, and to check if eyes are closed or opened. By introducing the Kinect sensor to the game industry, Microsoft was able to position the controller-free gaming device as en entirely new way to experience entertainment in the living room. With Kinect,games-players no longer need to memorize different commands for a hand-held control, they are the controllers themselves [4] [5]. For a visual tracking algorithm to be useful in real-world scenarios, it should be designed to handle and overcome cases where the target's appearance changes from frame-to-frame. Significant and rapid appearance variation due to noise, occlusions, background clutter, pose, scale and illumination changes are the major challenge situations that a detector needs to overcome. Many novel methods have been proposed to resolve each of these variations [6] [7]. The accuracy of a trained face detector is heavily related to the data and algorithm used for the training. In this paper we highlight the importance of the choice of the training parameters values and show how this choice impact the accuracy of the resulted detector.

A. Face detection problem

Human emotions like sadness, happiness and anger are often expressed throw the face, these facial expressions make the human face a very dynamic body part. This high degree of variation combined with pose, scale and illumination changes makes of face detection a difficult problem. Over the two past decades, face detection problem has been an attractive research area for the computer vision community. Real time face detection was made possible since the publication of the seminal approach of Viola and Jones [8], in which they used a cascade of increasing complexity classifiers to detect up- right faces. The face detector accuracy depends not only on the features used for the face representation, but also on the training data and parameters.

B. Objective and Contribution outline

Training an accurate boosting model requires a data-set with a high degree of variation and a fine tuning of the training parameters. In this work we revisit the face detection problem to find the best training parameters that lead to an accurate face detector, the impact of each training parameter is examined by training classifiers with different parameter values. And to overcome the drawback of using markers in augmented reality applications, we integrate our face detector in a 3D augmented reality where the position of the face is used as a marker-less object for placing 3D models.

The contributions of this paper are :

1. Fine-tuning a boosting based detector by varying the training parameters values.
2. Integration the face detector model and a 3D blender model in the Ogre 3D framework to overcome the draw- back of markers based augmented reality applications.

1- fine-tune a boosting based detector by varying training parameters values and 2- Integrating a 3D blender model in a real time augmented reality.

II. Related Work

Classifiers are built by taking a set of labeled examples and using them to come up with a rule that will assign a label to any new example. In the general problem, we have a training data set (,); each of the xi consists of measurements of the properties of different types of object, and yi are labels giving the type of the object that generated the example. In this paper we will use different learning-based techniques like decision tree learning [9] that is one of the most widely used and prac- tical methods for inductive inference. The boosting [10] is one of the most popular learning techniques, widely used for object detection, it consists of combining many weak learners to form a strong classifier. For this study will experiment classification using Gentle AdaBoost, Real AdaBoost and LogitAdaboost learning techniques, the algorithms train models sequentially, with a new model trained at each round. At

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the end of each round, miss-classified examples are identified and have their emphasis increased in a new training set which is then fed back into the start of the next round, and a new model is trained. Viola and Jones [8] introduced the approach of cascade of boosted classifiers. [11] proposed random forests, which is a collection of random trees (RT). Random trees are structurally identical to classical decision trees but are trained differently. During training not an exhaustive search of the possible test candidates is considered but only a randomized subset in order to allow for creating several different and independent random trees.

III. Image Representation

A. The original LBP

The local binary pattern (LBP) [12] [13] is defined as a gray-scale invariant texture measure, derived from a general definition of texture in a local neighborhood. The original LBP operator labels the pixels of an image by thresholding the *3- by-3* neighborhood of each pixel with the center pixel value and considering the result as a binary number. The decimal result is the sum of, the thresholds multiplied by their weights values, as it can be seen in Fig. 1.

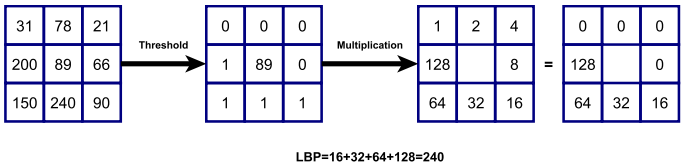

Fig. 1. The original local binary pattern calculation, the central pixel is compared with its neighbors, the thresholded values are then multiplied by a power of 2^i, where i is the pixel index, the sum of all values results to the LBP code.

In other words given a pixel position (x_c, y_c), LBP is defined as an ordered set of binary comparisons of pixels intensities between the central pixel and its surrounding pixels.

The resulting label value of the 8-*bit* word can be expressed as follows :

$$LBP(x_c, y_c) = \sum_{n=0}^{7} t(l_n - l_c)2^n \tag{1}$$

where l_c corresponds to the gray value of the central pixel, l_c the gray value of the neighbor pixel n, and function $t(k)$ is defined as following :

$$t(k) = \begin{cases} 1, & \text{for } k \geq 0 \quad (2) \\ 0, & \text{for } k < 0 \quad (3) \end{cases}$$

According to (2), the LBP code is invariant to monotonic gray- scale transformations, thus the LBP representation may be less sensitive to illumination changes.

The 256-bin histogram of the labels computed over an image can be used as texture descriptor. Each bin of histogram (LBP code) can be regarded as micro-texton and the histogram characterizes occurrence statistics of simple texture primitive. The histogram of the labeled image $f_l(x, y)$ can be defined as:

$$H_i = \sum_{x,y} I(f_l(x, y) = i), i = 0, .., L - 1 \tag{4}$$

where L is the number of different labels produced by the LBP operator and $l(A)$ is 1 if A true and 0 otherwise.

B. Multi-block LBP

The LBP operator has been extended to consider difference between blocks, the MB-LBP [14] operator is defined by comparing the central rectangles average intensity g_c with those of its neighborhood rectangles g_0, ..., g_8. In this way, it can give us a binary sequence. An output value of the MBLBP operator can be obtained as follows:

$$MBLBP = \sum_{i=1}^{8} t(g_i - g_c)2^i \tag{5}$$

where g_c is the average intensity of the center rectangle, $g_i (i = 0, .., 8)$ are those of its neighborhood rectangles. Fig. 2 demonstrates how the MB-LBP features are calculated.

IV. Fine-tuning Training Parameters

A. Data set preparation

To train the classifiers we use a subset of the FERET [15] face database.

Fig. 3. Samples of the cropped training faces from the Feret dataset.

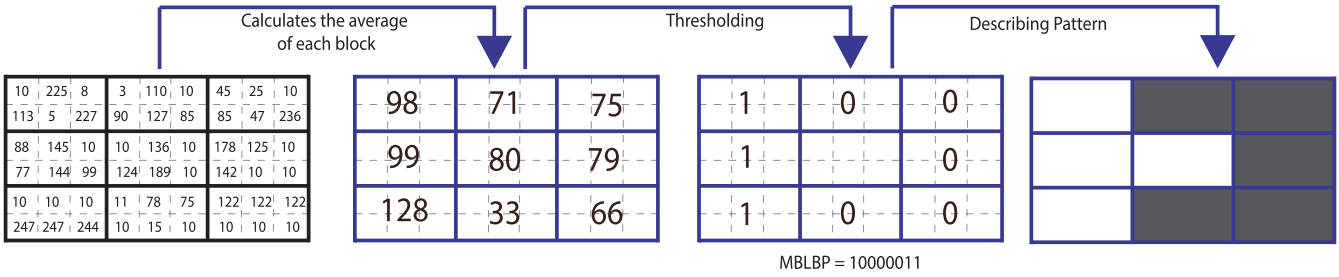

Fig. 2. The multi-block variant of the local binary pattern.

The database contains 14051 face images of over 1000 subjects and has variations in expression, lighting, pose and acquisition time. Only frontal views of the different faces have markups of eyes and mouth position, these markups, see Fig.4 are used to crop the face from the image. Thus the training data set is reduced to 5324.

Fig. 4: Feret labeled sample.

For the testing purpose we use the BioID Face database [16]. The dataset consists of 1521 gray level images with a resolution of 384286 pixel. Each one shows the frontal view of a face of one out of 23 different test persons. There are 20 manually placed points on each image. The markup scheme is shown on Figure 5.

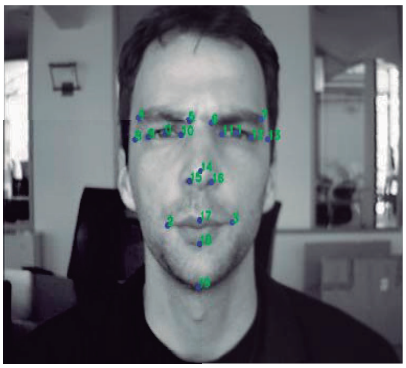

Fig. 5. BioID labeled face image sample.

The top left corner point of the ground truth face (the region of interest) is obtained by subtracting 10 pixel from the left temple x coordinate, index 8 on the figure 5, and by adding 15 pixel to the highest eye brow point, index 7 in this image example. The right bottom corner point of the region of interest is obtained adding 10 to the right temple x coordinate and taking the tip of chin y coordinate, index 19 on the image , as the y coordinate.

TABLE I
List of Labels Indexes and Their Description

Label index	Description
0	Right eye pupil
1	Left eye pupil
2	Right mouth corner
3	Left mouth corner
4	Outer end of right eyebrow
5	Inner end of right eyebrow
6	Inner end of left eyebrow
7	Outer end of left eyebrow
8	Right temple
9	Outer corner of right eye
10	Inner corner of right eye
11	Inner corner of left eye
12	Outer corner of left eye
13	Left temple
14	Tip of nose
15	Right nostril
16	Left nostril
17	Centre point on outer edge of upper lip
18	Centre point on outer edge of lower lip
19	Tip of chin

B. Experiments & Results

The choice of the training parameter values has an important impact on the trained classifiers accuracy. For the Multi-Blocklocal binary pattern features we choose a range of parameter values to apply and we plot a roc curve of each classifier to highlight the influence of each parameter.

1) Minimum hit rate parameter:

The first set of experiments consists of varying the diffrent values used for the parameter minHitRate, the minimum desired hit rate for each stage of the classifier. The Overall hit rate can be estimated as: $(MinHitRate^{number-Of\ -stages})$. Table II lists some values used for the training.

TABLE II. Variation of the Minimum Hit Rate
Parameter to Train MB-LBP Based Classifiers

Classifier	MinHitRate
C_1	0.5
C_2	0.6
C_3	0.7
C_4	0.8
C_5	0.9

2) Maximum false alarm parameter:

In the second set of experiments, we vary the values of the parameter **MaxFalseAlarm**, the maximum desired false alarm rate for each stage classifier. The Overall false alarm rate is estimated as: $(MaxFalseAlarm^{number-Of-stages})$. Table III lists the parameter values used for each feature. Table III lists the different values used for this parameter.

TABLE III. Variation of the Maximum
False Alarm Parameter to Train MB-LBP Classifiers

Classifier	MaxFalseAlarm
C_1	0.3
C_2	0.4
C_3	0.5
C_4	0.6
C_5	0.7

3) Max depth parameter:

In the third set of experiments, we vary the values of the parameter **maxDepth**, the maximum depth in each single weak classifier. Table IV lists the different values used for this parameter.

TABLE IV. Variation of the Maximum
Depth Parameter to Train MB-LBP Classifiers

Classifier	Max Depth
C_1	1
C_2	2
C_3	3
C_4	4

4) The boosting variant parameter:

In the last set of experiments, we vary the values of the boosting type parameter **Boost Type**, Table V lists the different values used for this parameter.

C. Performance evaluation

The resulting classifiers have been applied on the BioID Face database, we present the detection performance by the Receiver Operating Characteristic curves [17].

TABLE V. The Different Boosting Algorithms Variants Used to Train the MB-LBP Features Based Classifiers

Classifier	Boosting variant
C_1	Gentle Adaboost (GAB)
C_2	Discrete Adaboost (DAB)
C_3	Real Adaboost (RAB)
C_4	Logit Adaboost (LB)

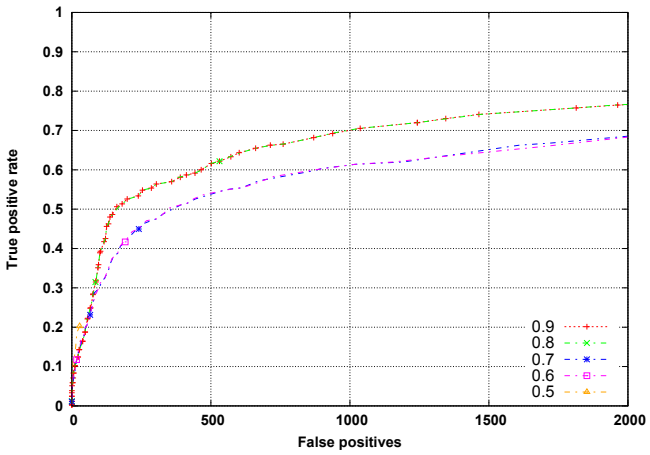

Fig. 6. Variation of the minimum hite rate parameter values for the MB-LBP features based classifiers.

The ROC curves shown in the figures 6, 7, 9 and 8 are obtained by scoring the detected windows on each test image and applying a threshold to decide if the detected window is a face or not. To represent the degree of match between a detection d_i and an annotated region I_j, we employ the commonly used ratio of intersected areas to joined areas:

$$S(d_i, l_i) = \frac{area(l_i) \cap area(d_i)}{area(l_i) \cup area(d_i)} \quad (6)$$

And we use a slightly modified version of the evaluation tool provided by [18], in where we use a rectangular face annotation rather than an elliptical one.

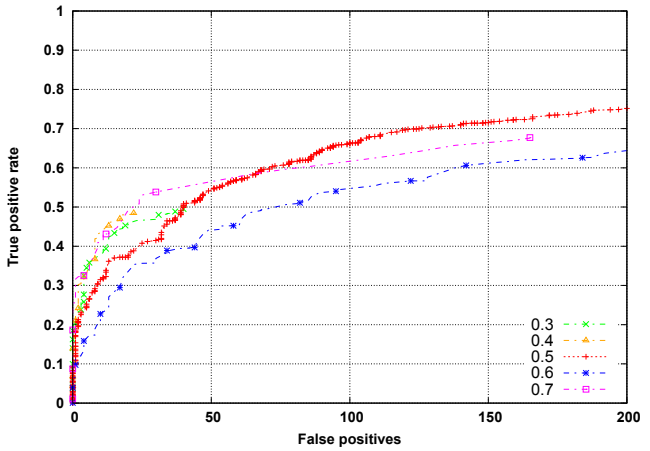

Fig. 7. Variation of the maximum false alarm parameter values for the MB-LBP features based classifiers.

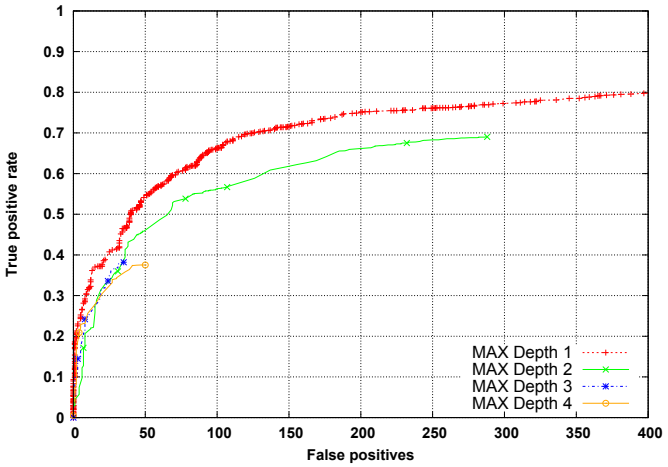

Fig. 8. Variation of the maximum depth parameter (Maximum depth per weak learner) values for the MB-LBP features based classifiers.

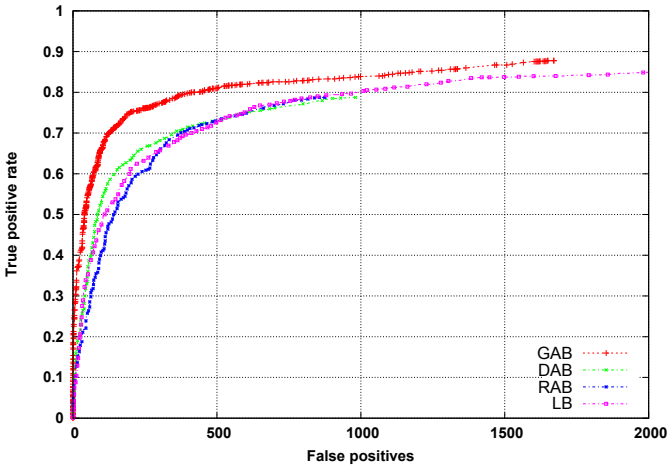

Fig. 9. Different variants of boosting algorithm for the MB-LBP features based classifiers.

D. Results discussion

Figure 6 shows how the values 0:9 and 0:8 of the minimum hit rate parameter give the best result for the Multi-block local binary features. Choosing the value 0:7 for the maximum false alarm parameter gives the best result in the second set of experiments as shown in Figure 7. In Figure 9 we see how applying the Gentle AdaBoost variant gives the more accurate results in the third set of experiments. Finally, the figure 8 shows that a classifier based on weak learner of only one depth performs more accurately than a classifier with deeper weak learners.

These different experiments have shown how a single parameter value can influence the accuracy of a face classifier and for each type of object detection, user might need to use multiple combinations of the different parameters values to find an accurate classifier.

V. Application to Augmented Reality

Augmented Reality (AR) employs computer vision, image processing and computer graphics techniques to merge digital content into the real world. It enables real-time interaction between the user, real objects and virtual objects. AR can, for example, be used to embed 3D graphics into a video in such a way as if the virtual elements were part of the real environment. This technology has known an increasing interest in many fields and it has been explored in the e-commerce

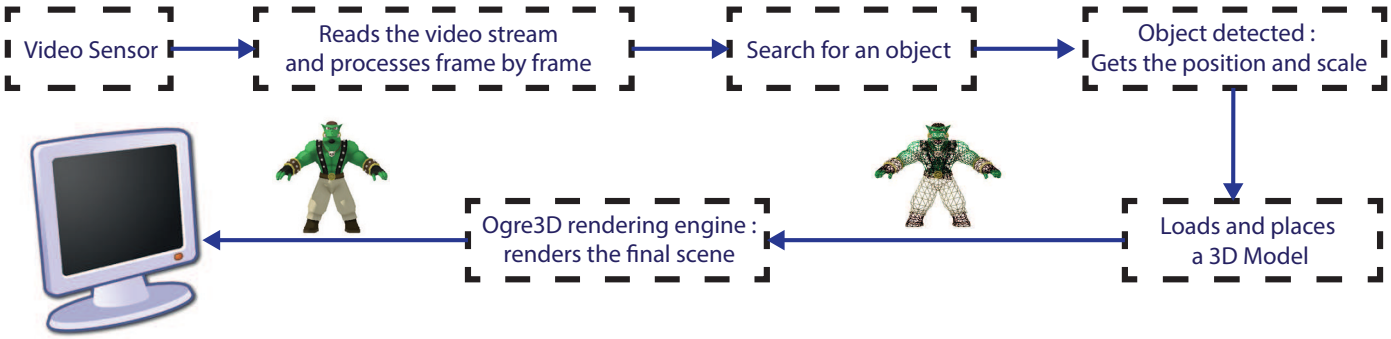

Fig. 10. Augmented reality application workflow.

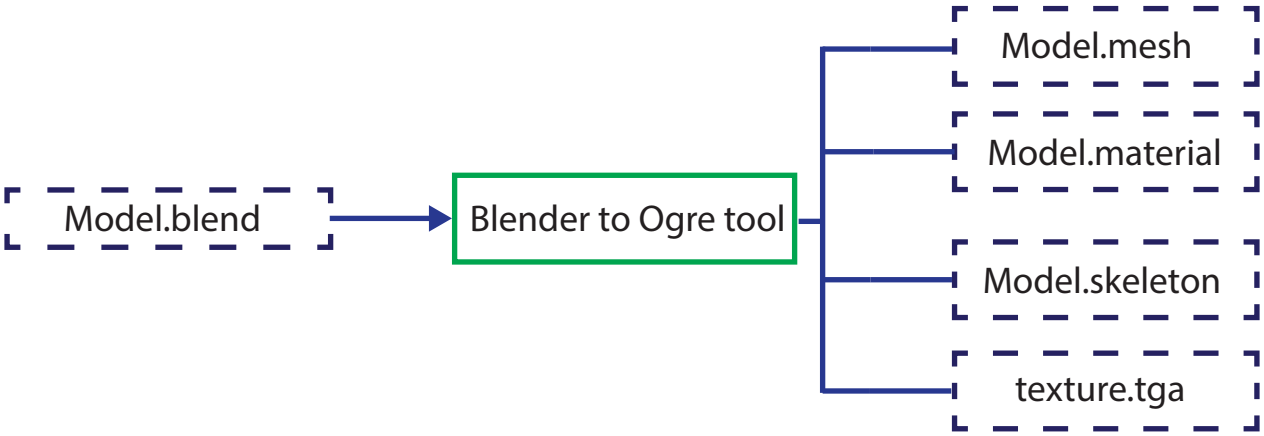

Fig. 11. Converting the blender 3D model to Ogre 3D format.

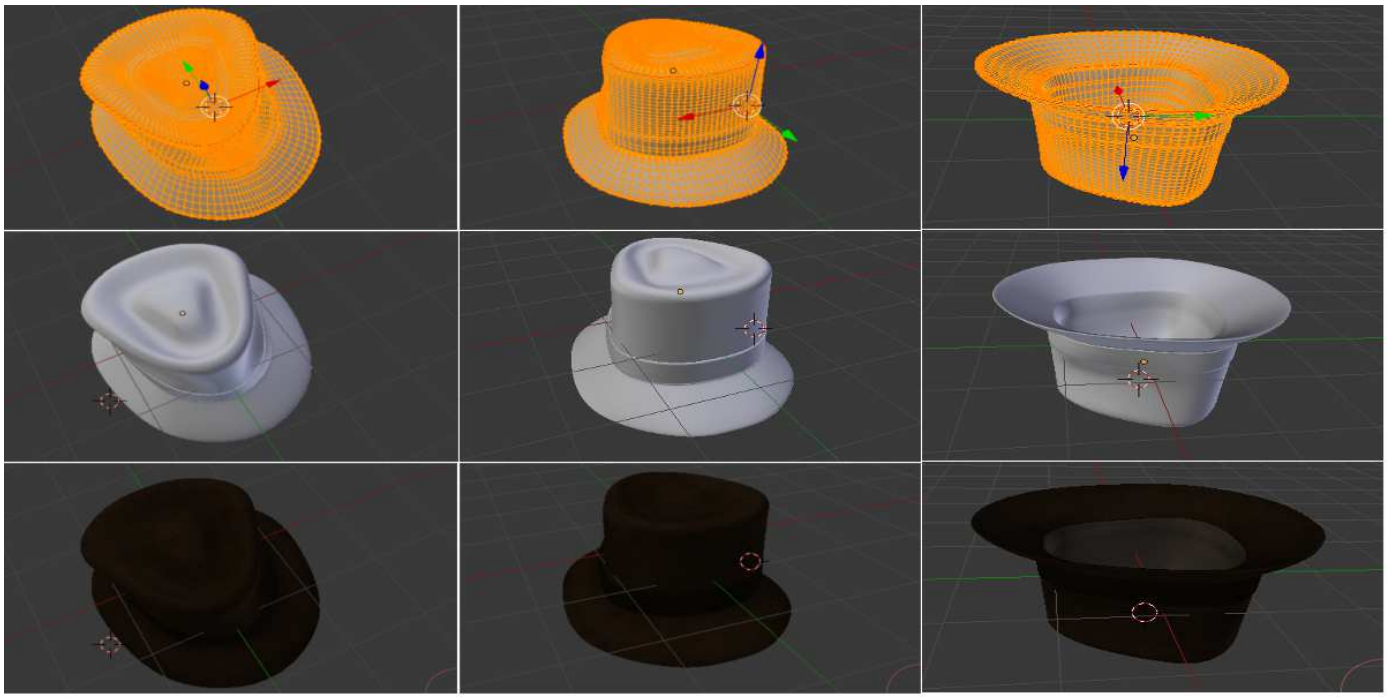

Fig. 12: The Blender 3D hat model.

applications [19] where clients try clothes online, discover and test itmes they are interested in without having to move to a store. It was also applied in the e-learning [20] where the classic teaching way can be mixed with the augmented reality to make students having fun while learning new things in a new manner.

For augmented reality, marker-less model-based tracking approaches [21] appear to be the most promising among the standard vision techniques currently applied in AR applications. While marker-based approaches such as ARToolkit [22] or commercial tracking systems such as ART provide a robust and stable solution for controlled environments, it is not feasible to equip a larger outdoor space with fiducial markers. Hence, any such system has to rely on models of natural features such as architectural lines or feature points extracted from reference images. The proposed augmented reality of this work

makes use of the powerful open source real time 3D rendering engine OGRE [23] and the 3D modeling tool Blender. OGRE enables a programmer to deal with the threedimensional graphical presentation of a particular application in a very object oriented manner and that is exactly what explain the name OGRE, Object-Oriented Graphics Rendering Engine. It acts as wrapper to the rendering subsystem (OpenGL or DirectX), allowing us to focus on the application rather than the rendering details.

Fig.10 shows the workflow of an OGRE based application, in which a standard web camera is use to capture the video stream, the trained face detector is then loaded using the open computer vision library [24] and used to detect faces present on each frame of the video. finally, ogre is used to place a 3D object over the face region and the video stream is rendered to the user.

A. Modeling a 3D Hat

The 3D model that we use for our application is a 3D hat, see Fig.12. To model the hat we use the powerful modeling tool blender. The Ogre rendering engine uses meshes and skeletons for movable objects, in order to use the modeled hat, we need to convert blender format to resources that are managed by Ogre to render a 3D model. Figure 11 shows the generated resources from converting the blender 3D model to Ogre format.

B. Adding the 3D model to an Ogre scene

Every 3D rendering library uses a scene graph to organize its renderable items. This scene graph typically is optimized for fast search- ing and querying, providing the user with the ability to find items in the vicinity of other items, and allowing the library to find, sort, and cull polygons as needed in order to provide the most efficient rendering possible. For the proposed augmented reality application, the background of the scene will be the stream captured by the camera. Then for adding the 3D model to our scene, we process the camera stream frame by frame to detect the face position and to place the 3d model. Using the trained face detector, we process frame by frame to detect the face position. Fig. 13 shows the resulted scene, where the user is wearing a virtual 3D hat.

Fig. 13. A real scene augmeted by a 3D hat model.

VI. Conclusion

In this paper, we presented an augmented reality application using the 3D rendering engine Ogre. We experimented the different boosting techniques using the local binary pattern features by applying multiple values for the classifier training task. The chosen approach of using boosting techniques with a real time based augmented reality system has shown a satisfying results and has avoided the end user the burden of wearing any form of markers to interact with the computer.

The perspectives of this work are to use deep learning for hand gesture recognition and to apply the different gestures for an augmented reality applications in the domain of education. The institutions from rural zones suffers from the lack of funding for buying laboratory materials, virtual experiments can come for help to reduce the gap between theory and practice for subjects like physics and chemistry.

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Push Recovery for Humanoid Robot in Dynamic Environment and Classifying the Data Using K-Mean

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Maharshi Dayanand University, Rohtak
PDM College of Engineering,Rohtak

***Abstract* — Push recovery is prime ability that is essential to be incorporated in the process of developing a robust humanoid robot to support bipedalism. In real environment it is very essential for humanoid robot to maintain balance. In this paper we are generating a control system and push recovery controller for humanoid robot walking. We apply different kind of pushes to humanoid robot and the algorithm that can bring a change in the walking stage to sustain walking. The simulation is done in 3D environment using Webots. This paper describes techniques for feature selection to foreshow push recovery for hip, ankle and knee joint. We train the system by K-Mean algorithm and testing is done on crouch data and tested results are reported. Random push data of humanoid robot is collected and classified to see whether push lie in safer region and then tested on given proposed system.**

***Keywords* — Bipedal Walking, Push Recovery, Humanoid Robot, K-Mean Classification, Zero Moment Point, Linear Inverted Pendulum.**

I. Introduction

Now a day's human robots are developed to perform many human activities. Bipedal robots are comparable to human walking. Though we can say human locomotion seems effortless but it is exceptionally complex [1].

When we talk about the push recovery features in humanoid robot we face difficulties as compared to animals and humans. Humans and animals are completely versed where as humanoid robots have certain other features [2]. It's contemplated to make a humanoid robot that can work smoothly and practically. There are many uncertain disturbances that emerge like push is one of the common problems that get created during locomotion. The goal of this paper is to search easy, lucid way for push recovery walking in humanoid robots. So we collect the push data by pushing humanoid robot from behind and we train the system by applying K-Mean algorithm and using crouch as data. Therefore we get a trained system which can analyse and work on any push recovery strategy. [18]- [20]

In this paper we apply four different types of pushes. The first difficulty that arises in humanoid robot is mainly due to ZMP (Zero Moment Point). A humanoid robot will be stable if and only if its ZMP is within the geometry of its foot.

In figure 2 the red line tells how the ZMP must lie within the sole of the robot through the complete motion. Green line shows that the trajectory of robot must emphasis on keeping the centre of gravity (COG) between the two feet of robot. Dark grey division show safe region of the foot for single support phase of humanoid motion. And light grey region shows safe region for double support phase of humanoid motion.

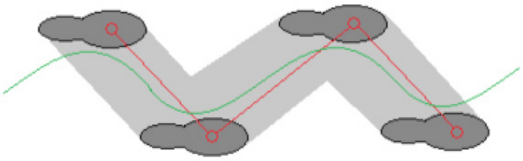

Fig. 1. Proposed Trajectory of Humanoid's ZMP.

When an external push is applied to a humanoid robot we have 3 approaches, i.e. ankle, step and hip strategy shown in figure 2.

Fig. 2. Three basic balancing strategies in the presence of external forces.

It is troublesome to obtain perfect motion like human gait when there is high Degree of Freedom and variable mechanical structure of a human body. Inverted Pendulum Model (IPM) is utilized for gathering human motion gait [8] [9] [10] [11] robotics and biomechanics [12] [13] [14] [15] [16].The IPM presumes reaction force Counter-revolution obtained from the floor which is produce from the point and penetrates the COG (Centre of Gravity) of the IPM, resulting as absence of angular moments around COG. The linear acceleration of centre of mass will be more than that of the gravity acceleration when the humanoid is pushed very hardly on the Centre of Mass (COM). And as surface always has friction force therefore upper part of body will move faster than lower part of body. So in order to avoid this we eradicate the undesirable momentum induced from push therefore, humanoid robot may move steadily.

A. Proposed system

In the context of this paper first stage involves to analyse the push recovery pattern. Push recovery pattern can be analysed by collecting different data. To find this pattern we need machine learning Technique. In second stage we gather the data of humanoid robot by pushing it from a rigid ball from behind. In third stage we calculate leg joint angles using inverse kinematics [4] [5] [6]. In fourth stage we train the system using K-Mean classification and crouch data is tested on it. In fifth stage we find out the push recovery strategy of humanoid robot on given training system to get better results or push recovery. Then from the classifier we see whether the ZMP lie in safe region (from Fig. 1) or

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not. If it doesn't fall in safe region, we make the humanoid robot learn by modifying the algorithm and to sustain its walking.

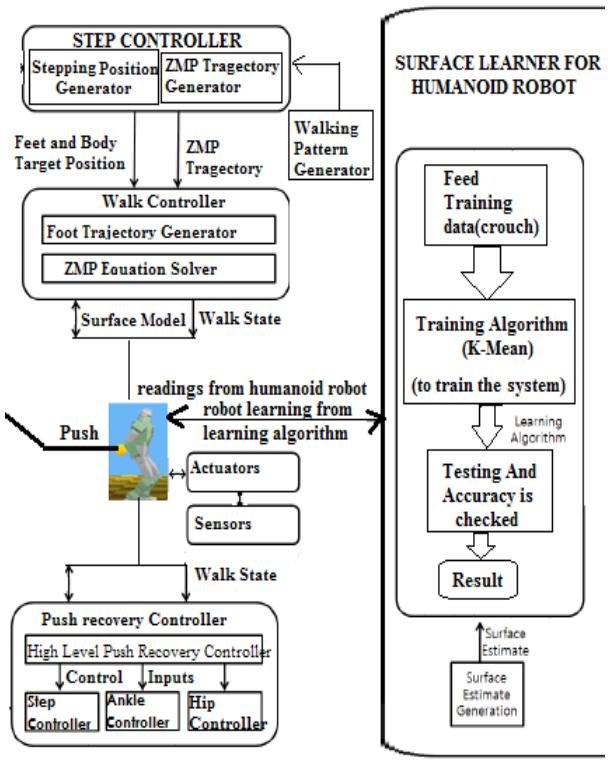

Fig. 3. Proposed System for Push Recovery for Humanoid Robot and Classifying the Data Using K-Mean.

B. *Push recovery controller*

The work of Push Recovery Controller (PRC) is to remove anxiety raised because of external disturbances or modelling error. On uneven surface chances of perturbations is very high so PRC is more required. PRC can be categorised into 3 categories (based on Fig.2)

1) *Ankle Controller*

To keep COM within the base support the torque is applied on the ankle joints by the ankle controller. It is effectuated as,

$$\Delta\theta \text{ ankle} = \text{x ankle}$$

here x (ankle) denotes the input of ankle controller and $\Delta\theta$ denotes the joint angle bias.

Step Controller

It controls the moves of the base to support in taking steps. With the relative target foot position a new step is inserted by overriding the step controller as $x_{capture.}$

Hip Controller

It puts the angular acceleration of torso and limbs in use to create backward ground reaction force to pull COM back towards base support. To implement it we use,

$$\mathbf{Z_{hip}(w) = \tau_{maxi}\, a(w) - 2\tau_{maxi}\, a(w\text{-}Z_{Y1}) + \tau_{maxi}\, a(w\text{-}Z_{Y2})}$$

where τ_{maxi} is maximum torque that joint can apply, a(w) is unit step function, Z_{Y1} is the time when torso stops accelerating and Z_{Y2} is the time at which torso stops.

C. *Hip strategy stability criteria*

Hip strategy implements push recovery by intensifying the torque of the hip joint to overcome the forces of push. The torque of the hip is applied closer to COM of the robot, and therefore produces greater reaction force [18]. The hip strategy can create greater counter forces therefore it is used for recovering from larger pushes in comparison with ankle strategy.

In general Linear Inverted Pendulum (LIP) is applied to humanoid robot [7] but this strategy deficit rotational inertia, which is very essential for hip strategy to balance push recovery. Therefore we exercise Angular Moment with Inverted Pendulum.

The classification of angular disturbance (in Fig. 4) can be done by control algorithm by comparing the sagittal and coronal torques [19]. The angular torque can be represented by following equation,

$$\tau = \tau_x \cos(\alpha) + \tau_y \sin(\alpha)$$

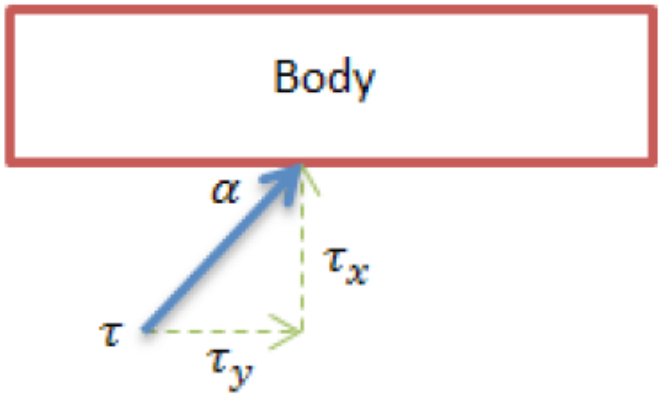

Fig. 4. Angular Disturbance.

Figure 5 is used to find the control for humanoid. The motion of COG is controlled to make sure robot is stable during walking. The motion of COG of robot is affected by gravity and the contractility of the robot. Due to this the derivation of the robot's kinematic equations [17] comes into picture.

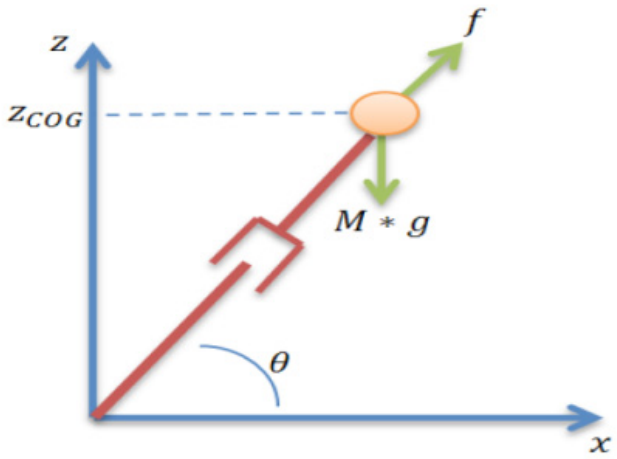

Fig. 5. Linear Inverse Pendulum Model.

By analysing the humanoid robot's COG in figure 4, the equation can be obtained, Mx"=f*sin (θ).

Based on the above discussion hip controller algorithm is designed.

Algorithm-1 stiffness controller working and Target angle $Ø_{hip}$

$Ø_{hip} = Ø_{hip,\ initz}$
stiffness = stiffness $_{initz}$
else
if b= **not true and** push detected **and** ground contact **then**
$Ø_{hip} = Ø_{hip,\ curr}$
stiffness= stiffness $_{minimum}$
b=**true**
end if
if $Ø_{hip} \epsilon [_{Ø\ hip,\ min,\ Ø,\ max}\ ]$ **and** stiffess<= stiffess $_{maximum}$ **then**
$Ø_{hip=} Ø_{hip,\ curr}$
stiffness = stiffness + $\Delta_{stiffness}$
else
A= **false**
$Ø_{hip} = Ø_{hip,\ initz}$
stiffness = stiffness $_{init}$
end if
end if

The stiffness controller gets real position and the strength of activation of joint. It then calculates the strength of activation and the target joint position. To calculate the torque for the joint, the output from the stiffness controllers is passed to low-level joint setup.

II. Methodology

A. To gather data and extract feature

Data is captured using body sensor based Human Motion Capture Device (HMCD) and potentiometer.Then data is collected using accelerometer sensor. It gives the meticulous acceleration and user can analyse the moment.

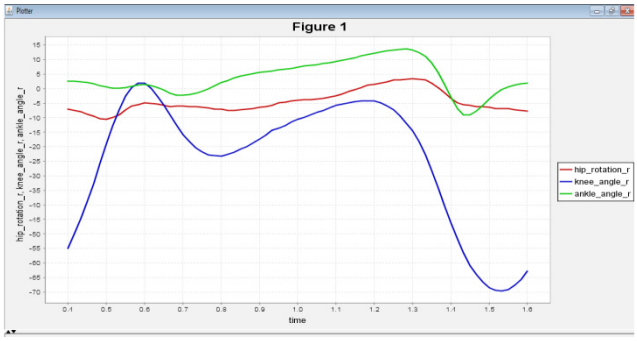

Fig. 6. hip ankle and knee joint.

Figure 6 shows the simulation of hip, ankle and knee joint with respect to time. Red curve is for hip, blue curve represent knee and green curve show ankle. Then we apply the push, i.e. four sorts of pushes are applied categorized as low, medium, medium high and high. Then the data is collected and Force sensing resistor(FSR 3105) is used to estimate push from back. To obtain joint angles of hip and knee we use inverse kinematics, and it employs to control the position of a humanoid's extremities.

B. Joint angle calculation

Inverse kinematics is used to gather the result of link manipulator. Now the human leg is represented as two link manipulator in Fig.7 [8]

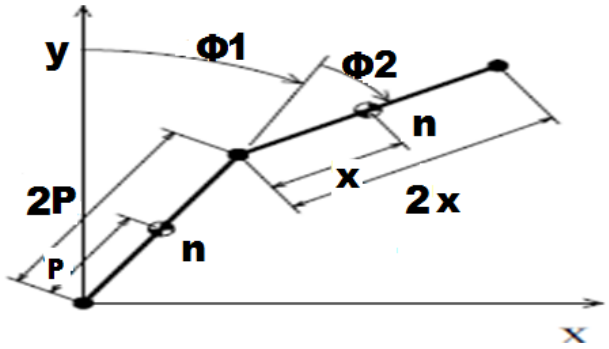

Fig.7. Two link manipulator.

The dynamics of 2-link manipulator is shown by,

$$N(\Phi(a))\,\Phi(a) + X(\Phi(a), \Phi(a)) + D\Phi(a) = \kappa\,(a-P)$$

Where N is inertia matrix, X is centripetal and coriolis torque, κ is input torques and P is a dead line time. Each element is calculated as

$N(\boldsymbol{\Phi}\,(a))=$
$X(\boldsymbol{\Phi(a)},\boldsymbol{\Phi}(a)) =$
$D=$, $\boldsymbol{\kappa}=\boldsymbol{(a}\text{-}L) =$
$J_1=I_1+(m_1+4m_2)\,i1_2$, $J_2=I_2+(m_1+4m_2)\,i_{22}$
$B=2m_2I_1I_2$, $I1=1/3m_1I_1^2$, $I_2=1/3m_2I_2^2$

Now the code is written for classification using Matlab. This is unsupervised classification technique. Appropriate area of training is selected for each class. Here .CSV (comma separated value) file is used to store training areas and the corresponding class.

C. Training

The system is trained using K-mean algorithm which is an unsupervised classification technique.

Algorithm 2: train the system using K-Mean algorithm

```
START
[1] Choose any arbitrary vector mean when a=0,

[2] Mean will be [w1, w2, w3…wz]^a  where z is no. of
cluster head.

[3] After this classification of raw data is done
according to distance from mean at a=0.

[4] DO (Until threshold value is not reached that is
the convergence criteria is not satisfied).

[5] Again calculate mean vector for a=a+1 and
consequently do the classification.

[6] Modify a=a+1;

[7] Convergence criteria

[8] Calculate the Euclidean distance
    ||w(a)-w(a-1)||<z

[9] Use w(a) as solution
ELSE

[10] Go to step 5
END
UNTIL the data not classified/*classification gait=
{normal, croach1, croach2, croach3, croach4}*/
END
```

Now the K-Mean algorithm (Algorithm-2) is framed in order to classify the crouch data, we make a minor modification in Algorithm-2, in order to classify the trajectories (in fig-1) of humanoid robot so as to find out which trajectory is safe push and which trajectory is not and we make four clusters (from fig-1) and see where trajectory lies i.e. grey, dark grey, green line or outside this.

So there will be 3 centroids and we use K-Mean algorithm to minimize an *objective function*,

$$J = \sum_{j-1}^{k} \sum_{i-1}^{n} \left\| x_i^{(j)} - c_j \right\|^2$$

,

$\left\|x_i^{(j)} - c_j\right\|^2$ is distance between data point $x_i^{(j)}$, c_j is cluster centre which indicates cluster centres of the distance of n data points.

Suppose n is the sample feature vectors x_1, x_2... x_n, and falls under k compact clusters. Say z_i is in cluster i depicts mean of the vectors, where i represents 3 clusters i.e. in grey region, dark grey, green line or if not anyone then it lies outside this, If the clusters are properly distinguished, we can use a minimum-distance classifier to distinguish them, i.e. x belongs to cluster i if || x - z_i || is smallest among all the distances of k.

D. Classification

It is the selection feature where classification is done on the data set. Learning must be done in standard way in order to obtain the best results of system. It classifies the gait data where a set of data is already given as crouch data. The training is done using K-Mean algorithm then new push recovery data collected from humanoid robot is tested on the same system to predict the behavior of humanoid robot learning.

Different joint angles (knee, hip, and ankle) were captured and control reverse torques can be calculated for the joints in a bipedal humanoid using the following equation,

$$\tau = W(\Phi)\,\theta'' + C(\Phi, \Phi')\,\theta' + G(\Phi)$$

where W(Φ) -inertial torque, C(Φ) - centripetal and coriolis forces, G(Φ) - gravitational force.

Once this is done, now the trajectories of push data is classified in order to check whether the humanoid robot lies in safe region or the humanoid robot cannot recover from the push.

III. Experimental Results

In simulated environment after training of push recovery controller we validate walking of humanoid robot.

A. Experimental setup

The simulation is done in WEBOTS, where the humanoid robot is equipped with accelerometer in the pelvic. In the experiment, similar motion of the simulation is produced to intensify the push force by modifying the COM position. We keep changing the pushing force and push data is analysed using classifier. As the data is collected by humanoid robot it is passed through the proposed algorithm and it shows the learning pattern of push recovery.

B. Push simulation

Here a rigid ball is used to push the humanoid robot from behind shown in figure 8[24].

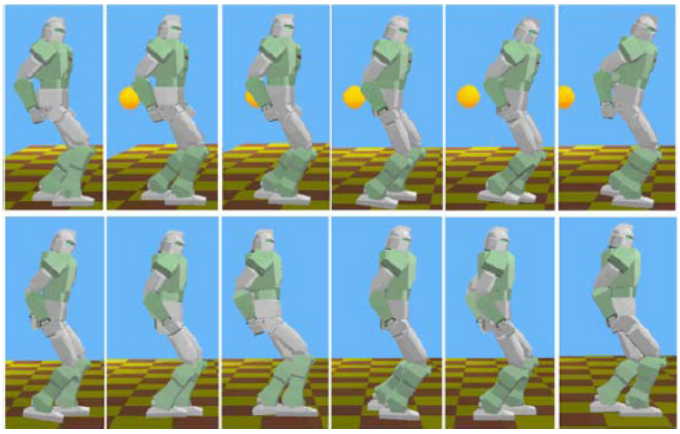

Fig. 8. Simulation results as humanoid robot manages to walk normally by recovering from push strategy.

Figure 9 shows the influence inducement as an abrupt rise in the velocity of ball. To recover the humanoid robot the controller controls it and the unsupervised learning is done through K-Mean and manages it to it normal walking position.

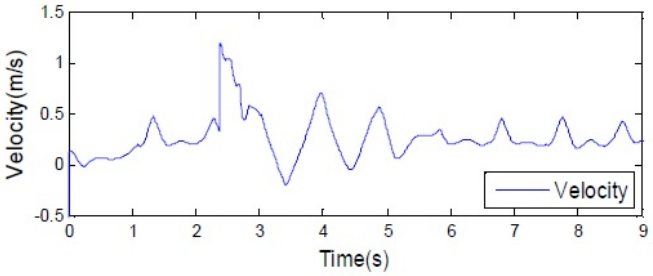

Fig. 9. Velocity vs. Time diagram.

Once the push recovery strategy is applied, now the push recovery walking strategy is produced by controller and thus it will return to normal walking trajectory. Then ZMP controller generates centre of mass trajectory that will keep track of ZMP.

The different type of data set is collected when the robot is pushed from behind from different four strategies i.e. low, medium, medium high and high. When the classification of data is done the overall accuracy obtained is 60.275% shown in figure 10.

IV. Discussion

A. Performance of system

Webots is chosen for the simulation as it uses an accurate physics engine. It simulates gravity and frictional forces that influence the humanoid robot's motion. Webots can easily simulate every position while applying gravity and external forces.

Therefore we get the applied force by simulation program. When the push is applied then the performance of proposed system is best and its impact lies near COM. As the pushes occur away from COM the angular momentum will be greater and the performance of system will degrade and it becomes difficult for humanoid robot to recover. Therefore as soon as the pushes occur away from COM we classify the data and try to bring it under COM.

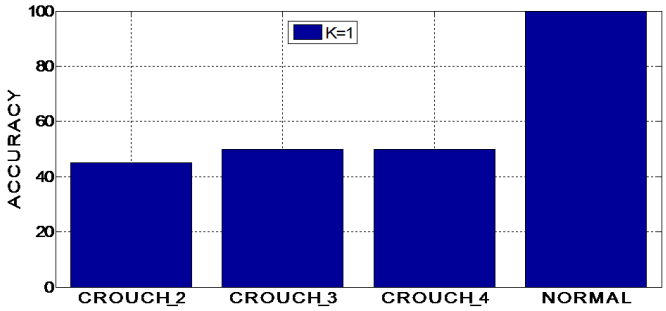

Fig. 10. Shows overall accuracy for training data set.

B. Conclusion

Figure 11 shows that different clusters could be shown according to COM that falls in classification in 4 different points while doing classification of Figure 1.

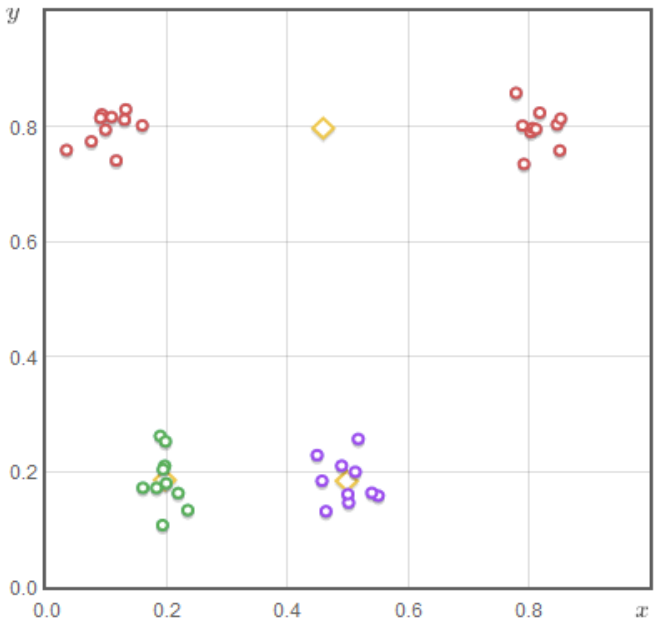

Fig.11. Data points clustered at 4 distinct positions.

When the humanoid robot is tested with respect to proposed system, it shows the better push recovery strategy. Therefore we used the K-Mean classification technique which gives accuracy rate up to 60%. Hence the push recovery data is classified properly and push recovery strategy is efficiently implied for humanoid robot.

So by the experimental comparisons, the proposed method can reduce perturbations up to large extend and it indicates that this method is an effective approach and can be use in the motion rules for humanoid robot walking and running.

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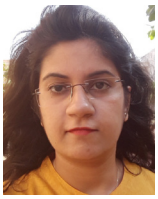

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Erythrocyte Features for Malaria Parasite Detection in Microscopic Images of Thin Blood Smear: A Review

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***Abstract* — Microscopic image analysis of blood smear plays a very important role in characterization of erythrocytes in screening of malaria parasites. The characteristics feature of erythrocyte changes due to malaria parasite infection. The microscopic features of the erythrocyte include morphology, intensity and texture. In this paper, the different features used to differentiate the non-infected and malaria infected erythrocyte have been reviewed.**

***Keywords* — Medical imaging, erythrocyte, malaria parasite, erythrocyte features.**

I. Introduction

Malaria is an infectious disease due to Plasmodia parasites. There are different parasite species causing human malaria i.e *Plasmodium falciparum, Plasmodium vivax, Plasmodium malariae, Plasmodium knowlesi and Plasmodium ovale.* Malaria is the priority tropical disease of the World Health Organization [1]. In 2013 malaria report from World Health Organization, it has been reported that there are 97 countries and territories with ongoing malaria transmission. Globally, total 3.4 billion people are in risk of malaria. The present scenario of malaria in India is best described as malaria endemic country with more than 95% of population at risk and north-eastern state of India contributes about 10%. *In India,* both *Plasmodium falciparum* and *Plasmodium vivax* are commonly reported. To diagnose the presence of malaria parasite in erythrocyte, the microscopic examination of the blood smear is done by the clinical expert. The blood smears are of two different type i.e. thick smear and thin smear. In thin smear, the changes in characteristic of the erythrocyte due to malaria parasite infection can be studied but in thick smears, the appearance of the parasite is much more distorted [2]. The erythrocyte is mainly used to diagnose the different diseases such as malaria, cancer, etc. The medical image processing is becoming very important to diagnose the diseases such as cancer, malaria, tumour detection, etc [3-4].

However, the microscopic analysis of blood smear by clinical expert is very tedious process and depends on the skill of the clinical expert. To avoid such a problem, different image analysis techniques are being explored to timely diagnose the malaria parasite infection in human being. The image analysis approach used different features to differentiate the infected and non-infected erythrocyte. The microscopic feature used for the analysis of the characteristic erythrocytes to detect the infected erythrocyte includes morphology, intensity and texture. Structural changes in erythrocyte take place due to malaria parasite infection. The features usually specific to morphology, intensity and texture. In some of the malaria species, the morphological feature does not affect but the textural changes occur. The morphological feature of different malaria parasites is shown in Table 1.

TABLE I. Morphological Feature of Malaria Parasites

Species	Stages	Size	Stippling
P. falciparum	Trophozoites Gametocytes	Normal	Maurer's dot
P. vivax	Schizonts Trophozoites Gametocytes	Enlarged	Schuffner's dots
P.ovale	Schizonts Trophozoites Gametocytes	Enlarged	Schuffner's dots
P. malariae	Schizonts Trophozoites Gametocytes	Normal	Ziemann's dots

Several researchers have used different feature set to classify the infected and non-infected erythrocytes [5-19]. The microscopic image of the thin blood smear is shown in Figure 1. The image contains both the infected and non-infected erythrocyte. It can be seen that there is variation in morphological features infected and non-infected erythrocyte.

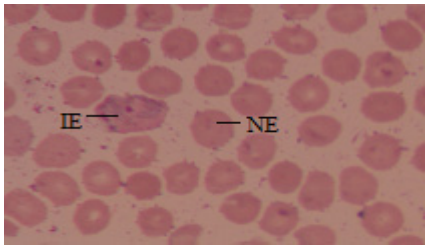

Fig. 1. Microscopic thin blood smear image
IE-Infected Erythrocyte, NE- Normal Erythrocyte

The contained of the paper is organised as follows. In section II, Morphological features of the erythrocyte are discussed. Microscopic feature of erythrocyte used for detection of malaria infected erythrocyte is studied in Section III. Conclusion is presented in the section IV of the paper.

II. Erythrocyte Morphology

Erythrocyte is a cell found in blood which carry oxygen and collect carbon dioxide through the use of haemoglobin. It has a life of about 120 days. For the diagnosis of several diseases such as malaria, cancer, etc, the microscopic image analysis of the blood cell is done [4]. The differentiation of the abnormal and normal erythrocyte can be done by using the features such as texture, color, size. Under normal conditions,

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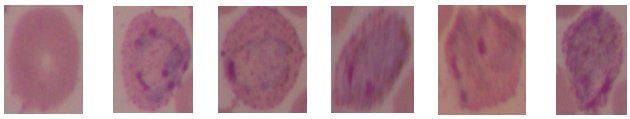
mature erythrocytes are round, biconcave disc-shaped, a nuclear cells with size of around 7-8 microns in diameter. The term normocytic is used to express normality of erythrocyte. Due to the malaria infection, the morphological features of the erythrocyte changes as shown in Fig. 2.



(a) (b) (c) (d) (e) (f)

Fig. 2. Erythrocyte image (a)- normal (b-f)-infected

III. Microscopic feature extraction

Feature extraction is the quantitative measurements of images typically used for identifying objects or region of interest and/or analyzes the pathology of a structure or tissues in the pathology slides. Once the features have been computed, appropriate selection of a subgroup of the significant and robust features is necessary to improve the classification accuracy and minimizing the overall complexity. In order to distinguish between infected and non-infected erythrocytes, different features have been used from the image array and compute new variables that concentrate information to separate classes. Such feature set consist of features leading to large between-class distance and small within-class variance in the feature vector space, i.e. the set of features can discriminate between different classes as well as possible. Some set of features that can distinguish between infected and non-infected erythrocytes are morphological features, intensity features and textures features.

Morphological features characterize the overall shape and size of the erythrocyte without taking the density into account. It is also reported that the size of the erythrocyte enlarged in *P.vivax and P.ovale* infection. In case of *P.falciparum*, the size of the erythrocyte remains same. Morphological features include shape features such as area, perimeter, compactness ratio, eccentricity, bending energy, minor axis of the bestfit ellipse, major axis of the best fit ellipse, Hu's moment, area granulometry, roundness ratio [5]. The texture feature gives the spatial distribution of the intensity in a particular region. An intensity and texture features includes gray level co occurrence matrix (GLCM), Gray level run length matrix, histogram, local binary pattern, color histogram, entropy, laplacian texture, gradient texture, color channel histogram such as saturation histogram [6] [7][8]. There are several feature set used by researchers in order to classify the infected and non-infected erythrocyte. F. Boray Tek et. al. used a set of feature which consist of colour histogram, colour auto-correlogram, area granuometry, relative shape measurements, Hu moments, scale invariance and number of colours to diagnose the malaria parasite infection in erythrocyte [7]. Automated image processing method for the diagnosis and classification of malaria infected erythrocyte using relative size and eccentricity features on thin blood smears had been proposed [8]. G.Diaz et. al. proposed a semi-automatic method for quantification and classification of malaria infected erythrocytes. Here, erythrocyte feature is described by a set of histogram features such as color histogram, saturation level histogram, gray scale histogram, tamura texture histogram, and sobel histogram [9]. Springl et. al. proposed an automatic malaria diagnosis through microscopic imaging. In this paper, the features such as Hu set of invariant moment, relative shape measurement, intensity histogram, gradient features, laplacian features, flat texture, co-occurrence matrix, run-length matrix are used to classify the erythrocytes [10]. Digital analysis of changes by *Plasmodium vivax* had been analysed using perimeter, area and form factor [11]. M.I.Khan et.at.[12] proposed a content based image retrieval approaches for detection of malarial parasite in blood images using intensity histogram and Hu moment as feature.

The color as well as statistical features which include area, perimeter, compactness ratio, metric, saturation histogram, gray scale histogram are used for automatic malaria detection [13]. Kumarasamy et. al. extract a set of feature such as Nuclear density, Nucleo-cytoplasmic ratio, Euler numberare used for automatic identification of malaria parasite stages [14]. The percentage of chromatin dot stained pixels, ring part stained pixels and the standard deviation of the value channel of the HSV representation of each ROI are used as features to classify the malaria infected erythrocytes [15]. A web accessible framework for automated storage with compression and textural classification of malaria parasite images using textural features such as fractal dimension, gray level co-occurrence matrix, run length matrix, local binary pattern [16]. Features such as colour histogram, Hu moment, relative shape measurement, colour auto-correlogram based Mobile Support for Diagnosis of Communicable Diseases in Remote Locations has also been proposed [17]. N. Ahirwar et. al.[18] proposed an image analysis based system for automatic detection and classification of malarial parasite in blood images using gray level texture, geometric features and colour attributes. Multiscale laplacian of Gaussian filter and gabor filter based malaria parasite detection has also been proposed [19]. M.Gosh et. al proposed a textural approach quantitative characterisation of Plasmodium vivax in infected erythrocytes [20]. Automatic screening of malaria parasite based on machine learning with a total 96 features which include entropy, haralick texture, fractal dimension, local binary pattern, histogram based features, gray level run length matrix, gray level co occurrence matrix, shape features, Hu's moment [21]. Malaria Parasite Detection in Giemsa–Stained Blood Cell Images based on features i.e. gradient, flat texture, colour histogram, area granulometry had been studied [22]. Malaria diagnostic system using morphological features has also been proposed [23]. A. N. Nithyaa et.al.[24] proposed a powerful diagnostic tool for automatic classification of various blood diseases using digital image processing technique. Here, histogram based features of various colour channels such as hue, saturation and intensity are used to identify the normal and infected erythrocytes. Fractal dimension and colour channel histogram are used for automatic malaria parasite identification [25]. Malaria disease identification and analysis using image processing based on histogram features had been proposed [26]. Memeu et. al. used the morphological feature as well as textural features for rapid malaria diagnosis. It includes the features such as form factor, roundness, aspect ratio, solidity, extent, compactness, convexity and statistical moment [27]. The diagnosis of malaria on thin blood smears had been proposed. To detect the presence of malaria parasite and to classify the malaria species, image features based on texture, color and geometry of the erythrocyte have been extracted. Features include phase of the image, skewness, kurtosis, standard deviation, energy [28]. N.Linder et. al. [29] proposed a malaria diagnostic tool based on computer vision screening and visualization of plasmodium falciparum candidate areas in digitized blood smears. The method achieved a diagnostic system using a feature set of local binary pattern-rotation invariant local contrast, scale invariant feature transform. Automatic characterization and classification of malaria-infected stages using light microscopic images of thin blood smears had been proposed with total 80 textures features and 16 morphological features [30]. The microscopic features of malaria classification are listed in table 2.

TABLE II. Microscopic Features of Malaria Classification

Authors	Features		Performance statistics (%)
	Morphological	Texture and Intensity	
C.Di. Ruberto (2001)	Granulometry, Regional Extrema		----
F. Boray Tek (2006)	Hu's moment, Relative shape measurements	Colour histogram	Sensitivity-74 Specificity-98 Positive prediction value-95 Negative prediction value-95
F. Boray Tek (2010)	Area granuometry, Relative shape measurements, Hu moments, Scale invariance	Colour auto-correlogram, Colour histogram	Sensitivity-72.4 Specificity-97.6
N. E. Ross (2006)	Relative size, Eccentricity		Sensitivity- 85 Positive prediction value-81
G. Diaz (2009)		Color histogram, Saturation level histogram, Gray scale histogram, Tamura texture histogram, Sobel histogram	Sensitivity-94 Specificity-98.7
V. Springl (2009)	Hu invariant moment, Relative shape measurement	Intensity histogram, Gradient features, Laplacian features, Flat texture, Co-occurrence matrix, Run-length matrix	----
M. Edison (2011)	Perimeter, Area, Form factor		----
M. I. Khan (2011)	Hu moments	Intensity histogram	Sensitivity-85.5 Positive prediction value-81
S. S. Savkare (2011)	Area, Perimeter, Compactness ratio, Metric	Saturation histogram, Gray scale histogram	Sensitivity-93.12 Specificity-93.17
S. K. Kumarasamy (2011)	Nuclear density, Nucleo-cytoplasmic ratio, Euler number		Accuracy Eythrocyte-97 Infected erythrocyte-85.3 Parasitaemia-85.3
K.Prasad (2012)	Percentage, Standard Deviation		
M.Maity (2012)		Fractal dimension, Gray level co-occurrence matrix, Run length matrix, Local binary pattern	Sensitivity-99 Specificity-99.8 Precision-99.1
M.Cesario (2012)	Hu moments, Relative shape measurement	Colour auto-correlogram, Colour histogram	----
N.Ahirwar (2012)	Geometric (shape, size)	Gray level texture, Colour histogram	----
S.Suryawanshi (2013)		Multiscale Laplacian of Gaussian, Gabor	----
M. Ghosh (2013)		Fractal dimension, Gray level co-occurrence matrix	Accuracy-98
D. K. Das (2013)	Shape features, Hu moment	Entropy, Haralick texture, Fractal dimension, Local binary pattern, Histogram based features, Gray level run length matrix, Gray level co occurrence matrix	Accuracy-84
L.Malihi(2013)	Area granuometry, Hu moment	Gradient, Flat texture, Colour histogram,	Accuracy-91

Authors	Features		Performance statistics (%)
	Morphological	Texture and Intensity	
V.P.Vink (2013)		Histogram based features (mean, Variance, kurtosis, skewness, energy, entropy)	Sensitivity-75 Specificity-99.99
A. N. Nithyaa (2013)		Hue histogram, Saturation histogram, Intensity histogram (mean, Variance, kurtosis, skewness, energy, entropy)	-----
M.Chayadevi (2014)		Fractal dimension, Colour channel intensity	Accuracy-94.45, Specificity-94.68, Sensitivity-94.32, Precision-96.41
S.N.Chavan (2014)		Histogram based features (mean, Variance, kurtosis, skewness, energy, entropy)	Accuracy-98.25
D.M. Memeu (2014)	Form factor, Roundness, Aspect ratio, Solidity, Extent, Compactness, Convexity and Statistical moment		Accuracy-79
S. Annaldas (2014)		Histogram based features (phase of the image, skewness, kurtosis, standard deviation, energy)	Accuracy-98.25
N. Linder (2014)		Local binary pattern-rotation invariant local contrast, Scale invariant feature transform	Sensitivity-92.5 Specificity-100
D. K Das (2015)	Shape features, Hu moment	Entropy, Haralick texture, Fractal dimension, Local binary pattern, Histogram based features, Gray level run length matrix,	Accuracy-96.84

IV. Conclusion

This paper gives an outline of different feature sets used for malaria infected erythrocyte classification. Different set of features can be developed to effectively classify the infected and non-infected erythrocytes. The main goal of the erythrocyte feature extraction is to effectively diagnose the presence of the malaria parasite host inside the erythrocyte. In malaria parasite infection, the structural features of the erythrocyte changes for every parasite life-cycle stages. From the analysis of the different set of features, it may be concluded that there is no individual features which can be considered good for the classification of infected, non-infected erythrocyte and malaria infection stages classification. Further analysis can be done to improve the classification accuracy of the system by introducing strong and efficient features.

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Temporal Information Processing and Stability Analysis of the MHSN Neuron Model in DDF

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***Abstract* — Implementation of a neuron like information processing structure at hardware level is a burning research problem. In this article, we analyze the modified hybrid spiking neuron model (the MHSN model) in distributed delay framework (DDF) for hardware level implementation point of view. We investigate its temporal information processing capability in term of inter-spike-interval (ISI) distribution. We also perform the stability analysis of the MHSN model, in which, we compute nullclines, steady state solution, eigenvalues corresponding the MHSN model. During phase plane analysis, we notice that the MHSN model generates limit cycle oscillations which is an important phenomenon in many biological processes. Qualitative behavior of these limit cycle does not changes due to the variation in applied input stimulus, however, delay effect the spiking activity and duration of cycle get altered.**

***Keywords* — Distributed Delay, Dynamical System, Eigen Value, Hybrid Spiking Neuron, ISI Distribution, Neuromorphic Engineering, Phase Plane Analysis.**

I. Introduction

The human brain is the most complex dynamical system with 11th order of neuron and 15th order of total synaptic connections among themselves [1, 2, 3, 4]. Researchers are involve in understanding the biophysical dynamics and information processing functionality of the brain since last six decades, so that an artificial brain like structure can be implemented at software as well as at hardware level [5, 6, 7, 8, 9, 10, 11, 12]. Hardware level implementation of the artificial brain lies in the domain of Neuromorphic engineering in which one implements few functionality of a real neuron on a chip [9, 13]. Integrate-and-fire (IF), leaky integrate-and-fire (LIF) and hybrid spiking neuron models are suitable choice for chip level implementation due to their simple mathematical treatment [3, 9, 13, 14]. These neuron models are threshold based models [8, 15, 16]. For hardware level implementation of a threshold based neuron model, one has to focus on two prime issues, namely, (i) How to implement the reset condition of membrane potential after spiking activity? (ii) How to maintain the threshold value and control the variability of threshold value due to the rise in temperature of the chip [3, 5, 9, 17]. Izhikevich two dimensional hybrid spiking neuron model has the mechanism to overcome the first issue at its hardware level implementation [3]. But it is still a challenging problem to fix the variability in threshold value at implementation level, which generates a large variation in spiking pattern.

A varying time delay occurs in neuronal information processing system due to the varying length of axons, structure of neurons and flow of neurotransmitters form one region to another region into the nervous system [10, 18, 19]. Distributed delay framework suggested by Mar at. al. [6] has the virtue to incorporate the varying time delay in a neuron model in terms of distributed delay kernel functions. Karmeshu *et. al*. [20, 21] has investigated the LIF model with stochastic input stimulus in DDF and has explained many interesting neurological phenomenon such as transient bimodality in spiking activity of a neuron.

Bhati *et. al.* [22] has calculated the analytical explicit expressions for membrane potential and recovery variable in hybrid spiking neuron model with constant input stimulus in DDF with minor modification. Choudhary *et. al*. [23] has investigated the spiking activity of the *modified hybrid spiking neuron model in DDF* (MHSN model) with four different kinds of input stimulus in DDF and noticed very small variability in its spiking pattern against large variation in input stimulus.

In this article, we perform the stability analysis and temporal information processing capability of hybrid spiking neuron model in DDF. The article is organized into five sections. Section II describes the MHSN model in detail. Section III investigates the temporal information processing of the MHSN model. Section IV is devoted in stability analysis of the MHSN model. In this section, we also perform the phase analysis of the model. Last section V contains the conclusion and scope for the future research work.

I. The Modified Hybrid Spiking Neuron Model in DDF

Izhikevich [3] has suggested a family of threshold based neuron models governed by two state variables, namely membrane potential (V) and recovery variable (U), in term of a system of coupled differential equations.

$$\frac{dV}{dt} = f(V) - U(E - V) + I \tag{1}$$

$$\frac{dU}{dt} = a(bV - U) \tag{2}$$

with after spiking reset condition (threshold constraint): if $V \geq V_T$ then $V \leftarrow V_R$ and $U \leftarrow U + U_I$.

Here, $f(V)$ is membrane potential-current relationship function. I, E, V_T and V_R are input stimulus, reversal potential, membrane potential threshold and resting potential, respectively. a and b are model parameters.

Following Bharti *et. al.* [22], the MHSN model takes the form

$$\frac{dV}{dt} = \int_0^t K(t-\tau)V(\tau)d\tau - U + I \tag{3}$$

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$$\frac{dU}{dt} = a(bV - U) \tag{4}$$

Here, $K(t)$ is the distributed delay kernel function. There may be a number of choices of $K(t)$, but Bharti *et. al.* [22] has studied the MHSN with exponential distributed delay kernel function, which is also known as weak delay. In presence of exponential distributed delay kernel function MHSN model becomes

$$\frac{dV}{dt} = \int_0^t \eta e^{-\eta(t-\tau)} V(\tau) d\tau - U + I \tag{5}$$

$$\frac{dU}{dt} = a(bV - U) \tag{6}$$

with initial condition: $V = V_0$ and $U = U_0$ at $t = 0$. Here η is the delay parameter. Eqns. (5) and (6) make a system of coupled integro-differential equations. Its investigation is a complex task due to the presence of integro-differential term. By applying Laplace transform and inverse Laplace transform, Bharti *et. al*. [22] has calculated the explicit expression for V and U with constant I which given as below.

Case: [1] when $a \geq 4b$, the membrane potential and recovery variable takes the form

$$V(t) = A_1 + B_1 e^{\alpha_1 t} + C_1 e^{\beta_1 t} \tag{7}$$

where

$$A_1 = \frac{aI}{\alpha_1 \beta_1}, \quad B_1 = \frac{\alpha_1(\alpha_1 V_0 + aV_0 - U_0 + \eta + I) + aI}{\alpha_1(\alpha_1 - \beta_1)},$$

$$C_1 = -\frac{\beta_1(\beta_1 V_0 + aV_0 - U_0 + \eta + I) + aI}{\beta_1(\alpha_1 - \beta_1)}$$

and

$$U(t) = A_2 + B_2 e^{-\eta t} + C_2 e^{\alpha_2 t} + D_2 e^{\beta_2 t} \tag{8}$$

where

$$A_2 = \frac{ab(V_0 + I)}{\alpha_2 \beta_2}, \quad B_2 = \frac{abI}{(\alpha_2 + \eta)(\beta_2 + \eta)},$$

$$C_2 = \frac{\alpha_2^2 U_0 + [ab(\eta + V_0 + I) + U_0\eta]\alpha_2 + ab\eta(V_0 + I)}{\alpha_2(\alpha_2 + \eta)(\alpha_2 - \beta_2)}$$

$$D_3 = -\frac{\beta_3^2 U_0 + [ab(\eta + V_0 + I) + \eta U_0]\alpha_3 + ab\eta(V_0 + I)}{\beta_3(\beta_3 + \eta)(\alpha_3 - \beta_3)}$$

Case: [2] when $a < 4b$, the membrane potential and recovery variable takes the form

$$V(t) = A_3 + e^{\alpha_3 t}[B_3 \cos\beta_3 t + (\alpha_3 B_3 + C_3)\sin\beta_3 t] \tag{9}$$

where

$$A_3 = \frac{aI}{\alpha_3^2 + \beta_3^2}, \quad B_3 = \frac{(\alpha_3^2 + \beta_3^2)V_0 + aI}{\alpha_3^2 + \beta_3^2},$$

$$C_3 = \frac{(\alpha_3^2 + \beta_3^2)(aV_0 - U_0 + \eta + I) + 2a\alpha_3 I}{\alpha_3^2 + \beta_3^2}$$

and

$$U(t) = A_4 + B_4 e^{-\eta t} + e^{\alpha_4 t}[C_4 \cos\beta_4 t + (\alpha_4 C_4 + D_4)\sin\beta_4 t] \tag{10}$$

where

$$A_4 = -\frac{(\eta + 2\alpha_4)[ab(\eta + V_0 + I) + \eta U_0] + U_0(\alpha_4^2 + \beta_4^2)}{\alpha_4(\alpha_4^2 + \beta_4^2)[\alpha_4^2(2 - \eta - 2\alpha_3) + 2(\beta_4^2 + \eta^2 + 2\eta\alpha_4)]},$$

$$B_4 = \frac{ab(\eta + V_0 + I) + \eta U_0}{(\alpha_4^2 + \beta_4^2)} + \frac{(\alpha_4^2 - 2\eta)[(\eta + 2\alpha_4)\{ab(\eta + V_0 + I) + \eta U_0\} + U_0(\alpha_4^2 + \beta_4^2)]}{(\alpha_4^2 + \beta_4^2)[\alpha_4^2(2 - \eta - 2\alpha_4) + 2(\beta_4^2 + \eta^2 + 2\eta\alpha_4)]},$$

$$C_4 = -\frac{ab(\eta + V_0 + I) + \eta U_0}{(\alpha_4^2 + \beta_4^2)} + \frac{(2\alpha_4 + \beta_4^2)}{\alpha_4(\alpha_4^2 + \beta_4^2)^2} \frac{[(\eta + 2\alpha_4)\{ab(\eta + V_0 + I) + \eta U_0\} + U_0(\alpha_4^2 + \beta_4^2)]}{[\alpha_4^2(2 - \eta - 2\alpha_3) + 2(\beta_4^2 + \eta^2 + 2\eta\alpha_4)]},$$

$$D_4 = ab(V_0 + I) + \frac{\beta_4^2[(\eta + 2\alpha_4)}{\alpha_4(\alpha_4^2 + \beta_4^2)} \frac{\{ab(\eta + V_0 + I) + \eta U_0\} + U_0(\alpha_4^2 + \beta_4^2)]}{[\alpha_4^2(2 - \eta - 2\alpha_3) + 2(\beta_4^2 + \eta^2 + 2\eta\alpha_4)]}$$

It is a too complex to further investigate the MHSN model with integro-differential equation term. In presence of intego-differential term, the membrane potential evolution process $V(t)$ becomes a non-Markovian process. In order to transform $V(t)$ into a Markovian process, the MHSN model can be extended in infinite dimensional space [20, 24]. Following Choudhary *et. al.* [23], substitution of $\int_0^t \eta e^{-\eta(t-\tau)} V(\tau) d\tau$ by $X_0(t)$ in the MHSN model and after some simplification, the three dimensional MHSN model with exponential distributed delay kernel function in extended space takes the form:

$$\frac{dV}{dt} = X_0 - U + I \tag{11}$$

$$\frac{dU}{dt} = a(bV - U) \tag{12}$$

$$\frac{dX_0}{dt} = \eta(V - X_0) \tag{13}$$

Eqns. (11), (12) and (13) make a system of coupled linear differential equation. Its analytical as well as simulation based investigation is an easier task. We consider the above stated three dimensional MHSN model in our investigation. We perform the simulation based study to investigate the temporal information processing capability of the MHSN model in the next section.

II. Temporal Information Processing

Spiking activity is an essential feature in neuronal information processing [14, 25]. A neuron encodes processes and transmits information in the term of epoch of membrane potential (spike) [4, 14, 25, 26]. Rate coding and temporal coding are two important encoding strategies in neuronal information processing [11, 14, 16, 25]. Time interval between two consecutive spikes, which is also known as inter-spike-interval (ISI), is the important parameter for temporal coding scheme [1, 14, 25]. Here, ISI distribution becomes a prominent statistical measure to quantify the encoded temporal information. Mathematically, the investigation of ISI distribution becomes the first-passage-time (FPT) problem, *i.e.* the study of time interval distribution of first occurrence of the membrane potential epoch [11, 20, 21, 26]. The analytical study of the FPT problem associated with the neuron model is a difficult task. Explicit expression of solution for the FPT problem is available only for the IF model and in some special cases for the LIF model [20, 21]. To this end, simulation based investigation technique becomes an important tool for obtaining the approximate ISI distribution and for investigating other related neuronal dynamical features.

We investigate the ISI distribution for the MHSN model with four different kinds of input stimuli, namely, constant input, Gaussian distributed input, uniformly distributed input and stochastic input stimuli. We apply the Monte-Carlo simulation technique to yield the approximate solution of the ISI distribution. There are many simulation techniques suggested in literature, we use the following Euler-Maruyama simulation strategy to simulate the three dimensional MHSN model [27, 28].

The total simulation time T Time is divided into n equal subintervals $t_0 = 0 < t_1 < t_2 < .... < t_n = T$ with size $h = T/n$. In each subinterval, a discrete value of the membrane potential is calculated at the upper time limit. Let V_0, U_0 and X_0 be the initial values of the variables V, U and X then in subinterval $[t_{i-1}, t_i]$ these variables attains the following value.

$$\begin{aligned} V(i) &= V(i-1) + (X_0(i-1) - U(i-1))h + I(t_i) \\ U(i) &= U(i-1) + a(bV(i-1) - U(i-1))h \\ X_0(i) &= X_0(i-1) + \eta(V(i-1) - X_0(i-1))h \end{aligned} \quad (14)$$

for $i = 1, 2, ..., n$. Here $I(t_i)$ is the value of applied input stimulus i^{th} discrete time point. Following Izhikevich [3], we use $a = 0.02$, $b = 0.2$, $V_0 = -65$, $U_0 = bV_0 = -13$, $X_0 = 0$, $U_I = 8$ and $V_T = 30$ in our investigation. Fig. 1 illustrates the ISI distribution for the MHSN model with delay parameter $\eta = -0.1$. Here, subfigure (a) depicts the ISI distribution for constant input stimulus of intensity 0.1. Subfigures (b) and (c) are the ISI distribution obtained for standard Gaussian distributed input stimulus and uniformly distributed input stimulus in range [0,1], respectively. Qualitative behavior of these three ISI distributions is identical. As shown in Fig. 1, they are triangular distributed.

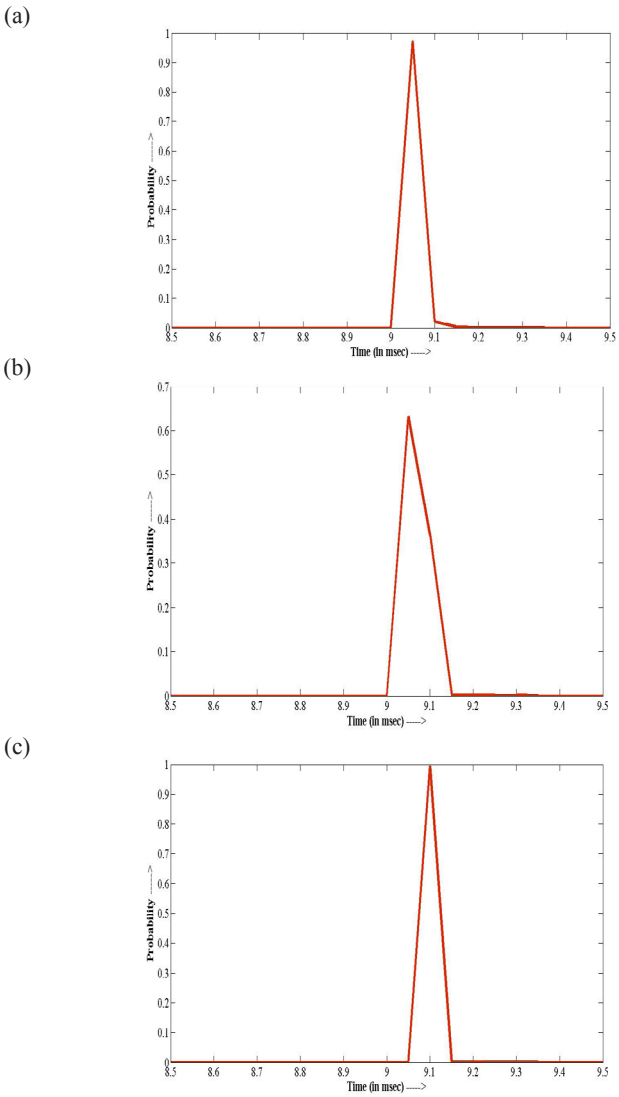
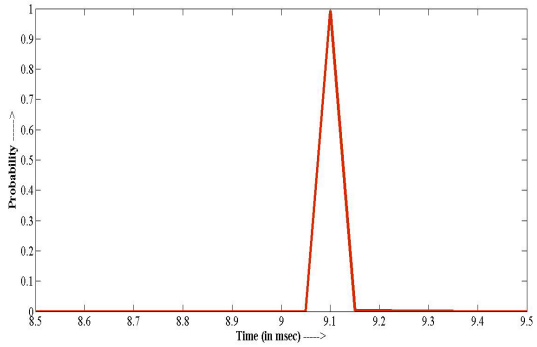


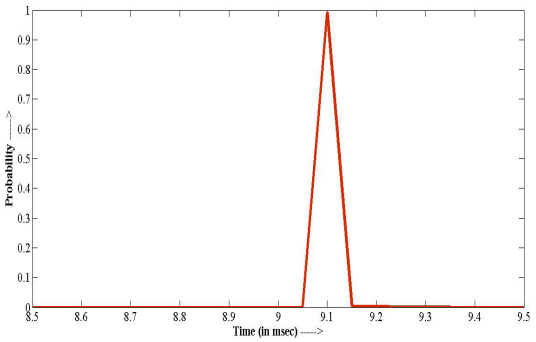
Fig. 1. ISI Distribution for the MHSN Model with (a) Constant Input. (b) Gaussian Distributed Input (c) Uniformly Distributed Input

The ISI distribution for the considered model with stochastic input stimulus having mean μ and noise intensity σ is shown in Fig. 2. It has three subfigures corresponding to three different combination of parameter values η, μ and σ. Subfigure (a) depicts the ISI distribution for (η, μ, σ) = (−0.1,1,0.1). It has the qualitatively behavior similar to the Fig. 1. In subfigure (b) and (c), we use (η, μ, σ) = (−1,1,0.1) and (η, μ, σ) = (−1,0.5,0.5) parameter values, respectively, and notice the similar qualitative behavior but quantitatively changed behavior in ISI distribution patterns. As shown in subfigure (b) and (c), we notice the shift in ISI distribution towards its origin which indicates that the spiking activity of the MHSN model increases due the increase in negative value of delay parameter. This increase in delay parameter works as a memory element so that the membrane potential of the neuron reaches to its firing threshold in comparatively less time.

(a)



(b)



(c)

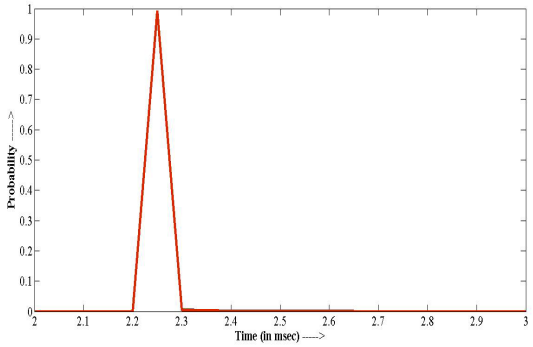


Fig. 2. ISI Distribution for the MHSN Model with stochastic input and (a) $\eta = -0.1$ (b) $\eta = -1$ (c) $\eta = -1$

In order to perform stability in next section, we compute the eigenvalues and steady state solution of the three dimensional MHSN model. Here, we also complete the phase plane analysis of the MHSN model.

III. Stability Analysis

Investigation for the evolution of the behavior of state variables is studied under sensitivity analysis [13, 19, 24]. The MHSN model in extended space is a system of three coupled differential equations. It includes two important tasks. In first task, we compute the nullclines and steady state solution for the dynamical system where as second task deals with the phase plane analysis [13, 24]. In phase plane analysis, one analyzes the evolution of temporal behavior of state variables in phase space. In our study, we compute the nullclines, steady state solution, eigenvalues for the dynamical system and perform the phase plane analysis.

The MHSN model given as in Eqns. (11), (12) and (13), is a system of three coupled linear differential equations. Their matrix representation become [13]

$$\dot{Y} = AY + B \tag{15}$$

where $Y = (V, U, X_0)^T$, $A = \begin{pmatrix} 0 & -1 & 1 \\ ab & -1 & 0 \\ \eta & 0 & -\eta \end{pmatrix}$ and $B = (I, 0, 0)^T$.

Nullclines and Steady State Solution:

Nullclines are the trajectories in phase space along which the behavior of the state variable changes [13, 24]. Intersection point of these trajectories yields the steady state solution [13]. Nullclines for the dynamical system can be computed by substituting the first derivative term equal to 0 [24]. Substitution of $\dot{Y} = 0$ in the dynamical system defined in Eq. (15) results the required nullclines as $X_0 - U + I = 0$, $bV - U = 0$ and $X_0 - V = 0$. Nullclines for the investigated dynamical model result a system of three linear simultaneous equations. On solving these simultaneous equations, we get steady state solution $(V^S, U^S, X_0{}^S) = \left(\frac{I}{b-I}, \frac{bI}{b-I}, \frac{I}{b-I}\right)$, provided $b \neq I$. Here, we obtain a single steady state which can be a state or an unstable state which is investigated in next subsection phase plane analysis. Here, we further notice that the model parameter a and delay parameter η don't affect the steady state solution of the model.

Computation for the Eigenvalues:

Let λ be an eigenvalue of the dynamical model (15), and then it can be computed by solving the equation $|A - \lambda I| = 0$ [9, 22]. Its simplification results a cubic polynomial

$$\lambda^3 + (1+\eta)\lambda^2 + ab\lambda + (ab+1)\eta = 0 \tag{16}$$

Following the Cardano's method for solving a cubic polynomial, substitution of $\lambda = Z + \left(-\frac{1+\eta}{3}\right)$ into Eq. (16) and after some simplification results [29]

$$Z^3 + K_1 Z + K_2 = 0 \tag{17}$$

where $K_1 = ab - \frac{(1+\eta)^2}{3}$ and $K_2 = \frac{2(1+\eta)^3 - 3(1+\eta)ab + 9(ab+1)}{9}$.

Following Lal [29], here two cases exist.

Case 1: If $K_1 = 0$ i.e. $\eta = -1 \pm \sqrt{3ab}$

Then eigenvalues for the investigated dynamical system become α, $\alpha\omega$ and $\alpha\omega^2$, where $\alpha = (K_2)^{1/3}$ and ω is the cube root of unity.

Case 2: Otherwise, $(K_1 \neq 0)$

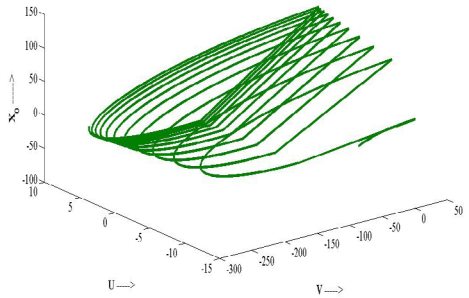
Then eigenvalues takes the form as $(P_1 + P_2)$, $(P_1\omega + P_2\omega^2)$ and $(P_1\omega^2 + P_2\omega)$, where $P_1 = -\frac{K_2}{2} + \sqrt{\frac{-4K_1^3 - 27K_2^2}{108}}$ and $P_2 = -\frac{K_2}{2} - \sqrt{\frac{-4K_1^3 - 27K_2^2}{108}}$.

Phase Plane Analysis:

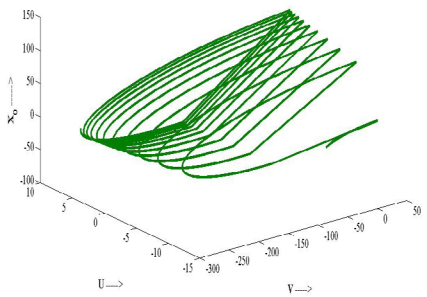
Phase space is a multidimensional space whose coordinates are the system variables [2, 13, 24]. It clearly depicts the dynamical behavior of the state variables [2, 13]. Dynamical system given in Eq. (15) has three state variables V, U and X_0, thus we obtain a three dimensional phase space. We simulate this dynamical system same parameter values and simulation strategy as given in Section III.

In Fig. (3), subfigure (a), (b) and (c) show the temporal evolution of state variable with constant input, Gaussian distributed input and uniformly distributed input stimuli, respectively. Here, we observe the limit cycle oscillations generating a spiral structure due to the threshold constraint. This limit cycle oscillation is an important aspect in many biological processes [2].

(a)



(b)



(c)

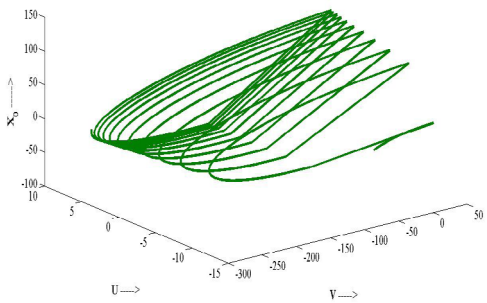
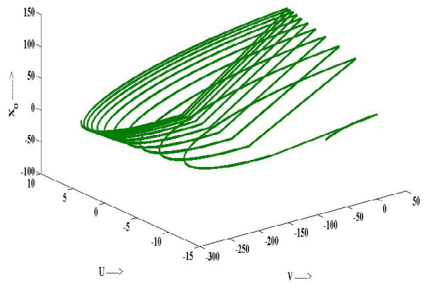


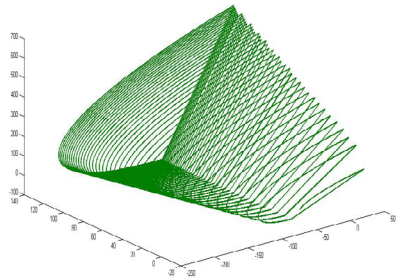
Fig. 3. Phase Plane Analysis for the MHSN Model with
(a) Constant Input (b) Gaussian Distributed Input
(c) Uniformly Distributed Input

Fig. 4 shows the mutual behavior of state variables in the MHSN model with stochastic input stimulus. Here subfigure (a) reflects the evolution of state variables with small magnitude of delay parameter $\eta = -0.1$ and it qualitatively similar with the trajectories obtained in Fig. 3. We increase the magnitude of η to -1 and maintain the rest parameter values same as taken for Fig. (2). Here, once again, we obtain limit cycle oscillation but time duration of the cycle reduces. This finding suggests that the development of values in state variables occur in quicker time so that the spiking activity of the neuron increases. From Figs. 3 and 4, it is evident that the phase plane dynamics of the model does not alter due to the different kinds of input stimulus; however parameter η reduces the time duration of cycle.

(a)



(b)



(c)

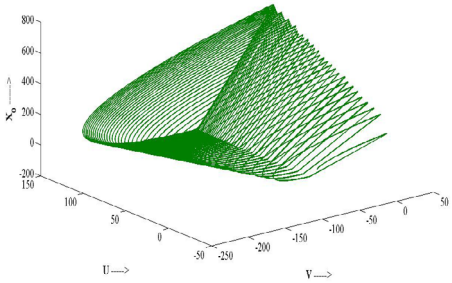


Fig. 4. Phase Plane Analysis for the MHSN Model with stochastic input.
(a) $\eta = -0.1$ (b) $\eta = -1$ (c) $\eta = -1$

IV. Conclusion and Future Work

The detailed investigation of the MHSN model in term of information processing capability reveals that the spiking activity of the considered neuron model is invariant under the influence of a large fluctuation of applied input stimulus. The state variable X_0 of the model in extended space along with the delay parameter η curtails the variation in spiking activity. However, increase in the negative value of η increases the spiking of the neuron. This delay parameter works as a memory element and helps the membrane potential to reach its firing value in quicker time so that the ISI reduces and the ISI distribution gets scaled with minus values as depicted in Fig. 2. We notice a single unstable steady state solution of the model during stability analysis

which is independent of delay parameter. Choudhary *et. al.* [30] has shown that "*the distributed delay has no effect on stationary state membrane potential distribution of a LIF neuron*". In addition, we say that *the distributed delay has no effect on steady state solution of the threshold based linear neuron models*.

Being the extension of Izhikevich neuron model [3], the MHSN model has the inherited property related to the implementation of after spiking reset condition at hardware level. Invariant spiking activity of the MHSN model reveals that the model is capable to handle the threshold variability and other noisy parameters like temperature increment in the chip. Lim et. al. [9] has implemented the neuristor-based leaky integrate-and-fire neuron model with aforementioned two critical issues to form an artificial neural network at hardware level. As the MHSN model is free from above stated prime issues, we recommend that *the MHSN model should be a better choice for chip level implementation*.

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Euclidean Distance Distortion Based Robust and Blind Mesh Watermarking

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***Abstract* — The three-dimensional (3D) polygonal meshes are recently widely used in several domains, which necessitate the realistic visualization of the objects. Moreover, there is an urgent need to protect the 3D data properties for preventing unauthorized reproduction. The 3D digital watermarking technology is one of the best solutions to protect data from piracy during transmission through the internet. The current work proposed a novel robust watermarking scheme of polygonal meshes for copyright protection purposes. The proposed algorithm is based on the characteristics of the mesh geometry to embed a sequence of data bits into the object by slightly adjusting the vertex positions. Furthermore, the proposed method used a blind detection scheme. The watermarked model is perceptually indistinguishable from the original one and the embedded watermark is invariant to affine transformation. Through simulations, the quality of the watermarked object as well as the inserted watermark robustness against various types of attacks were tested and evaluated to prove the validity and the efficiency of our algorithm.**

***Keywords* — Mesh Watermarking, Robust, Blind, Turbo Code, Euclidean Distance, Copyright Protection.**

I. Introduction

Recently, due to the rapid growth of computer graphics and computer vision, 3D models are widely used in several applications [1], [2]. In the 3D computer graphics, 3D modeling aims to create realistic visual content of objects in suitable structure for rendering and display.

Numerous other scientific domains rely on the analysis of such geometric data. In the mechanical field, virtual 3D models simulate critical performance engineering attributes for mechanical systems. In culture heritage, these models assist the preservation of archaeological sites and virtual museums achievement. In architecture, these models have the potential to truly advance the project impact. A similar abundance of 3D models can be observed in other disciplines, including scientific and medical applications [3], [4], entertainment industry (movies, cartoons and video games) and in electronic commerce to build Customer Relationships.

In this imminent scenario, it is obligatory to develop techniques to protect the original 3D data ownership and to prevent their unauthorized copying. Typically, the digital watermarking is probably one of the best solutions for data protection and authorization. The basic idea of the digital watermarking is to combine information to the media in a persistent way. The watermark is embedded by changing properties or some features of the digital media. Thus, the associated data is indispensably attached to the host media. This combination can be used for many different applications such as copyright protection where the watermark carries data about the owner or the creator of the digital media. The watermarks used for copyright protection are often called robust watermarks that provide an evidence of the owner's identity and control the model illegal reproduction.

Watermarking 3D models [5]-[7] was a relatively new digital watermarking frontier through inserting information into 3D models [8] in an imperceptible way. Compared to the 2D watermarking [9], [10], the 3D technique is more complex due to the increased complications associated with 3D objects in arbitrary shapes. The design of these algorithms is considered difficult mainly due to the existence of many insoluble geometrical and topological attacks. The geometric attacks alter only the vertices positions; however, the connectivity attacks can completely change the geometry and the connectivity information of the watermarked mesh. Other common operations used in various applications are similarity transformations which include translation, rotation and uniform scaling. When performing these basic operations on watermarked object, the inserted watermark must be completely preserved.

In this paper, a new robust and blind watermarking algorithm based on the alteration of the vertices positions in order to embed the watermark bits aiming to protect the intellectual property of the 3D objects was presented. The proposed approach is robust to affine transformations. It was applied to the triangular polygonal meshes and it modified only the geometrical data. The rest of the paper is organized as follows. The related works are described in Sect. 2. In Sect. 3, the new watermarking approach is presented. The experimental results are presented in Sect. 4. Finally, Sect. 5 concludes the work.

II. Related Works

Generally, the mesh watermarking techniques inserts the watermark by modifying the geometry of the polygonal models [11], [12]. Some of these algorithms are spatial approaches and the embedding process modifies the vertices positions and geometrical invariants. The earliest 3D watermarking algorithms were proposed by Ohbuchi et al.[13]. A variety of techniques in the spatial domain such as Triangle Similarity Quadruple method (TSQ) were suggested. This method was blind and modified the triangular mesh geometry; however it was not robust to connectivity attacks. Benedens [14] proposed two robust watermark algorithms with high insertion capacity. The author carried out a flood vertex algorithm to modify the model geometry. It does not require the object topology during the watermarking scheme. This algorithm was based on the modification of the vertex position by changing the distance between the vertex to be watermarked and the center of gravity of a reference triangle chosen in order to bring the vertex in the desired range. Moreover, the author proposed another watermarking scheme, namely the flood triangle algorithm. This algorithm employed both the geometrical and topological information to generate a single path of the mesh triangles. The triangles vertices in this path were modified to insert the watermark bits by changing the height of the triangles.

The robust watermarking algorithm of Harte et al. [15] was based

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on modifying the locations of selected vertices according to the watermark bit to be embedded. Two different envelopes based on the separation plane and ellipsoidal were considered for inserting the watermark. The bit '1' is inserted by moving the vertex inside the envelope defined by the neighbors' vertices. However, to encode the bit '0', the vertex was moved outside the envelope. The watermark can be recovered after affine transformations. The algorithm proposed by Zafeiriou et al.[16] embedded the watermark bit in multiple vertices. The mesh was normalized, thus the model was translated and rotated so that its mass center coincides with the origin of the coordinate system. The principal component was aligned with the z axis. Afterward, the vertices coordinates were transformed from the Cartesian to spherical coordinates. The embedding process was achieved by altering the norm values of the selected vertices. The proposed algorithm was robust to affine transformations, noise addition and simplification, but fragile to cropping. Cho et al. [17] proposed two blind and robust watermarking methods which alter the distribution of vertex norms. The first method changed the mean value of the distribution and the second modified its variance. The proposed approaches were robust against similarity transformations and vertex reordering. However, they were less robust against various other types of attacks. Wang et al. [18] proposed a robust and blind watermarking algorithm based on volume moments. The scheme used cylindrical domain to decompose the mesh into patches after its normalization. Then, the watermark was inserted in each patch by quantizing the zero order moment. The experimental results illustrated watermark imperceptibility and robustness under various attacks. Zhan et al. [19] proposed a robust and blind watermarking algorithm for polygonal meshes based on vertex curvature. The insertion process first calculated the root mean square curvature for each vertex then separates it into bins according to the ordered fluctuation values. The watermark bits were embedded by modulating the root mean square curvature fluctuation. The algorithm presented good robustness under various attacks.

III. The methodology and proposed Watermarking Framework

The framework is characterized by blind extraction of the inserted watermark. The watermark is represented by a unique sequence of bits representing the copyright signature to be inserted. The proposed algorithm provided an invariant embedded watermark to the affine transformation, including translation, rotation and uniform scaling. In order to evaluate the proposed system, a data set of four 3D triangular mesh models provided by Stanford University as test models: Bunny (34835 vertices and 69666 faces), Dragon (50000 vertices and 100000 faces), Hand (36619 vertices and 72958 faces) and Cow (2904 vertices and 5804 faces) were used.

A. Watermark embedding

The adopted embedding scheme is an imperceptible adjusting of some selected vertices positions. The modification is performed due to the quantization of the Euclidean distance between the mass center of the model and the selected vertices in order to insert the code bits. This approach introduced a bit of the signature in each vertex. Figure 1 demonstrated the robust watermark embedding scheme specifying the following steps.

The proposed algorithm is first identified the vertices that will be watermarked as illustrated in Figure 1. The vertices are selected based on a secret key that will be used in the extraction process to identify the watermarked vertices. The use of a secret key ensures the watermarking security in both the insertion and the extraction processes.

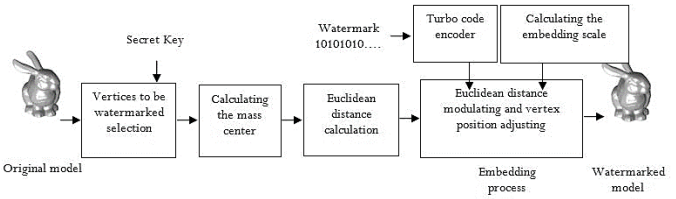

Fig. 1. Watermark embedding.

Since, the turbo encoder results from the association of two or more encoders which are Recursive Systematic Coder (RSC). It provides three outputs, so it can distribute information even if one part of the message is damaged, still information exist elsewhere. Consequently, the watermark to be embedded in the current work is encoded using the turbo code [20], [21] which is an error correcting code. This code adds redundancy to the embedded information used to correct errors caused by disturbances and improve robustness against attacks. It is obvious that using a correcting code is more efficient than a simple duplication of watermark bits.

Decoding is considered to be collaboration between the decoders to exchange the information in an iterative manner to improve the reliability of decision on each decoded bit. Iteration involves the activation of each decoder once. Hence, the more iterations over the turbo decoder leads to converge toward the right solution.

The mesh geometry M(F,V) consists of faces where F specifying their connectivity and a set of vertices $V=\{v_1,\ldots,v_n\}$ with $v_i \in \in R^3$, n is the number of vertices. The mass center K of the model is calculated using following expression:

$$K = \frac{1}{n}\sum_{i=1}^{n} v_i \tag{1}$$

The Euclidean distance d from a selected vertex to the mass center is defined by (2).

$$d_i = \sqrt{(v_{ix} - k_x)^2 + (v_{iy} - k_y)^2 + (v_{iz} - k_z)^2} \tag{2}$$

Where $\{v_{ix}, v_{iy}, v_{iz}\}$ are the coordinates of the vertex.

After calculating the Euclidean distance from the mass center and selected vertices, this distance is modulated according to the bit value to be embedded. The distance is divided into intervals using the embedding scale e which is provided from the following expression:

$$e = D / m \tag{3}$$

Where, D is the furthest Euclidian distance from the faces center to the mesh center of mass dCf_i obtained by (4), and m is a specified value. The faces center Cf_i of a given triangular face f_i is provided by (5).

$$dCf_i = \sqrt{(Cf_{ix} - k_x)^2 + (Cf_{iy} - k_y)^2 + (Cf_{iz} - k_z)^2} \tag{4}$$

$$Cf_i = \frac{1}{3}\sum_{j=1}^{3} v_{ij} \tag{5}$$

Where, V_{ij} are the vertices of the face f_i.

To embed the watermark bits w(i), the integer N_i is calculated using (6) specifying the intervals number within the distance d_i where

$$N_i = d_i / e \tag{6}$$

As a convention, the intervals are assigned by alternation the bits '0' and '1' beginning with the bit '0'. If w(i) is 0, selected vertex V_i position should be modified so that N_i is an odd value and an even value if w(i) is 1. This change is implemented by decreasing the Euclidean distance between the vertex V_i and the mass center K from d to d'. The position of the selected vertex will be slightly changed according to the modulated distance d'. The coordinates of the marked vertex $V_{i'}$ are adjusted to be in the desired position using the following expression:

$$V_i' = K + (V_i - K) \times \frac{d'}{d} \tag{7}$$

The embedded watermark in the proposed approach is invariant to any affine transformations. In fact, the ratio between the Euclidian distance from the selected vertices to the mesh mass center and the embedding scale e which is proportional to the mesh geometry remains the same after applying translation, rotation or uniform scaling transformations to the model. In order to obtain a small embedding scale e ensuring a minimal distortion in the resulting watermarked model by assigning m a large value.

B. Watermark distorsion

The watermark insertion introduced some amount of distortion to the original meshes. This distortion must be imperceptible to maintain the object value. In fact, the basic requirement for any watermarking system is the quality of the watermarked media. The embedding process should not introduce noticeable changes.

The quality of the 3D mesh geometry was measured by the maximum root mean square error (MRMS) using Metro [22] which provides two RMS distances ($d_{RMS}(M,M')$, $d_{RMS}(M',M)$). The MRMS is the maximum between the two RMS distances calculated by:

$$MRMS = \max\left(d_{RMS}(M,M'), d_{RMS}(M',M)\right) \tag{8}$$

$$d_{RMS}(M,M') = \sqrt{\frac{1}{|M|}\int\int_{V\in M} d(v,M')\,dM} \tag{9}$$

Where M and M' represent the original and the watermarked meshes, respectively.

Attacks are a critical factor in the design of mesh watermarking algorithms to evaluate the robustness performance of the watermark. Typically, most attacks are extrapolated from image attacks and adapted to the polygonal meshes. In addition there are other specific and sophisticated attacks to polygonal mesh such as simplification and subdivision

The robustness is evaluated in terms of the correlation between the extracted watermark bit sequence B and the originally inserted one A as given by the following equation [23]:

$$Corr(A,B) = \frac{\sum_n (A_n - \overline{A})(B_n - \overline{B})}{\sqrt{(\sum_n (A_n - \overline{A})^2)(\sum_n (B_n - \overline{B})^2)}} \tag{10}$$

Where $\overline{A}$ and $\overline{B}$ respectively indicate the average of the watermark bit sequence A and B and n is the watermark size.

In addition, the errors are measured on the extracted watermark by the bit error rate (BER) determined as a ratio of the total lost bits to the total embedded bits.

C. Watermark extraction

The watermark extraction steps are almost the reverse of the watermark insertion algorithm steps. In this blind extraction process, the secret key generated in the insertion process is used to restore the watermark. Figure 2 illustrates the blind watermark extraction scheme.

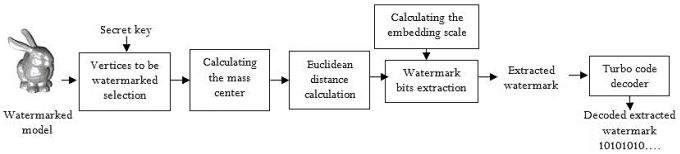

Fig. 2. Watermark extraction.

As demonstrated in Figure 2, the watermarked vertices are selected using a secret key and the mass center is calculated. Afterward, the Euclidean distance from the mass center and the watermarked vertex are computed and divided into intervals using the embedding scale e. The watermark bit is simply reported according to the intervals number. This process continues until all the watermarked information is extracted. The final step is the recovery of the initial watermark using the turbo code decoder.

IV. Experimental Results

A set of experiments was conducted without attacks on the used dataset using the proposed watermarking scheme to evaluate its effectiveness. In addition, another set of experiments was conducted under various types of attacks. The inserted watermark imperceptibility is evaluated using the watermarked model without attacks. After that, a set of attacks reported in [24] is applied on the watermarked object to evaluate the robustness and the resistance of the embedded watermark. The 3D attacked object quality is also evaluated.

A. Proposed system evaluation without attacks

The watermark imperceptibility is a crucial requirement for a robust 3D watermarking used to protect copyright. In addition, it is important that the watermarked object keep the same visual appearance as the original one to serve for its typical expected use. The size of the watermark in these tests is 64 bits inserted by redundancy using a turbo code to ensure better robustness. Figure 3 demonstrates the 3D tested objects along with the corresponding watermarked meshes.

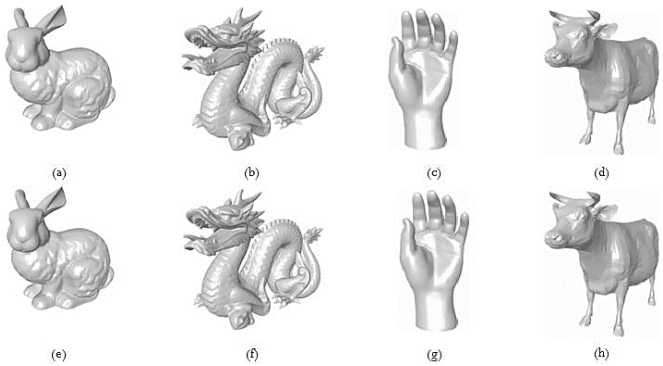

Fig. 3. 3D tested objects (a) Bunny, (b) Dragon, (c) Hand and (d) Cow. The corresponding watermarked meshes are provided from (e) to (h)

Figure 3 depicts that compared to the original objects; the watermarked corresponding objects prove the invisibility of the applied changes. Visually, the watermark is completely invisible and does not affect the shape and the appearance of the watermarked objects.

Table 1 provides the quality evaluation results using the MRMS based on the expression in equation (8).

TABLE I

RESULTS OF THE MRMS DISTANCE

Model	MRMS($\times 10^{-3}$)
Bunny	0.043
Dragon	0.025
Hand	0.012
Cow	0.10

Table 1 depicts that the MRMS values prove the better quality of the watermarked models and the imperceptibility of the embedded watermarks. A slight loss of information is caused by the proposed algorithm.

The watermark was inserted into the object and recovered successfully when no attack was considered. This is checked by the BER measure which is equal to 0 and a measure of correlation equal to 1 for all the test objects.

B. Proposed system evaluation under various types of attacks

The robustness results and the resistance of the embedded watermark under different types of attacks are discussed. Some of these attacks are innocent, which may be used to adapt the object to personal use, while others are malicious, on which the watermarking algorithms try to resist. These attacks can be classified into two categories: geometric attacks and connectivity attacks. Geometric attacks modifies only the geometry of the watermarked mesh, i.e. the vertices coordinates. The number of vertices and the connectivity information are always kept unchanged. Affine transformations, noise addition, smoothing and uniform coordinate quantification are considered as geometric attacks.

Connectivity attacks are mainly mesh simplification, subdivision and cropping. In these attacks, the first combinational elements (vertices, edges and facets) of the watermarked mesh can be removed while some new elements can be inserted. In general, connectivity attacks are much more difficult to handle. Figure 4 illustrates examples of attacked models.

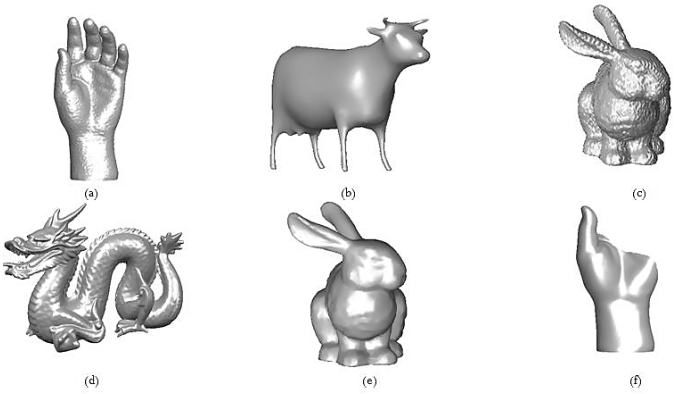

Fig. 4. Attacked watermarked models: (a) 0.50% additive noise on Hand model, (b) 50 iterations Laplacian smoothing with $\alpha = 0.10$ on Cow model, (c) 7 bit coordinate quantization on Bunny model, (d) Loop subdivision on Dragon model, (e) Uniform simplification by 90% on Bunny model and (f) 50% cropping on Hand model.

The algorithm is also tested under geometry attacks. Table 2 provides robustness results against the uniform noise addition. Table 2 establishes that the proposed scheme has a high robustness against noise addition. From the BER results, an average of 70% of the watermark is recovered in the case of the amplitude 0.5%.

TABLE II

ROBUSTNESS AND QUALITY RESULTS AGAINST THE UNIFORM NOISE ATTACK

Model	Amplitude (%)	BER	Correlation	MRMS($\times 10^{-3}$)
Bunny	0.05	0	1	0.11
	0.1	0.07	0.73	0.22
	0.3	0.29	0.58	0.63
	0.5	0.46	0.44	1.01
Dragon	0.05	0	1	0.12
	0.1	0.04	0.84	0.24
	0.3	0.07	0.72	0.67
	0.5	0.20	0.62	1.06
Hand	0.05	0	1	0.11
	0.1	0.01	0.87	0.23
	0.3	0.27	0.70	0.66
	0.5	0.26	0.53	1.06
Cow	0.05	0.08	0.95	0.17
	0.1	0.16	0.82	0.28
	0.3	0.23	0.71	0.80
	0.5	0.31	0.50	1.32

Tables 3 and 4 present the robustness evaluations against smoothing and uniform coordinate quantization; respectively.

TABLE III

ROBUSTNESS RESULTS AGAINST LAPLACIAN SMOOTHING ATTACK

Model	Iteration	BER	Correlation	MRMS ($\times 10^{-3}$)
Bunny	5	0.10	0.72	0.37
	10	0.13	0.55	0.67
	30	0.26	0.52	1.62
	50	0.23	0.48	2.39
Dragon	5	0.13	0.61	0.44
	10	0.16	0.58	0.83
	30	0.20	0.53	1.15
	50	0.23	0.56	1.87
Hand	5	0.01	0.85	0.19
	10	0.10	0.69	0.37
	30	0.20	0.51	1.04
	50	0.23	0.58	1.60
Cow	5	0.10	0.73	0.19
	10	0.16	0.65	0.35
	30	0.23	0.56	0.84
	50	0.36	0.41	1.46

TABLE IV

ROBUSTNESS AND QUALITY AGAINST THE QUANTIZATION ATTACK

Model	Intensity	BER	Correlation	MRMS ($\times 10^{-3}$)
Bunny	10 bit	0.01	0.73	0.26
	9 bit	0.28	0.60	0.52
	8 bit	0.32	0.54	1.04
	7 bit	0.46	0.41	2.07
Dragon	10 bit	0.07	0.83	0.26
	9 bit	0.16	0.68	0.47
	8 bit	0.20	0.61	0.82
	7 bit	0.26	0.76	1.01
Hand	10 bit	0.10	0.71	0.19
	9 bit	0.32	0.72	0.38
	8 bit	0.26	0.66	0.74
	7 bit	0.10	0.64	0.75
Cow	10 bit	0.02	0.76	0.24
	9 bit	0.14	0.70	0.46
	8 bit	0.22	0.59	0.88
	7 bit	0.35	0.53	1.59

Tables 3 and 4 depict that for smoothing attack the robustness is very satisfactory with a BER average of 0.17. Furthermore, we can deduce that robustness evaluations under uniform coordinate quantization are very acceptable. Furthermore, the robustness of the proposed algorithm against connectivity attacks including simplification, subdivision and cropping is evaluated. Table 5 presents the robustness evaluations against mesh simplification attack.

TABLE V

Robustness and Quality Against the Simplification

Model	Reduction ratio	BER	Correlation	MRMS ($\times 10^{-3}$)
Bunny	50%	0.33	0.56	0.11
	70%	0.42	0.44	0.18
	90%	0.50	0.47	0.41
	95%	0.43	0.48	0.67
	97.5%	0.48	0.42	1.18
Dragon	50%	0.23	0.67	0.62
	70%	0.29	0.59	1.14
	90%	0.46	0.56	1.19
	95%	0.53	0.48	3.23
	97.5%	0.56	0.44	3.5
Hand	50%	0.20	0.55	0.15
	70%	0.16	0.58	0.27
	90%	0.16	0.56	0.65
	95%	0.26	0.62	1.15
	97.5%	0.30	0.66	2.16
Cow	50%	0.16	0.53	0.046
	70%	0.22	0.51	0.085
	90%	0.26	0.51	0.22
	95%	0.13	0.49	0.43
	97.5%	0.20	0.45	0.89

Simplification is a strong attack that changes the object mesh which affects the inserted watermark. As an example, using BER results for the dragon model, more than 80% of the watermark after having removed 90% of the vertices is achieved. Consequently, the results are very satisfactory for models under such heavy attacks. Tables 6 and 7 display the robustness evaluation against subdivision and cropping; respectively.

Tables 6 and 7 establish that the subdivision attacks include the midpoint scheme, the sqrt3 scheme and the loop scheme [25]. It is clear that the proposed algorithm presents a high robustness against these attacks. Cropping is a very strong attack where one part of the object is cut off and lost. This damage causes a loss of information that affects the number of vertices, faces or edges. However, the recovery rate of the watermark is very satisfactory with respect to the implemented changes and this is due to the redundancy of the watermark embedding.

Generally, the correlation results prove a high robustness in most cases for all attacks. Moreover, the quality of the attacked watermarked test objects is evaluated using MRMS. It is obvious that the stronger the attack is, the higher the MRMS values are and therefore the more the object quality decreases.

From the preceding results it is reported that high robustness of the proposed algorithm against the applied disturbances is achieved. This proves the proposed watermarking scheme ability to withstand most attacks. From the experimental results evaluation, the robustness of the inserted watermark is ensured, which ensures the validity of the proposed robust watermarking algorithm. Although the results are positive and promising, there was a principal limitation, namely the simplification attack is the most destructive of the inserted watermark. Further evaluation will be focused on increasing the watermark robustness of the proposed method to other types of attacks as a future work.

TABLE VI

Robustness and Quality Against Subdivision

Model	Scheme	BER	Correlation	MRMS($\times 10^{-3}$)
Bunny	Midpoint	0	1	0.047
	Sqrt3	0.04	0.74	0.19
	Loop	0.32	0.62	0.23
Dragon	Midpoint	0.08	0.95	0.10
	Sqrt3	0.23	0.61	1.03
	Loop	0.07	0.87	1.26
Hand	Midpoint	0	1	0.026
	Sqrt3	0.04	0.82	0.21
	Loop	0.20	0.51	0.27
Cow	Midpoint	0	1	0.012
	Sqrt3	0.02	0.87	0.10
	Loop	0.07	0.72	0.10

TABLE VII

Robustness Against Cropping

Model	Cropping percentage	BER	Correlation
Bunny	10%	0.10	0.81
	30%	0.24	0.61
	50%	0.22	0.72
Dragon	10%	0	1
	30%	0.13	0.48
	50%	0.20	0.44
Hand	10%	0.01	0.83
	30%	0.10	0.60
	50%	0.13	0.51
Cow	10%	0	1
	30%	0.16	0.44
	50%	0	1

V. Conclusion

In this paper, a new and blind mesh watermarking approach was proposed. This method is a robust 3D watermarking scheme dedicated to copyright protection and characterized by a blind extraction of the inserted watermark. The watermark embedding was achieved by slightly shifting vertices' positions. The proposed algorithm has the advantage of causing no clear alterations in the host model during the insertion process; otherwise it is invariant to similarity transformations. Moreover, it proved to be highly robust against a variety of attacks, such as noise addition, smoothing, quantization, simplification, subdivision and cropping. This was also improved by using the Turbo code on the watermark. The experimental results show that the requirements of the watermark imperceptibility and robustness are very satisfactory.

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Genetic Algorithm for Restricted Maximum *k*-Satisfiability in the Hopfield Network

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***Abstract* — The restricted Maximum k-Satisfiability MAX-kSAT is an enhanced Boolean satisfiability counterpart that has attracted numerous amount of research. Genetic algorithm has been the prominent optimization heuristic algorithm to solve constraint optimization problem. The core motivation of this paper is to introduce Hopfield network incorporated with genetic algorithm in solving MAX-kSAT problem. Genetic algorithm will be integrated with Hopfield network as a single network. The proposed method will be compared with the conventional Hopfield network. The results demonstrate that Hopfield network with genetic algorithm outperforms conventional Hopfield networks. Furthermore, the outcome had provided a solid evidence of the robustness of our proposed algorithms to be used in other satisfiability problem.**

***Keywords* — Exhaustive Search, Genetic Algorithm, Hopfield Neural Network, Restricted Maximum k-satisfiability.**

I. Introduction

Since decades ago, optimization has provided intensified algorithmic research for the development of constraint satisfaction and Boolean satisfiability. Hybridization between both field are motivated by application in scheduling, VLSI circuit, pattern reconstruction and many other applications. However, the main problem for both area is to assign interpretation or value to variables such that it makes the whole system become feasible [1]. Before it can be considered as optimization problem, both field must merge their character and able to produce their hybridized cost function [2]. Motivated by notable counterpart of Boolean satisfiability, restricted maximum k-satifiability (MAX-kSAT) has been a wide subject in constraint optimization problem. Restricted MAX-kSAT can be defined as a problem to assign value to Boolean variable with k literal per clause that maximize the number of satisfied clauses.

The idea of implementing artificial neural network to provide solution to optimization problem has been utilized by various researcher in artificial intelligence field. It is a fascinating field of study because it provides an alternatives way of doing computation and it is a paradigm towards understanding of the intelligence. It is a pursuit to visualize and represent information processing capabilities of an actual nervous system [3]. Hopfield neural network [4] is a simple recurrent network that has an efficient associative memory and resembled the biological brain [5]. The important property of the Hopfield neural network is the minimization of energy whenever there is any change in inputs. Due to effectiveness of energy changes in Hopfield neural network, several researchers have merged the idea of logic programming with Hopfield neural network. Several celebrated models were developed by Sathasivam [6] and Wan Abdullah [3]. Most of the model employed the cost function based on inconsistencies of the Horn clauses [5]. The cost function of the logic will be exploited in order to find the connection strength that act as a building block of the energy minimization.

Due to the complexity of network when the number of neuron increased, method of searching satisfied interpretation in a given MAX-*k*SAT clause should comply with traditional Hopfield network. The easiest method that compliment with Hopfield network is exhaustive search method (ES). The combination of exhaustive search method (ES) and Hopfield network namely HNN-MAX*k*SATES will be utilized to represent the conventional Hopfield network [32].

Genetic algorithm (GA) is increasingly viewed as optimization technique to a wide range of problem. Strictly speaking, genetic algorithm combines the idea of evolutionary improvement, recombination and mutation among the candidate solution. Since Hopfield neural network often providing a local minimum to solution [7], genetic algorithm will be incorporated with Hopfield network to do MAX-*k*SAT problem. The combination of genetic algorithm and Hopfield neural network were proven effective by many researchers in solving various optimization problem [8, 9, 10]. Thus, genetic algorithm is introduced in this study to supplement the Hopfield neural network to facilitate the search process of MAX-*k*SAT solution. HNN-*k*SATGA indicates the combination of Hopfield network and Genetic algorithm in solving any given MAX-*k*SAT problem. Although the solution obtained may stuck at local minima, the performance of the MAX-*k*SAT solution based on this hybrid algorithm was indeed promising.

This paper has been organized as follows. Section II introduces the *k*-satisfiability (*k*-SAT) and maximum *k*-satisfiability (MAX-*k*SAT). In section III, neuro searching methods including exhaustive search (ES) and genetic algorithm method (GA) in doing MAX-*k*SAT will be discussed. In section IV, neuro-logic paradigm comprises of the Hopfield model, Wan Abdullah's method and Sathasivam's relaxation method will be discussed. Furthermore, the implementation of our proposed method will be discussed in section V. Finally, section VI and VII enclose the experimental results and conclusion.

II. Maximum k-Satisfiability Problem

A. *k*-Satisfiability Problem

The *k*-SAT problem can be delineated as a conundrum of determining satisfiability of sets of clauses comprise of at most *k* literals per clause (*k*-CNF formulas). It is a general form of satisfiability problem that can be divided into the randomized satisfiability and maximum satisfiability [41]. Additionally, *k*-SAT problem can be expressed as *k*-CNF (*k*-Conjunctive Normal Form) or Krom formula [38]. Besides, *k*-SAT problem is considered as a NP problem or non-deterministic problem. Hence, the *k*-SAT problem involves logic formula that can be translated into an optimization problem. Therefore, the three core components of *k*-SAT are simplified as follows:

1. Consists of a set of *m* variables, $x_1, x_2, \ldots\ldots, x_m$

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2. A set of literals. A literal is a variable or a negation of a variable.

3. A set of *n* distinct clauses: $C_1, C_2 \ldots\ldots C_n$. Each clause consists of only literals combined by just logical OR "V". Each clause must contain of variables.

In addition, the Boolean values are bipolar, consisting of 1 and -1 that could have exemplified the idea of true or false [45]. Hence, the goal of the *k*-SAT problem is to decide whether there exits an assignment of truth values to variables that makes the following formula satisfiable.

$$P = \bigwedge_{i=1}^{n} C_i \tag{1}$$

Where $\wedge$ is a logical AND connector, *P* denotes the entire Boolean formula for k-SAT. C_i is a clausal form of DNF with *k* variables. In our case, we investigated *k*=2 and *k*=3 for our satisfiability problem where the clause in randomized 2-SAT and 3-SAT has the following form:

$$C_i = \bigvee_{j=1}^{k} \left(x_{ij}, y_{ij}\right), \ k = 2 \tag{2}$$

$$C_i = \bigvee_{j=1}^{k} \left(x_{ij}, y_{ij}, z_{ij}\right), \ k = 3 \tag{3}$$

B. Restricted Maximum k-Satisfiability

Restricted maximum *k*-Satisfiability problem (MAX-*k*SAT) can be defined as generalized form of Boolean satisfiability problem [37]. Given a Boolean formula *P* in conjunctive normal form (CNF) with *n* clauses containing variable each and positive integer g where $g \leq m$. MAX-*k*SAT can be defined specifying implicitly a pair (λ, θ) [44] where λ is the set if all possible solution $\{1, -1\}^n$ and θ is a mapping $\lambda \rightarrow \xi$ which is denotes the score of the assignments. ξ is scored based on true clauses. Therefore, MAX-*k*SAT problem contains of defining the best bipolar/binary assignments to the variables in *P* that simultaneously satisfies at least *g* of the *m* clauses. Moreover, the mission is to decide the "optimized" assignment that can satisfy the maximum number of clauses containing *k* variables. Fundamentally, there are 2^n possible solutions to this problems. It was proven that MAX-*k*SAT is NP-complete problem for any $k \geq 3$.

There are numerous classifications of the MAX-*k*SAT namely, weighted MAXSAT [42] and Partial MAXSAT [43]. However, restricted MAX-*k*SAT constrained optimization problem that can be included in maximization problem [39]. Additionally, restricted MAX-*k*SAT can be ventured in logic programming [40]. In this exploration, we limit our analysis to *k*=2 and *k*=3. For instance, we can form the following 2-SAT formula:

$$P = (x \vee y) \wedge (x \vee \neg y) \wedge (\neg x \vee y) \wedge (\neg x \vee \neg y) \tag{4}$$

Equation (4) is not possible to satisfy because no particular assignment will drive to all the clauses true. The following Table 1 portrays the truth table for *P*.

Table 1 depicts that entire assignments will not be able to make formula *P* true. Hence, every clause will be checked in order to compute the maximum number of satisfied clause. All in all, the maximum number of clauses satisfied by the assignment is 3 out of 4.

TABLE I
TRUTH TABLE FOR P

x	*y*	$(x \vee y)$	$(x \vee \neg y)$	$(\neg x \vee y)$	$(\neg x \vee y)$	P
1	-1	1	1	-1	1	-1
-1	1	1	-1	1	1	-1
-1	-1	-1	1	1	1	-1
1	1	1	1	1	-1	-1

III. NEURO- SEARCHING PARADIGM

Neuro-searching paradigm consists the algorithmic method in finding the solutions. Previously, Hopfield neural network alone has been utilized in doing logic programming. The usage of Hopfield neural network (HNN) in doing logic programming is proven effective when the number of neurons were small. In order to make a fair comparison between standalone Hopfield neural network and Hopfield neural network incorporated with genetic algorithm, we embedded exhaustive search technique to enhance the traditional HNN in doing MAX*k*SAT. In this paper, neuro-searching paradigms were used in hunting the maximum number of clauses for restricted maximum 2-satisfiability and restricted maximum 3-satisfiability problem.

A. Exhaustive Search (ES)

Exhaustive search (ES) algorithm can be demarcated as a local search technique for an element with a particular property among combinatorial forte such as permutations, combinations, logics, satisfiability or subsets of a set [32].

Roughly speaking, the ES algorithm will brutally hunt for the total potential clause, even if the search dimension was getting bigger and more complex [5]. Technically, the exhaustive search is the most primitive algorithm for checking the logic satisfaction. ES is theoretically simple to implement. In our exploration, we embedded ES to traditional Hopfield neural network in order to enhance the primitive solution checking by Hopfield neural network. The exhaustive search will facilitate traditional Hopfield neural network to check the satisfaction clause by clause in order to generate the maximum number of satisfied clause.

However, the main drawback of exhaustive search (ES) is the speed of the algorithm [35]. Subsequently, exhaustive search devours more computation time in searching for the maximum number of satisfied clauses completely [28]. In this paper, we will generate random bit strings and compute the number of satisfied clauses directly, clause by clause. It will be a huge possibility that the bit strings are not converging to global maxima during the first iteration of ES. Thus, the iterations will be repeated 100 times. The ES might look decent for the simpler case, but what would happen if we increase the number of clauses?

We will encounter with the complexity of the hybrid network when we attempted with more complex bit strings. Thus, the computation time will become very high if we increase the complexity of the hybrid network. Therefore, the computation complexity is represented as $O(2^n)$ [6]. For the ES algorithm, the satisfied assignment is gained after performing a 'trial and error' procedure exhaustively. Henceforth, the correct assignment will be stored into the Hopfield's artificial brain in the form of content addressable memory (CAM). Some related work on exhaustive search has been done by a few neural network practicioners such as Aiman & Asrar [27], Kaushik [28], and Zinovik *et al*. [32]. In this paper, we hybridized ES algorithm with the Hopfield neural network as a network based on logic programming to solve MAX-*k*SAT problems (HNN-MAX2SATES and HNN-MAX3SATES).

B. .Genetic Algorithm (GA)

Genetic algorithms are robust evolutionary paradigms that have attracted a prolific amount of research in optimization and maximization problem [46]. According to mathematicians' standpoint, the genetic algorithm is a staple computational paradigm inspired from the Darwin's theory of evolution, namely survival for the fittest model [29, 30]. For instance, every generation is represented by an array of bit strings similar to the chromosomes of DNA. In our case, we have a set of bit string that represent the interpretation of the MAX*k*SAT. This is motivated by the previous work by Aiman and Asrar [27] that highlighted on the genetic algorithm to solve randomized 3-SAT problem. On the contrary, the fundamental impetus of genetic algorithm is to find the bit string that maximize the number of satisfied clauses before we incorporate with Hopfield network. Specifically, the genetic algorithm in doing MAX*k*SAT consists of distinctive stages.

Stage 1: Initialization

In this stage, 100 random populations in the form of bit strings were initialized [27]. Each assignment consists of possible solution to randomized MAX*k*SAT problem.

Stage 2: Fitness evaluation

Next. all the bit string will undergo fitness evaluation. Each of the correct bit which result in satisfied MAX*k*SAT clause will be "awarded". During fitness evaluation, the number of satisfied clauses will represent the fitness of the chromosome (bit string). The fitness function is widely used as an objective function by a few notable works [46, 47, 48]. The objective function of the genetic algorithm is as follows:

$$f_{MAXkSAT} = \max[c_1(x) + c_2(x) + c_3(x) ... + c_N(x)] \quad (5)$$

Where $c_1, c_2, c_3 ..... c_N$ are the number of clause checked by genetic algorithm and N is the number of clauses present in the formula. Specifically, the role of the fitness function is to evaluate the candidate bit strings.

Stage 3: Selection

During this stage, 10 candidate bit strings with the highest fitness will go to the next generation. The selected candidate bit strings will have the privilege to perform the crossover process.

Stage 4: Crossover

During crossover, bit strings will be chosen randomly and the exchange of information between two sub-structure of the bit strings occurred. Bit string. For example,

Before crossover

Bit string A = -1 1 1 1

Bit string B = 1 -1 1 -1

After crossover =

Bit string A = -1 -1 1 1

Bit string B = 1 1 1 -1

The location of crossover in a particular bit string is randomly defined since we want to maintain genetic diversity of the bit strings. Crossover usually increase the number of satisfied clause of the newly bit strings children. This feature helps the best bit string of the generation to survive and improve further. On top of that, the crossover operator imitates the biological amalgamation between two single-chromosomes (haploid) in organisms. After crossover, all the bit strings children undergo fitness evaluation in order to check their corresponding fitness.

Stage 5: Mutation

Mutation operator is the real game changer for genetic algorithm. Local maxima could occur during simulation. Local maxima occurred when the fitness of the bit string varies significantly to the expected maximum fitness. This will create non-improving solution of MAX*k*SAT clauses. In order to create "out of the blue" bit string, we utilized mutation. Mutation involve flipping the state of the bit string from 1 to -1 or -1 to 1 [27]. Position of the mutation in a particular bit string is random. For example,

Before mutation

Bit string A = -1 -1 1 1

After mutation

Bit string A = -1 1 1 1

The second position of the bit string was flipped from -1 to 1. In this case, different bit string was created after mutation.

Thus, we can calculate the fitness value for the newly formed bit strings [27, 36].

Genetic algorithm in doing MAX*k*SAT has been proven effective by previous researchers to avoid global maxima. If the bit string does not achieve the desired fitness (local maxima), the current bit string will improve further during the next generation via crossover and mutation. Most of the researchers set up to 100 to 1000 generations in order to improve the solution. Since we are dealing bipolar search which only involve 1 or -1, it will be easy for bit strings to converge to global maxima (Maximum fitness). In this paper, we hybridized GA algorithm with the Hopfield neural network as a network based on logic programming to solve MAX-*k*SAT problems (HNN-MAX2SATGA and HNN-MAX3SATGA).

Figure 1 shows the algorithm for this paradigm.

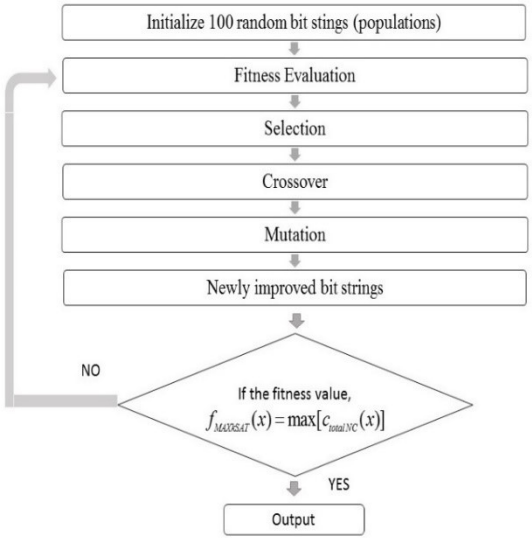

Fig. 1. Algorithm/flowchart for genetic algorithm.

IV. Neuro- Logic In Hopfield Neural Network

A. The Hopfield Neural Network

For many years, Hopfield model has been recognized as an effective optimization method [4]. Since the first application of Hopfield network to optimization problem, this approach has well drawn many attention

towards various field such as computer network, pattern recognition and scheduling problem.

Theoretically, the model comprises of interconnected unit called neurons, forming a network. Computation in Hopfield network is executed by collections of interconnected neurons [4, 11]. Most of the literature suggest Hopfield network contains good properties including parallel execution for fast solutions to computationally intensive optimization problems with exceptionally good accuracy [9]. In this connection, we choose Hopfield network to do logic programming because it is well distributed, consist of CAM [12], smooth implementation and easy to blend with other algorithm.

The units in Hopfield nets are called binary threshold unit [13] which can only take bipolar values such as 1 and -1. The paramount definition for unit I's activation, a_i are given:

$$a_i = \begin{cases} 1 \quad if \sum_j W_{ij} S_j > \xi_i \\ -1 \; Otherwise \end{cases} \tag{6}$$

Where W_{ij} is the connection strength from unit j to i. S_j is the state of unit j and ξ_i is the threshold of unit i. The network comprises of N recognized neurons, each is described by an Ising spin variable. The connection in Hopfield net contain no connection with itself $W_{ii} = W_{jj} = 0$. Thus it makes the Hopfield connections became symmetric or bidirectional [4, 14]. Neuron is basically bipolar $S_i \in \{1, -1\}$ thus it follows the dynamics $S_i \rightarrow \mathrm{sgn}(h_i)$ where h_i is the local field of the connection. When dealing with higher order connection, the local field modifies to

$$h_i = ... + \sum_j W_{ijk}^{(3)} S_j S_k + \sum_j W_{ij}^{(2)} S_j + W_i^{(1)} \tag{7}$$

Since the weight (connection strength) in Hopfield network is constantly symmetrical, the updating rule maintains as follows [15]:

$$S_i(t+1) = \mathrm{sgn}\left[h_i(t)\right] \tag{8}$$

The dynamic is to ensure the energy decrease monotonically which following the activation system. The generalized lypunov energy equation is as followed:

$$= -\frac{1}{3}\sum_i \sum_j \sum_k W_{ijk}^{(3)} S_i S_j S_k - \frac{1}{2}\sum_i \sum_j W_{ij}^{(2)} S_i S_j - \sum_i W_i^{(1)}{}_j \tag{9}$$

This energy function is significant because it establishes the degree of convergence of the network [16, 4]. The energy value obtained from the equation will be checked through and will be classified as global or local minimum energy. As it stands, the network is hunting for global minimum energy (correct solution) compared to local minimum energy (wrong solution). The process of obtaining global minimum energy always associated with how we define the weight of the network. In this work, we implemented Wan Abdullah's updating technique to obtain the weights for our network [3, 17].

B. Wan Abdullah's Method in Learning MAX-kSAT Clauses

MAX-*k*SAT can be treated as one of the constrained optimization problem that being carried out on Hopfield neural network. Wan Abdullah's method became the pioneer in weight extraction based on logical inconsistencies [17]. Truth values were assigned to each atoms. The minimized cost function can be created by maximizing the number of satisfied clauses.

For example, Consider the following MAX-2SAT and MAX-3SAT problem with α and ϕ

$$\alpha = (A \vee B) \wedge (A \vee \neg B) \wedge (\neg A \vee B) \wedge (\neg A \vee \neg B) \tag{10}$$

$$\begin{aligned} \phi = {} & (P \vee Q \vee R) \wedge (\neg P \vee Q \vee R) \wedge (P \vee \neg Q \vee R) \\ & \wedge (P \vee Q \vee \neg R) \wedge (\neg P \vee \neg Q \vee R) \wedge (\neg P \vee Q \vee \neg R) \\ & \wedge (P \vee \neg Q \vee \neg R) \wedge (\neg P \vee \neg Q \vee \neg R) \end{aligned} \tag{11}$$

Cost function f_{cost} for both equation (8) and (9) are as followed

$$\begin{aligned} f_{\mathrm{cost}\,\alpha} = {} & \frac{1}{2}(1-S_A)\frac{1}{2}(1-S_B) + \frac{1}{2}(1-S_A) + \frac{1}{2}(1+S_B) \\ & + \frac{1}{2}(1+S_A)\frac{1}{2}(1-S_B) + \frac{1}{2}(1+S_A)\frac{1}{2}(1+S_B) \end{aligned} \tag{12}$$

$$\begin{aligned} f_{\mathrm{cost}\,\phi} = {} & \frac{1}{2}(1-S_P)\frac{1}{2}(1-S_Q)\frac{1}{2}(1-S_R) + \frac{1}{2}(1+S_P)\frac{1}{2}(1-S_Q)\frac{1}{2}(1-S_R) \\ & + \frac{1}{2}(1-S_P)\frac{1}{2}(1+S_Q)\frac{1}{2}(1-S_R) + \frac{1}{2}(1-S_P)\frac{1}{2}(1-S_Q)\frac{1}{2}(1+S_R) \\ & + \frac{1}{2}(1+S_P)\frac{1}{2}(1+S_Q)\frac{1}{2}(1-S_R) + \frac{1}{2}(1+S_P)\frac{1}{2}(1-S_Q)\frac{1}{2}(1+S_R) \\ & + \frac{1}{2}(1-S_P)\frac{1}{2}(1+S_Q)\frac{1}{2}(1+S_R) + \frac{1}{2}(1+S_P)\frac{1}{2}(1+S_Q)\frac{1}{2}(1+S_R) \end{aligned} \tag{13}$$

By comparing equation (12), (13) with equation (9), we obtained synaptic weight for α and ϕ. The synaptic weights are shown in Table 2 and Table 3.

TABLE II

SYNAPTIC WEIGHT FOR α BASED ON WAN ABDULLAH'S METHOD

W	C_1	C_2	C_3	C_4
$W_A^{(1)}$	1/4	1/4	-1/4	-1/4
$W_B^{(1)}$	1/4	-1/4	1/4	-1/4
$W_{AB}^{(2)}$	-1/2	1/2	1/2	-1/2

TABLE III

SYNAPTIC WEIGHT FOR ϕ BASED ON WAN ABDULLAH'S METHOD

W	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
$W_P^{(1)}$	1/8	-1/8	1/8	1/8	-1/8	-1/8	1/8	-1/8
$W_Q^{(1)}$	1/8	1/8	-1/8	1/8	-1/8	1/8	-1/8	-1/8
$W_R^{(1)}$	1/8	1/8	1/8	-1/8	1/8	-1/8	-1/8	-1/8
$W_{PQ}^{(2)}$	-1/8	1/8	1/8	-1/8	-1/8	1/8	1/8	-1/8
$W_{QR}^{(2)}$	-1/8	-1/8	1/8	1/8	1/8	1/8	-1/8	-1/8
$W_{PR}^{(2)}$	-1/8	1/8	-1/8	1/8	1/8	-1/8	1/8	-1/8
$W_{PQR}^{(3)}$	1/16	-1/16	-1/16	-1/16	1/16	1/16	1/16	-1/16

Normally, weight can be determined by using traditional Hebbian learning concept [18]. Sathasivam has shown that the weight obtained by using Wan Abdullah's method are similar due to clausal MAX-*k*SAT similarity. Although both method is expected to produce the similar weight, Wan Abdullah's method is proven to minimize the spurious minima produced by logic compared to Hebbian learning [17, 18].

C. Network Relaxation

The nature of the solution obtained by Hopfield network can affected by multiple factors. According to Zeng & Martinez [19], the firing and receiving information among neurons can influence the output of the network. In this case, network relaxation helps the network to exchange information efficiently. As the number of neuron increased, more interconnected neurons involved in firing and receiving information. Without proper relaxation mechanism network tend to produce more local minima solution. Since MAX-*k*SAT contain more clausal constrained, we applied Sathasivam's relaxation technique [14] to ensure the network relaxed to equilibrium states. Information exchange between neurons will be updated based on the following equation

$$\frac{dh_i^{new}}{dt} = R\frac{dh_i}{dt} \tag{14}$$

Where R denotes the relaxation rate and $\boldsymbol{h_i}$ refers to the local field of the network as listed in equation (7). In this case, we consider a constant relaxation R since it will improve the network relaxation compared to dynamic relaxation.

D. Hyperbolic Activation Function

Other than relaxation rate, the choice of activation function can affect the performance of the network. Traditional McCulloch-Pitts activation function is prone to few weaknesses such as computational burdening and lack of efficiency on producing desired result [20]. In order to get network's full potential, we utilized Hyperbolic tangent activation function. The Hyperbolic tangent activation function is written as follows:

$$g(h_i) = \frac{e^{h_i} - e^{-h_i}}{e^{h_i} + e^{-h_i}} \tag{15}$$

Where $\boldsymbol{h_i}$ refers to the local field of the network. The Hyperbolic tangent can act as an efficient squashing function for local field and produce a well-defined output (between 1 and -1). In addition, the usage of activation function is to avoid the network from collapse into a simple linear function [21].

V. Implementation

The simulations for HNN-MAX*k*SATGA and HNN-MAX*k*SATES were executed on Microsoft Visual C++ 2013 for Windows 10. Firstly, the restricted MAX-*k*SAT clauses were generated randomly. After that, the initial states for the neurons were initialized in the MAX-*k*SAT clauses. The network evolved until it reached the final state. Once the program had reached the final state, the neuron state was updated via equation (7). As soon as the network relaxed via equation (14), the final state obtained. Furthermore, if the state had remained unaffected for five runs, neurons achieved stable states. Hence, by permitting an ANN to evolve, sooner or later, shall lead to a stable state where the energy function obtained would not change further. Subsequently, the corresponding final energy for the stable state was calculated. If the difference between the final energy and the global minimum energy is within the tolerance value, the solution would be considered as a global solution. Both algorithms were repeated 100 times with 100 neuron combinations. The termination criteria for the final energy was 0.001. Sathasivam et al. [11] highlighted the fact that 0.001 was selected as the termination criteria because it could minimize the statistical errors. The analysis will involve the global minima ratio, ratio of satisfied clause, fitness landscape value, Hamming distance and computation time as the performance measure and indicator.

VI. Result and Discussion

A. Global Minima Ratio

Global minima ratio is defined as the ratio between the global solutions over total number of runs [18]. Each simulation will produce 10000 bit strings solutions. 0.9524 global minima ratio value shows 9524 bit strings are global minimum and 476 bit strings are local minimum.

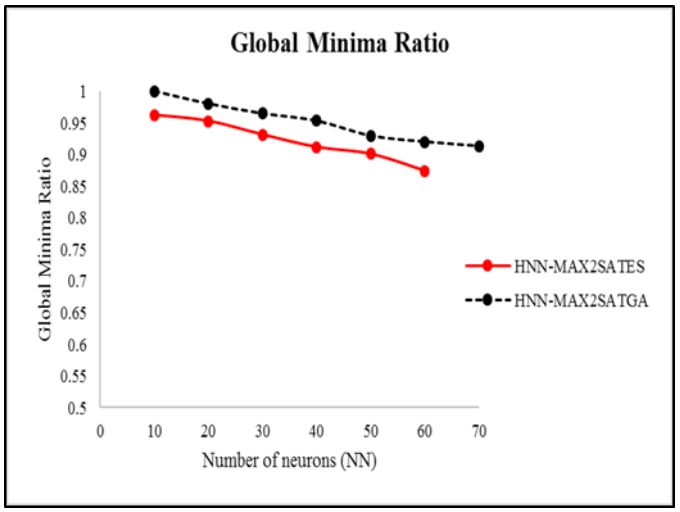

Fig. 2. Global minima ratio for HNN-MAX2SATES and HNN-MAX2SATGA.

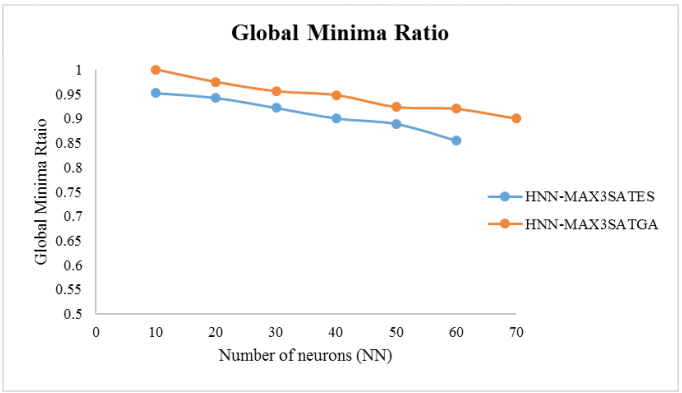

Fig. 3. Global minima ratio for HNN-MAX3SATES and HNN-MAX3SATGA.

Figure 2 and 3 represent the global minima ratio obtained by HNN-MAX2SATGA, HNN-MAX2SATES and HNN-MAX3SATGA, HNN-MAX3SATES. The efficiency of both networks can be determined by calculating their global minima ratio. According to Sathasivam [18], if the global minima ratio of the proposed network close to one, almost all solutions in the network reached global minimum energy (global solution). HNN-*k*MAXGA is able to recall more correct states

compared to HNN-MAX-*k*SATES. The limit for HNN-MAX-*k*SATES is 60 neurons. After 60 neurons, the network in HNN-MAX-*k*SATES trapped in trial and error state and consume more time to find the solution. On contrary, HNN-*k*MAXGA is able to withstand number of neurons up to 70 neurons. Genetic algorithm is proven to reduce the complexity of the searching technique. Unsatisfied bit string can be improved through the crossover among the best offspring (highest fitness). The bit strings are expected to improve in term of fitness (satisfied clauses) as the number of generation increased. As a result, the bit string produced by genetic algorithm achieved global minima compared to traditional exhaustive search method. Mutation in genetic algorithm was added to reduce the chances for the bit string to reach local maxima (non-improving solution) [22, 23]. Besides, less complexity during searching can gives more time for the network to relax. Effective relaxation will reduce the number of suboptimal solution during the computation [14].

B. Ratio of Satisfied Clauses

Ratio of satisfied clauses can be defined as the total number of satisfied clauses over the total number of clauses [24]

TABLE IV

RATIO OF SATISFIED CLAUSE

NN	HNN-MAX2SATES	HNN-MAX2SATGA	HNN-MAX3SATES	HNN-MAX3SATGA
10	0.745	0.750	0.800	0.875
20	0.723	0.750	0.787	0.850
30	0.716	0.743	0.764	0.834
40	0.700	0.739	0.732	0.827
50	0.688	0.732	0.700	0.815
60	0.632	0.728	0.688	0.799
70	-	0.722	-	0.774

NN=Number of neurons.

Table 4 depicts the ratio of the satisfied clauses over total clause obtained HNN-MAX2SATGA, HNN-MAX2SATES and HNN-MAX3SATGA, HNN-MAX3SATES. In maximum satisfiability problem, MAX-2SAT and MAX-3SAT clauses will never be fully satisfied. We can further deduce that, the higher the ratio obtained, the more clauses will be satisfied in any MAX-*k*SAT problem. According to Table 4, HNN-MAX*k*SATGA is proven to obtain more satisfied clauses in MAX-*k*SAT compared to traditional exhaustive search method. As the number of neurons increased, the HNN-MAX*k*SATGA is still able to maintain the quality of the ratio. On the other hand, HNN-MAX*k*SATES will produce a lower ratio of satisfied clauses since most of the solution obtained trapped at suboptimal solution (local minima).

C. Fitness Energy Landscape Value

Fitness energy landscape value is associated with each point according to the pattern storing capability. Since Hopfield network concern about the ruggedness of the energy model, the fitness energy landscape must be taken into account. The fitness energy landscape value is based on Kauffman's model [25].

Figure 4 and 5 depicts the fitness energy landscape value obtained for HNN-MAX*k*SATGA and HNN-MAX*k*SATES. As observed, the difference in energy for HNN-MAX*k*SATGA is almost flat (zero) compared to HNN-MAX*k*SATES. MAX-*k*SAT clauses is always related to the ruggedness of the energy landscape. The more rugged the energy landscape, the harder it will to obtain good solution [26]. Since the complexity of the solution searching has been reduce drastically by genetic algorithm in HNN-MAX*k*SATGA, more relaxation time was added before the network retrieve the final states. As a result, HNN-MAX*k*SATGA has a greater capability to store MAX*k*SAT pattern compared to HNN-MAX*k*SATES. Hence, more global minimum energy produced.

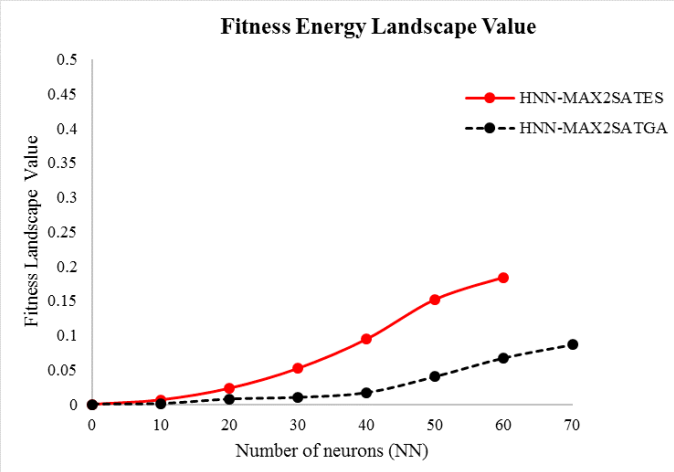

Fig. 4. Fitness energy landscape value for HNN-MAX2SATES and HNN-MAX2SATGA.

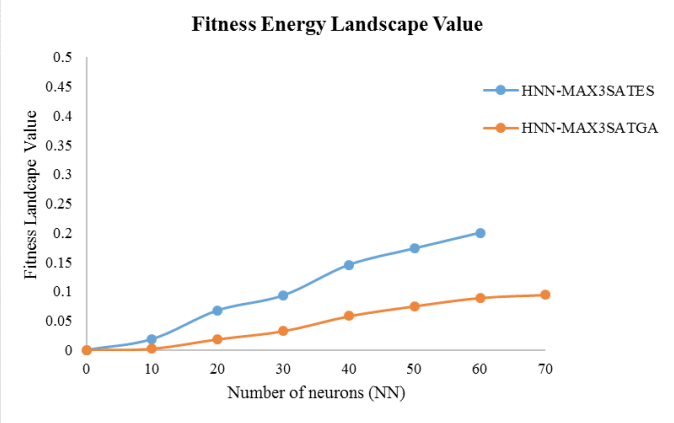

Fig. 5. Fitness energy landscape value for HNN-MAX3SATES and HNN-MAX3SATGA.

D. Hamming Distance

Hamming distance is demarcated as the number of positions at which the corresponding binary values between two strings are different. In our context, Hamming distance measures the closeness of bits between the stable state and the global state of the neurons upon relaxation process [14].

TABLE V

GLOBAL HAMMING DISTANCE

NN	HNN-MAX2SATES	HNN-MAX2SATGA	HNN-MAX3SATES	HNN-MAX3SATGA
10	0.00804	0.00215	0.00986	0.00382
20	0.01558	0.00624	0.01980	0.00845
30	0.02340	0.01002	0.02976	0.01367
40	0.03478	0.01555	0.03867	0.01822
50	0.04682	0.01930	0.04922	0.02138
60	0.06099	0.02889	0.07133	0.02990
70	-	0.03302	-	0.03673

NN=Number of neurons.

Table 5 portrays the obvious success of genetic algorithm compared to exhaustive search in generating the maximum satisfied clauses. According to Sathasivam [17], if the Hamming distance of the network close to zero, almost all outputs produced by the network are considered as global solutions. Based on table 4, Hamming distance for HNN-MAX*k*SATGA and HNN-MAX*k*SATES are close to zero.

This is due to the power of GA in ascertaining the satisfied clause, especially during the crossover stage where the clause was being improved by certain rate to achieve the highest fitness value. Additionally, HNN-MAX*k*SATGA would be able to recall the correct states that contributed to the lower hamming distance. Conversely, the exhaustive search algorithm emphasized the trial and error process during clause satisfaction process. When the complexity increased, HNN-MAX*k*SATES were able to sustain up to 60 neurons and HNN-MAX*k*SATGA with the limitation until 70 neurons. The main reason is due to the nature of exhaustive search that increased the computation burden to get correct neuron states. Hence, the ability to sustain huge number of neurons is due to the special ability of GA that reduces the computation burden in hunting the correct states.

E. Computation Time

The computation time is an important measure or indicator to analyze the performance of our proposed algorithm. According to our exploration context, the computation time can be delineated as the expanse of time for which our network was used to complete the whole computation process [6, 13]. The computation process involves the training and generating the maximum satisfied clauses via our proposed paradigm [14].

TABLE VI
COMPUTATION TIME

NN	HNN-MAX2SATES	HNN-MAX2SATGA	HNN-MAX3SATES	HNN-MAX3SATGA
10	24	1	32	2
20	108	17	159	23
30	357	76	482	98
40	2880	280	3461	340
50	11452	633	13708	784
60	88562	1550	102855	1699
70	-	3124	-	3322

NN=Number of neurons.

Table 6 depicts the computation time for our proposed algorithms, HNN-MAX2SATGA and HNN-MAX3SATGA together with the conventional algorithm, HNN-MAX2SATES and HNN-MAX3SATES. A nearer look at the running time indicates as the network become more complex, more computation time are needed to generate the global solutions. Since we deal with MAX-2SAT and MAX-3SAT clauses, the training process consumes more time to minimize the logical inconsistencies than the randomized k-SAT problem. For instance, as the number of neuron increased, the computation time taken to generate the maximum number of clauses also increased.

This is due to the fact that maximum k-satisfiability problem will never be fully satisfied, but we can possibly calculate the maximum number of clauses that will be satisfied. Hence, the states retrieved from the network can improve the global solutions that maximize the number of satisfied clauses. Thus, the whole process incurs more computation time. Generally, MAX-3SAT requires more time than MAX-2SAT due to complexity as the number of literals entrenched in the formula also higher.

According to Table 6, HNN-MAX2SATGA and HNN-MAX3SATGA require less computation time compared to the other counterparts, HNN-MAX2SATES and HNN-MAX3SATES. The undoubted evidence beyond that results are due to more neurons being forced to jump the energy barrier to relax into global solutions during the training process [14]. Additionally, the training process by using exhaustive search requires more computational time due to the trial and error process in hunting the maximum number of satisfied assignments. One of the important fact is for the maximum satisfiability problem, MAX-2SAT and MAX-3SAT clauses are never be satisfied 100%. On the contrary, when we implemented genetic algorithm, the computation time was faster due to the crossover and mutation process that speed up the training process. This is due to the fact that the unsatisfied bit string can be enhanced through the crossover among the finest offspring. The mutation process can avoid the bit string to achieve local minima. Hence, the bit string created by genetic algorithm achieved global minima swiftly compared to traditional exhaustive search method.

VII. CONCLUSION

Inspired by the Darwin's survival of the fittest theory together with biological genetic operators and engaging concept in artificial intelligence, a hybrid paradigm had been proposed. We had successfully develop a network by using genetic algorithm incorporated with Hopfield neural network in performing restricted maximum k-satisfiability logic programming (HNN-MAX*k*SATGA). The proposed model, later, was compared with a conventional technique; ES with Hopfield neural network (HNN-MAX*k*SATES). The work, reported in this paper, revealed decent performances of HNN-MAX*k*SATGA in terms of the global minima ratio, ratio of satisfied clause, Hamming distance, fitness landscape value and the compuatation time. According to the experimental results, the HNN-MAXkSATGA outperformed HNN-MAX*k*SATES in all of those measures. In addition, the proposed framework provides solid platform for evaluating various type of satisfiability problem. Our future work revolves on the robustness of other metaheuristic technique to solve restricted maximum k-satisfiability problem.

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Integrating Agents into a Collaborative Knowledge-based System for Business Rules Consistency Management

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***Abstract* — Capitalization and reuse of expert knowledge are very important for the survival of an enterprise. This paper presents a collaborative approach that utilizes domain ontology and agents. Thanks to our knowledge formalizing process, we give to domain expert an opportunity to store different forms of retrieved knowledge from experiences, design rules, business rules, decision processes, etc. The ontology is built to support business rules management. The global architecture is mainly composed of agents such as Expert agent, Evaluator agent, Translator agent, Security agent and Supervisor agent. The Evaluator agent is at the heart of our functional architecture, its role is to detect the problems that may arise in the consistency management module and provides a solution to these problems in order to validate the accuracy of business rules. In addition, a Security agent is defined to handle both security aspects in rules modeling and multi-agent system. The proposed approach is different from the others in terms of the number of rule's inconsistencies which are detected and treated like contradiction, redundancy, invalid rules, domain violation and rules never applicable, the collaboration that is initiated among business experts and the guarantee of security of the business rules and all the agents which constitute our system. The developed collaborative system is applied in an industrial case study.**

***Keywords* — Business rules (BR), Collaboration, Consistency Management, Knowledge-based System, Multi-agents Systems (MAS), Ontologies.**

I. Introduction

Small and medium enterprises (SME) are facing a high-level market competition. Despite the modernization of manufacturing processes, the use of experts (local and foreign) is costly. It becomes crucial to invest in knowledge and knowledge management systems. Especially, when the decision-making can be improved by using knowledge-based systems as mentioned in [1].

Companies tend to pay more and more attention on the subject of knowledge, thereby moving the improvement of the business strategy from product quality to the design of systems for knowledge.

The experts' knowledge capitalization has become a major goal of companies. Consulting an expert for a simple advice or an opinion on a critical situation in an organization has become necessary to guarantee the efficiency of decision making.

As mentioned in [2], Knowledge Management (KM) is a process of managing knowledge, which aims to manage existing and acquired knowledge assents to meet needs for now and develop opportunities in the future. Nowadays, Knowledge Management has been a focus in both academic and industrial fields. Thus, in knowledge-based engineering, many approaches are used to capture and reuse knowledge [3][4].

Tacit knowledge (experiences, competencies, etc.) usually resides in the people's brain, the effective and efficient way to utilize this type of knowledge is consulting the expert. However, domain experts could be unavailable when they are needed to participate in knowledge management system. This can be essentially due to the complexity of expertise and knowledge needs [5]. It has been well acknowledged that the difficulty of knowledge sharing lies in the sharing of tacit knowledge, especially when decision-makers come from very different backgrounds. Furthermore, they sometimes face confusing terms (such as communities, groupware), knowledge management and knowledge network are being used simultaneously [6].

Senior managers of SME enterprise are investing massively in the conception and implementation of knowledge bases to improve business processes, management and sharing of knowledge and retaining expertise, even after the employees' departure from the organization [7].

With regard of new technologies, the formal representation of knowledge has evolved with the tools of artificial intelligence. In a formal representation, knowledge is represented by logical objects linked by properties, axioms and rules.

As described in the literature, agent paradigm can be used in order to effectively model the dynamic aspect of the organizational environment. Agents are, by definition, autonomous entities, proactive and capable of social interaction in dynamic environments [8]. Additionally, they are thus capable of handling this issue when they are considered as components of agents groups with the given possibility to interact together (cooperation, collaboration) for the purpose of achieving their common goals.

We get inspired by the definition given in [9], the main idea is that the concept of knowledge can be included within the agents organizations, this will give more power to the proposed model : ''An organization of agents is a community of knowledge sharing in which agents collaborate and exchange knowledge to carry out their activities.''

Our paper aims to transfer knowledge from SMEs' experts to formal representations, which allow systems to reason with such knowledge. The main idea behind this study is to join the agent-based modeling and ontology-based approach, in order to take benefit of the advantages of the both.

The major objective is to automatically manage the consistency of business rules introduced by the experts during the capitalization of the business rules process as part of a collaborative system. Our proposal is mainly based on agents such as Expert agent, Evaluator agent, Translator agent, Supervisor agent and Security agent.

The remainder of this paper is organized as follows. Following the introduction, a state of art highlighting the problems associated with knowledge management and security is proposed in Section 2. In this section, we also describe some related works and our contribution.

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Section 3 presents our system architecture. To illustrate the feasibility of our proposed approach, the experimentations results are given in Section 4. Finally, Section 5 provides the conclusion of this paper, including possible limitations of our approach and potential direction for future research.

II. Background

Generally speaking, the business rules management has given birth to the Business Rules Management Systems technology or BRMS, which has rapidly become the best solution to the problem of effectively maintaining business rules. In this section, we will introduce the foundational concepts and briefly review related works on the domains that influence our work: Business rules management systems, the agent-based modeling and security techniques.

A. Literature review on Business Rules Management Systems

The work presented in [10] tackles the rule acquisition problem, which is crucial and critical for the development of BRMS. The proposed approach assumes that regulations written in natural language are an important and essential source of knowledge, but turning them into formal statements is a complex task that cannot be completely automated. The authors propose to decompose the acquisition process into two principal phases: the translation of natural language statements into controlled language and their formalization into an operational rule base. The authors focus on the normalization phase. As a limitation of this work, the rules acquisition from natural language is a complex task and cannot enumerate all the possible cases.

The business rules and procedures are usually provided in the text, the proposed method in [11] allows the acquisition of business rules from texts. Thus, they construct and operate a documented rules model, an "index" structure which connects the source text, the ontology that defines the conceptual domain vocabulary and the rules drawn from the text.

The paper in [12] describes a simple formalism designed to encode lexicalized ontologies and shows how it is used in a business rule management platform of the automotive domain.

In [13][14], the authors show two prototypes based on the BRMS WODM (WebSphere Operational Decision Management). The first prototype allows the creation and execution of business rules over OWL ontologies. The second prototype detects the inconsistencies that may be caused by the ontology evolution and proposes solutions to solve them.

The aim of the paper presented in [15] was to indicate possible applications of rule-based approach in production planning and scheduling. Besides, many solutions described in the study can be implemented also in the computer decision support systems for iron cast manufacturers.

B. Motivation of using agent-based modeling in support of knowledge management

We behold the continuous incorporation of agent technology into knowledge management systems. We believe that there are a lot of related works on integrating agent technology into knowledge management systems. For example, the research reported in [16] is aimed at conceiving an adaptable data-sourcing service in order to deploy business rules effectively in supply chain management. The authors propose an agent-based mechanism that dynamically maps business terms in business rules to the data objects in the enterprise data model.

A knowledge management platform for marketing decision making is proposed in [17]. The authors utilize an agent technology with fuzzy logic and fuzzy Analytical Hierarchy Process (AHP).

The author in [18] proposes a heterogeneous and distributed knowledge management system, called OCEAN that is based on ontologies and multi-agents system. The OCEAN system is based on a knowledge life cycle composed of four steps that are: identification, extraction, validation and knowledge reuse. Each step is the goal of an organization of agents.

In addition, another work has been done in this area, it consists of a methodology named DOCK, Girondo et al. [19] have designed an intelligent knowledge-based system in order to support the knowledge management process. The main objective of the MAS is to support the decision-making process within design projects and allow engineers to capitalize, share and reuse the knowledge generated throughout decision-making steps and more generally throughout design projects in order to gain in efficiency.

As mentioned in [20], Multi-agent systems can be considered as a good solution because of its distributed nature, autonomy and solidarity. Moreover, they ensure the coordination and cooperation between agents which have some capabilities of reasoning and facilitating the achievement of overall objectives. Multi-agent systems are considered as autonomous platforms that perform their actions to achieve a predefined set of objectives. They are able to provide an infrastructure that facilitates the construction of complex and composite tasks. More precisely, the work tackled the problem of Globus Resource Allocation Manager (GRAM) and proposed a model on the basis of a multi-agent system between the user and grid client. Furthermore, they used the hidden Markov models for the matchmaker process and Telecom Italia Lab approach for developing their system. This latter has been implemented by using the Java Agent Development Framework (JADE).

Regarding the role that multi-agents systems play in enterprise management in general, we can distinguish the work developed in [21]. In this paper, authors have envisaged a combination of Software agents and Web services within a platform of an enterprise software. In addition, they considered a contract net protocol among the agents and invoked the contract net from a web service. This work can be added to the direct applications of SMA in enterprise projects.

In [22], authors have proposed an automated multi-agent negotiation framework for decision making in the construction domain. The presented Architecture allowed software agents to mimic human behaviors and styles in building an automated negotiation system. In this work, BDI (Belief-Desire-Intention) agents have been chosen in order to take benefit from their intelligence in elaborating efficient decisions.

C. Security

We firstly consider the security integration in computer systems and particularly the modeling of business rules then in a second time, we will focus on the security in MAS. Finally, we end this section by expressing our motivation to use a security agent to guarantee this role in the two cases.

1) Security in business rules modeling

Capitalization of experts' knowledge is essential to the decision-making and strategic management of businesses. Facing with abundant information and continuous interactions, One question may arise: how to secure the knowledge and expertise of businesses? We cannot talk about the acquisition and capitalization of experts' knowledge in companies without addressing the crucial issue of security. To improve the knowledge safety and accessibility by the experts, the notion of cryptography has emerged as a basic concept in the business rules modeling.

2) Security aspect in multi-agents systems

As mentioned in many studies, security is a decisive factor to multi-agent technology to gain widespread use and provide viable solutions on a wider scale for commercial applications [23][24][25].

More precisely, Foner [26] provided a general discussion about the need for security in Multi-agent systems; here, the author discussed the threats and possible attacks that may occur in the system, He focused on the privacy of the users' information.

As we know, agents and multi-agent systems are distinguished from other software applications by a certain number of properties or characteristics. Such distinctions can make them vulnerable to attacks, intrusions and malicious programs.

As a first propriety which can be a subject of serious security concerns; is the autonomy of the agents. Generally, these latter are recognized to perform several actions in order to achieve their goals without human assistance.

Due to this autonomy, agents could be forced to commit malicious tasks that will conduct to a failure in the general functioning of the system; it will be possible for them to use the powerful features for malicious or suspicious purposes if they are not well controlled.

In multi-agent systems, the system security does not only depend on data confidentiality and integrity, but also on communications in message exchanges. Generally, agents must interact by cooperating, collaborating or negotiating their goals. One can say that problems deriving from social ability (in terms of interactions) are difficult to solve.

Agents, as any other software system, when distributed over a network, they must be prepared to face the classic security problems, such as breach of confidentiality, integrity attacks, and attempts to block the availability of a resource or the whole system [27].

In MAS, the communication is very important as we know agents are capable of executing any task to achieve their goals, and this implies the ability to communicate and interact with other parties (other agents, non-agents, humans) that constitute the global environment.

All these agents use social ability through cooperation, collaboration, coordination and negotiation once launched.

As argued by [28], in MAS especially when agents communicate with each other, they are subject of threats as well as conventional computer networks. The authors affirm that they will be considered as passive if they want to hear the communication otherwise (means active) when they try to intercept and modify the data related to the exchanges.

Several authors have discussed in many works the security issue in multi-agents systems providing some techniques or proposals. They sometimes add a security feature to the MAS and sometimes they try to solve this problem by integrating tools in the developed architecture.

D. Our contribution

Our suggested system allows the detection and management of inconsistencies in the business rules, following a rigorous control strategy implying the expert opinion in most situations. To do so, we develop a domain ontology that represents the enterprise's business model and supports checking for inconsistencies.

We can summarize our contribution in the following key-points:

- Knowledge acquisition from business experts through a user-friendly and ergonomic web editor.
- Design and development of domain ontology to generate the company's business model.
- Design and implementation of an agent-based architecture, where the Evaluator agent plays an important role.

This paper focuses on the decisions generation, this can be facilitated by executing the suggested rules in an automatic manner. Our approach makes it possible for businesses to respond rapidly to changes in business needs, thus enhancing the overall business efficiency.

In table 1, we present a comparison between some related works and ours. We just sort the items by using ' + ' to indicate that the option exists and ' - ' to indicate that the option doesn't exist. We put our approach in the bottom of table 1. Some indications are given with the table1 in order to clarify some criteria that are used in the comparison:

A: Use of Agents

B: Use of Ontology

C: Business rules consistency types

C1: The contradiction

C2: The rules never applicable

C3: The domain violation

C4: The invalid rules

C5: The redundancy

C6: The equivalence

D: Security aspect

E: Collaboration or cooperation between experts

TABLE I

Comparison Between Some Related Works and Our Approach

Works	A	B	C						D	E
			C1	C2	C3	C4	C5	C6		
Guissé et al. [10]	-	+	-	-	-	-	-	-	-	-
Guissé et al. [11]	-	+	-	-	-	-	-	-	-	-
Omrane et al. [12]	-	+	-	-	-	-	-	-	-	-
Chniti et al, [14]	-	+	-	+	+	-	-	-	-	-
Ram and Liu, [16]	+	+	-	-	-	-	-	-	-	+
Moradi et al., [17]	+	-	-	-	-	-	-	-	-	+
Our approach	+	+	+	+	+	+	+	-	+	+

As the Table 1 shows, our proposed approach has major advantages related to past approaches. We note that the security aspect is not taken into account by any of the competitor works as well as the collaboration between experts except some works that describe agents in cooperation. We can also notice that our approach treats more cases of rules consistency compared to other approaches (it treats 5/6 of the possible cases).

In the following section, we will describe in details our agent-based approach with more attention given to the management of business rules consistency.

III. The suggested Model

Our approach permits to acquire and capitalize the business experts' knowledge as business rules through an agent-based platform. Domain ontology is used in order to generate the business model corresponding to the enterprise and check the consistency of business rules.

The knowledge-based system is composed of several components as described in Fig. 1 [29]. We can cite, for example: Development

environment that defines the business model and the rules model (we use the standard format IF <Conditions> Then <Actions> because it offers more possibility to describe complex conditions and actions) as well as some necessary functions for the application development, a collaborative Interface and Knowledge management system.

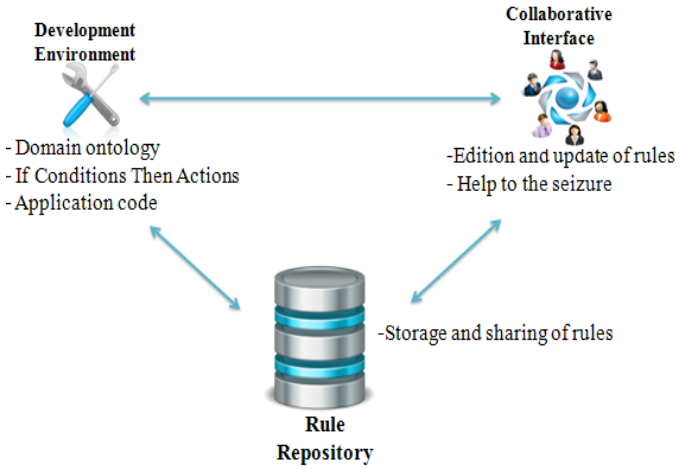

Fig. 1. The proposed model.

A. Domain ontology

It is necessary to provide an intuitive rule language easy to handle using the business vocabulary, in order to enable business experts to implement and maintain up to date their rule-based systems. Business language should allow representing the entities of the business domain, the actions that can be taken and the strategies to follow. To do this, our BRMS is based on domain ontology, representing all business entities and their properties and relations.

Domain experts may have difficulties expressing their knowledge in formalized logic languages because they are not business rules experts. One of our goals is to support them in their management of the knowledge needed to write these rules.

The use of different vocabularies for the same things by the experts is one of the difficulties with business rules modeling, so they cannot understand each other immediately [12]. In order to represent the business vocabulary used to express the rules, we propose using domain ontology as a unified model. This later will help the experts to express their rules more efficiently, to reduce misunderstandings and guarantee that people are discussing the same thing.

Our domain ontology is developed by acquiring knowledge from documents, collection and capitalization of business rules processes with domain experts and the interviews with company managers. Currently, we have implemented our ontology in Protégé 4.0.2. Fig. 2 depicts an overview of the main concepts and classes of the domain ontology that is applied to an e-business enterprise.

We have created our ontology according to the method described in what follow:

- Our ontology is built manually,
- Ontology Enrichment: we use the TERMINAE method which is a method and platform that assists users in designing terminological and ontological resources from texts [30].

The main objective is to save the different terms that are related to the conceptual vocabulary. We use the SKOS-based approach [12] to save the various linguistic units that denote a concept, instance or role.

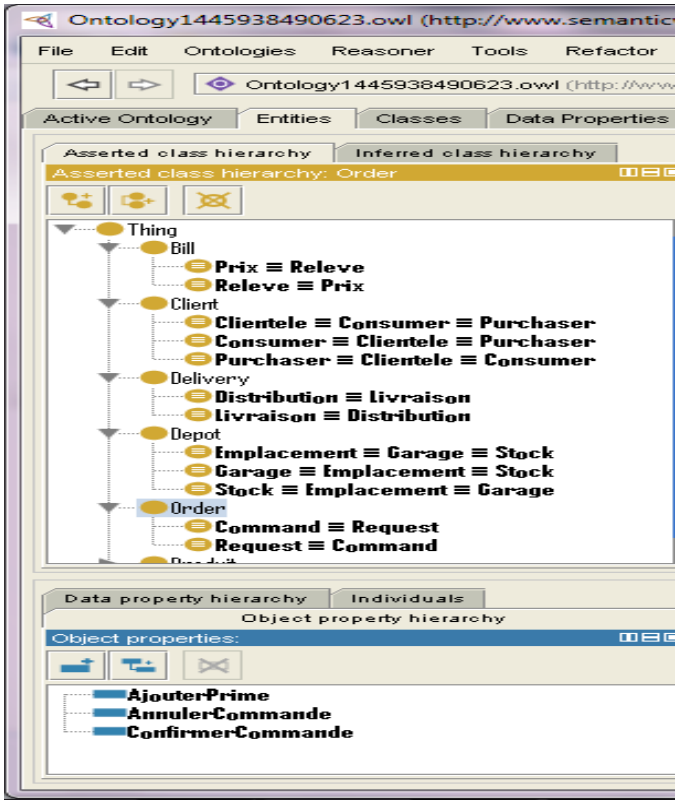

Fig. 2. A snapshot of our domain ontology.

B. Agent-based modeling

To achieve all functionalities, we use a multi-agents system that is composed of several agents (see Fig. 3):

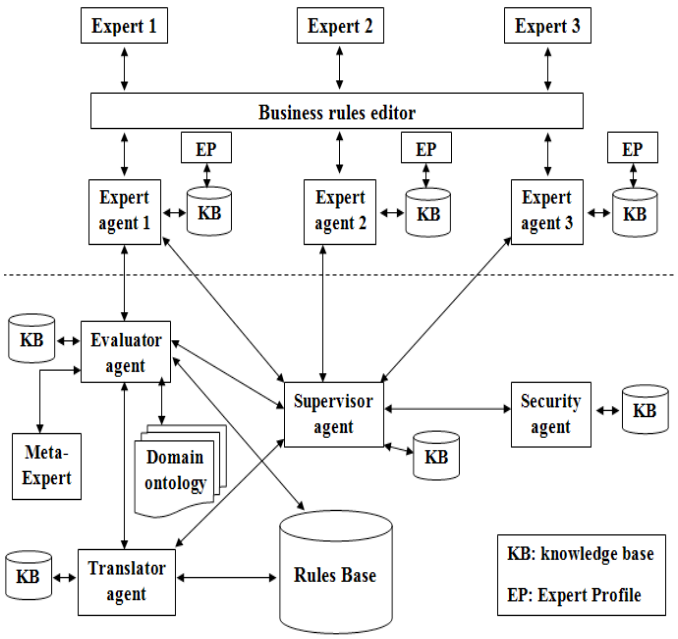

Fig. 3. An agent-based architecture.

1) Expert agent

This agent is responsible for the recuperation of the rules seized by the expert. This agent saves the rules and transmits them to the Evaluator agent. In the case of consistency problem, it receives a message from the Evaluator agent and displays the notifications and

recommendations on the rule editor. The Expert agent stores its data in a knowledge base that contains all the information about the rule being introduced (See Fig. 4).

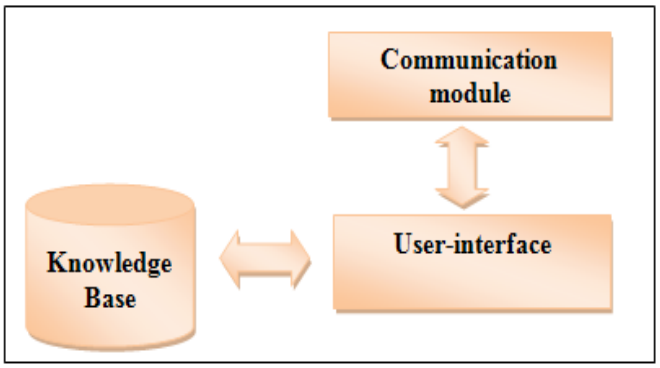

Fig. 4. Expert Agent Structure..

The communication module is responsible for the agent's interaction with the other agents in the system to get, send and receive some information.

The user-interface permits the interaction with the business expert to allow him to interact with our system.

In the knowledge base, all knowledge of the agent is stored:

- The information transmitted by the Evaluator agent,
- Profiles of business experts,
- The profile of the current expert.

2) *Supervisor agent*

This agent performs all control tasks in the system, that means it verifies if there is no failure or blockage in the whole system. This agent monitors and controls the accessibility and the sequence of the running of all the agents. Furthermore, it keeps the history of the agents and their tasks during the system execution.

The Supervisor agent plays a very important role within the MAS. Indeed, all interactions between the different agents of the MAS pass through it. In other words, if an agent A wants to send a message M to an agent B, then the agent A must firstly contact the Supervisor agent to know if agent B exists or not. In this case, the Supervisor agent checks whether the agent B exists or not, if yes then an ACK message will be sent to the agent A, otherwise it regenerates the agent B and sends the ACK to the agent A.

3) *Evaluator agent*

This agent is responsible for checking the consistency of the business rules. It recovers the rule from the Expert agent, browses the domain ontology to extract the set of concepts that correspond to the introduced rule and accesses to the rules repository to test if this rule poses a problem with another rule. If it is the case, then the Evaluator agent sends a message to the Expert agent and the Translator agent, otherwise it sends the rule to the Meta-expert.

We propose to use our Ontology to have benefit of the semantic similarity between the concepts as it offers a structured and unambiguous representation of knowledge in the form of conceptualizations interconnected by means of semantic pointers.

The Evaluator agent is composed of several modules such as (see Fig. 5):

- Consistency module: manages the consistency of business rules.
- Similarity Module: permits to value the similarity and dissimilarity between the concepts of the rule and the ontology. This latter is representing a very reliable and structured knowledge source used to compute semantic likeness.
- Communication Module: allows the interaction with the other agents in the system.
- Knowledge Base: contains all the information recorded by the Evaluator agent.
- Rules Base: contains all the consistent business rules of the enterprise.
- Domain ontology: permits to define a set of knowledge in a given domain.

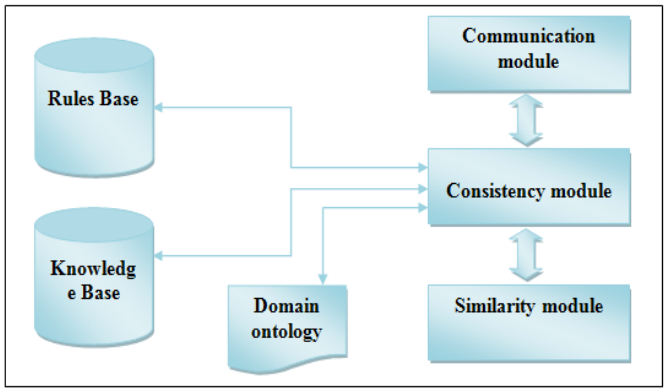

Fig. 5. Evaluator Agent Structure.

4) *Translator agent*

The Translator agent retrieves the rule from the Evaluator agent, and translates the introduced rule into a technical rule. The internal database of the Translator agent contains all mapping information for translating the rule.

To translate the business rules, we adopted the approach presented in [16], with some changes according to our needs.

The mechanism of translation consists of three parts: a business rules model, an enterprise data model, and a Translator agent linking these two models. The enterprise data model defines the data objects about which business rules are expressed, the business rules model captures semantics of the business rules and the Translator agent maps business terms to data objects usually attributes in the enterprise data model.

The Translator agent establishes a link between the business rules and the enterprise data model. To connect business rules with the enterprise data model, the agent performs the following steps:

- It identifies business terms in the business rule.
- It maps the identified business terms to data objects in the enterprise data model.

Translator agent is composed of several modules as described in Fig. 6:

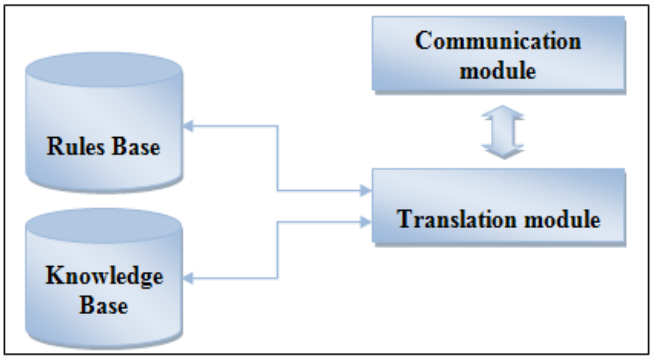

Fig. 6. Translator Agent Structure.

- Translation module: translates the business rules into technical rules.
- Communication Module: allows the interaction with the other agents in the system.
- Knowledge Base: stores all the knowledge that is manipulated by this agent.
- Rules Base: contains all the consistent business rules related to the enterprise.

5) Security agent

This agent maintains the security in the system; its role is to maintain the encryption and decryption of the business rule. For security reasons, exchanges between agents are encrypted by a hybrid system; the keys are provided by the Security agent.

This agent applies an encryption/decryption algorithm to allow confidentiality, authenticity and integrity of the most important rules. So, to increase the rules security, we use the well-known hybrid or mixed cryptography (see Fig. 7) in order to take benefit of the advantages of symmetric and asymmetric algorithms. The secret key exchange is done thanks to the RSA public key algorithm. The communication that follows is encoded by using the AES secret key algorithm. In [31], we have demonstrated through several sets of experiments the efficiency of the AES algorithm in terms of response time, space memory and security.

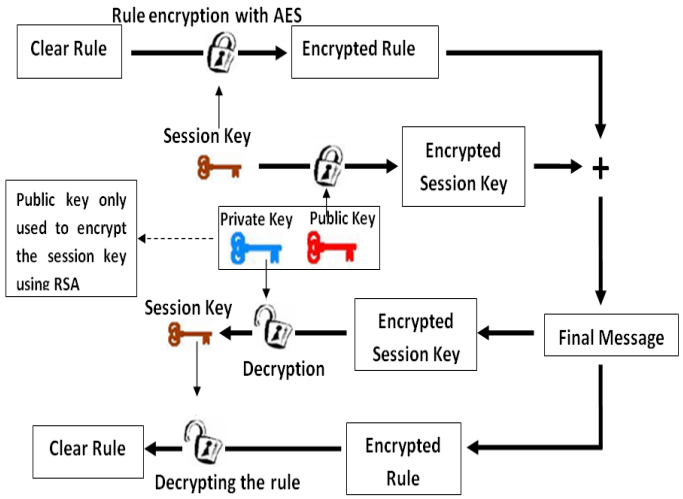

Fig. 7. Process of encryption and decryption.

C. Communication between agents

The interaction among the different agents of the system is shown by the sequence diagram that is expressed in AUML and represented in Fig. 8. There are several possibilities with knowledge management in MAS:

- Every agent has knowledge about its problem domain.
- Each of the agents has its own knowledge representation.
- If new information exists, an agent sends a message to all agents which might be interested.

D. Business rules consistency management

Currently, the effectiveness and correctness of business rules defined by the experts have always been a challenging problem. Our system should ensure that the complete set of business rules includes only the rules that are consistent and do not conflict among themselves. A possible way is to group the rules by the objects they constrain or actions they trigger and to check if there are any conflicts [32].

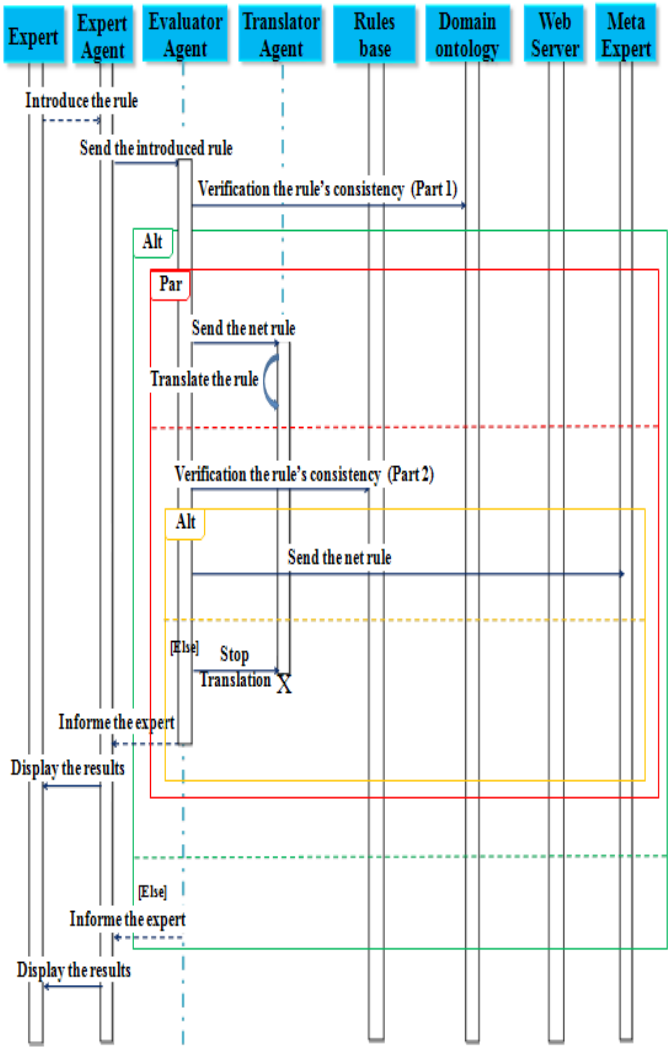

Fig. 8. Sequence diagram of our system,

In what follows, we will present the different types of inconsistencies that may impact a set of rules, and the solution brought to each type of inconsistency.

E. Business rules consistency management

Currently, the effectiveness and correctness of business rules defined by the experts have always been a challenging problem. Our system should ensure that the complete set of business rules includes only the rules that are consistent and do not conflict among themselves. A possible way is to group the rules by the objects they constrain or actions they trigger and to check if there are any conflicts [32].

In what follows, we will present the different types of inconsistencies that may impact a set of rules, and the solution brought to each type of inconsistency.

1) The contradiction

A contradiction is detected in a set of rules R, if this set contains, at least, two rules that have the same condition part and assign two different values to a same attribute in the action part.

If this type of problem is detected, the system sends a notification to the expert who introduced this rule with a very detailed report on the problem description.

The expert must respond to this notification and provide a solution to this problem as soon as possible, either by deleting or changing the rule.

2) The rules never applicable

A rule is never applicable if its condition part can never be verified.

The system sends a notification to the expert if this type of problem is detected with a very detailed description on the part of the rule which causes the problem as well as the range and interval of values requested for this attribute.

The expert must respond to this notification in the briefest delays and modifies the rule according to the sent report. In the case where the expert wants to modify the values or the properties of an attribute, he should contact the administrator to update the vocabulary of the domain according to new market changes.

3) The domain violation

A domain violation is detected in a set of rules, if this later contains, at least, one rule with a particular statement: it means in the action part, the assigned value to the attribute is out of its domain.

If this problem is detected, the business expert would receive a notification with recommendations on the editor with an explanation of the problem encountered as well as the values and properties allowed for this attribute. The expert must answer this notification in the briefest delays and modifies the rule according to the sent report.

4) The invalid rules

A rule is invalid if it uses in its premise or conclusion part, a concept or a property that does not belong to the ontology from which the rules were edited. To check if the rule is valid or not, the system accesses the domain ontology and follows these steps:

1. Search if the concept exists, if the concept does not exist then the system sends a notification message to the business expert and delete the rule, otherwise go to 2.
2. Search if the property exists, if it is not the case then the system sends a notification to the business expert and delete the rule, otherwise the system assumes that the rule is valid.

5) The redundancy

Two rules are called redundant if they have the same condition and produce the same action.

If this type of problem is detected, the system deletes the rule and sends notifications to the expert to inform him that the rule creates a redundancy problem and consequently it has been deleted.

6) The equivalence

Two rules are equivalent if the condition of the first one is included in the condition of the second and both rules produce the same action. To solve this problem, the system sends a message containing the equivalent rules to the expert and asked him to integrate and merge all equivalent rules into a single coherent rule.

The main idea of our work is the integration of ontologies and business rules in order to enable experts representing knowledge that describes the constraints and the business decisions. This integration creates a dependency between ontologies and rules due to the fact that the rules are edited from concepts and properties of the ontology. The domain ontology can be modified in two cases, which are:

1. In the case of the detection of some rules inconsistencies such as invalid rule, domain violation or rule never applicable, the expert is asked to correct the rule, three alternatives are possible: change the rule by using one of the stored values that exist in the ontology, delete completely the rule or update the vocabulary. To do this, the expert must work with the administrator in order to update the domain ontology.
2. To meet the new needs and the market changes, the ontology must be modified by the administrator in collaboration with the domain experts. This modification may cause some inconsistencies in business rules. Actually, we are studying the impact of the ontology evolution on the business rules consistency.

We present in the following the pseudo code of business rules consistency management (see Algorithm 1).

Algorithm 1: Checking the consistency of business rules

```
1.  Input : a business rule
2.  Output : the rule is consistent or not
3.  Eliminate the empty words
4.  Extract the Property, Concept, Test, Value and Action of the business rule
5.  Access to the domain ontology
6.  // The verification of the invalid rules
7.  for all concepts of the ontology do
8.      if (ConceptOnto.equals(Concept)) then
        // check whether the concept exists
9.        The Concept exists
10.           if (Concept is a term) then
11.             Recover the concept of the
        term
12.           end if
13.       Get all the properties of this concept
14.     for all properties of this concept do //
        check if the property exists
15.           if (propertyOnto.equals(Property))
        then
16.             The Property exists
17.               Get the main property if
        exists
18.             // The verification of not applicable
        rules
19.             // The case where the property contains predefined
        values
20.             try {
21.             Get the predefined property values and their types
22.                 if (ValueProp.contains(Value))
        then
23.                     The rule is
        applicable
24.                 else
25.                     The rule is not
        applicable
26.                 end if
27.             } catch (Exception e) {
28.             // The case where the property has a
        type
29.             Get the type of the property
30.             Parse the value according to the property
        type
31.                 if (Property Type.
        equals("ValueType")) then
```

```
32.                                The rule is applicable
33.                        else
34.                                The rule is not applicable
35.                        end if
36.                }
37.                else
38.                        The rule is invalid // The concept exists but the property does not exist
39.                end if
40.        end for
41.        else
42.                The rule is invalid // The concept does not exist
43.        end if
44. end for
45. Connection to the Rules Base
46. for all number of rules do
47.    // The redundancy verification
48.        if (the same condition and the same action exist) then
49.                The rule is redundant
50.        else
51.                The rule is not redundant
52.        end if
53.    // Verification of the contradiction
54.    Recover contradictory actions with this action
55.        if (the same condition exists and at least one contradictory action exists) then
56.                The rule is contradictory
57.        else
58.                The rule is not contradictory
59.        end if
60. end for
```

F. The collaboration between experts in the case of inconsistencies

In the case of inconsistencies, the business expert receives a notification on the editor to correct its introduced rule according to the sent report. If the expert doesn't answer before XX days (the number of days is defined by the enterprise), the system sends to him an e-mail and SMS to correct the rule. If the expert doesn't answer after XX days, then the system sends the rule as well as the assessment report to the other experts and to the meta-expert to ask for their help and their opinion.

Each expert can answer by «Yes» or «No». In the case of «Yes», the expert should send the new modified and corrected rule.

After harvesting responses from business experts, a voting system is launched to decide. If all experts vote «No», therefore the rule will be definitely deleted and the system sends a notification message to the expert who introduced this rule, otherwise the experts can correct the wrong rule and this later pass through the reparation process (see Fig. 9).

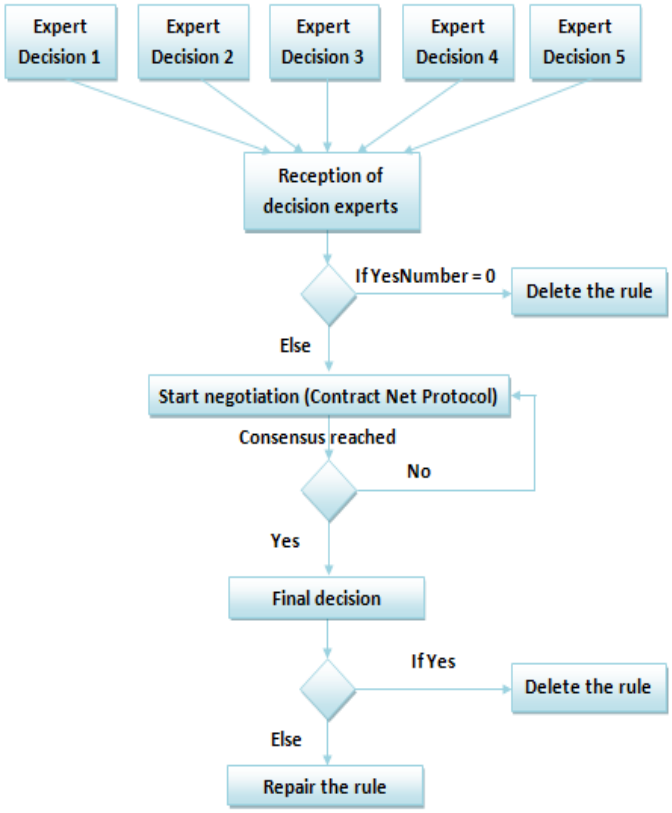

Fig. 9. Collaboration between experts in the case of inconsistencies.

The negotiation mechanism among the experts is based on the well-known Contract Net Protocol which is a model for which only the manager emits propositions. The contractors can only make an offer, but not counter-propositions. In our case, we propose to extend the CNP to consider the opinion of contractors (experts) in order to find more quickly a common accepted solution. In our approach, we use the Contract Net Protocol for its advantage to be a dynamic and easy to implement as an algorithm. The suggested negotiation model operates on a business rule, thus other tasks are added to the manager. This will eventually influence its decision- making.

IV. Implementation and Discussion

This section is divided into two parts; the first one is dedicated to the collaborative graphical platform that allows the experts to introduce, update their rules and launch simple or advanced research by using some keywords. In the second part, some experiments are done to test the business rules consistency management and evaluate the agents' performance. The system was implemented with Java language and JADE (Java Agent Development) interface. The knowledge base and rules base was implemented by using WampServer. We used Apache Tomcat as an open source web server and servlet container. The open source ontology editor Protégé 4.0.2 was used for the creation and visualization of the ontology. We have developed our application and launched the simulations on a computer Intel (R) Core (TM) i5-3230M CPU at a speed of 2.60 GHz, equipped with a Memory capacity of 4.00 GB of RAM on Windows 7.

A. How to edit the rules

Once authenticated, the expert can access to the rules editor, here he will capitalize his knowledge and experience in a particular domain. For example, thanks to the editor, the expert can introduce the following rule (See Fig. 10):

If the customer's state is MIN and the customer's category is GOLD Then Position the discount of the order to 10%.

The rule used here is extracted from a detailed case study of the work done in [33]. We prefer using the known rule base for our scenario in order to compare the most relevant results.

Our editor offers other features like advanced research mainly based on some keywords and criteria, update and deletion of the rules. The editor permits to the experts to interact with each other.

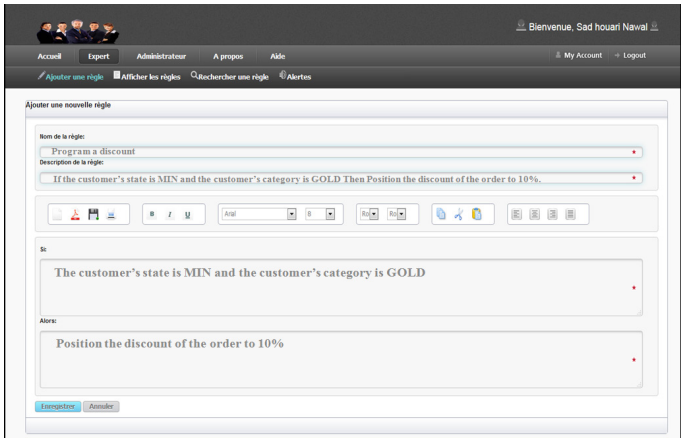

Fig. 10. Business rules editor interface.

B. Evaluation of the platform usability

An evaluation of system usability using a questionnaire was conducted to show the effectiveness of the proposed platform. We get inspired by the questionnaire given in [34] and we develop our questions regarding the system we suggested.

The questionnaire was distributed to 10 users consisting of experienced and un-experienced users, including business experts from the enterprise.

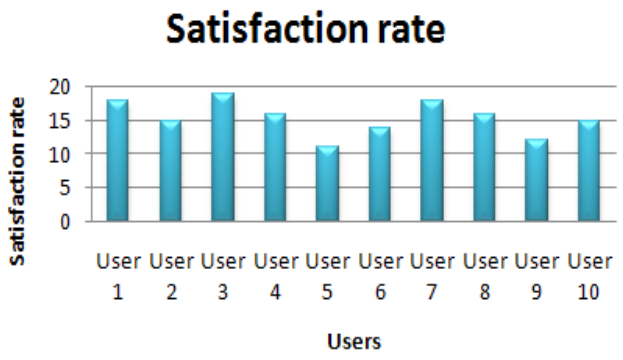

Fig. 11. Evaluation of the platform usability.

Fig. 11 shows the usability results obtained from the questionnaire, in which some questions are followed by a reversed question to reveal opposing facts. For some questions, we assigned a weight. At the end, we count the sum of weight to find the user's satisfaction level according to the formula 1. We note that some questions are not included in the calculation. These questions just give us information, conclusions and directions for future improvement of the platform.

$$Satisfaction\_rate_j = \sum_{i=0}^{n} Expert\_Response_i \quad (1)$$

Where :
j : the expert number j
n : Number of questions

Expert_Response$_i$: the expert response on the question number i. We note that: Expert_Response$_i$ $\leq$ Weight$_i$ where Weight$_i$ = the weight assigned to the question number i.

Some questions of the questionnaire are presented in what follow:

- If you have three words to describe the platform, what are these words?
- Which part of the platform did you find most interesting?
- Which part of the platform do you want to discuss or treat in more depth? And why?
- Would you like to add anything else? Do you have any other comments?
- On a scale of 0-5, how would you value the performance of the platform (response time and access)?
- On a scale of 0 to 5, how much do you value the ergonomics / the ease of use of the tool?
- On a scale of 0 to 5, how much do you value the overall tool?
- There were inconsistencies in the navigation? Yes Or No
- The interaction components (buttons, menus, text fields, drop-down lists, etc.) can be easily understood? Yes Or No
- Do you need to learn many things before using the platform? Yes Or No
- Is it easy and effective to share your experiences in the platform? Yes Or No

TABLE II
BUSINESS RULES SET

Inconsistency type	Rules number	Number of rules detected
Invalid rules	12	12
Domain violation	7	7
Rules never applicable	11	11
Redundancy	8	8
Contradiction	12	12
Equivalence	10	0

From the questionnaire results, one could argue that the usability/ readability of the platform is reasonably high.

C. Experimentations

An important factor for an acceptance of our system is its runtime performance. This section provides various scenarios to evaluate our prototype and test the feasibility of our approach on several business rules. It also serves to confirm the claims that were made through the paper.

1) Experiment 1: Test of our consistency management module

In order to test our system, we launched 60 business rules which contain: 12 contradictory rules, 8 redundant rules, 10 equivalent rules, 12 invalid rules, 11 rules never applicable and 7 rules that pose a domain violation problem (see Table 2). We note that our rule base already contains 30 consistent rules.

The obtained results are very encouraging and show that the developed system treats the problem of contradiction, redundancy, domain violation, invalid rules and rules never applicable but does not treat the equivalence problem.

2) Experiment 2: Agents performance

Table 3 presents the execution time of the system agents in milliseconds with 8 business rules. The execution time of the Evaluator agent depends greatly on both: the ontology size and rules base size.

TABLE III
RESPONSE TIME OF THE SYSTEM AGENTS

A \ R	R1	R2	R3	R4	R5	R6	R7	R8
EA	315	388	484	328	367	312	434	420
TA	801	760	749	750	845	716	758	791
EvA	860	760	663	822	768	795	915	760
SA	227	211	222	210	230	207	220	230
SuA	218	225	218	302	323	360	277	334
Total	2421	2344	2336	2412	2533	2390	2604	2535

A: Agents
R: Rules
EA: Expert Agent
TA: Translator Agent
AvA: Evaluator Agent
SA: Security Agent
SuA: Supervisor Agent

In Table 4, we calculate the average response time of each agent.

TABLE IV
AVERAGE RESPONSE TIME OF THE SYSTEM AGENTS

Agents \ Rules	Average response time
Expert Agent	381
Translator Agent	771.25
Evaluator Agent	792.875
Security Agent	219.625
Supervisor Agent	282.125
Total	2446.875

Table 5 presents the space memory, in bytes, occupied by each agent when introducing the business rules.

TABLE V
SPACE MEMORY OCCUPIED BY THE SYSTEM AGENTS

R \ A	EA	*TA*	*AvA*	*SA*	*SuA*	Total
R1	5,217,000	12,888,168	5,045,912	8,465,032	9,089,840	40,705,952
R2	4,882,304	13,843,472	4,994,128	8,057,272	8,455,584	40,232,760
R3	3,845,216	11,084,144	5,010,560	8,143,848	8,169,928	36,253,696
R4	4,083,520	12,610,440	4,981,352	8,073,504	10,518,416	40,267,232
R5	3,393,840	13,430,088	5,142,112	8,183,336	7,659,904	37,809,280
R6	2,653,456	14,204,656	5,062,320	8,192,048	12,227,992	42,340,472
R7	3,981,064	14,131,048	5,020,184	8,083,992	9,343,208	40,559,496
R8	3,735,376	13,035,096	5,012,224	7,921,296	11,764,176	41,468,168

A: Agents
R: Rules
EA: Expert Agent
TA: Translator Agent
AvA: Evaluator Agent
SA: Security Agent
SuA: Supervisor Agent

In Table 6, we calculate the average space memory of each agent.

TABLE VI
AVERAGE SPACE MEMORY OCCUPIED BY THE SYSTEM AGENTS

Agents \ Rules	Average space memory
Expert Agent	3,973,972
Translator Agent	13,153,389
Evaluator Agent	5,033,599
Security Agent	8,140,041
Supervisor Agent	9,653,631
Total	39,954,632

3) *Experiment 3: Supervisor agent performance*

Table 7 shows the response time required to regenerate an agent which breaks down in milliseconds. We launched several simulations and calculate the average response time at a detected fault. In what follows, we will explain the results obtained by the Expert agent: when the Expert agent is planted for the first time, the required period to resolve the problem is 1 ms, in the second time, the system took 3 ms in order to create it again. For the third and the fifth time, 2 ms are required to be active in the system. Concerning the fourth time, we observed 6 ms for starting. As a final result, we can estimate the average response time required to generate the Expert agent in the case of its failure (blockage or failure) to 2.8 ms.

TABLE VII
RESPONSE TIME EVALUATED IN CASE OF AGENT FAILURE

Agents \ Test	1	2	3	4	5	Average response time
Expert Agent	1	3	2	4	2	2.8
Evaluator Agent	2	1	5	10	1	3.8
Translator Agent	1	11	1	1	2	3.2
Security Agent	1	8	2	9	1	4.2

4) *Experiment 4: Communication between agents under JADE*

The JADE print screen will show the agents' communication as it appears in Fig. 12. In this work, Sniffer Agent provided by JADE was employed to monitor the communication among agents on the agent platform. After getting authenticated, the human expert accessed to the rules editor, and the system automatically generates an Expert agent. If the expert wants to introduce a new rule, so the Expert agent saves the rule that is introduced in its knowledge base. In what follow, we will explain each message which is exchanged between agents:

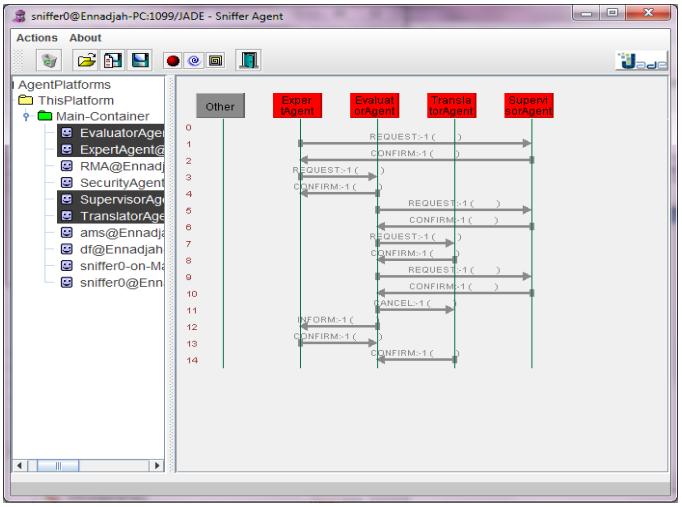

Fig. 12. Agents communicating with JADE platform.

Message 1 (Request): The Expert agent sends a request message to the Supervisor agent in order to ask whether the Evaluator agent exists or not.

Message 2 (Confirm): The Supervisor agent answers with a confirmation indicating the existence of Evaluator agent (if this later does not exist, the Supervisor agent will recreate it again).

Message 3 (Request): The Expert agent sends the rule that is introduced to the Evaluator agent.

Message 4 (Confirm): An acknowledgment of receipt is sent to the Expert agent once the Evaluator agent receives the rule.

Message 5 (Request): The Evaluator agent asks the Supervisor agent if the Translator agent exists.

Message 6 (Confirm): The Supervisor agent sends a confirmation in order to indicate that the Translator agent is ready to accomplish its tasks.

Message 7 (Request): The Evaluator agent accesses to the domain ontology for the first consistency check (verification of the validity, applicability and domain violation of the rule). At this stage, if there is no consistency problem then the Evaluator agent sends the net rule to the Translator agent for the technical translation and accesses to the rules base for the second step of the consistency checking (verify whether the rule is redundant or contradictory).

Message 8 (Confirm): Once the Translator agent receives the rule to translate, it responds with a confirmation message.

Message 9 (Request): The Evaluator agent sends a request asking the Supervisor agent whether the Translator and the Expert agents exist.

Message 10 (Confirm): The Supervisor agent confirm positively.

Message 11 (Cancel): The Evaluator agent sends a message to the Evaluator agent in order to stop the translation of this rule because it is inconsistent.

Message 12 (Inform): The Evaluator agent sends a message to the Expert agent to notify the human expert that the rule is inconsistent (here we take an example of a redundancy rule).

Message 13 (Confirm): The Expert agent sends a confirmation message to the Evaluator agent and displays the results on the rules editor.

Message 14 (Confirm): The Translator agent stops the translation and sends an acknowledgment of receipt to the Evaluator agent.

V. Conclusion

Distributed environments, artificial intelligence tools and collaborative technologies are factors that considerably influence our current research work.

This paper proposes a novel collaborative approach for business rules consistency management in a typical small and medium enterprise. The suggested approach is utilizing domain ontology within an agent-based architecture. Compared to other major business rules modeling approaches, our works aim to take well into account the organizational aspects as well as the security one in both rules level and agents level.

The modeling is based on agents to increase the execution speed of processes and effective response. In our system, all agents are autonomous and cognitive. They can aid experts and have the ability to explain their actions to other agents. Furthermore, they can adapt their actions to environmental changes.

The Expert agent can interact with human (expert) directly. Other agents communicate with each other to fulfill their common goal under the control of the Supervisor agent. In order to represent the business vocabulary used to express the rules, we propose using domain ontology as a formal model. On the one hand, the ontology gives the vocabulary used in expressing the rules and on the other hand, it provides a structured vocabulary that encodes relationships between concepts and supports checking for inconsistencies.

Our work is dedicated to the knowledge capitalization of industry experts. The knowledge management process involves two phases: first, the experts have an editor for entering their knowledge, all the update processing, and safeguard are insured. The consistency management of knowledge (rules) is also provided, and the case of redundancy, contradiction, invalid rules, domain violation and rules never applicable are investigated and verified by the system. According to the obtained result, we notice that our approach can detect all types of inconsistency except the equivalence problem. From the results of Table 1, we can say that our approach provides better results reports to the competing approaches, and it can detect almost any possible case of inconsistencies. Second, in the case of incoherent rule, a collaboration session is initiated between experts; this step can lead to a negotiation among participants. This model enables effective collaborative decision-making and also facilitates exchanges and knowledge sharing between the different actors in safety. Our collaborative system provides:

- An editor easy to use,
- It offers features that stimulate business users and developers to use it,
- Automate precise, highly variable decisions,
- Easy, safe and predictable rule management.

As a future work, we envisage to test and evaluate our prototype in other SME enterprises with a large number of rules and handle the problem of equivalence rules.

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Novel Agent Based-approach for Industrial Diagnosis: A Combined Use between Case-based Reasoning and Similarity Measures

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***Abstract* — In spunlace nonwovens industry, the maintenance task is very complex, it requires experts and operators collaboration. In this paper, we propose a new approach integrating an agent-based modelling with case-based reasoning that utilizes similarity measures and preferences module. The main purpose of our study is to compare and evaluate the most suitable similarity measure for our case. Furthermore, operators that are usually geographically dispersed, have to collaborate and negotiate to achieve mutual agreements, especially when their proposals (diagnosis) lead to a conflicting situation. The experimentation shows that the suggested agent-based approach is very interesting and efficient for operators and experts who collaborate in INOTIS enterprise.**

***Keywords* —Agent, Case-based Reasoning, Collaboration, Diagnosis, INOTIS, Similarity Measures.**

I. Introduction

In the industrial processes, the major failures that are related to machines' breakdowns have an impact on the production process, especially, when a corresponding diagnosis has been established on the right time. The anticipation of the failure at the beginning of its appearance can avoid dysfunctions and breakdowns.

The increasing complexity of automated industrial systems and competitiveness constraints in terms of production cost, availability, and safety of installations, have mobilized in recent years a large community of researchers to improve the monitoring and diagnosis of such processes. The diagnosis is a research theme addressed by several scientific communities (Automatic Computing, Industrial Engineering ...). It is nowadays the heart of industrial concerns [1].

Our research is oriented towards the nonwovens industry and «INOTIS» enterprise which is the candidate for our study. This enterprise was established in 2003, its major mission is to develop manufacture and sell world-class spunlace fabric for critical environments, where contaminated control and comfort of the use are of vital importance. This will be achieved through cost-effective production, consistency, and reliability. Besides, it provides a high level of both service and quality [2].

In fact, the market of nonwovens bonded by water jet (also called spunlace or hydroentanglement nonwovens) showed in the last years a considerable growth rate, which will also grow strongly in the future. These products are mainly used in the medical and hygienic field, but also the technical applications are being more and more important.

In spite of a very versatile range of applications, opportunities for growth exist in the market for hydroentangled (spunlaced) nonwovens, but they can only be continuously realized by the innovative introduction of products following the market's needs.

In [3], authors designed the first Collaborative Decision Support System «CDSS» to deal with complex decision problems that are related to spunlace nonwovens industry.

This system was based on a collaborative decision making process that exploits the represented knowledge in domain ontology and uses a case-based reasoning. CDSS proposed a collaborative platform that relies on Web 2.0 technologies and allowed operators, production managers, or experts to share and exchange experiences in industrial diagnosis such as machines 'breakdowns.

A. Major contribution

The aim of this study is to provide a multi agents system for solving industrial diagnostic problems. It encourages industrial nonwovens operators to collaborate and find solutions to their problems without resorting to the domain expert in a quick and efficient manner.

Our contribution deals mainly with two aspects:

1. We propose, an agent-based approach to provide a classification of the solutions given by the nonwoven operators in order to solve a new problem. Nonwovens operators don't only want to get solutions to their problems, but they also required the relevant solutions in the top positions of the list. We set up a method for ranking the solutions proposed by these operators using nonwovens domain ontology. This method is based on the information content of solutions and operators' preferences (vote), in which this later provides more relevant rankings.
2. We conduct a comparative study to choose a suitable similarity measure and improve the case-based reasoning results in order to measure the degree of similarity (or dissimilarity) between the target case and cases sources; our cases-base contains some cases of industrial diagnosis that have been registered since 2009 to INOTIS enterprise. These cases were recovered from meetings, and interviews after being filtered and reformulated.

B. Paper organization

This paper is organized as the following: In Section 2, we describe some related works. In Section 3, we present our approach: Firstly, we explain how we use case-based reasoning. We give a detailed description of the multi agents system. Then, we present the negotiation protocol. In section 4, we present a discussion of the obtained results. Finally, we conclude with some future works which are outlined in section 5.

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II. Background and Related Work

In this section, we analyze some works which are related to several approaches that integrate case-based reasoning and multi-agent system for industrial diagnosis. Through this study, we address the following summary.

A. Case-based reasoning systems

The case-based reasoning is the nearest of human reasoning. It provides the ability to make decisions in the way human beings take in the real time. The case-based reasoning allows reasoning on issues already resolved and stored in the cases-base. Past experiences are reused to solve new problems. The learning process is easier to be treated in the approach of case-based reasoning [4].

Another major advantage of this approach over other approaches of reasoning, is the value of the solution. In the adaptation phase, the proposed solution is revised and adapted to the problem constraints; this phase enhances the solutions and makes an effective case-based reasoning. The errors of the previous solutions do not propagate into future ones [5].

In [6], authors developed a cost model for the conceptual phases of Case Based Reasoning (CBR). This model used the concept of Euclidean distance for the similarity measure and Genetic Algorithms for the optimization of the weights of attributes.

In [7], authors used a cases-base for diagnosis and industrial maintenance using an ontology. Each CBR' phase is implemented by including the adaptation phase that uses decision rules. The authors used an ontology to characterize a case (problem) and the comparison between the cases was done by applying a weighted measure of similarity.

In [8], authors proposed an approach based on case-based reasoning (3R model) with a three phases cycle (Researching, Retrieving, and Retaining). They calculated the optimum weight of the attributes of each case automatically in order to extract the similar cases and deliver the final solution. They proposed a model for negotiation strategy to predict the behavior of the seller.

In order to evaluate the equipment maintenance support effectiveness, a conducted research was made by [9]. Their focus was basically structured on case-based reasoning. During this process, they used the representation and storage methods, where they analyzed the equipment maintenance case.

The work presented in [10], was focusing on the decision-making processes that are involved in maintenance. Authors proposed a knowledge operating approach, which is used in case-based reasoning system for the resolution of maintenance problems. This approach depended on the extension of the similarity measure on the basis of some case descriptors.

B. Multi-agent systems for industrial diagnosis

It is impossible to content with a centralized and rigid approach to design a diagnostic system. Distribute the diagnostic procedure seems obvious in this case. Consequently, the idea appears in order to multiply intelligent entities and to equip them with communication skills. These entities can communicate with each other and cooperate to build a solution for diagnosis problem. Multi-agent system is adapted to this problematic. In fact, the agent contributes to solve a problem. It communicates with several agents in order to emerge towards a comprehensive solution. Multi-agent approach makes the solution implementation possible same as a human organization. The first advantage to use this paradigm is to lead modular systems where adding an agent or modifying the structure of a system does not induce a Re-design of a solution, but converges automatically to a new comprehensive solution. The second advantage is to decompose complex problems to some elementary problems and create capable entities to solve them by cooperating [1].

Three phase induction motors were presented by [11] in order to improve and identify faults by means of a multi-agents system.

In the future, distribution and complexity of processes must be handled by the fault diagnosis systems. Authors in [12] described the fault detection and isolation (FDI) agents, where the reactive layer was fundamentally structured on the decomposition wavelet methods.

Much attention has been given to designing the process in [13] a framework. They masterfully presented an essential element of mechanism design for a multi-agent system.

In [1] authors provided an multi-agent system for the collective diagnosis of complex systems using the technique of logical diagnosis based on consistency with a particular interest in the distribution of diagnostic analysis stage.

Multi-agent systems can be used in several domains. We cite below someone.

The study presented in [14] deals with an automated multi-agent negotiation framework in order to elaborate decision making in the construction domain. The proposed framework was composed of negotiation algorithm, negotiation style, negotiation protocol, and solution generators that were integrated into agent architecture. Furthermore, negotiation base and the conflict resolution algorithm, were blended within the environment in order to facilitate the negotiation process. The proposed architecture enabled software agents to conduct negotiations and autonomously make decisions.

Authors presented in their work a model that is based on multi-agent system active between the user and grid client as Globus Resource Allocation Manager (GRAM). They displayed a designing scheduler process by using multi-agent systems. To achieve their goal, they used the hidden Markov models for the matchmaker process and Telecom Italia Lab approach for developing their system [15].

In [16], authors was interested in the integration of web service. They presented storage solutions which were based on a dynamic partial replication and they proposed a distributed architecture by using some agents in order to stand for this mechanism.

III. Methodology

In this section, we present the main aspect of our contribution.

A. Case-based reasoning

To solve the problems of the nonwovens industry, we utilize previous situations which were stored in the cases-base. To cope with new problems, we already used solved past problems that have a large degree of similarity comparing to current situations (new problems). We give more details in the following subsections as shown in Fig. 1.

1) Cases-base

To perform any inference task, reasoning engine requires knowledge of the target area. In the case-based reasoning system, this knowledge is taken from the cases-base.

Our CBR system starts reasoning from a number of cases. These cases cover the target area very well consequently, interesting solutions are returned. We have recovered industrial diagnosis cases from Pv (s) and annual interviews of INOTIS company.

2) Indexing case

Case-based reasoning system is interesting only if it has a significant cases-base, we obviously considered indexing event cases as a solution

to find similar cases quickly.

There are many ways to order cases, we opted for indexing by keywords which are using a textual representation for the case description.

Cases are indexed and ranked in the cases-base according to the keywords that are given in their description. Thus, the keywords contained in the event table are used to locate the corresponding event.

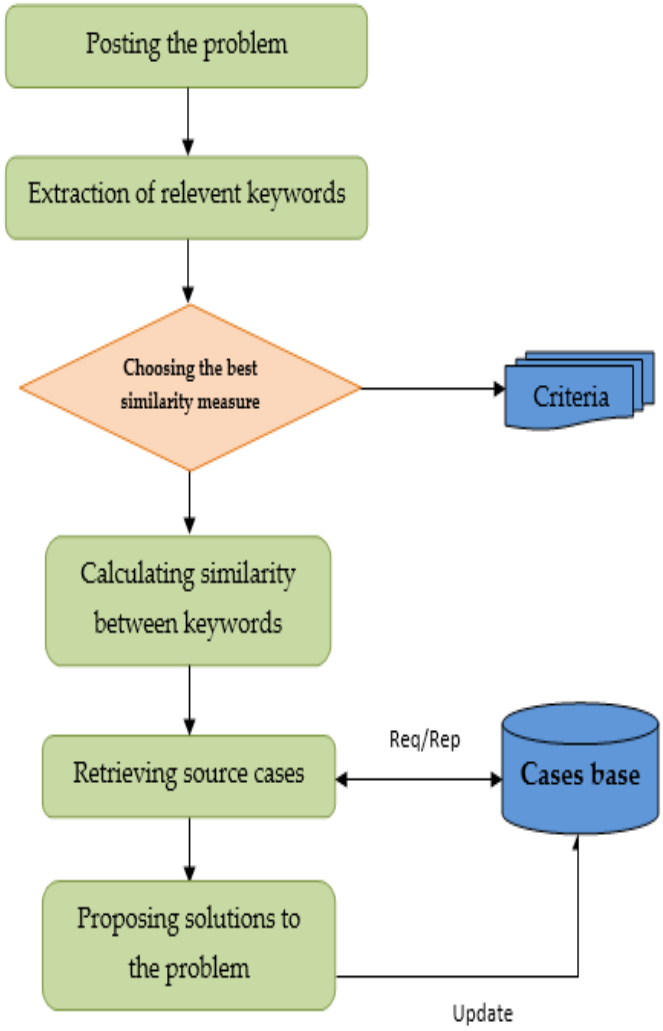

Fig. 1. Researching solutions using CBR system.

3) Case-based reasoning process

The case-based reasoning aims to solve new problems by comparing them to source cases that are recorded in the cases-base. In our work, we use 3R model represented in three (3) main phases (Representing, Reusing, and Retaining). These phases can be described as the following.

1. Representing a new problem (target case): That allows acquisition of any relevant information that describes the new problem (relevant words). This phase gives the system an initial description. It includes: structuring, modeling, and case representation. This latter is presented in a similar manner to a source case.
2. Reusing cases (sources): Corresponds to search for the most similar cases. This phase maps the descriptors source cases with descriptors of the target case. We use the technique of calculating the degree of matching descriptors (similarity between both cases) to achieve this objective. We justify a used similarity measure in the comparative study.
3. Retaining case: In this step, the target case is added to the cases-base which cases-base is synthesized, and amended where arguably the system can learn new skills.

B. Multi agent system

We propose a multi-agent system which is composed of four (4) agents, in which each one has a specific role as shown in Fig. 2.

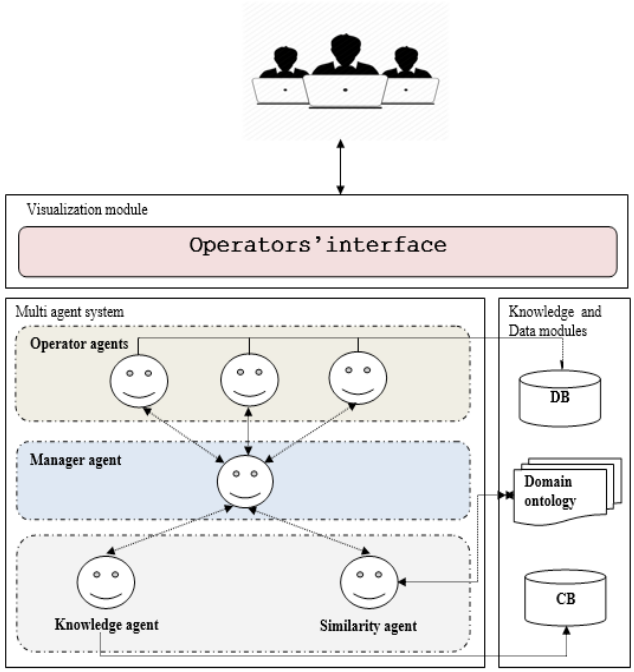

Fig. 2. Our multi agent system.

1) Agents

Below, we describe each agent and its aim.

1. Operator agent: This agent is created when operator connects to the platform. It analyzes and decomposes the operator's message (Problem and / or solution) into a set of relevant words (see Fig. 3). It scores the solutions according to its preferences introduced through the preferences module. Operator agent retrieves and recommends some solutions to the operators.

Algorithm 1: Extracting relevant elements (↓Pbm, ↓Keywords, ↑List_MP)

String Txt; List Words;

Begin

Txt	←	Elimination of stop words (Pbm)
Words	←	Searching_synonymes (Words);
Words	←	Elimination words of very high occurrence (Words);
List_MP	←	Words + Keywords;

End

Fig. 3. Extracting relevant elements algorithm.

2. Manager agent: In addition to managing agents, it prompts similarity agent to pre-order the list of proposals (solutions). Then, it invites operator agents to vote. The operator should score solutions before the deadline and the best mark of solution is 10/10 (criteria). After that, it diffuses subsequently an ordered list of solutions. The vote is detailed in Fig. 4.

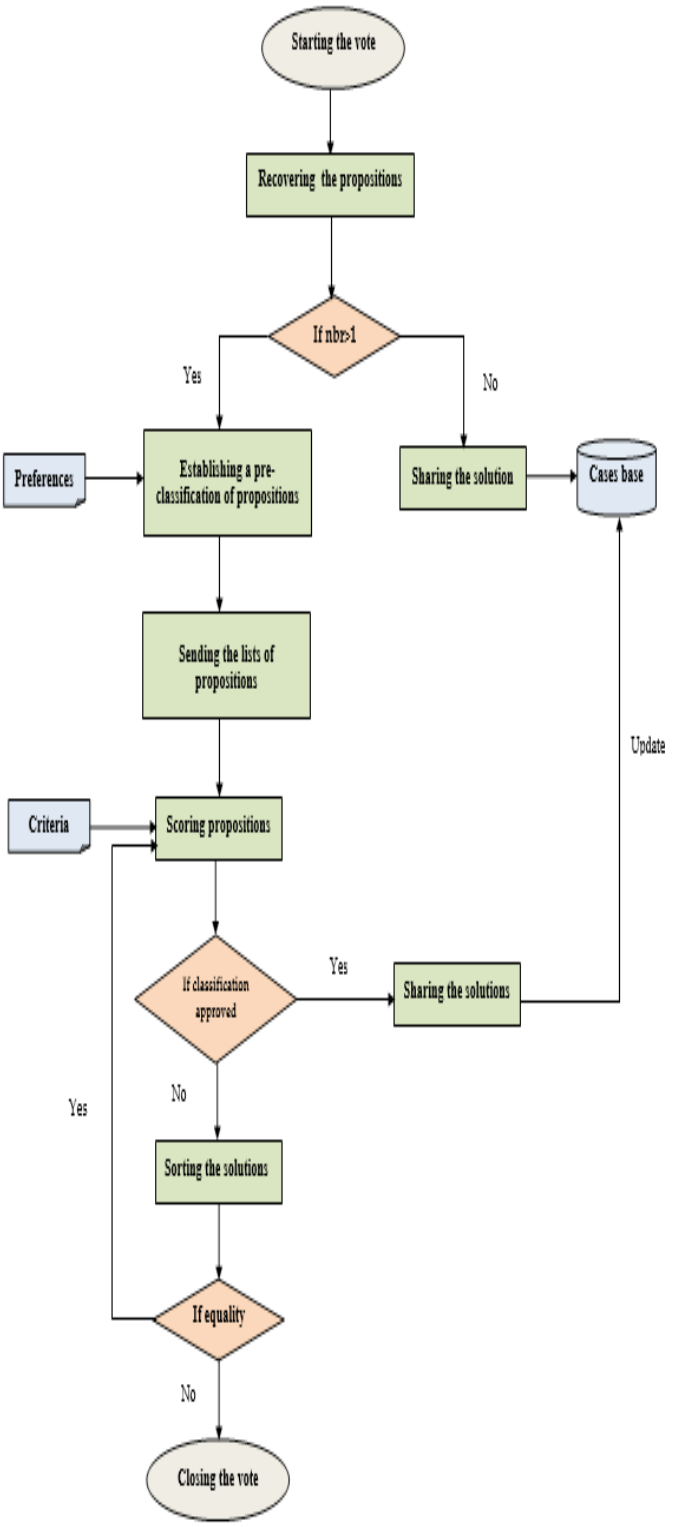

Fig. 4. Steps of the vote.

3. Similarity agent: it has two main functions: First, it compares between target case and source cases using a similarity measure. Second, it orders the list of proposals sent by the manager agent. This order is carried out according to the information content of the proposals.
4. Knowledge agent: It retrieves the similarity results calculated by the similarity agent and recovers solutions from CB (see Fig. 5), then it updates the cases-base.

Algorithm 2: Finding Solutions (↓ Case, ↓List_MP, ↑List_solutions)

```
float Val ← 0;

Begin
For (int i = 0, i < CB.size(), i ++) do
Val ← similarity (Case, Case[i]);
If (Val> = 0.5) then
List_solutions ← Solution [i];
End if
End do
End
```

Fig. 5. Finding solutions algorithm.

2) *Interaction between agents*

The agents act by groups, and they are characterized by the sharing tasks. This collaboration requires their interaction.

An agent (operator, similarity or knowledge) sends a message in two cases: When receiving a message from another agent (data reception required to process), during the execution of an action.

In addition, the manager agent sends messages when it starts voting.

Table 1 shows the types of messages exchanged between agents.

TABLE I
EXCHANGED MESSAGES BETWEEN AGENTS

Action	Sender	Receiver	Content
Inform	Operator agent	Manager agent	Life message
Request	Manager agent	Similarity agent, Knowledge, operator agent	Preorder list of solution, update CB, need solution
Propose	Manager agent	Operator agent	Scoring solutions
Confirm	Manager agent	Operator agent	Final list of solutions

C. *Negotiation protocol*

The proposed negotiation protocol is characterized by a succession of messages exchanged among the agents; it is divided into three important phases:

1. Distribution of the problem: it is the first phase of our negotiation protocol, it initiates the negotiation. The message is sent by the manager to all operator agents that are considered to be able to carry out the task. Operator agents propose solutions and after that, they send them to the manager.
2. The conversation phase: it is the second phase, where the manager agent requests similarity agent to establish a pre-ordered list of propositions. This pre-order is realized with similarity measure. Similarity agent calculates information content of each proposition based on domain ontology. Then, the manager agent shares the list of solutions with the operator agents. According to operator agents' preferences, they establish a score and attribute it to each proposition and return the list to the manager agent.
3. Final decision: It is the third and the final phase where the manager agent gathers all its received scores and organizes the final list of solutions. If two solutions are equals, it invites operator agents to vote with a restricted list of solutions.

The agent's strategies are defined in the sequence diagram shown in Fig. 6.

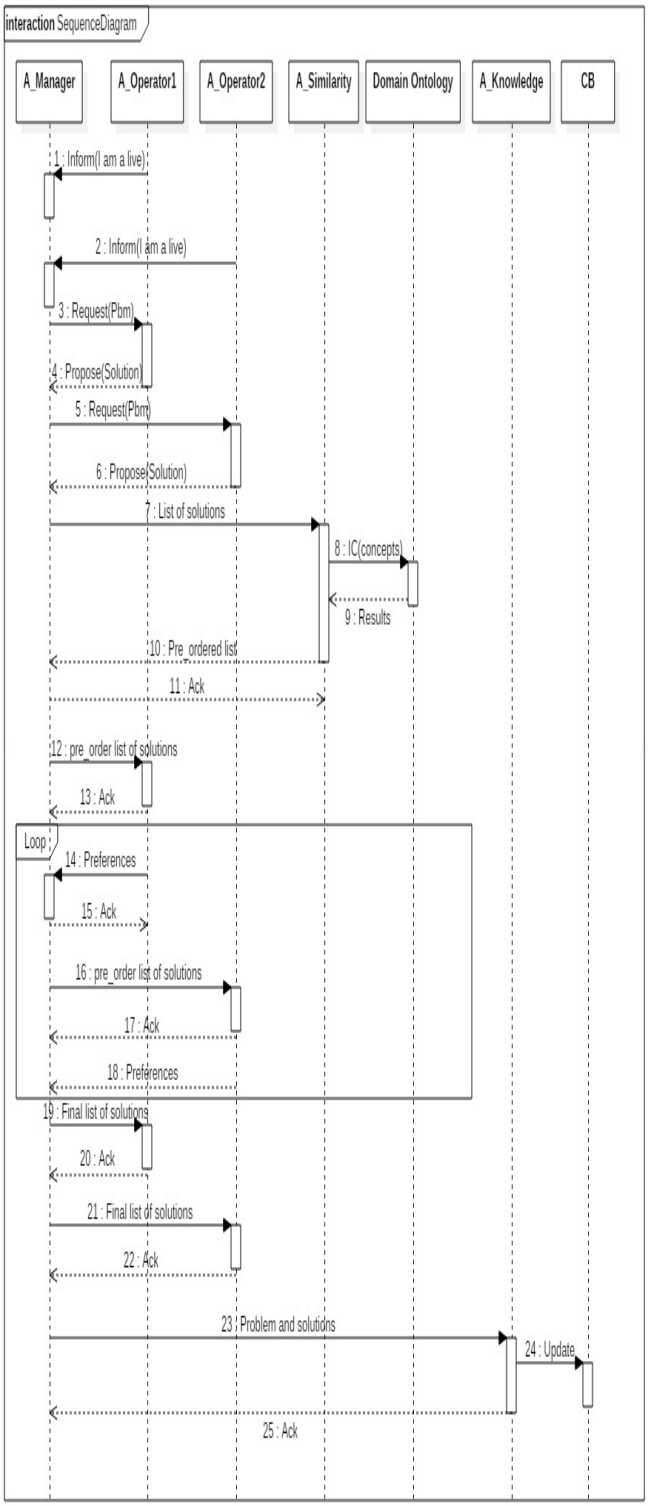

Fig. 6. Time sequence of the multi-agent process with AUML.

1) Negotiation cardinality

Our protocol is based on the exchange of messages between a manager and several operators, so it allows negotiations from 1 to n. We allow the simultaneous filing solutions of several problems. Otherwise, many manager agents can simultaneously propose a vote to operator agents, it is therefore negotiating n to m agents, more accurately n simultaneous negotiations 1 to m agents.

2) Default response time

During negotiations, operator might not respond to the manager proposal because he is absent, or a fault has occurred.

It is necessary to continue, for that reason an answer waiting time mechanism is in place, and when that time is up, the manager considers a default response for the operator. This default response will be the average scores provided by the rest of operators. In fact, waiting time is limited to 60 minutes.

3) Number of responses needed for ranking solutions

In order to classify the solutions, the manager need all operators 'responses. When the operators don't reply, the manager takes the average score, for each solution as a default response.

4) Scenario 1 (without conflict)

Here, we present a concrete example to illustrate the operation of the vote. The operators 'notes are between 1 and 10 which is considered as the best possible rating for a solution. The solutions ranking is therefore obtained from taking solutions in descending order from the highest rating to the lowest.

In this example, four solutions are presented: S1 to S4, the manager agent invites three operators to vote, namely O1, O2 and O3. It sends the solutions list to similarity agent. This latter establishes a ranking of solutions by giving a score to each one.

The following table shows respective solutions 'notes for each operator and the order established by the similarity agent.

TABLE II
SOLUTION'S SCORE GIVEN BY SEVERAL AGENTS

Solution	Similarity agent	O1	O2	O3
S1	10	8	1	10
S2	8	10	7	8
S3	5	9	10	2
S4	2	3	9	5

From Table 2, the order that is given by the similarity agent is {S1, S2, S3, S4}, this order is based on similarity measure. First, operator 1 classifies the solutions in this way {S2, S3, S1, S4}. Second, operator 2 prefers this one {S3, S4, S2, S1}. Finally, operator 3 gives the following order: {S1, S2, S4, S3}.

After the vote, the manager agent calculates the score of each solution according to the following formula:

$$Score(S_i) = \sum_{j=0}^{n} note_j \quad (1)$$

Where **n** is the number of participants in the vote (operators and the similarity agent) the similarity agent intervenes only during the first round of the vote.

i is the solution on which participants must vote.

$\mathbf{note}_j$ Is the score given by each participant.

Score (S1) = 10 + 8 + 1+ 10 = 29

Score (S2) = 8 + 10 + 7 + 8 = 33

Score (S3) = 5 + 9 + 10 + 2 = 26

Score (S4) = 2 + 3 + 9 + 5 = 19

After voting, the manager agent notifies the other agents with the following list of solutions: {S2, S1, S3, S4}.

To be more precise, the significance of the obtained solutions is

given in Table 3.

TABLE III
SOLUTIONS COLLECTED FROM OPERATORS

Number	Solution
S1	Change the bladder
S2	Check the communication and power part
S3	Drain the strainer
S4	Measure the PH of process water

5) Scenario 2 (with conflict)

Let us consider now the case of equal solutions. Here, the manager agent starts for the second time the vote only between operators. The results are described in Table 4.

TABLE IV
PRIORITY OF SOLUTION GIVEN BY SEVERAL AGENTS

Solution	Similarity agent	O1	O2	O3
S1	10	8	1	10
S2	8	10	7	8
S3	6	9	10	4
S4	2	3	9	5

Score (S1) = 10 + 8 + 1+ 10 = 29

Score (S2) = 8 + 10 + 7 + 8 = 33

Score (S3) = 5 + 9 + 10 + 2 = 29

Score (S4) = 2 + 3 + 9 + 5 = 19

S1 and S3 are equal since both of them have the same score (= 29). The manager agent restarts again the vote between operators for S1 and S3. The corresponding results are shown in Table 5.

TABLE V
PRIORITY OF SOLUTION GIVEN BY SEVERAL AGENTS

Solution	O1	O2	O3
S1	9	10	7
S3	8	6	10

Score (S1) = 9 + 10 + 7 = 26

Score (S3) = 8 + 6 + 10 = 24

The final ranking of solutions becomes: {S2, S1, S3, and S4}.

1. Checking the communication and power part,
2. Changing the bladder,
3. Draining the strainer,
4. Measuring the PH of process water.

This scoring formula takes into account the preferences of each operator and the similarity agent proposal for each suggested solution.

IV. RESULTS AND DISCUSSION

A. Comparison between semantic similarity measures

Below, we propose a comparative study between three (3) semantic similarity measures [17], [18], and [19]. To retrieve similar cases in a cases-base, we focus on some keywords that are specific to nonwovens domain.

Thus, the dispersion of the analysis is reduced. This approach is primarily depending on the ontology that we have developed. To determine the best similarity measure, we conducted a comparative study between the semantic similarity measures specifically semantic measures based on taxonomic distance.

We took a sample of twenty (20) cases most representative sources cases from CB (Cases-Base) including eight (8) relevant cases and eleven (11) irrelevant. Knowing that a relevant case is a matter of couple and a single solution provided from experts; an irrelevant case is a couple of problem and some solutions, Fig.7 shows that sample. To better explain this comparative study, we took an example for each measure. According to several experiments, we concluded that the suitable similarity threshold in this study is 0.5, a threshold higher than 0.5 will give the same solutions for each problem (shown in Table 6).

TABLE VI
CASES CHOSEN TO ILLUSTRATE THE EXPERIENCE

-	Id	Problem	Keywords
Source case	6	Nitrogen gas leak	Pompe_HP, HP2, Vessie
Target case	21	lubricating oil leak	HP4, Pompe_ HP

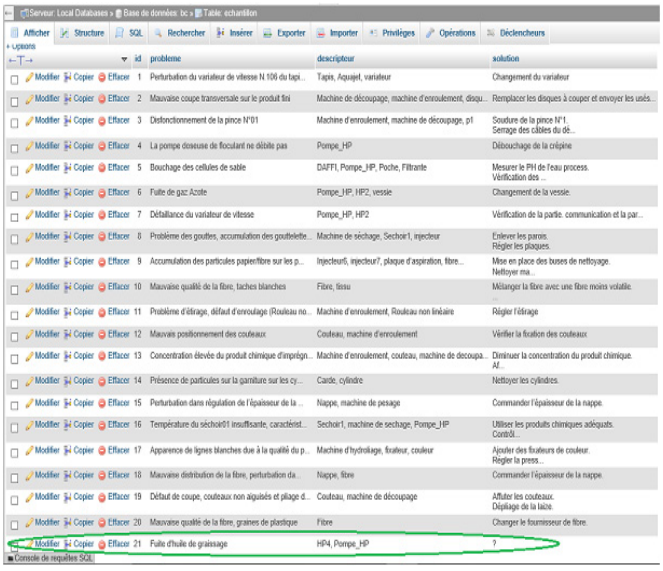

Fig. 7. Sample of source cases.

To compare the relevance of the measures, we rely on the relevance of the following indicators.

Precision: is the fraction of retrieved instances that are relevant; it measures the system's ability to reject irrelevant solutions.

Recall: which calculates the ratio of relevant results existed in relation to relevant results not existed; it measures the system's ability to provide all relevant solutions.

The F-measure: is used for combining and weighing the two indicators accuracy and recall. It measures the system's ability to provide all relevant solutions and reject others.

1) Example according to [17]

Table 7 shows the results obtained during calculations of similarity between keywords, the similarity threshold is fixed at 0, 5. The similarity is between [0, 1], we take values which are greater than (or equal) to 0.5. Rada measure is presented in equation 2. It uses a metric dist (c1, c2), which indicates the minimum number of arcs between concept 1 and concept 2 in the domain ontology.

TABLE VII
SIMILARITY BETWEEN KEYWORDS

Keyword/ Keyword	Pompe_HP	HP2	Vessie
HP4	0,5	0,33	**0,25**

$$Sim_{Rada}(c1,c2) = 1/1 + dist(c1,c2) \quad (2)$$

dist (Vessie;HP4) = 3

Sim_{Rada} (Vessie; HP4) = 1 / 1 + dist (V essie;HP4) = **0,25**.

The proposed solutions to the problem of lubricating oil leaking are:

1. Draining the strainer,
2. Measuring the PH of water process, checking the dosing pumps chemicals, checking the ADT system, putting the system in manual mode, making the cons cell washing, changing the filter bags of 05 microns. Table 8 presents evaluation results of Rada measure.

TABLE VIII
DETAILED EVALUATION OF [17] MEASURE ACCORDING TO PRECISION (P), RECALL (R) AND F-MEASURE (F)

Precision	Recall	F-measure
50%	12,5%	20%

2) Example according to [18]

Table 9 shows the results obtained during calculations of similarity between keywords. Wu measure is presented in equation 3, where N1 represents number of arcs between concept1 and generalizing concept, N2 is number of arcs between concept2 and generalizing concept, N3 is number of arcs between generalizing concept and the root in the domain ontology.

TABLE IX
SIMILARITY BETWEEN KEYWORDS

Keyword/ Keyword	Pompe_HP	HP2	Vessie
HP4	0,67	0,80	**0,54**

$$Sim_{w\&p}(c1,c2) = 2 * N3/N1 + N2 + (2 * N3) \quad (3)$$

N1 (Vessie, Pompe_HP) = 2

N2 (HP4, Pompe_HP) = 2

N3 (Pompe_HP) = 4

$Sim_{W\&P}$ (Vessie; HP4) = (2 * 4) / (1 + 2 + 2*4) = **0, 54.**

The solutions (ordered by number of keywords which contain) to the problem of lubricating oil leaking are:

1. Changing the bladder,
2. Checking the communication and power part,
3. Draining the strainer,
4. Measuring the PH of process water; checking the dosing pumps chemicals; checking the ADT system; putting the system in manual mode; making the cons cell washing; changing the filter bags of 05 microns.

We get the results shown in Table 10.

TABLE X
DETAILED EVALUATION OF [18] MEASURE ACCORDING TO PRECISION (P), RECALL (R) AND F-MEASURE (F)

Precision	Recall	F-measure
50%	25%	33,33%

3) Example according to [19]

The results presented below are not affected by the variation of similarity threshold. The value obtained by [19] as a given concept is relative to domain ontology. Seco measure is presented in equation 4 where hypo(c) represents the number of hyponym concepts, maxwn indicates the number of concepts of the domain ontology (shown in Table 11).

TABLE XI
SIMILARITY BETWEEN KEYWORDS

Keyword	Pompe_HP	HP2	Vessie	HP4
Value	0,331	0,294	**0,262**	0,294

$$Sim_{Seco} = 1 - (\log(hypo(c) + 1) / \log(\max_{w}) \quad (4)$$

$Max_{ontology}$ = 200

Hypo (Vessie) = 6

Sim_{Seco} = **0,262**

The solutions to lubricating oil leaking are:

1. Changing the bladder.
2. Checking the communication and power part.
3. Draining the strainer.
4. Measuring the PH of process water; checking the dosing pumps chemicals; checking the ADT system; putting the system in manual mode; making the cons cell washing; changing the filter bags of 05 microns.

Table 12 shows the evaluation results of Seco measure.

TABLE XII
DETAILED EVALUATION OF [19] MEASURE ACCORDING TO PRECISION (P), RECALL (R) AND F-MEASURE (F)

Precision	Recall	F-measure
50%	25%	33,33%

In the graph below (Fig.8), the three lines may represent the performance of different measures. When the curve is high, this demonstrates that the concentration of relevant solutions is important. Wu measure and Seco are winner of this comparison, at least until the recall rate of 25%. Measuring Rada is well below Wu and Seco. This study was conducted on a set of event sources including 8 relevant and 12 irrelevant solutions.

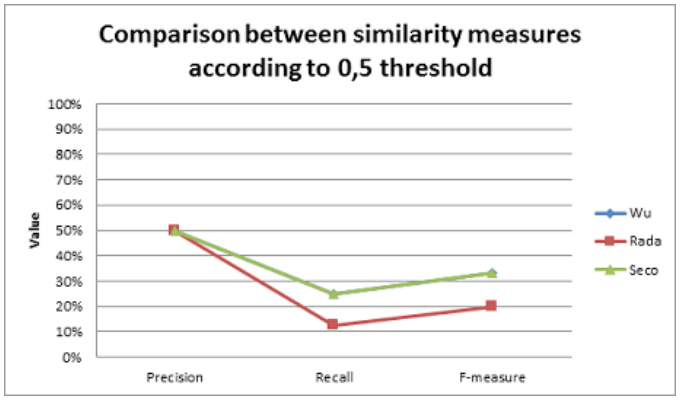

Fig. 8. Comparison results between semantic similarity measures.

Fig.9 shows number of retrieved solutions for each semantic measure. We can see that Wu and Seco retrieve same number of solutions (25% relevant solutions and about 17% irrelevant solutions), Rada et al has about 13% relevant solutions and 9% irrelevant ones from the cases-base.

TABLE XIII
COMPARISON WITH OTHER INDUSTRIAL SYSTEMS [1]

Reference	[20]	[21]	[22]	[1]	Our system
Year	2003	2002	2009	xxxx	2016
Distinction between detection and analysis steps	Yes	Yes	No	Yes	No
Detection step	Distributed	Distributed	-	Distributed	-
Analysis step	Centralized	Distributed	-	Distributed	Centralized
Cooperation between agents for collective decision making	No	No	Yes	Yes	Yes
Application domain	Industrial	Industrial	Medical	Industrial and medical	Industrial

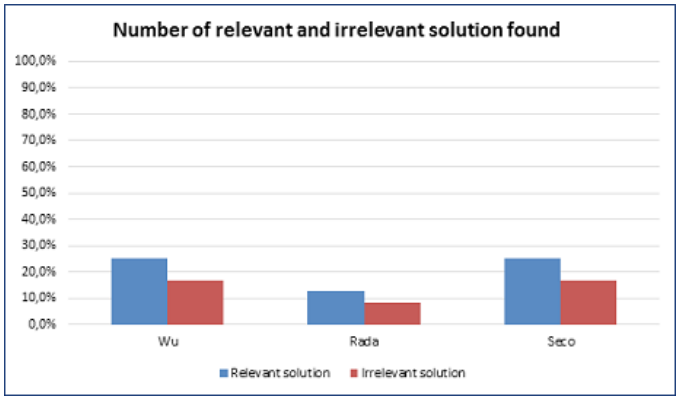

Fig. 9. Number of relevant and irrelevant solution found by each measure.

B. Comparison with other diagnosis systems

There are several studies that use multi-agent systems in order to solve the diagnosis problem in several domains.

We compare our system with four (4) other systems dedicated to the diagnostic task: MAGIC (Multi-Agent-based Diagnostic Data Acquisition and Management in Complex Systems) [20] DIAMOND (Distributed Architecture for MONitoring and Diagnosis) [21], CMDS (Contract Net based Medical Diagnosis System) [22] and [1] based on the criteria listed below.

Distinction between detection and analysis steps: [20], [21] systems distinguish between detection step and analysis step for that they combine two different types of agents, [22] the system doesn't distinct between these two steps. As the [20] system [1] distinguish between the detection and analysis steps. Our system does not differentiate between these two steps of diagnosis.

The detection step is distributed on dedicated agents called diagnostic agents in MAGIC and control agents in DIAMOND. It is also distributed in the system proposed by Allem where various agents are called detection agents. Our system does not detect defects on the production process.

The analysis step: in MAGIC location is centralized in the diagnostic decision making agent while in DIAMOND is distributed on various diagnostic agents. In [1], it is also distributed on different analysis agents. In our system the task is supported by the operator agents then transmitted to the manager agent.

Cooperation between agents for collective decision making: MAGIC in decision making is performed by a single agent while in DIAMOND. It is distributed over several diagnostic agents. However, there is a real cooperation for the diagnosis overall. CMDS system describes a cooperative problem resolution by medical agents. In [1], analysis agent interacts with other agents of the same type to calculate a cooperative manner in its own local diagnosis. Our problem solving system is shared between the operator agent, manager agent, similarity agent and knowledge agent.

Scope of application: MAGIC and DIAMOND systems are dedicated to the industrial diagnostic, CMDS is specialized into medical diagnosis. In [1], system can be used in the both. Our system is dedicated only to the industrial domain.

After identifying the problem, nonwovens operators can use the developed CDSS [3] in order to find some solutions to their problem in two several ways. First, throughout case based reasoning, it compares the target case to source cases based on similarity measure. Second, it invites operators to collaborate together and solve their problem. Our system requires negotiation strategy when operators have a conflict situation. All agents cooperate for a final decision making.

In comparison with other works that were previously mentioned, the system that we proposed is mainly based on a new collaborative decision-making process. Our objective is to involve operators, experts, and managers who are working in the field of nonwoven industry in the whole process.

Here, collaboration is done in two phases: the first is used to generate solutions to the various problems that are posted by the operators. The second is related to the negotiation of some operators with others or with the experts for the classification of solutions taking into account the operators preferences for the final vote.

In our system, the operator is at the center of reflections on the future of the company. We give him a great deal of participation in decision making. The senior managers of INOTIS enterprise rely on the group's decision and not on personal positions.

The case-based reasoning used in our system is structured on the knowledge represented in ontological form. The domain ontology exploited solutions during the search phase which is dedicated to the field of nonwovens. It is created, tested, and validated by domain experts.

So, our system provides a space for collaboration and knowledge capitalization tool.

C. System complexity

Here, we present a theoretical complexity which is calculated based on the messages exchanged in our negotiation protocol. We don't take into consideration the kind of platform and the living messages that are exchanged by the operator agents. However, we rely on the other messages of vote.

Complexity is an important feature for negotiation. We consider the complexity in number of messages induced by our protocol.

In the worst case, the number of messages can be $O(m)^n$ where

n is the depth of the cascade process and m is the number of agents involved in the negotiation.

Suppose m agents are involved in the negotiations (1 manager agent, 1 agent similarity, 1 Knowledge agent, and m - 3 operators).We should take into consideration that there is no equality between the solutions.

The manager provides a list of solutions in which nonwovens operator scores each solution. After that, the manager diffuses the ordered list of solutions: 3 * (m - 3) + 2 messages are exchanged, including one message to recover the pre-ordered list and another to update CB by knowledge agent.

Once there is a gender solution, the manager asked for another vote to operators who turn solutions' scores. 2 * (m - 3) messages are exchanged. The manager sends a final list of solutions, which adds 3 * (m - 3) messages.

A total of 5 * (m-1) + 2 messages are exchanged, taking account of the first proposal of the manager and the operators responses where at least one is negative. The manager sends 3 * (m - 3) + 2 messages and receives 2 * (m - 3) + 1. Each operator receives three (3) messages and sends two (2).

Ordered solutions, with or without equal solutions, has an overall complexity of O (m), straight to the manager and O (1) for operators.

D. Agents' performances

Although an agent is defined as an autonomous capable entity of acting alone, it is consider as a program that can at any time bug. To address this situation, we save agents states (operator agent, manager agent, similarity agent, and knowledge agent). Each agent is able to recover its saved state.

The agent manager represents the most important agent in our system. It executes many instructions and has a long run time.

V. Conclusion and Future Works

The work presented in this paper is a real contribution to the problems resolution of diagnosis in nonwovens industry.

In fact, diagnosis system is the method which determines whether the industrial system is affected by any defect and discriminates the cause of the fault.

Aiming to build a system that provides solutions to industrial problems, we opted for a case-based reasoning (CBR). It is proposed as an alternative to use reasoning rules, costly in terms of learning. More generally, we found a distinction between two motivations for CBR system: first, analogic heuristic, which is chosen for its effectiveness (in terms of computation time, etc.). Secondly, heuristic which is interested in the outcome of reasoning rather than the effectiveness of the reasoning.

During this work, we tried to combine the two approaches to benefit from the speed calculations with multi- agent system on one side and also to the quality of solutions that are based on the similarity measure of [18]. All this work will provide some answers as quickly as possible to the nonwovens operators who are often impatient to finalize their diagnostic problems. Besides, our system aims to classify the provided solutions by its operators through a trading strategy including both operators 'preferences (preferences module), and the information content of solutions.

The results presented in this paper provide the basis for future research in several areas. Firstly, when CBR systems are applied to real-world problems as it is for us (nonwovens industry), retrieved solutions can rarely be directly used as adequate solutions for each new problem. Retrieved solutions, in general, require adaptations in order to be applied to new contexts.

Secondly, one future direction of our work is to develop and extend the model of agents allowing them to change their goals. For this reason, we aim to develop an argumentation based strategy of negotiation, which will be more flexible than the voting method but it requires a greater reasoning mechanism that is incorporated in the agents.

Thirdly, it will be very interesting to test our system in other nonwovens company located in Algeria in order to obtain a feedback on the usability of the developed CDSS.

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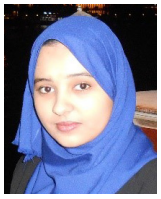

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Intelligent e-Learning Systems: An Educational Paradigm Shift

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***Abstract* — Learning is the long process of transforming information as well as experience into knowledge, skills, attitude and behaviors. To make up the wide gap between the demand of increasing higher education and comparatively limited resources, more and more educational institutes are looking into instructional technology. Use of online resources not only reduces the cost of education but also meet the needs of society. Intelligent e-learning has become one of the important channels to reach out to students exceeding geographic boundaries. Besides this, the characteristics of e-learning have complicated the process of education, and have brought challenges to both instructors and students. This paper will focus on the discussion of different discipline of intelligent e-learning like scaffolding based e-learning, personalized e-learning, confidence based e-learning, intelligent tutoring system, etc. to illuminate the educational paradigm shift in intelligent e-learning system.**

***Keywords* — Confidence Based e-Learning, Intelligent e-learning system, Intelligent Tutoring System, Personalized e-Learning, Scaffolding based e-Learning, Technology Enhanced Learning and Educational paradigm shift.**

I. Introduction

E-LEARNING is the computer and network-enabled transfer of skills and knowledge. Application of e-learning includes computer-based learning, web-based learning, virtual education opportunities etc. Content is provided via the Internet, audio or video tape and CD-ROM etc. It can be self-paced or instructor-led and it also includes various media in the form of text, image, audio, video, animation etc. It is learner centric learning mechanism irrespective of time and distance.

The Contemporary scenario of education and training is undergoing a paradigm shift under the impact of information and communication technology. The widespread uses of computers and access to the Internet have created many opportunities for online education, including improved distance-learning and classroom support. Intelligent Tutoring Systems (ITS) extend traditional computerized content-delivery learning systems by incorporating intelligence to improve the quality of a learner's experience resulting in better achievement of learning objectives. This normally involves personalized tutoring, using factors such as learner's knowledge, emotion or learning style to alter the sequence and style of learning material.

Besides this, in conventional/classical contact mode teaching-learning process, a teacher has plenty of opportunities to facilitate a student as per his or her level of understanding. Along with this a teacher can modulate his/her training procedure according to the various responses obtained from the learners. E-learning, under normal circumstances, cannot provide a learner the privilege of teacher's timely intervention as and when a learner requires. Human tutors have the wisdom of tuning the teaching strategy to harmonize with the student's learning style and need [22]. But the facilities are hardly present in the case of e-learning environment. Therefore in an e-learning environment, the learner faces the additional challenge of retaining learning interest in the absence of a teacher and his encouragement as well as personal care.

To face these types of challenge lot of innovative methods of in e-learning have been introduced among which a major part is based on intelligent e-learning. These types of e-Learning technology help to bridge the gap and reduce the social restrictions and facilitate a learner in many ways to achieve his objective of learning a particular subject.

In this paper the paradigm shift in intelligent e-learning has been discussed. Few areas like 'Scaffolding Based e-Learning', 'Personalized e-Learning', 'Confidence Based e-Learning', 'Intelligent Tutoring System' and 'Technology Enhanced Learning are shortly discussed with recent research activates on those fields. Several works on the said area has been discussed with their limitation and motivation. The main focus of this paper is to enlighten the educational paradigm shift of intelligent e-learning system.

Rest of the paper is organized as follows. Section 2 (Some Popular Techniques Of E-Learning) that describe some common method like scaffolding based e-learning, personalized e-learning, confidence based e-learning, etc. to elaborate the paradigm shift of intelligent e-learning. Section 3 describes a comparative study on some recent research work on intelligent e-learning. Section 4 provides conclusion.

II. Some Popular Techniques of E-Learning

In this section some popular techniques, like scaffolding based e-learning, personalized e-learning, confidence based e-learning, intelligent tutoring system, and technology enhanced learning have been discussed in short with a few related works.

A. Scaffolding based E-Learning

The Scaffolding based E-Learning strategy provides individualized support based on the learner's zone of proximal development (ZPD). When using the scaffolding based e-learning strategy the goal of the learner is actually to become an independent and self-regulating learner and problem solver. Learners are guided and supported through learning activities that serve as interactive bridge to get them to the next level. Thus the learner develops or constructs new understandings by elaborating on their prior knowledge through the support provided by more capable instructors. The learner does not passively receive the information presented instead learner builds on prior knowledge and forms new knowledge with the help of teacher's prompting. Another advantage of scaffolding based e-learning is that it motivates the student so that they want to learn. Beside this it can minimize the level of frustration of the learner.

However, it is different to implement scaffolding based e-learning irrespective of any subject specially which are related to arts and literature. In the year 2014, Pratama and others [26] proposed a report

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on Scaffolding based e-learning domain. According to this report, there was a solution to solve non-stationary classification problems. A Generic-Classifier (g-Class), which is a kind of novel meta-cognitive-based scaffolding classifier, is proposed to solve this problem. Meta-cognitive learning not only focused on how-to-learn but also on what-to-learn and when-to-learn. Generic-Classifier is able to provide an encouraging numerical value which can maintain a balance between predictive accuracy and classifier's complexity. Ghazi and others [15] proposed a report on the effectiveness of Cognitive and Meta-cognitive Strategies on learning system in the year 2013. The objective was to identify the effect of cognitive and meta-cognitive strategies on learning system, which can be either self-regulated learning system or formal learning system. Some tools or techniques were used in this research work, i.e. Motivated Strategies for Learning Questionnaire (MSLQ), SPSS-16, Cross-tab and Chi-square. In 2012, Tseng and others [31], proposed a report on enhancing the interest of children reading wit e-books by scaffold participatory learning approach. Children are more interested in learning those materials are which combinations of visual and verbal narrative. This research work proposed a scaffolded participation learning model. In 2012, Sengupta and others [28] proposed a report on Scaffolding based learning that support Personalized Synchronous e-learning. One of the major advantages of web based learning systems was that it was self-paced, independent on time and distance. Besides this, it was more effective with a supportive test case session that meant synchronous tutorial session. According to this research work, automated scaffolding technique was designed to hold the important information about learner. This information used by the learner with monitor in the 'Synchronous learning Session' was to make the overall system more applicable

B. Personalized e-Learning

PLE (Personal Learning Environment) is suggested as the next-generation e-learning system [19].The personalization can also be a static or dynamic process, depending on when the selection and presentation of material takes place: if the material is decided once in advance, we say that the course is configured; when the material is stated at run-time, that is during the course delivery, the course is said to be adaptive.

Personalized e-Learning not only customized the learning environment, but also offered "preferences" and "settings" options, the most digital tools offer nowadays. Personalized e-learning seems to reduce learning gaps between instructor and learner. In personalized e-learning this is expected that the learning materials will be generated as per the preference of the learner. Finally the entire webpage will appear to the learner in the most confortable way to him or her. In 2015, Zhanga and others [34], proposed a system on Personalized e-learning which is based on Google Web Toolkit. In this modern age due to huge development of internet technology, information overloading may be formed. Sometimes it is difficult for user to retrieve their specific information. To solve this issue this research work proposed a personalized e-learning system with collaborative filtering recommender algorithm, based on Google Web Toolkit. So, as a result of this, recommendation of personalized information can be achieved very easily and also the learning efficiency can also be improved simultaneously. In the Google Web Toolkit the client and server use single programming language to develop web application.

In 2014, Nandigam and others [23], proposed a report on personalized learning and made a review on its current status and potential. The objective of this research work is to identify 'Acceptable Personalized, which was learning suitable for specific educators for particular learning course. This proposed report presented a coherent framework for personalized learning and used to provide 'Acceptable Personalized Learning' for specific learner. This research work used the higher education teaching and learning platform through group discussion to improve learning outcomes. In 2013, Bezza and others [3] proposed an approach for Personalizing Learning Content. This research work represented two methods for modeling learner profile and personalizing, as well as adapting a specific content to match with the particular learner profile. These two methods are inductive and deductive. The inductive method means there is no user intervention and the deductive one means there is user intervention. In 2013, Chunzhi and others [7] proposed a report on the study about e-learning system which was based on 'Personalized Knowledge Search'. This research work creates a domain to build an interest model and this model is embedded in Notch search engine to identify the personalized knowledge search. This research work proposed that, through the construction of domain ontology the personalized knowledge search could be able to increase the learner's learning interests and could be able to fulfill any requirement of individual learner according to their learning courses.

C. Confidence Based E-Learning

Confidence-Based Learning or CBL is a methodology used for both learning and training that measures a learner's knowledge level and quality prior to any knowledge dissemination. Measurement of knowledge is done by determining both the correctness and confidence that the learner already has. To fulfill the objective of CBL it always passes an individual learner through an assessment prior to the delivery of the content. The assessment not only identifies the learner's knowledge level but also checks out the level of confidence she has in her knowledge level. This process of assessment is known as Confidence Based Assessment (CBA). CBL is operated with the help of three different phases Diagnose, Prescribe, Learn. The Diagnose phase deals with the diagnosis of the true knowledge of learners (i.e., what they actually know vs. what they think they know.).Learner's knowledge gaps (if any) are identified through the diagnostic session and in the Prescribe session the CBL system immediately provides an individual learning plan for the learner to improve the confidence of learner. In the initial phase learner is able to start learning according to the prescribed plan. Confidence Based Learning is affordable and scalable. Confidence Based Learning is useful to upgrade individual confidence according to learning objectives. Confidence Based Learning is not suitable for vocational education. Persons new in a field might not find Confidence Based Learning as an acceptable mechanism; rather conventional mechanism might work better. In Confidence Based Learning, it is difficult to measure appropriate level of confidence in numerical value.

In 2012, Liu and others [20] proposed a report on Confidence Based Learning domain. This research work proposed a social learning with the help of constant called bounded confidence. In this research work identify that a group can learn the true state if and only if the bound of confidence is more than the positive threshold and this work also proposed a neighborhood-preserved strategy. In 2012, Ananatharman [2] proposed a system which can be able to manage knowledge and e-learning. The objectives of this research work were providing a usage of e-learning and provide some facility with proper assessment for the learner. This research work discussed about various learning models such as blended learning, creative learning, interactive learning etc. In 2012, Zhang and others [33] are proposed a report on Interactive Learning for Social Agents which was based on Confidence Degree. In the Multi-Agent Systems, autonomous agents are capable to acquire cooperative behavior with the help learning process. The confidence is helpful to apply the proper knowledge in the application field. A social agent can acquire this confidence through interactive learning process. In 2011, Grozavu and others [17] proposed a report on learning confidence domain. The objective of collaborative clustering is to identify the common structure of different data which are distributed

on various sites. This research work represents the approach for Self-Organizing Maps.

D. Intelligent Tutoring System

The aim of an 'Intelligent Tutoring System' is to provide immediate and customized instruction as per the feedback of learners. Usually in this type of system the physical instructor is absent.

Intelligent tutoring system has the common goal of enabling learning in a meaningful and effective manner by using a variety of computing technologies. There are many examples of 'Intelligent Tutoring System' which are being used in both formal education and professional settings in which they have demonstrated their capabilities and limitations. An Intelligent Tutoring System aims to solve the problem of over-dependency of students on teachers for quality education. It aims to provide access to high quality education to each and every learner, thus reforming the entire education system. Areas that have used Intelligent Tutoring System include natural language processing, machine learning, planning, multi-agent systems, semantic Web, and social and emotional computing. In addition, other technologies such as multimedia, object-oriented systems, modeling, simulation, and statistics have also been connected to or combined with Intelligent Tutoring System. Some recognized strengths of Intelligent Tutoring System are their ability to provide immediate yes/no feedback, individual task selection, on-demand hints, and support mastery learning. Intelligent Tutoring Systems are expensive both to develop and implement. Evaluation of an Intelligent Tutoring System is an important phase; however, it is often difficult, costly, and time consuming. In 2015, Elghibari and others [13] are proposed a model of intelligent e-learning system for maintenance of various updates courses. The teaching methods become more effective with the help of e-learning technology. But lack of learning course update can create some problem for learner. So it is important to maintain or update the learning course content regularly. This research work proposed a model for automatic updating and maintaining learning course content using Multi-Agent Systems.

In 2013, Otsuki and others, [24] proposed an Intelligent Tutoring System which could be able to provide a support for Case-Based e-learning for the project management. This research work encouraged the learner to think as many possible solutions on his/her own through the dialogue function between the teacher and learner. It is helpful to the learner to develop the problem solving ability. In 2012, Moore and others, [21] proposed a Personalized Intelligent e-learning for specific context on demand basis. This research work provided an overview of open research questions and some observation to enable effective personalization. This work presented an overview on the educational landscape, web 2.0 technologies, context-aware systems, intelligent context processing. It also renders an algorithm which is used for context matching. In 2013, Almohammadi and Hagras [1] proposed a system which was based on adaptive fuzzy logic and used for improving the knowledge delivery on the intelligent e-learning platforms. This research work created a self-learning system which could be able to generate a fuzzy logic based model. This model represented various learners' capabilities and their needs and through this, it had also improved the learner's performance. This work also provided an overview on artificial intelligence techniques and fuzzy logic systems on adaptive educational systems.

E. Technology Enhanced Learning

E-learning, also known as online learning or technology enhanced learning (TEL), adheres to the basic tenets of face-to-face teaching, e.g. clear aims, specific learning outcomes, valid and reliable evaluation and assessment but with an additional flexibility through the use of technology. TEL and e-learning describe the broad approach to use technology to support teaching and learning processes, design and delivery.

The use of technology can add value to learning by enhancing the information the accessibility of over a greater choice of time, place and pace of study. It is able to provide the opportunities for reflection and planning in personal learning spaces. Technology Enhanced Learning is a more active learning process by means of interactive technologies and multimedia resources. But there are some disadvantages of Technology Enhance Learning process. To deal with this Technology Enhanced Learning a person should be technology literate. Technology Enhanced Learning is expensive to develop and implement. So for this reason it is difficult to install many Technology Enhanced Learning systems due to financial problem and some environmental problem.

In 2015, Erdt and others [14] proposed a quantitative survey on evaluating recommender systems. Recommender systems Technology Enhanced Learning need specific requirements which are different from that of e-commerce. This research work highlights the strengths and the shortcomings of the evaluation of Technology Enhanced Learning. This evaluation is based on measuring recommender system performance, measuring user-centric effects, measuring effects on learning etc. In 2015, Trepule and others, [30] proposed an approach of introducing technology enhanced learning curriculum for teaching staff in higher education. The objective of this research work is to maintain a quantitative survey between teaching staff and learner, and make a statistical analysis on the basis of survey outcomes. In 2011, Ivanovic and others [18], proposed a report on experiences of Technology Enhanced Learning for various courses. This research work collected various experiences and made a comparison among those gathered bits of information. This report provided some methodologies for learning and learner's assessment. In 2011, Dagdag and others [9] proposed a teacher's tool for analysis and management of a Technology-Enhanced Learning environment. The objective of this research work was to develop a software tools that could help the teachers to analyze technology-enhanced learning environment and with this tools teacher could be able to monitor the learner in real time, and make a proper assessment towards their progress at any time. In the year 2009 Oscar Sanjuán Martínez [35] proposed a recommendation system for e-learning environments at degree level. This recommendation Systems try to help the user, presenting him those objects he could be more interested in, based on his known preferences or on those of other users with similar characteristics. This document tries to present the current situation with regards to recommendation systems and their application on distance education over the internet. Beside that in 2014, Jordán Pascual Espada [36] proposed a method for analyzing the user experience in MOOC platforms. This research aims to develop a specific method for evaluating the user experience of MOOC platforms. The method is based on the general principles of Web user experience and highlights the aspects influencing MOOCs. The system proposed in this paper calculates a quantifiable index, useful for comparing different MOOC platforms, quantifying the quality evolution of the user experience, and promoting further studies so as to determine the impact of the user experience on students: satisfaction in surveys, enrollment figures, dropout rates, among others.

III. Comparative Study

In this section some recent works on intelligent e-learning are compared with their motivation and limitation. This research work is based on some of the recent works of the paradigm shift of intelligent e-learning. A review on different aspect of e-learning techniques such as Scaffolding based e-learning, Personalized E-Learning, Confidence Based E-Learning, Intelligent Tutoring System, Technology Enhanced Learning are presented in the table 1.

Table I. Comparative Study Report

Sl. No.	Reference No.	Summary	Limitation
1	11	This paper represented a new approach to the integration of web services for e-learning platform through cloud computing system. The primary objective was to improve the performance of the e-learning system where group adaptation was applied. This integration was based on a web application which was developed for managing the various learning systems. Integration of the Moodle was enables between the OpenLDAP directory which was used to control various user accounts, and the OpenNebula toolkit which was used for managing a cloud computing infrastructure.	One of the main limitations of this proposed approach is, this research work is based on group personalization and it does not provide support to any kind of real time adaptation. This approach is prepared for courses which require extensive usage of various hardware and also software resources and it may not be suitable for courses, having different requirements.
2	33	This research work investigated the various factors that can create effect on the learning outcomes of an interactive e-learning system. This research job was trying to use analytical path model, t-test and one-way ANOVA to determine the various effecting factors which were directly related to the interactive e-learning tools. It had also considered multiple factors such as various students' course perceptions (CP) and evaluation of self-efficacy (SE) beliefs.	In the real time environment the course perceptions (CP) do not provide direct support to measure specific learning outcome.
3	8	The main objective of this research paper was to discuss how Personal Learning Environments (PLEs) provide a platform for integrating both formal and informal learning and also self-regulated learning in the context of higher education. Social media could be facilitated in the creation of Personal Learning Environments that would help various learners to aggregate and participate in the process of collective knowledge generation.	Studies such as proper time management, goal setting (objectives), self-monitoring and self-evaluation also need to be considered for different kind of students.
4	10	This research work proposed a comprehensive framework which could be able to provide support to the personalization and also helps in adaptation of e-learning courses. The objective of this comprehensive framework was to get its pedagogical significance by the Vygotski Theory.	In the real world environments it is not able to provide real time framework for each individual's educational activities.
5	5	This research work represented CobLE (Confidence-Based Learning Ensembles), and CobLE is one kind of approach for creating an ensemble of classifiers and each and every classifier is estimated by measuring its confidence level function.	In the real world environments it is very difficult to estimate proper confidence level function.
6	4	This research work represented a platform which was able to provide an interface to e-learner under the online web based e-learning domain. On the basis of the concept map trees, it was possible to intelligently identify the learning pattern of an individual e-learner. It helped the learner to attain learning objectives through the various recommender agents.	This research work offers an environment based on personalized e-learning with the help of different access patterns. But in the real world environment it is very difficult by the recommender agent to recognize various learning pattern for the different kind of e-learner.
7	25	This research paper introduced an e-learning Ecosystem (ELES) which could be able to provide supports for the implement of modern technologies. Combination of both Cloud Computing and Web 2.0 technologies was used for the development of dynamic e-learning based ecosystems.	The cost and the risk can influence the overall e-learning ecosystem management which is based on combination of Cloud Computing and Web 2.0 technologies. This research work does but not concentrates on web 3.0.
8	27	This research work represented an intelligent fuzzy evaluation system which was based on innovative evaluation method for e-learning. This paper also introduced an expert system which could be able to provide solutions to the 'Measurement Theory Problem'.	In the real world sometimes it is not possible to provide absolutely correct and specific evaluation for e-learning.
9	6	This research work concentrated at the learning possibilities of the integrating social media and web 2.0 technologies in a Problem-Based Learning (PBL) approach. This research work proposed that social media not only provide a very interesting perspective, and also look at various factors such as collaboration, different student activity and participation in problem-based learning.	
10	12	In the proposed system, various learners shared their resource with their friends in the online social network. The similarity between two friends was derived from their mutual rating's history. A learner could ask his friend various resource rating query through the online social network and could also solve the problem.	In the real environment it is very cost effective and this type of system is applicable for those people who are modern technology friendly.
11	29	This paper proposed an 'Intelligent Decision Supporting Tutor (IDST)' system for the management of Virtual Group Operation' of e-learning system. Interactive Tutor Robot Networking (ITRN) and advanced simulation technology were also implemented by this research work. According to this paper, Intelligent Decision Supporting Tutor had two different kinds of knowledge based engines, the first one was the database of knowledge which was present in cloud computing server and the second one was used to make a fusion of human brains which was again constructed by Interactive Tutor Robot Networking.	To design this type of system in real world is time consuming and costly.

IV. Conclusion

The objective of this research work is to elaborate the paradigm shift in intelligent e-learning system. In this paper various details of different e-learning techniques are included. A discussion about advantages and disadvantages of these techniques and a review on the basis of recent work of this intelligent e-learning domain like Scaffolding based E-Learning, personalized e-learning, confidence based e-Learning, intelligent system, technology enhanced learning etc, are included in this paper. In the e-learning domain intelligent learning technology facilitates a learner in many ways to achieve his objective of learning a particular subject. Scaffolding based e-learning motivates the students so that they want to learn, which in turn, can minimize the level of frustration of the learner. Confidence based learning is useful to upgrade individual confidence. The strengths of intelligent tutoring system are their ability to provide immediate yes/no feedback, individual task selection, on-demand hints, and support mastery learning. Disadvantage of e-learning domain is lacks of standardization and it needs computer literacy.

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Design and Implementation of a Combinatorial Optimization Multi-population Meta-heuristic for Solving Vehicle Routing Problems

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***Abstract* — This paper aims to give a presentation of the PhD defended by Eneko Osaba on November 16th, 2015, at the University of Deusto. The thesis can be placed in the field of artificial intelligence. Specifically, it is related with multi-population meta-heuristics for solving vehicle routing problems. The dissertation was held in the main auditorium of the University, in a publicly open presentation. After the presentation, Eneko was awarded with the highest grade (cum laude). Additionally, Eneko obtained the PhD obtaining award granted by the Basque Government through.**

***Keywords* — Meta-heuristics, Transportation, Vehicle Routing Problem, Traveling Salesman Problem, Golden Ball.**

I. Introduction

On November 16th, 2015, Eneko Osaba defended his PhD thesis related with multi-population meta-heuristics for solving vehicle routing problems, at the University of Deusto [1]. The dissertation was held in the main auditorium of the University. After the presentation, and the corresponding doubts and questions raised by the assessing committee, Eneko was awarded with the highest grade (cum laude).

The thesis was supervised by Dr. Fernando Diaz, associate professor in the University of Deusto. On the other hand, the assessing committee of the PhD dissertation was composed of Professor Mario Piattini (University of Castilla-La Mancha), Dr. Esther Alvarez (University of Deusto), and Dr. Xin-She Yang (University of Middlesex, London, UK).

The development of the thesis was funded by the Basque Government, thanks to a grant awarded through a competitive process by the education, language policy and culture department (Grant ID: BFI. 2011-56). It is also important to highlight that the thesis has the International Mention, and that Eneko obtained the *PhD obtaining award* granted by the Basque Government through a competitive process.

The main publications associated with the PhD thesis are [2-5]. The full text of the thesis, the main papers published, and the source code of the developed method are available on the personal webpage associated with the University of Deusto[1].

II. Summary of the performed work

Transportation is an essential area in the nowadays society. There are different kinds of transportation systems, each one with its own characteristics. In the same way, various areas of knowledge can deal efficiently with the transport planning. Concretely, the thesis is focused in the area of artificial intelligence and vehicle routing problems.

The majority of the problems related with the transport and logistics have common characteristics. This means that they can be modeled as optimization problems, being able to see them as special cases of other generic problems. Much of the problems of this type have an exceptional complexity, requiring the employment of techniques for its treatment. There are different sorts of these methods. Specifically, the thesis centers its attention on meta-heuristics.

A great amount of meta-heuristics can be found it the literature. Anyway, due to the high complexity of the problems, there is no technique able to solve all these problems optimally. This fact makes the field of vehicle routing problems be a hot topic of research. For this reason, the thesis focuses its efforts on developing a new meta-heuristic to solve different kind of vehicle routing problems. The presented technique offers an added value compared to existing methods, either in relation to the performance, and the contribution of conceptual originality. Specifically, the designed meta-heuristic has been called Golden-Ball (GB), and it is based in soccer concepts [2, 3].

The main characteristics of the GB can be summarized as follows. The GB is a multiple-population based meta-heuristic. First, the whole population of solutions (called players) is randomly created. Then, these created players are randomly divided among a fixed number of subpopulations (called team). Each team has its own training method (or coach), which is randomly assigned in this first phase. This training is the way in which each player in the team individually evolves along the execution. Another important training is the called Custom Training. In these trainings, a player which is trapped in a local optimum receives a special training in cooperation with the best player of its team. Once this first phase is finished, the competition phase starts. This second step is divided in seasons, composed by weeks. All the teams train independently every week, and they face each other creating a competition league. At the end of every season, a transfer procedure takes place. In this procedure the players and coaches can switch teams. The competition phase is repeated until the termination criterion is reached.

With the aim of validating the proposed model, its obtained results were compared with the ones obtained by other four algorithms of similar philosophy. Additionally, four well-known routing problems were used in this experimentation. Additionally, in order to perform a fair and rigorous comparison, two different statistical tests were carried out: the Friedman's test and the Holm's test. Thanks to this experimentation it can be affirmed that the proposed method is competitive in terms of performance and originality.

Besides this, how the GB works with more complex problems has been also shown in the thesis. These complex problems have been directly extracted from real world situations. For this purpose, different transportation problems have been modeled and treated as

1 http://paginaspersonales.deusto.es/e.osaba

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complex routing problems. In this aspect, the contribution is not only the application of the GB to these problems. It should be added the formulation and the treatment of them, because it is the first time that such problems are addressed in the literature.

One of the most interesting real-world situations faced in the thesis is related to the newspaper distribution [5]. More specifically, the object of study was a medium-sized newspaper distribution company. The area of coverage of this company is at a provincial level, which means that it has to serve a set of customers distributed in separate towns and cities. The company has some principles, which are the base of their logistic planning. The first principle is to treat towns and cities as separate units. In this way, if one vehicle enters a city, or a town, it was forced to serve each and every customer located therein.

On the other hand, due to the current environmental requirements, the company has a simple but robust paper recycling policy. In this case, the objects to recycle are the newspapers not sold the previous day. Thus, as can be deduced, vehicles not only have to meet the delivery demands of the customers. Besides that, they have to collect at each point those newspapers that were not sold the day before.

In addition, the company takes into account certain factors in the routes planning process. The first one is related to the hours at which the deliveries and collections are done. The service is performed daily during morning from 6:00am to 15:00. Within this time window exists one range considered as *peak hours*. In this way, traveling costs from one point to another are greater if they are performed at *peak hours*.

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Eneko Osaba received the University degree and the Ph.D. degree in computer sciences from the University of Deusto, Bilbao, Spain, in 2010 and 2015, respectively. His doctoral thesis is focused on artificial intelligence, specifically in the field of combinatorial optimization, studying and developing heuristics and metaheuristics solving routing problems. At the same time, in September 2014, he began his career as a Lecturer, teaching statistics at the University of Deusto. He has participated in the development of more than 45 papers, published in different international scientific journals and conferences, being the first author in 29 of them. Among these papers, 21 of them have been published in international journals, having 15 of them JCR Impact factor (including 9 Q1). According to Scopus, he is the most prolific authors of the last 5 years under the search terms "Traveling Salesman Problem". He served as a member of the program committee of international conferences such as GECCO, HM and HAIS. Besides this, he is a regular reviewer in several scientific journals such as Soft Computing, Information Sciences, and Computers in Industry, and member of the editorial board of International Journal of Artificial Intelligence.

Fernando Diaz holds a BA in Computer Science and a PhD in Computer Science from the University of Deusto, and he is currently a lecturer of the Telecommunications Department at the Faculty of Engineering of Deusto University. From 1990 to 1992 he was an assistant researcher in the Artificial Intelligence Department of LABEIN research center (Bilbao, Spain). From 1992 to 1996 he was a PhD candidate in the Computing Languages and Systems Department at Deusto University, studying neural network algorithms for combinatorial optimization. His educational activity centers on the area of mathematics, teaching BA courses on Industrial Engineering, Computer Engineering, and Telecommunications Engineering. His main research interests include combinatorial optimization meta-heuristics applied to production scheduling and logistics. Other research interests include artificial neural networks and data mining. During the past few years he has carried out diverse studies in the areas of intelligent information retrieval, neural networks, genetic and evolving algorithms, and production scheduling and distribution, participating in various research projects funded by the European Commission, and the Basque Regional Government. He is also part of the Industrial Management and Logistics research team of the Engineering Faculty of Deusto University.

A Review on Block Matching Motion Estimation and Automata Theory based Approaches for Fractal Coding

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***Abstract* --- Fractal compression is the lossy compression technique in the field of gray/color image and video compression. It gives high compression ratio, better image quality with fast decoding time but improvement in encoding time is a challenge. This review paper/article presents the analysis of most significant existing approaches in the field of fractal based gray/color images and video compression, different block matching motion estimation approaches for finding out the motion vectors in a frame based on inter-frame coding and intra-frame coding i.e. individual frame coding and automata theory based coding approaches to represent an image/sequence of images. Though different review papers exist related to fractal coding, this paper is different in many sense. One can develop the new shape pattern for motion estimation and modify the existing block matching motion estimation with automata coding to explore the fractal compression technique with specific focus on reducing the encoding time and achieving better image/video reconstruction quality. This paper is useful for the beginners in the domain of video compression.**

***Keywords* --- Fractal Compression, Compression Ratio, Encoding Time, Decoding Time, Automata, Motion Estimation.**

I. Introduction

With the most challenging area in computer animations and multimedia technology, data compression remains a key issue regarding the cost of storage space and transmission times. Fractal Compression was first promoted by M. Barnsley which is based on Iterated Function System (IFS) [1][2]. It basically deals with the exploration of the self-similarity present in the given image. Though the Fractal coding is advantageous with respect to the compression ratio and image reconstruction quality, but it has the heavier non-acceptance related to the time elapsed for the check of similarity. It is suitable for the gray level image compression, but later some new techniques were also developed for the color image/video compression. The collage theorem [3] is the basis for the fractal transform. The collage theorem for an input image I, a new set W(I) is computed by the union of n number of sub-images, each of which is formed by applying a contractive affine transformation w_i on I as given in (1). A practical reality was given to fractal compression by Jacquin with partitioned IFS (PIFS) [3].

$$W(I) = \bigcup_{i=0}^{n} w_i(I) \quad (1)$$

Video compression deals with the compression mechanism for the series of image sequences. In coding, the correlation between the adjacent image frames may get explored, as well as the relativity between them may also be used in the development of the compression mechanism. Generally, the adjacent image frame does not differ much. The probable difference lies in the displacement of the object in the given image frame with respect to the previous image frame. Grey and color videos (i.e. image sequences of gray or color image frame) are the customers for the video compression approach. Different color spaces [4] can be used for the video images from the processing point of view. With the very fast development in multimedia communication with moving video pictures, processing on color images plays a very important role. A color image is represented by 24 bits/ pixel in RGB color space format, with each color component represented by 8 bits.

Block matching motion estimation is a popular technique for many motion compensated video coding standards. Video compression standards, in general, are used for the video coding. Basic video compression standards are- Video coding standards are related to the organizations- ITU-T Rec. H.261, ITU-T Rec. H.263, ISO/IEC MPEG-1, ISO/IEC MPEG-2, ISO/IEC MPEG-4, and recent progress is H.264/AVC. In a series of the image sequence, there are spatial, temporal and statistical data redundancy that arises between frames. Motion estimation and compensation are used to reduce temporal redundancy between successive frames. Motion estimation computes the motion/movement of an object in a given image. For achieving data compression in a sequence of images, the motion compensation uses the knowledge of the motion object. Different searching techniques are available to compute the motion estimation between frames.

A finite automaton is a mathematical model used in the theoretical foundation of computer science to show acceptance or rejection of a particular string of an algorithm. Transition diagram, i.e. graph, is a convenient way of designing finite automata. Any image can be represented by a finite automaton. Because of its simple mathematical structure, a finite automation is used in fractal image/ video compression. The principle of finite automata is based on the self-similarity present within the picture itself. Image compression with finite automata can also be applied to digital video sequences, which are typically represented by a series of frames or digital images [5]. The concept of finite automata is now generalized to weighted finite automata.

The remainder of this paper is organized as follows: An overview of fractal Image compression is given in section 2. Section 3 describes the related work on fractal image coding. An overview of fractal video coding is given in Section 4. Section 5 describes a related work on automata theory based coding. Section 6 focuses on work carried out on fractal video coding using block matching motion estimation. This section elaborates the different motion estimation approaches and Section 7 discusses about the quality measures associated with video processing. Section 8 summarizes the conclusion from the studied existing approaches. Finally, the paper ends with the future scope in section 9 followed by references.

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II. Overview of Fractal Image Coding

In general, there are two types of compression—Lossless and Lossy. In lossy data compression techniques some amount of the original data is lost during the compression process. For fast transmission of images across the internet media lossy techniques are used in World Wide Web. Examples of lossy techniques are JPEG, GIF, Wavelet, Fractal, DCT etc. In lossless data compression techniques very few amount of data is lost. Examples of lossless techniques are: TIFF, CCD RAW, etc.

Fractal coding techniques are generally applied on gray level images. For color image compression, each of red, green and blue component is compressed individually using gray image fractal coding algorithm. Fractal coding is a block-based processing technique which takes long encoding time for compression but less decoding time for decompression and it falls in the category of lossy compression technique. In basic fractal image coding, the original image is divided into small non-overlapping range block (R block) of fixed size which is nothing but a group of a collection of horizontal and vertical pixels. For each R block, find overlapping domain block (D block) of fixed size which is also a group of a collection of horizontal and vertical pixels and are generally two or four times the size of the range block. For instance, If the image of size $I=2^N \times 2^N$ is divided into non-overlapping range block $R_{i=0,1,2,\ldots m}$ of size $2^n \times 2^n$, then search for the best match overlapping domain block $D_{j=0,1,2,\ldots n}$ of size $2^{n+1} \times 2^{n+1}$ i.e. double the size of range block . The number of range block for a single plane is $R_m = (2^N \times 2^N) / 2^n \times 2^n$ and the number of domain block for a single plane is $D_n = ((2^N \times 2^N) - (2^{n+1} \times 2^{n+1}) + 1)^2$. Domain pool D_p consists of all the transformed and under-sampled domain block such that it matches to the size of the range block. Block schematic of basic fractal coding encoder is shown in Fig. 1. The steps for basic fractal encoding algorithm [6] are as follows.

1. Divide the original image to be encoded to get the non overlapping range blocks R_i.
2. Divide the original image to be encoded to get the overlapping Domain blocks D_j..
3. Generate domain pool D_P consisting of all transformed and shrink domain blocks D_j^t.
4. For each domain block D_j^t in domain pool D_p, using least square regression method [3] given in equation (2) and (3), compute the values of contrast factor-s and brightness factor-o by referring R_i and D_j^t in domain pool D_p. Given a pair of range block R_i and transformed and shrink domain block D_j^t in domain pool D_p of n pixels with intensities $r_1, r_2 \ldots r_n$ and $d_1, d_2, \ldots d_n$ to minimize the quantity i.e R.

$$R = \sum_{i=1}^{n} (s.d_i + o - r_i)^2$$

where $s = \frac{[n \sum_{i=1}^{n} d_i r_i - \sum_{i=1}^{n} d_i \sum_{i=1}^{n} r_i]}{[n \sum_{i=1}^{n} d_i^2 - (\sum_{i=1}^{n} d_i)^2]}$ (2)

and $o = \frac{1}{n}[\sum_{i=1}^{n} r_i - s \sum_{i=1}^{n} d_i]$ (3)

5. Compute error $E(R_i, D_j^t)$ using equation (4) and Quantize factor s and o using uniform quantizer.

$$E(R_i, D_p)^2 = \frac{1}{n}\left[\sum_{i=1}^{n} r_i^2 + s\left(s \sum_{i=0}^{n} d_i^2 - 2 \sum_{i=1}^{n} d_i\ r_i + 2o \sum_{i=1}^{n} d_i\right) + o(no - 2 \sum_{i=1}^{n} r_i)\right] \quad (4)$$

if $[n \sum_{i=1}^{n} d_i^2 - (\sum_{i=1}^{n} d_i)^2] = 0$ then s =0 and o = $\frac{1}{n}[\sum_{i=1}^{n} r_i]$

6. Search all domain blocks D_j^t in domain pool D_p for a particular range block to be encoded R_i and find the most suitable block D_j^t with minimal error $(R_i, D_j^t) = \min E(R_i, D_p)$.

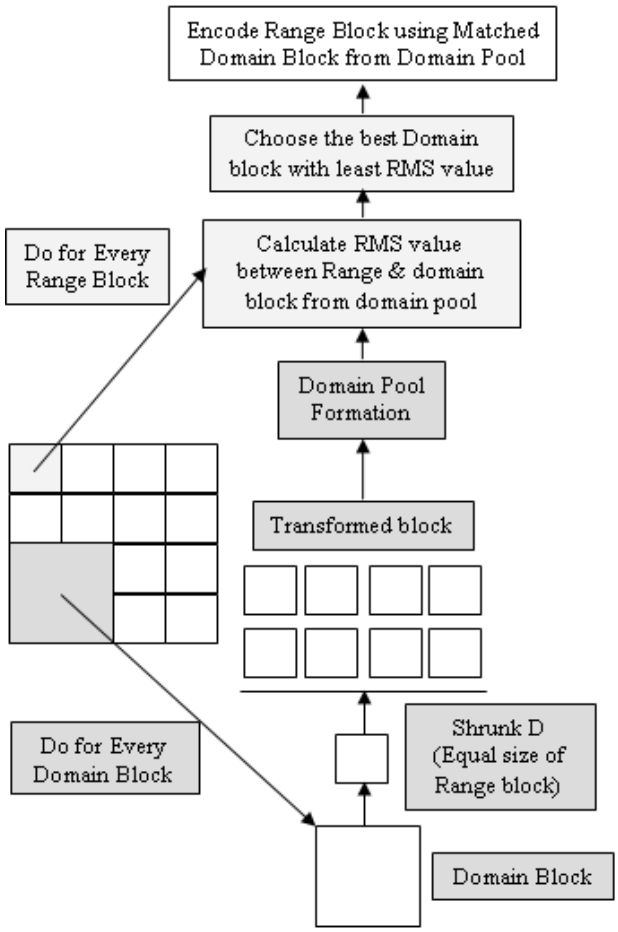


Fig. 1. Schematic of Basic Fractal Coding Encoder Mechanism.

The decoding of a compressed image can be easily achieved with a starting value $B^{(0)}$ given in relation (5)

$$B^{(q)} = W(B^{(q-1)}) \quad (5)$$

Where W is Fractal Transformations applied on each domain block, q is number of transformations i.e. Eight affine/linear transformations and $\{B^{(0)}, B^{(1)}, B^{(2)}, B^{(q-1)}, B^{(q)}\}$ set of sequence of transformation. The Peak-signal-noise-ratio(PSNR) value describes the image quality of the decoded image computed by using equation (6).

$$PSNR = 10 \cdot \log_{10}\left[\frac{A^2}{MSE}\right] \quad (6)$$

Where A is amplitude of the signal and is given as $A=2^8-1=255$ 8-bit gray image and MSE is computed as follows

$$MSE = \frac{1}{n}\sum_{i=1}^{N}(Y_{i,j} - X_{i,j})^2 \quad (7)$$

Where $X_{i,j}$ and $Y_{i,j}$ are the pixel (i, j) intensities of original and decoded image respectively.

In sequentially approximating each range block by suitable domain block, the major drawback is exhaustive searching that is required for finding a best matching domain block, which leads to increase encoding time. Several approaches have been proposed for reducing encoding time. In this review paper, we present various approaches for reducing encoding time for the image as well as video fractal coding. Classification of fractal image and video coding approaches is represented using Block schematic as shown in Fig. 2.

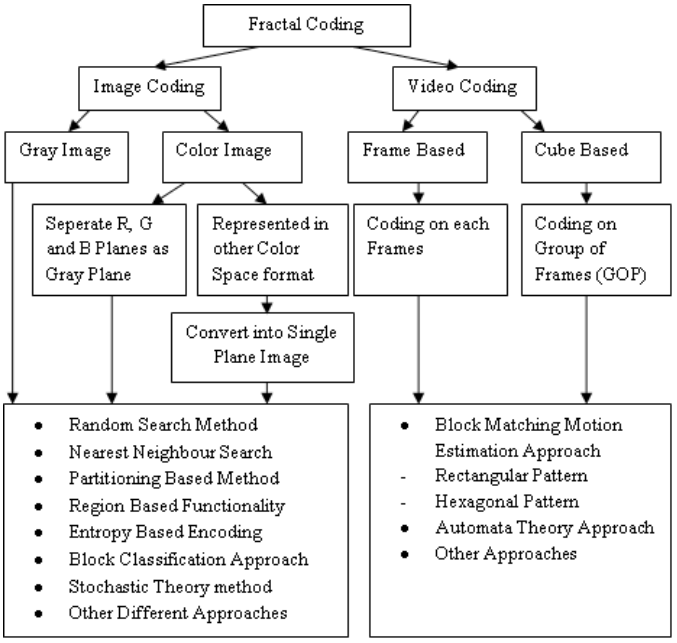


Fig. 2. Classification of Fractal Image and Video Coding Approaches.

III. Related Work on Fractal Image Coding

Literature available on Fractal gray image compression is very large and few report about the color image compression. Formulation of approximate nearest neighbor search in [7] is based on orthogonal projection and prequantization of the fractal transforms parameters. Ghosh et al. [8] searched domain blocks randomly for every range block to minimize the encoding time. Truong et al. [9] optimized the range blocks pool and domain blocks pool using spatial correlation to minimize the search space and searching time. The encoding algorithm in [10] based on the law of cosines. Fan and Liu [11] presented the matching algorithm based on the Standard Deviation (STD) between range blocks and domain blocks. Wang et al [12] proposed Correlation information feature to find nearest neighbor domain block for each range block.

Ghosh et al. [13] proposed an approach for fractal image coding based on an innovative concept of relative fractal coding which found to be suitable for coding multi-band satellite images. Conci and Aquino [14] used fractal dimensions for the image part classification where first the image block fractal dimension complexity is evaluated and then only parts within the same range of complexity are used for testing the better self-affine pairs. Li et al. [15] presented a kernel function clustering based on an ant colony algorithm. It automatically realizes classification of the domain block. Hartenstein et al. [16] presented bottom-up region merging approach where regions are merged on the basis of collage error. Belloulata and Konrad [17] proposed an approach to fractal image coding that permits region-based functionalities where images are coded region by region according to a previously-computed segmentation map. The method in [18] is particularly well suited for use with highly irregular image partitions for which most traditional (lossy) acceleration schemes lose a large part of their efficiency. Franco and Mala [19] presented an algorithm for adaptive image partitioning achieving designated rates under a computational complexity constraint. Wang [20] proposed a graph based image segmentation algorithm used to divide the image into the different logical area and each logical area is coded into adaptive threshold quadtree partitioning approach.

Hassaballah et al. [21] minimized domain pool size on the basis of entropy value of each domain block. Domain pool reduction is parameterized and non-adaptive by allowing an adjustable number of domains to be excluded from the domain pool based on the entropy value of the domain block. He et al. [22] utilized one-norm of a normalized block to minimize the domain pool search space, in which the search process might be terminated early, and thus remaining domain blocks could be safely discarded. Rowshanbin et al. [23] used a special characteristic vector to classify the domain blocks to minimize the searching time. The approach in [24] uses the minimum distortion and variance difference between the range block and domain block to minimize the domain pool and searching time. To speed up the encoding, in [25], the classification features are used to classify the image blocks. Xing et al. [26] used hierarchical partitioning to classify the domain pool. Fuzzy pattern classifier is utilized in [27], to classify the original image blocks. Qin et al. [28] sorted domain pool on a number of hopping and the variance of continuing positive and negative pixels in the given block. The approach in [29] reduces the memory requirement, and speeds up the reconstruction. In Stochastic image compression using Fractals [30], stochastic image coding based on the fractal theory of iterated contractive transformations is discussed. Fractal image compression based on the theory of iterated function system (IFS) with probabilities is explained in [31]. Gungor and Ozturk [32] discussed a hash function based image classification technique. No search fractal image compression in DCT domain is discussed in [33]. Eugene and Ong [34] discussed two pass encoding scheme to speed up the encoding process. The approach in [35] is based on computing the gray level difference of domain and range blocks. Peng et al. [36] obtained the range blocks by partitioning the image using adaptive quad trees. A direct allocating method to predict the desired transformation for similarity measure is discussed in [37]. Liu et al. [38] presented the entropy based encoding algorithm. Melnikov [39] presented the method of acceleration of the image fractal coding. Distasi et al. [40] proposed an approximation error based approach to classifying the blocks. The fundamental idea of this approach consists in deferring range and domain comparisons, based on feature vectors. A preset block $\bar{d}$, as a temporary replacement with which range and domain blocks are compared.

There are many color spaces [4] available to represent the color images. To display the image on the monitor, the RGB color space is generally used. For color image compression, the RGB model is best suited because it provides the highest correlation [41]. For color image compression on square architecture, the fractal coding is applied on different planes of a color image independently by treating each plane as a gray level image. This approach is Straight Fractal Coding or Separated Fractal Coding (SFC) [42]. Work related to fractal coding of color images reported in the literature are: Hurtgen et al. discussed a fractal transform coding of color images in [43]. To exploit the spectral redundancy in RGB components, the root mean square error (RMSE) measure in grey-scale space is extended to 3-dimensional color space for fractal-based color image coding in [44], where it is claimed that 1.5 compression ratio improvement can be obtained using vector distortion measure in fractal coding with fixed image partition as compared to separate fractal coding in RGB images. Comparative study of fractal color image compression in the L*a*b* color space with that of Jacquin's iterated transform technique for 3-dimensional color is presented in [45], where it is claimed that the use of uniform color space has yielded compressed images with less noticeable color distortion than other methods. Li et al. [46] presented fractal color image compression scheme based on the correlation between the three planes of RGB color space. Giusto et al. presented an approach for color image coding based on the joint use of the L*a*b* color space and Earth Mover's Distance in [47]. Thakur et al. [6] discussed a Fractal compression technique, which is basically a searching technique based on self-similarity search within an image and elaborated basic steps

required for Fractal coding technique i.e. partitioning into rang/domain blocks, searching each range block with all domain blocks and stores the values of best transformations. Thakur and Kakde [51] proposed a modified fractal coding approach on spiral architecture to optimize domain blocks using local search. One of the major challenges in fractal coding technique is to optimize/reduce the size of domain pool. Reducing the number of domain blocks in a domain pool reduces encoding time in fractal coding technique.

IV. Overview of Fractal Video Coding

There are two methods for fractal video: coding-Frame based and Cube based fractal video coding. In frame based coding, each single frame of image is partitioned into a range and domain square block, which is already described in section 2, and then each frame is coded based on inter-frame and intra-frame coding to reduce the redundant part of data within a frame and between two frames using fractal transformations. The inter-frame and intra-frame coding are discussed in section 4.1. Every range block of the current frame is encoded by the domain block from the previous frame i.e. encode every range block by using inter-frame similarity as shown in Fig. 3. The error occurs in the latter/next frames due to the inter-frame similarity, i.e use of domain block from the previous frame, and delay occurs between two successive frames during the processes of decoding, which are the major drawbacks in frame based video coding. This method is advantageous in achieving a high compression ratio and thus it is used in video transmission through the internet/www media.

In cube based coding, The video sequence to be coded is first combined into a group of frames(GoF) and then each GoF is partitioned into a set of range and domain cubes as shown in Fig. 4. For instance, image can be viewed as 3D /cubic digital image of size $I=2^N \times 2^N \times 2^N$, which is divided into non-overlapping range block $R_{i=0,1,2,\ldots m}$ of size $2^n \times 2^n \times 2^n$ then search for the best match overlapping domain block $D_{j=0,1,2,\ldots n}$ of size $2^{n+1} \times 2^{n+1} \times 2^{n+1}$ i.e double the size of range block . The number of range blocks for a single plane is $R_m = (2^N \times 2^N \times 2^N) / 2^n \times 2^n \times 2^n$ and the number of domain blocks for a single plane is $D_n = ((2^N \times 2^N \times 2^N) - (2^{n+1} \times 2^{n+1} \times 2^{n+1}) + 1)^2$. Domain pool D_p consists of all the transformed and under-sampled domain blocks such that it matches the size of the range blocks as shown in Fig. 5. If N = 2 and n = 1, then for a cubic digital image of size I=4 x 4 x 4 having a number of pixels 64, the number of range blocks $R_m = 8$, having a number of pixels in each range block that is 8, and the number of domain blocks Dn = 1, having a number of pixels in domain block that is 64. This method is advantageous in obtaining a high quality of decoded image in receiving end but disadvantageous in achieving a low compression ratio.

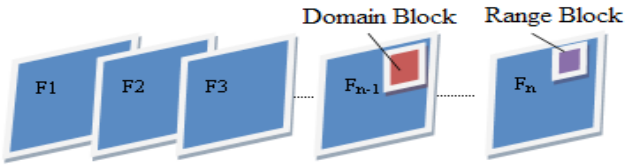


Fig. 3. Rang and Domain Blocks Formation in Frame based Video Coding.

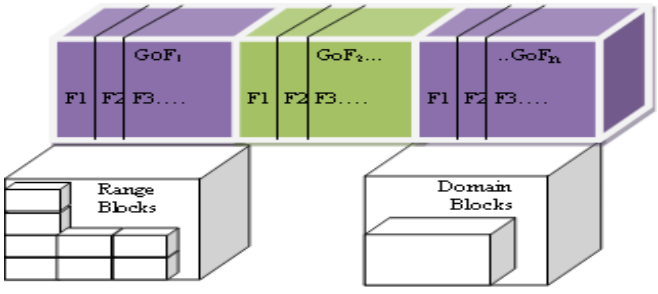


Fig. 4. Range and Domain Cubes Formation in Cube based Video Coding.

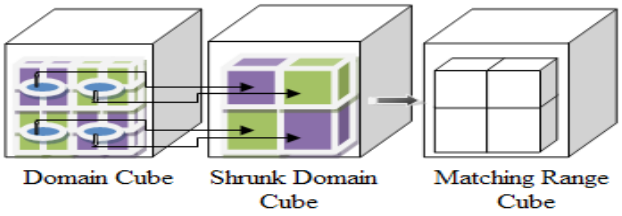


Fig. 5. Domain Cube Matching with Range Cube.

The basic fractal encoding algorithm for still images given in section 2 is easily extended to fractal video coding. The steps for obtaining frame based fractal video coding are as follows.

1. Extract image sequences from video $F_f = \{F_1, F_2, \ldots\ldots F_n\}$.
2. For each frame F_f $\{2 \le f \le n\}$ do
3. Apply fractal coding for still image F_{f-1} to compute decoded image DF_{f-1}.
4. Divide the frame F_f to get the non overlapping Range block R_i.
5. Divide the decoded frame DF_{f-1} to get the overlapping domain block D_j.
6. Generate domain pool D_p from decoded frame DF_{f-1} consisting of all transformed and shrink domain blocks D_j^t.
7. For each domain block D_j^t in domain pool D_p, using least square regression method [3] given in equation (2) and (3) compute the values of contrast factor-s and brightness factor-o by referring R_i and D_j^t in domain pool DP. Given a pair of range block R_i and transformed and shrink domain block D_j^t in domain pool D_p of n pixels with intensities $r_1, r_2 \ldots r_n$ and $d_1, d_2, \ldots d_n$ to minimized the quantity i.e R.

$$R = \sum_{i=1}^{n} (s.d_i + o - r_i)^2$$

8. Compute error $E(R_i, D_j^t)$ using equation (4) and Quantize factor s and o using uniform quantizer.
9. Searching all domain block D_j^t in domain pool D_p for a particular range block to be encoded R_i and find the most suitable block D_j^t with minimal error $(R_i, D_j^t) = \min E(R_i, D_p)$.

Similarly a basic fractal encoding algorithm for still image is easily extended for obtaining cube based fractal video coding are as follows.

1. Extract image sequences from video $F_f = \{F_1, F_2, \ldots\ldots F_n\}$.
2. Frame sequence is divided into $GoF_i = \{GoF_1, GoF_2, \ldots GoF_n\}$.
3. For each GoF_i do
4. Divide the GoF_i to get the non overlapping range cube block R_i.
5. Divide the GoF_i to get the overlapping domain cube block D_j.
6. Generate domain pool D_p from GoFi consisting of all transformed and shrink domain blocks D_j^t.
7. For each domain block D_j^t in domain pool D_p, using least square regression method [3] given in equation (2) and (3) compute the values of contrast factor-s and brightness factor-o by referring R_i and D_j^t in domain pool D_p. Given a pair of range block R_i and transformed and shrink domain block D_j^t in domain pool D_p of n pixels with intensities $r_1, r_2 \ldots r_n$ and $d_1, d_2, \ldots d_n$, to minimized the quantity i.e R .

$$R = \sum_{i=1}^{n} (s.d_i + o - r_i)^2$$

8. Compute error $E(R_i, D_j^t)$ using equation (4) and Quantize factor s and o using uniform quantizer.

9. Searching all domain blocks D_j^t in domain pool D_p for a particular range block to be encoded R_i and find the most suitable block D_j^t with minimal error $(R_i, D_j^t) = \min E(R_i, D_p)$.

A. Intra-frame and Inter-frame Coding

In video coding there are two ways to reduce the data present in the frames. Firstly, spatial redundancy elimination, which is called intra-frame coding, in which the frames are coded individually as done in JPEG compression technique. Within individual frame coding, similar data part can be coded with fewer bits per pixels than the original data part, therefore reducing bits per pixel is a minor loss in noticeable visual quality of individual frame coding. On the other hand, temporal redundancy elimination, which is called inter-frame coding, in which the redundant data are eliminated between the frames as done in MPEG compression technique. Inter-frame coding finds the difference between the previous frame and current frame and stores only difference i.e. displacement of pixels instead of complete frames. The displacements of pixels are estimated by using a well-known technique called block matching motion estimation. Block matching motion estimation techniques are used to find out the motion vectors in a frame and then the displacement of pixels block identified by motion estimation technique is coded. Later this block is considered as a previous frame and the next frame in a sequence is considered as a current frame for finding out the difference. This coding process is repeated for all the remaining frames in a video sequence. Fig. 6 shows the block schematic of intra-frame and inter-frame coding techniques.

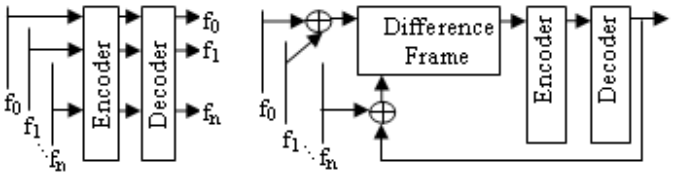


Fig. 6. Intra-frame (Spatial) and Inter-frame (Temporal) Coding Technique.

B. Video Coding Standards

Video compression standards, in general, are used for the video coding. Basic video compression standards are- Video coding standards are related to the organizations are- ITU-T Rec. - H.261, H.263, ISO/IEC- MPEG-1, MPEG-2, MPEG-4, and H.264/AVC. Summary of video coding standards with their properties are given in Table I. Block matching motion estimation algorithms play an important role in designing video coding standards. Video coding standards consist of motion estimation algorithm, encoding mechanism and decoding mechanism to eliminate redundant data.

C. Preliminaries of Automata Theory

In general, a finite automaton is a simple mathematical model used to recognize the strings generated by regular expression notation. In image / video compression technique, finite automata are used to represent the entire image and the address of each subimages of the entire image is specified by the regular expression i.e. $\sum^* = \{0, 1, 2, 3\}^*$ where 0, 1, 2 and 3 are the address of the subimages. Finite automata coding process is similar to the fractal coding process by extending finite automata model with the weighted finite automata (WFA) model. WFA is an extended version of finite automata in which a weighted transition is associated between the two states.

A WFA $M= (Q, \sum, W, I, F, q_0)$ consists of a finite set of states i.e. Q= {q0, q1, q2 ...qn}, a finite set of input symbol/quadrant address i.e. $\sum= \{0,1,2,3\}$ for Quadtree WFA , $\sum= \{0,1\}$ for Bintree WFA and $\sum= \{0,1,2,3,4,5,6,7,8\}$ for Nonatree WFA, the weight function between two states i.e. $W \in Q \times Q \rightarrow R$, for $W (q_0, q_1) = R$ where q_0, $q_1 \in Q$ and R is the real number i.e weight between state q_0 and q_1, the initial configuration (I) of states $Q \rightarrow R$ and indicates which states corresponds to the entire image $I(q_0)=1$ and $I(q_i)=0$, $q_0 \neq q_i$ where q_0, $q_i \in Q$ and i=1,2,3....n, the final configuration (F) of states $Q \rightarrow R$ e.g. $F (q_0) = f(\in)$ where $q_0 \in Q$ and $f(\in)$ is the average intensity (Greyness) of the entire image, and the initial state q_0 of the WFA means the entire original image i.e. $q0 \in Q$.

The extended version of weighted finite automata is called as extended weighted finite automata (EWFA), which is similar to WFA in which all the subimages in EWFA are transformed using transformation function i.e. scaling and rotation etc. Similarly to WFA, EWFA is also used to store and compress data represented as an image/matrix. In EWFA the numbers of states to store the subimages/matrix data are less as compared to WFA and therefore memory space required to store the states are less.

TABLE I

Summary of Video Coding Standards with Objectives/ Properties

Standard	Organization	Standards Properties
MPEG-1	ISO/IEC	Main application is multimedia video storage, video frame rate - 24 to 30 fps, bit rate- 1.5 Mbps, image format- CIF and no interlace.
MPEG-2	ISO/IEC	TV resolution- NTSC:704 x 480 Pixel, digital cable TV distribution similar to NTSC, PAL, SECAM at 4 -8 Mbps , HD television at 20 Mbps and interlace
MPEG-4	ISO/IEC	Object based coding and used in wide range of applications i.e. TV film, video communication, video cameras, Internet streaming, mobile phones etc. with choices of interactivity, scalability, error resilience, etc.
H.261 and H.263	ITU-T	Video conferencing applications over ISDN telephone lines
H.264	ITU-T and ISO/IEC	• Broadcast over cable, modems, ADSL, terrestrial etc. • Optical / magnetic storage devices and DVDs storages. • Video-on-demand or streaming service and Multimedia messaging service (MMS) over ISDN, LAN, Ethernet, modems, wireless and mobile networks etc, or their combinations.

V. Related Work on Automata Theory

Weighted Finite Automata (WFA) is a generalization of finite automata by attaching real numbers as weights to states and transitions proposed by Culik and Kari [49-50]. WFA provides a powerful tool for image generation and compression. The inference algorithm for WFA subdivides an image into a set of non-overlapping range images and then separately approximates each one with a linear combination of the domain image. A new predictive video-coding technique [50], using fractal image compression for intra-frame coding and second order geometric transformations for motion compensation in inter-frame predictive coding, is proposed. For motion compensation second order geometric transformations, compensating for translation, rotation, zooming, uneven stretching, and any combination of these, has been used. The decoded images can be displayed at arbitrary resolution without blockiness, which, together with the very high compression ratio achievable, is the most important advantage of the fractal-based image coding technique over the standard discrete cosine transform (DCT)-based image coding [50]. WFA is one of the techniques that have been used to compress digital images [51-52]. WFA represents an image in term of a weighted finite automaton with a very good

compression ratio. WFA is based on the idea of fractal that an image has self-similarity in itself. In this case, the self-similarity is sought from the symmetry of an image, so the encoding algorithm divides an image into multi-levels of quad-tree segmentations and creates an automaton from the sub-images [53]. As the developing of the fractal image compression, the fractal coding method has been applied in video sequence compression [54], for instance, the famous hybrid circular prediction mapping and non-contractive inter-frame mapping [55]. The circular prediction mapping / non-contractive inter-frame mapping combines the fractal coding algorithm with the well-known motion estimation and compensation algorithm that exploits the high temporal correlations between adjacent frames. WFA codec is modified such that it compresses the video at low bit-rates. The video is the sequence of frames (images). Here a hierarchical motion compensation (MC) [56] and bin-tree based WFA codec are integrated to exploit the correlation between successive frames [57]. The advantage is that WFA encoding can replace other transformation coding in video applications. At low bit-rates, WFA encoded images are typically half the size of comparable JPEG images. Video coding scheme based on bit-plane modeling and GFA representation is used to explore the inter-frame, inter-bit plane and inter-level similarities present in the video. To form a generalized finite automata-based compact representation of video sequence, the GFA modeling takes advantages of the binary fractal similarity of the video sequence in the wavelet domain. After exploring the similarities we get compact generalized finite automata representation of video [58-59]. Such schemes significantly outperform the H.26X [60] series coding schemes in rate distortion performance and retain an acceptable perceptual quality of the video.

A generalized finite automaton [61] is used to encode/decode the images automatically. When the GFA is combined with the wavelet transform technique, the GFA is constructed in such a way that each state represents one wavelet function. So this method combines the advantages of both, the classical wavelet compression method and GFA. While encoding the image, GFA doesn't have to solve equations. So encoding may take significantly less time. Decoding of images can also be done more quickly. This method of GFA allows any combination of rotations, flips, and complementation of the quadrant image [62]. Quad-tree based EWFA coding is used in fractal color video compression technique [66]. The quadtree partitioning scheme is used to specify the address of each sub-images i.e. a complete quadtree represents a pyramidal structure of an entire image that is required for the EWFA encoding and decoding process. The concept of intra-frame coding i.e. individual frame coding is used to encode the number of frames in a video. In Quadtree based EWFA coding, each color frame is converted into the YC_bC_r color space and then converted into gray scale [67, 68]. Each gray scale frame is divided into a fixed sized block ($2^n \times 2^n$) based on quadtree partitioning to represent the address of each pixel.

VI. Related Work on Motion Estimation

In circular prediction mapping and non-contractive inter-frame mapping, each range block is motion compensated by a domain block in the previous frame, which is of the same size as the range block even though the domain block is always larger than the range block in conventional fractal image codec. The main difference between circular prediction mapping and non-contractive inter-frame mapping is that circular prediction mapping should be contractive for the iterative decoding process to converge, while non-contractive inter-frame mapping needs not be contractive since the decoding depends on the already decoded frames and is non-iterative [66]. Recently, Wang [67] proposed a hybrid fractal video compression algorithm, which merges the advantages of a cube-based fractal compression method and a frame-based fractal compression method; in addition, an adaptive partition instead of fixed-size partition is discussed. The adaptive partition [68] and the hybrid compression algorithm exhibit, relatively, the high compression ratio for image [68] and the video conference sequences [67]. In conclusion, a fractal image codec performs better in terms of very fast decoding process as well as the promise of potentially good compression [69-73]. But at present, the fractal codec is not standardized because of its huge calculation amount and slow coding speed. In order to alleviate the above difficulties, a block-matching motion estimation technology [74, 75] can be used to improve the encoding speed and the compression quality [76].

Block-matching motion estimation is a vital process for many motion-compensated and video coding standards. Motion estimation could be very computationally intensive and can consume up to 60%-80% of the computational power of the encoding process [77]. So research on efficient and fast motion estimation algorithms is significant. Block matching algorithms are used widely because they are simple and easy to be applied. In the last two decades, many block matching algorithms are proposed for alleviating the heavy computations consumed by the brute-force full search algorithm which has the best prediction accuracy, such as the new three-step search [78], the four-step search [79], the block-based gradient descent search [80], the diamond search [81], the cross-diamond search [82], etc. All these searches employ rectangular search patterns of different sizes to fit the center-biased motion vector distribution characteristics [83-84]. Hexagon-based search employs a hexagon-shaped pattern and results in fewer search points with similar distortion [85]. Block-matching algorithm called Novel Cross-Hexagon Search algorithm is proposed in [75]. It uses small cross-shaped search patterns in the first two steps before the hexagon-based search and the proposed halfway stop technique [74]. It results in higher motion estimation speed on searching stationary and quasi-stationary blocks. The traditional algorithms use all the pixels of the block to calculate the distortions that result in heavy computations. Modified Partial Distortion Criterion [86] that uses certain pixels of the block, which alleviates the computations and has similar distortion can be used. New Cross-hexagon search algorithm (NHEXS) proposed in [87-88] consist of two cross search patterns and hexagon search patterns which are similar in [75] for fast block matching Motion Estimation. This search technique is a frame based fractal video compression technique that helps to reduce the encoding time and increases the compression quality in fractal coding.

A. Motion Estimation Algorithms

Motion estimation used in the area of video application such that video segmentation, object/video tracking, and video compression. Motion estimation means the displacement of pixels position from one frame to another frame which gives the best motion vector. For estimating a motion in a video sequence, block matching algorithms (BMA) are widely used in most of the video coding standards. In BMA a frame is divided into a non overlapping block and for that block motion vector is estimated. A motion vector is computed by finding best suitable matched block between previous frame-f and the next frame-f+1 as shown in Fig. 7. Motion vector for the block $B_f(x, y)$ is computed as (+1,-1) i.e. MV-$B_f(x, y)$=(+1,-1).

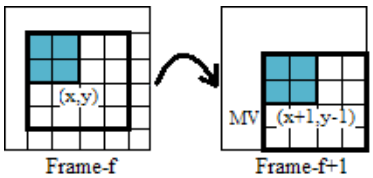


Fig. 7. Block Matching Motion Vector Estimation.

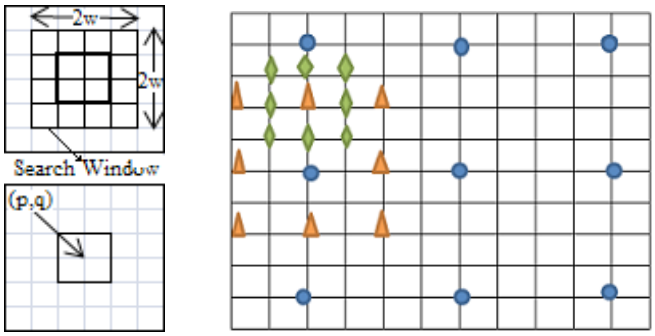
Still, research is going on for efficient and fast block matching motion estimation. Different types of block matching motion estimation algorithms are described below.

1) Full Search Motion Estimation

This algorithm also called as exhaustive search algorithm because motion vector is computed after a complete window of size (2w+1)*(2w+1) is exhaustively searched for the purpose of best matching of block size n x n pixels as shown in Fig. 8(a). Due to the exhaustive search, this algorithm gives a better accuracy in searching the best matching block. The major drawback of this algorithm is to require a number of computations for the best matching block. The computational complexity of this algorithm is very high when the window size is too large and block size is too small.

2) Three Step Search

Koga et al. [89] proposed a robust and very simple three step search motion estimation algorithm. This algorithm is one of the most popular algorithms for the low bit rate application because of its efficient performance. Computational cost of this algorithm is low as compared to the full search algorithm. First step is to define a search window size for searching the best match. In the first step, plot nine points in the search window at the equal distance of step size. In the second step, the step size is divided by 2 if minimum block distortion measure (BDM) point is one of the nine point of search window and consider this point as a center point in the third step. This process is repeated again until the step size is smaller than one. This complete process is shown in Fig. 8(b). If the step size is s=7 then the number of checking points required for TSS is 25 using equation given below. Number of checking points = $1 + 8 \log_2 (s+1)$ where s is step size of the search window.



(a) (b) 1st step: , 2nd step: , 3rd step:

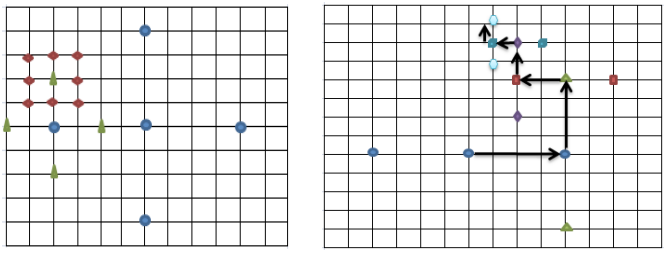
Fig. 8. (a) Full Search (b) Three Step Search.

3) 2D Logarithmic Search

This algorithm was originally proposed by Jain and Jain [90]. In this search strategy, an initial search window size is defined in the central area of the image. As compared to full search motion estimation algorithm, instead of searching all pixels in a complete search window, the search is done in five different directions which contain north, south, east, west and central direction as shown in Fig. 9(a), where Initial window: , Step size divided by 2: , Final step: . If the minimum BDM point is found at any of these five different directions then this direction is considered as a center of the search window for the next step in which search window area is divided by 2 and this process is repeated until the search window area is converted into 3x3 window size. At last, all the nine points are searched in the 3x3 search window and found minimum BDM point corresponds to best matching position that gives the motion vector i.e. block coordinates.

4) Orthogonal Search

A. Puri et al. [91] introduced an orthogonal search algorithm (OSA) based on the combination of three step search (TSS) and 2D logarithmic search algorithm. This algorithm performs firstly a horizontal search with 3 checking points and secondly a vertical search with 3 checking points including minimum BDM point as a center of the previous horizontal search. The step size is divided by 2 and this process is repeated until step size is one as shown in Fig. 9(b), where 1st step: Horizontal search , Vertical search , 2nd step: Horizontal search , Vertical search , 3rd step: Horizontal search , Vertical search . If the step size is s=7 then the number of checking points required for OSA is 3+2+2+2+2+2=13 using equation given below. Number of checking points = $1 + 4 \log_2 (s+1)$, where s is step size of the search window.



(a) (b)

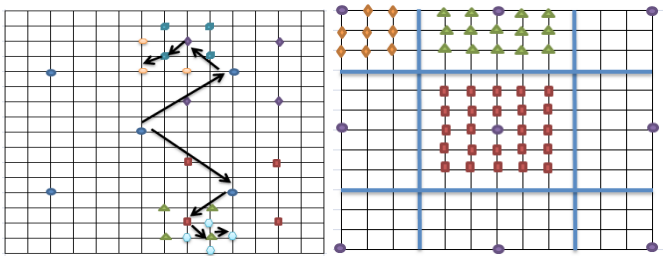
Fig. 9. (a) 2D Logarithmic Search (b) Orthogonal Search.

5) Cross search

M. Ganbari [92] proposed a cross search pattern algorithm (CSA) consisting of 5 checking points placed in a cross shape pattern (X). In each step find minimum BDM point then step size is divided by 2, consider this point as a center and place 4 points in cross shaped pattern across the center point. In the final step, as the step size is reduced to one, place cross search pattern (+) if minimum BDM point of the previous step found at any one of the checking point i.e. center, upper left corner and lower right corner otherwise place cross search pattern (X) as shown in Fig. 10(a), where 1st step: , 2nd step: , 3rd step: , 4th step: . If the step size is s=7 then the number of checking points required for cross search algorithm (CSA) is 5+4+4+4=17 using equation given below. Number of checking points = $5 + 4 \log_2 (s)$, where s is step size of the search window.

6) Binary Search

Binary search (BS) Algorithm is used in MPEG-Tool [93] for block matching motion estimation shown in Fig. 10(b), where 1st step: , 2nd step: best case, 2nd step: , average case, 2nd step: , Worst case. Firstly this algorithm divides the 9 checking outer points of the search window into small 9 search windows and, if minimum BDM point is found at any one of the search windows, then performs a search operation on corresponding search window. If minimum BDM point is found at the center, corner and middle of the search window then the number of checking points required for BSA is 25+9=33 for the worst case, 8+9=17 for the best case and 14+9=23 for the average case respectively. The pixels on the blue lines or the pixels between the search windows are not considered for searching.

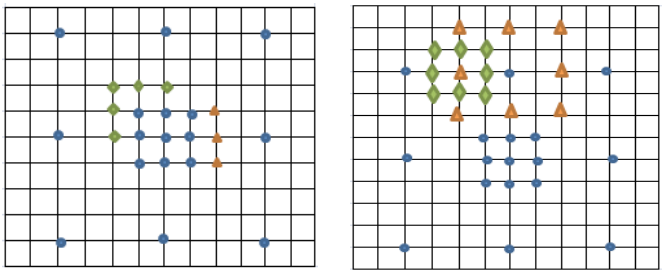


(a) (b)

Fig. 10. (a) Cross Search (b) Binary Search.

7) New Three Step Search

R. Li et al. [78] proposed a new three-step search (NTSS) algorithm consisting of two searching patterns, i.e. center biased checking pattern and halfway-stop technique (step size divided by 2) like three step search algorithm as shown in Fig. 11. This algorithm initially defines a search window size for searching the best match and plots 17 points on that search window size as shown in Fig. 11. From all the 17 points, plot 9 points on the 3x3 grid in the inner/central area of search window & rest of the eight points plot on the 9x9 grid in the outer area of the search window. If the minimum block distortion measure is found at the centre point of the search window then stop/halt searching, otherwise goto step 2. In step 2, if one of the central neighboring points on 3x3 grid is found to be minimum BDM point then go to step 3, otherwise goto step 4. In step 3, if minimum BDM point is found at the corner point or middle point on the 3x3 grid in the inner/central area of the search window of the horizontal and vertical axis, then consider these points are center point and plot/search additional 5 or 3 points respectively in the search window. In step 4, if minimum BDM point is found at corner points and middle points of every two corners on the 9x9 grid in the outer area of search window, then step size is divided by 2, this process is repeated until the step size is smaller than one. In this algorithm, the number of check points required for NTSS is 17 for the best case, 20 or 22 for average case and 33 for the worst case.



Center biased checking: Step 1, 2, & 3 Halfway stop technique: Step 4

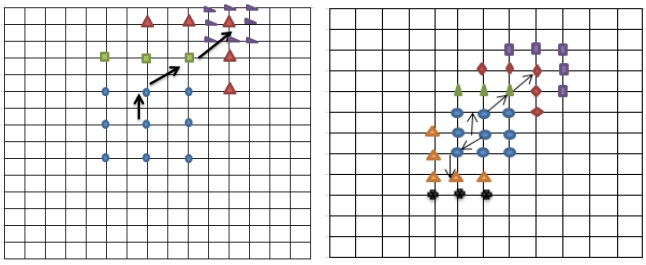
Fig. 11. New Three Step Search Motion Estimation

8) Four Step Search

Lai-Man Po et al. [79] proposed a novel four-step search (FSS) algorithm for block matching motion estimation. The performance measure of this search as compared to other search algorithm is better than TSS and similar to NTSS. Instead of the 9x9 search window in NTSS, this algorithm uses a central biased search pattern with 9 checking points on a 5x5 search window. If minimum BDM point is found at the center of 5x5 search window, then search window size is reduced to 3x3 window size i.e final step of FSS, otherwise goto next step. In next step, if minimum BDM point is found at any one of the four corners of the horizontal and vertical axis or midpoints between the two corners of search window, then check additional 5 points or 3 points in the search window. In the final step, a search window of size 5x5 is reduced to 3x3 window size and minimum BDM point is considered as a motion vector as shown in Fig. 12(a), where 1st Step: , 2nd Step: , 3rd Step: , 4th Step: . If the step size of the final step is greater than one, then again another FSS is performed with the final step of the previous FSS is the first step of the another FSS. The number of checking points required for FSS algorithm is 9+8 = 17 for the best case, 9+5+5+8 = 27 for the worst case, and 9+3+3+8=23 for average case if minimum BDM point found at center point in the first step, corner point in the second and third step and midpoint in the second and third step of the search window respectively.

9) Block- Based Gradient Descent Search

L.K.Liu et al. [80] proposed a block-based gradient descent search (BBGDS) algorithm based on central biased search pattern of 9 checking points. This algorithm performs an unrestricted search within a search window with a step size of one in each step of block generated search pattern. If minimum BDM point is found at the corners of the horizontal and vertical axis or mid points of two corners, then checked additional 5 or 3 points respectively in the search window. If the minimum BDM point is found at the center of current block searched pattern, then searching will stop or, if the search pattern reached to the search window boundary then also stop searching. This algorithm performs better for small motions. Search pattern of block based gradient descent search algorithm are shown in Fig. 12(b), where Upward MV: Step 1: , Step 2: , Step 3: .



(a) (b)

Fig. 12. (a) Four Step Search (b) Block-Based Gradient Descent Search.

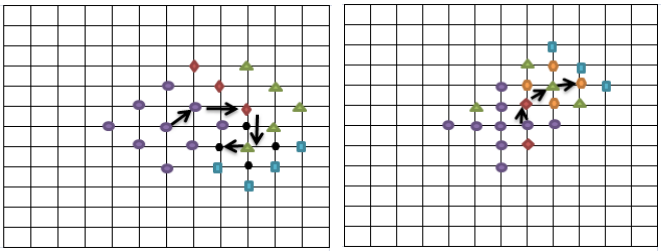
10) Diamond Search

S. Zhu et al. [81] proposed a two diamond shape search (DS) pattern called large diamond shape search pattern (LDSP) and small diamond shape search pattern (SDSP) consisting of nine and five checking points including center point to form a diamond shape respectively. This search initially starts with 9 checking points i.e. LDSP, continue searching with this LDSP to form a new LDSP until the minimum BDM point found on the center of the LDSP and then shifted a large diamond shape search pattern to small diamond shape search pattern. In the final step of this search, the minimum BDM point found in SDSP is considered as a final motion vector as shown in Fig. 13(a), where LDSP: 1st Step: , 2nd Step: , 3rd Step: , 4th Step: , SDSP : 5th Step: Final MV. The number of checking points required for Diamond search algorithm is 13 for the best case. The performance based on the checking points computation of diamond search algorithm is closely related to efficient three-step search algorithm (ETSS) and better than three step search (TSS), four-step search (FSS) and block-based gradient descent search algorithm.

11) Cross Diamond Search

C.H.Cheung et al. [82] proposed a cross diamond shape search pattern algorithm based on halfway stop technique for block matching motion estimation. This search algorithm initially starts with 9 checking points cross shape (+) search pattern instead of diamond shape search pattern in the diamond search algorithm. The performance based on checking points of this algorithm is better than the diamond search algorithm. In the first step, if minimum BDM point is found at the center of large cross shape search pattern (LCSP) i.e. 9 checking points, then stop searching. In the second step, search operation is performed on small cross shape search pattern (SCSP) i.e. 5 checking points. If minimum BDM point is found at the center of the SCSP, then stop searching, otherwise in step three check another extra two points nearer to the minimum BDM point found at the corner points of SCSP. If minimum BDM point found at the center of newly created SCSP, then stop searching, otherwise perform a diamond search in the final step as shown in Fig. 13(b), where LCSP: 1st Step: , SCSP: 2nd

Step: , 3rd Step: , Diamond search LDSP : & , SDSP : Final Step: Final MV.

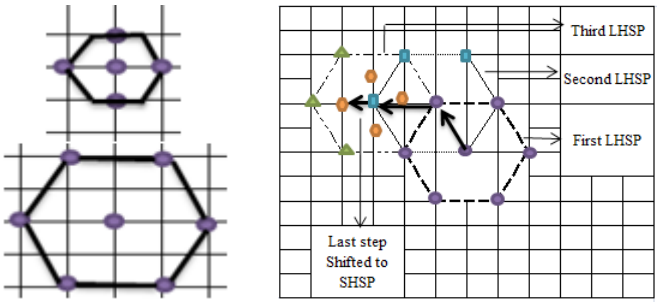


(a) (b)

Fig. 13. (a) Diamond Search (b) Cross Diamond Search.

12) Hexagon Search

Ce Zhu et al. [85] introduced an hexagonal search algorithm for motion estimation, which consists of two hexagon search patterns, Large Hexagon Search Pattern (LHSP) with 7 checking points and Small Hexagon Search Pattern (SHSP) with 5 checking points including center point of the hexagon as shown in Fig. 14(a). This search technique initially starts with LHSP, if minimum BDM point is found at the center of LHSP, then LHSP is shifted to SHSP and new minimum BDM point found in SHSP is the final motion vector of the search, otherwise minimum BDM point found acts as a center of LHSP and check three more points to form a new LHSP, this step is repeated until minimum BDM point found at the center of the new generated large shape pattern hexagon and then lastly shifted LHSP into SHSP. The number of checking points required for the hexagonal search is 11 for the best case. Search pattern of hexagon search algorithm is shown in Fig. 14(b).

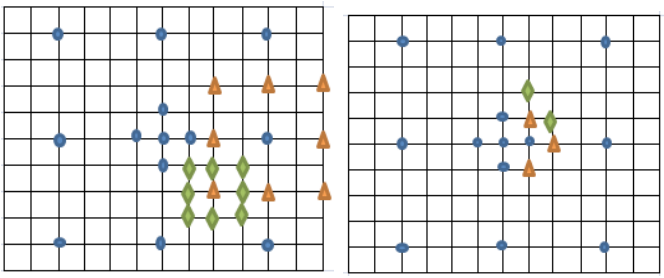


(a) (b)

Fig. 14. (a) Large Hexagon Search Pattern (LHSP) and Small Hexagon Search Pattern (SHSP) (b) Search Pattern of Hexagon Search.

13) Efficient Three Step Search

Xuan Jing et al. [94] proposed a modified version of three- step search algorithm for block matching motion estimation, which consists of unrestricted small diamond search pattern that is used to search the central area of defined search window and used in wide range of video applications like movies, sports etc. This algorithm initially defines a search window size and plots 13 points on that search window size. In step 1, outer 9 points and small diamond search pattern 4 points (Total 13 points) will be checked i.e. 4 points more than TSS and 4 points less than NTSS. If the minimum BDM point is in the center of search window then the search will be stopped/halts, otherwise goto step 2. In step 2, if minimum BDM point is one of the outer 8 points then TSS algorithm is used to search the point, otherwise goto step 3. In step 3, If minimum BDM point is one of the four points on the small diamond pattern, then consider this point as a center and checked another 3 points. This process is repeated until small diamond search pattern reaches to search window boundary. In this algorithm, the number of check points required for Efficient Three Step Search (ETSS) are 13 for the best case and greater than or equals to 29 for the worst case because of unrestricted small diamond search pattern at central part of search window as shown in Fig. 15.



Search pattern used in first step Small diamond search pattern

Fig. 15. Efficient Three Step Search.

14) New Cross Hexagonal Search

Kamel Belloulata et al. [88] introduces a new fast fractal cross hexagonal block matching motion estimation search algorithm consisting of two cross pattern search, i.e. a Small Cross Shape Pattern (SCSP) and Large Cross Shape Pattern (LCSP) as a few initial steps of search, and two cross hexagon search pattern, i.e. small and large hexagon search pattern as a subsequent steps of search as shown in Fig. 16, where SCSP: 1st step: , 2nd step: , LCSP: 3rd step: , LHSP: 4th step: and , SHHP: 5th step: Final MV. This algorithm initially starts with small cross shape pattern consisting of 5 points located at the center of the search window. If minimum BDM point is found at the center of the small cross shape pattern, then stop searching i.e. the number of checking points required for the new cross hexagonal search is 5 for the best case, which is better than all the techniques available for estimating a motion vector, otherwise consider a minimum BDM point as a center of newly formed small cross shape pattern. If minimum BDM point is found at the center of newly formed small shape pattern, then stop searching i.e. another best case solution is 8 checking points required for finding out best possible motion vector, otherwise check the other 3 unchecked points of large cross pattern and 2 unchecked points of the square center biased to show the best possible direction for the hexagonal search. A new large hexagonal shape pattern is formed by considering a center point as minimum BDM point found in small cross pattern search.

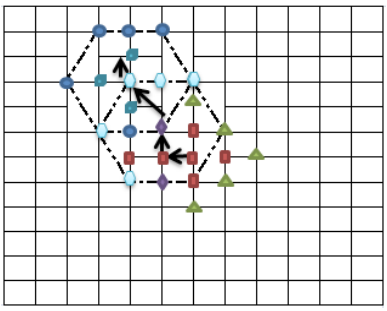
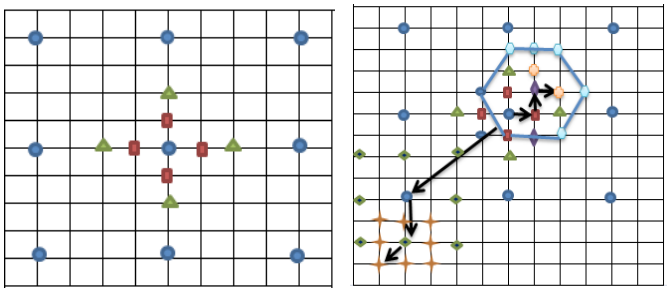


Fig. 16: Search Pattern in New Hexagon Search

If minimum point is found at the center of large hexagonal pattern, then large hexagonal pattern shifted /changed to small hexagonal pattern and find best motion vector in small hexagon shape pattern, otherwise again form a new large hexagon pattern, this formation of new large hexagon pattern is repeated until minimum BDM point is found at the center of large hexagonal pattern.

15) Modified Three Step Search

S. D. Kamble et al. [95] proposed another extended version of three-step search algorithm consisting of Two cross search pattern i.e. small and large cross search pattern and two cross hexagon search pattern i.e. large cross hexagon and small cross hexagon search pattern, which are used in the center part of search window to exploit central biased characteristic of MV in video sequences. Fig. 17 shows the search pattern used in modified three-step search. In the first step, total 9+4 points are checked out of 17 checking points. If minimum BDM point is found at the center of 9+4 points, then stop searching, otherwise go to the second step. If minimum BDM point is found at the outer part of the search window, then search process is same as TSS, otherwise go to the third step.



Search pattern used in first step Two Search pattern

Fig. 17: Search Pattern in Modified Three Step Search

If minimum BDM point is found at the 4 outer points of small cross search pattern, then search process is same as cross hexagon search. There is no restriction on searching in the center window part unless minimum BDM point is found at the center of large cross hexagon pattern or large cross hexagon search pattern reaches to the outer boundary of the search window. This unrestricted search in the central part of the window increases the probability of finding a true motion vector within the center area of the window.

Some other approaches are also proposed by Acharjee et al. [96-98]. Smaller block size based motion estimation approach for video compression is proposed in [96]. Based on the movement in the video, the low and high motion zone approach exists in [97], while the scope of parallel processing is experimented in [98] for motion vector estimation. Generation of the motion vector and motion compensation prediction error plays a key role in video encoding process. Therefore, motion vector dominates the quality of reconstructed frames/video. Y. -G. Wu and G. -F. Huang [99] proposed motion vector generation using gray theory [100] proposed in 1982. Fig. 18 shows video compression process flow using motion compensation WFA encoder.

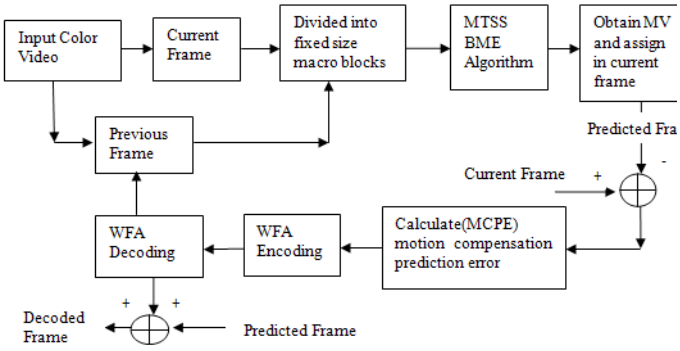


Fig. 18. Video Compression Process Flow.

VII. Quality Measure

Inter-frame and intra-frame coding are used to eliminate a large amount of temporal and spatial redundancy that exists in the video sequences and therefore, help in compressing them. The matching of the one current frame macro block and previous frame macro block is based on the output of matching criteria. The macro block that results in the minimum value is the one that matches the closest to current block with respect to the corresponding previous frame macro block. The popular matching criteria used for block matching motion estimation are mean of absolute difference (MAD), mean squared error (MSE) and sum of absolute difference (SAD) given by equation (8, 9 and 10) respectively.

$$\text{MAD (i,j)} = \frac{1}{N\times N}\sum_{i=0}^{i=N-1}\sum_{j=0}^{j=N-1}|Cij - Rij| \quad (8)$$

$$\text{MSE (i,j)} = \frac{1}{N\times N}\sum_{i=0}^{i=N-1}\sum_{j=0}^{j=N-1}(Cij - Rij)^2 \quad (9)$$

$$\text{SAD (i,j)} = \sum_{i=0}^{i=N-1}\sum_{j=0}^{j=N-1}|Cij - Rij| \quad (10)$$

where N×N is the row and column of the macro block, C_{ij} and R_{ij} are the pixels values compared in the current macro block and previous macro block, respectively. In Block matching algorithms, the size of macro block is the important parameter for motion estimation. Smaller macro block size results in more motion vectors and more macro blocks per frame. Therefore, quality of motion compensated prediction error (MCPE) is improved. Most video coding standards used a macro block of size 16×16 and 8×8. The best/single motion vector is computed for each macro block in the reference frame. On the other hand, the total number of search points to find motion vector per frame is one of the key parameters in block matching motion estimation algorithm.

The performance of video coding is measured in terms of compression ratio, quality of the video, encoding time and decoding time. The compression ratio is given by equation (11).

$$\text{Compression ratio (CR)} = \frac{\textit{Size of original Video}}{\textit{Size of compressed file}} \quad (11)$$

Therefore, the compression ratio in percentage is computed from (11) and given by equation (12).

$$\text{Compression ratio (CR) in \%} = (1 - 1/CR) \times 100) \quad (12)$$

When measuring the quality of the compressed video, the peak signal-to-noise ratio is used. Sometimes mean squared error (mse) is also used, which is given by equation (13).

$$\text{mse} = \frac{1}{n}\sum_{i=1}^{n}(Xi - Yi)^2 \quad (13)$$

From this, the PSNR for an 8-bit grayscale image is defined by equation (14)

$$\text{PSNR(dB)} = 10\log_{10}\left(\frac{255^2}{mse}\right) \quad (14)$$

Where 255 is the maximum value an 8-bit pixel can assume.

VIII. Discussion and Conclusion

Based on the studied literature, it is found that there is a scope of improvement on the challenging issues of fractal coding like searching best domain block, domain pool size reduction, partitioning scheme, domain pool classification and use of parallel computing architecture for fractal compression. The major challenge in fractal coding is how to reduce the encoding time due to a large number of computations involved in fractal coding. From the studied literature on automata

theory based existing compression approaches, any image/sequence of image is represented by the finite automata. The automata theory based coding technique is similar to the fractal coding technique for searching the self similarity parts present in the image/sequence of image and regular expression notation is used to specify the address of each subimage. Our observations from the experimentation carried out by contributors/authors who have already contributed their work on automata theory based coding approach on the different existing databases, it achieves the high compression ratio, good image/video reconstruction quality, fast decoding and reduction in encoding time. The existing different block matching motion estimation approaches for finding out the motion vectors in a frame are widely accepted by video compression research community/society and efficiently used in video compression standards are- H.261 to H.263 and MPEG-1 to MPEG-4. Our observations from the studied literature on different block matching motion estimation algorithms are given in Table II. Table II shows the performance comparison for different existing approaches discussed in this paper based on number of search points per block and Table III shows comparative performance analysis based on the parameters i.e. step size, number of steps required and performance for small/large motions.

TABLE II
PERFORMANCE COMPARISON BASED ON NUMBER OF SEARCH POINTS/ BLOCK

Search method	Search shape pattern	Best case	Average case	Worst case
TSS	Square	25	25	25
2DLS	Cross + Square	17	17	17
OSA	Line	13	13	13
CSA	Cross	17	17	17
BS	Square	17	17 to 33	33
NTSS	Square	17	17 to 33	33
FSS	Square	17	17 to 27	27
BBGDS	Square	09	09 to34	34
DS	Diamond	13	13 to 30	30
CDS	Cross + Diamond	09	09 to 29	29
HS	Hexagonal	11	11 to 30	30
ETSS	Square + Diamond	13	13 to <=29	<= 29
CHS	Cross + Hexagonal	5/8	5/8 to <36	< 36
MTSS	Square + Hexagonal + Cross	13	13 to <29	< 29

TABLE III
COMPARATIVE PERFORMANCE ANALYSIS ON PARAMETERS

Search method	Small motions	Large motions	Number of steps required
TSS	Not perform better	Perform better	3
2DLS	Not perform better	Perform better	3
OSA	Not perform better	Perform better	3
CSA	Not perform better	Perform better	Conditional
BS	Perform better	Not perform better	Boundary
NTSS	Perform better	Perform better	3
FSS	Not perform better	Perform better	4
BBGDS	Perform better	Not perform better	Boundary
DS	Perform better	Not perform better	Conditional
CDS	Perform better	Not perform better	Conditional
HS	Not Perform better	Perform better	Conditional
ETSS	Perform better	Perform better	3/ Boundary
CHS	Perform better	Perform better	Conditional
MTSS	Perform better	Perform better	3/Conditional

IX. FUTURE SCOPE

There is a scope of improvement in developing a new shape pattern or modifying existing shape pattern approaches by combining two different algorithms i.e. developing a hybrid approach for finding out the motion vectors for fractal and other compression techniques with specific focus on reducing the encoding time and better reconstruction quality of video.

We can extend the block motion estimation approach in future by combing with the extended version of the finite automata for exploring the fractal video compression. We can also use these block matching motion estimation approaches for tracking a single/multiple object tracking applications to track the objects in a video.

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