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False Alarm Reduction For The Cardiac Arrythmias: AI Based Comparative Analysis

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Abstract: In this paper various classification techniques have been discussed for the comparative analysis of cardiac arrhythmias. Cardiac arrhythmias can be acknowledged as nonuniform variations in heart health. 86% of false alarm ratio has been observed by in intensive care units (ICUs) by WHO and PHYSIONET. High false alarm ratio in intensive care units (ICUs) may be the root cause of a life threat to the patients. Missed ECG (electrocardiography) signals and missed heart rate variability(HRV) indications may cause sudden death. Less accuracy and precision of the monitoring equipment in intensive care units (ICUs) due to the wrong configurations, connections, calibrations originate high false alarm rate that may arise mental depression in patients and death toll. ECG (electrocardiogram) and ABP (arterial blood pressure) are commonly measured to identify the cardiac variations which may differ due to the uneven diagram. Diverse methodologies have been studied for the false alarm reduction in intensive care units (ICUs). Comparative analysis has been done for the fuzzy logic, ANN, Support vector machine (SVM), MLP, MLP-PSO, k-means, fuzzy k-means clustering, fuzzy logic controller (FLC), DWT (discrete wavelet transform) and DWT with ANN. Detailed contrastive survey of diversified schemes depicted that cuckoo-based optimization and Modified cuckoo search (MCS) could perform better. An adequate MCS algorithm is strongly suggested for the false alarm reduction in intensive care units (ICUs) vigorously.

Keywords: cardiac arrhythmias, false alarm detection, ECG, asystole, bradycardia, tachycardia

1.0 INTRODUCTION

False alarms found in cardiac observation affect the patients' health and also creates a negative impact for the hospitals as well. The accuracy of the ECG signals may be attenuated by various types of noises, data transmission issues, small battery backup that leads towards to the high false alarm ratio. Many reports and complaints have been received and recorded in Intensive care unit (ICU) regarding the increased false alarm rate. Up to 86% fake alert ratio has been noted that may cause the inattention of the doctors and patients as well [1]. Arrhythmias can be considered as the main basic abnormalities of heart functioning [1]. The electrocardiogram (ECG) signal is used widely to analyze the heart health. Arrhythmias can be regarded as the physical abnormalities and variations in heart used to investigate the disease. Analysis of irregular pattern is mandatory for the prevention of heart [2]. HRV (heart rate variability) is very fruitful in finding heart health [3]. Many classifiers and forecasting methods have been studied like ANN with fuzzy [4] Support vector machine [5] Generalized Discriminant Analysis [6] methods. Abundant schemes have been investigated using AI, NN, MLP, PSO and other rigor methods.

When the learning from the data is acquired that means no supervised learning will be used. Unsupervised classifier algorithms were used as these algorithms were adjusted accordingly and directly from the data having no competency level and no early information regarding the system.Two famous clustering mechanism, k-means and fuzzy k-means have been utilized. The fuzzy k-means performs same as k-means but the basic difference is that a sample is not fixedly designated to cluster; it is assigned with a degree.Bayesian classifier and fuzzy logic controller have been investigated as classifiers [7].

ABP and ECG data are collected automatically in Intensive care units (ICUs) on regular basis. If the observation lies beyond the specified threshold range it will initiate an alarm that would be propagated to the concerned health staff and patient. In spite of the fact that apparatus and machinery available in the ICUs for the continuous assessment of patients possess higher

sensitivity and precision so that it may not miss any fake alert [2]. The 86 % fake alert ratio constitutes a negative impact for the health center and patients as well.

2.0 RECENT TRENDS

Cardiac arrhythmias are the irregular pattern, shape and variations of heart beat of electrocardiogram (ECG). Few arrhythmias can be regarded as very hazardous for the patient's health. Cardia health is examined by the sympathetic and parasympathetic activity of autonomic nervous system (ANS). HRV (Heart rate variability) has been measured by various techniques like signal analysis and ANN methods [8-10]. DWT (Discrete wavelet transform) [11], ANN fuzzy logic [12-13], fuzzy logic [14] [15] and combination of ANN with DWT [16]. Data was gathered from MIT-BH standard directory [10].
Rhythm identifier code was developed in MATLAB to classify the frequencies having threshold from 5 to 15Hz. QRS complexes were recognized by the Thompkins's algorithm [17].

2.1 DATA COLLECTION

MIT-BIH arrhythmia database for the training of 750 records were provided by PHYSIONET.org and examined on 500 records. Irrational data segments were identified in each of the channel. QRS compounds and RR intervals were present in the signal.
Arrhythmias can be considered as the main basic abnormalities of heart functioning. ICU monitors have the capability to observe the arrhythmias. Arrhythmias can be classified as

a) **Asystole** (missed beats more than 4 sec)
b) **Bradycardia** (Heart rate is less than 40 beats per minute bpm)
c) **Tachycardia** (Heart rate is greater than 140 beats per minute bpm)
d) **Ventricular Tachycardia** (a pattern of ventricle beats greater than 100 beats per minute)
e) **Ventricular flutter/fibrillation** (oscillatory waveform more than 4seconds) [1].

The ECG signals were filtered to clean the powerline impedance of 30Hz. QRS complexes and Rs have been identified by the Pan and Tompkins algorithm [15]. Time series data was divided into small parts. Usually cardiovascular system can be categorized as non-linear system.

Currently False alarms in intensive care units (ICUs) have become critical issue. Varieties of design techniques have been followed to discriminate the true signal from false signal for example Extended Kalman Filtering (EKF) to improve the accuracy in identification of false alarms [18].

Wavelet Transform Technique was applied to identify the fake alerts in ventricular tachycardia [19]. Fake alerts in arterial blood pressure (ABP) were minimized by utilizing morphological and timing information [20]. Data mining based scheme has also been utilized for the false alarm classification in intensive care units (ICUs) [21].

The authors have categorized this review paper into four sections section 1 explains about the background and introduction while section 2 is related to the recent techniques which have been investigated for the false alarm reduction in cardia arrhythmias. In section 3 several methodologies have been discussed and analyzed for the ECG and ABP signals analysis to forecast the false alarms.

3.0 METHODOLOGY

The main motive of this research was to discriminate the fake alerts accurately. Invalid blocks (IA), QRS complexes and RR intervals were scrutinized and if there is a false alarm identified the procedure ends.

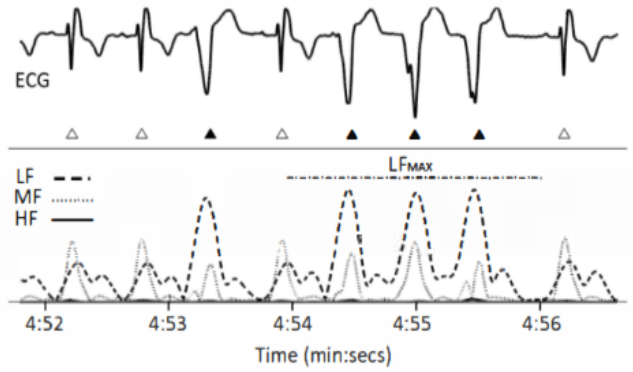

Figure 1. ECG signals [1]

Fig. 1 elaborates the identification of QRS complexes were based on amplitude envelopes of the ECG signal. The three frequency ranges for the amplitude envelopes were calculated by utilizing the Fourier and Hilbert transform – LF (1-8 Hz), MF(5-25Hz) and HF (50-75 Hz) [1]. QRS complexes were identified using ABP (Arterial blood pressure) and PPG (photoplethysmograph).

Minimum and maximum heart rate, summation and standard deviation of RRs were compared to the limits.
To minimize the false alarm in regular activity using QRS temporal distribution are explored in a 2-second-long window.

Proposed algorithms were data specific. Majority of the false alarms were detected in MIMIC II (multi-parameter intelligent monitoring in intensive care unit).
The approach comprised of three components

a. Feature Extraction
b. Feature Selection
c. Feature Classification

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In FFAD (Feature based false alarm detection) before the extraction irrelevant data is eliminated from the particular signal. ABP and ECG signals are processed to reduce the noise. The asystole and rate limit arrhythmias alarms must be triggered within 10 seconds. FA (positive), FA (negative) and classification accuracy were considered as the evaluation parameters. Decision Tree is a machine learning tool for classification and regression. It performs like SVM (support vector machine). Bagged decision is same as decision tree. The only difference is that doesn't take the whole data for the forecasting model. SVM was utilized for the classification on LibSVM [21].

MLP is widely used for the classification. MLP comprised of hidden layers input and output. MSE (measure of accuracy) and RMSE (root mean square) are usually measured and calculated to estimate the accuracy and actul error. To pick the hidden neurons to refrain from over and under fitness was very complex issue [22]. Freshly a new computational technique was proposed for optimization problem [23]. Hidden layers were optimized by the PSO to achieve better accuracy. Results proved that the integrated approach of PSO and MLP drastically improved the performance compared to the MLP [2] [24].

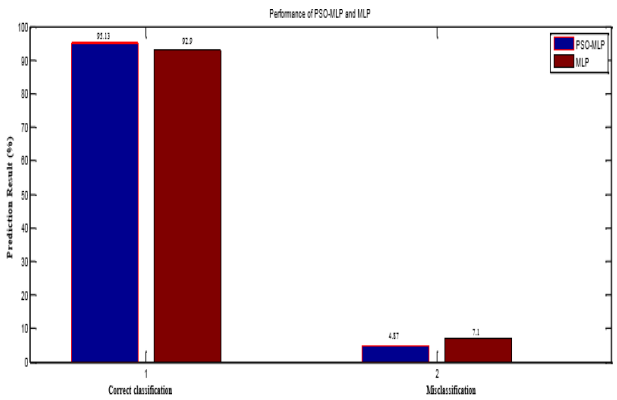

Figure 2. Graphical analysis of MLP and MLP PSO [2]

Fig. 2 shows the comparative results of both proposed algorithms. Blue on bar is for the MLP-PSO and red one for the MLP. Achieved results of MLP PSO are acknowledges as more competent to other algorithms [2].
Optimization can be considered as the modification of a system to make it more accurate, precise and reliable or searching for the best value and results. The cuckoo search was invented in 2009 by Yang and Deb. It is the inspiration by cuckoo birds, the cuckoo search was applied to the system it performed better than PSO and GA and Ant colony is also a famous optimization. The next invent is based on the current position.

Levy Flight:
A random walk in which steps are described.

Multimodal Optimization:
CS algorithm can result multiple solutions in both non-noise and additive white Gaussian Noise. Cuckoo search can find better value of optimization.
CKD (Chronic Kidney Disease) is the latest alarm crucial issue to the developed countries. WHO stated that in developing countries CKD is increasing briskly [25]. Preventive measures have been studied for the diabetes mellitus, hypertension and cardiovascular disease. This issue has become more challenging due to the lack of early forecasting system of CKD which may cause end stage renal failure (ESRD). Several machine learning approaches have been like support vector and Naïve Bayes for the prediction of CKD.SVM performed better [26]. SVM and Back propagation was proposed. Results showed that BPA improved the classification-Back propagation and learning vector Quantization (LVQ) was designed Data mixing procedure was applied for CKD diagnosis has a vital role in CKD prediction and categorization. The major critical issue raised in the model was getting stuck in local optima while searching for optimal weights for NN. In our work input weights were optimized by utilizing modified Cuckoo search optimization. The Modified Cuckoo Search (MCS) reduced the RMS (Root Mean Square) [27].
Cuckoo search: Cuckoos lay their eggs in other nests and the probability of egg that can be accepted or thrown away depends upon the similarities between the host egg and cuckoo eggs. Algorithm uses random walk in Levy Flight behavior.

The NN-MCS design model was compared with the PSO-NN design results concerning the following terms:

- Accuracy
- Precision

Simulations results demonstrated that NNARX and PSO based techniques also worked better [28].

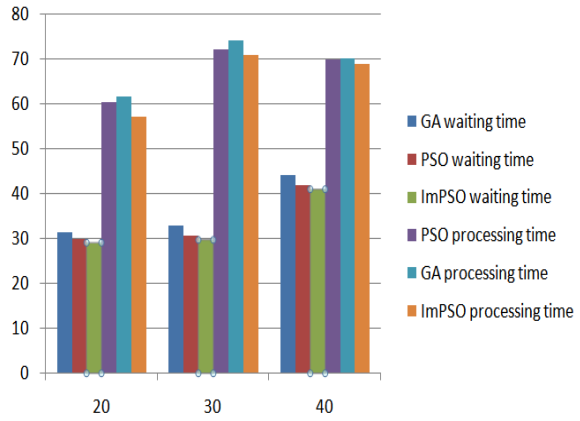

Figure 3. Comparitive output of GA, PSO and ImPSO [29]

Fig. 3 demonstrates the output results of GA (Genetic Algorithm), PSO (Particle swarm optimization) and ImPSO (Improved PSO). Results showed that ImPSO

worked better than GA and PSO and took less processing time for the selection of the best value hence it can also be acknowledged that ImPSO could be the best optimization technique [29].

4.0 RESULTS AND DISCUSSION

Techniques	Accuracy (%)	Precision (%)	FA (N) (%)
SVM	90.39	90.13	9.61
MSTSA	91.0	90	9.0
FLC	89.36	89.15	10.64
EKF	92.61	91	7.39
ANN	95.7	94.6	4.3
NNARX	95	95	5
MLP	96.33	95.74	3.67
GA	93.1	93	6.9
MLP-PSO	98.15	98.53	1.85
ImPSO	98.5	99.2	1.5
MCS	99.6	99.5	0.4
Hybrid MCS	99.7	99.5	0.3

Table 1: Accumulated summary on the basis of extensive literature review

Table 1 represents about the cumulative results of the various optimization procedures for the detection and elimination of false alarm rate found in intensive care units (ICUs). Evaluation parameters were more than accuracy and precision like fitness, Recall and F-measure but we have exhibited accuracy, precision and Negative false alarms found in intensive care units (ICUs). It is very obvious and easily understable from these evaluation parameters that which optimization and classification approach could perform more better than other approaches.

5.0 CONCLUSION AND FUTURE WORK

Almost all the classification approaches performed better or upto the mark. Exploratory experimental results clarified that SVM(support vector machine), MSTSA (multi-scale symbolic time series), FLC (fuzzy logic controller), EKF (extended kalman filtering), ANN (artificial neural network, NNARX (Neural Network Autoregressive Model with Exogenous Input), MLP (Multi-layer perceptron), GA (Genetic algorithm), MLP-PSO, ImPSO (Improved PSO|), MCS (Modified cuckoo search) and Hybrid MCS have achieved 90.39%, 91.0%, 89.36%, 92.61%, 95.7%, 95%, 96.33%, 93.1%, 98.15%, 98.5%, 99.6%, 99.7% accuracies respectively. On the basis of these portrayed results MLP with the combination of PSO and Hybrid MCS are firmly suggested in the furure work as the best classification schemes.

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