CLASSIFICATION OF CARDIAC ARRHYTHMIA USING ARTIFICIAL NEURAL NETWORK WITH OPTIMIZATION ALGORITHM

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Abstract: Electrocardiogram (AUTOMATIC) signal classification is one of the most powerful for the diagnosis of dangerous heart conditions. In this paper, first step is done the noise is removed from the digitized ECG signal. After that QRS complex, T and P waves are detected and finally done the delineated using different amplitude and threshold values. Finally the required features are extracted and then the ECG beats are classified into different heart abnormalities. In this paper, Myocardial Infarction, Ventricular Tachycardia, Premature Ventricular Contraction, ST deviation, Supra Ventricular arrhythmias, by using Feed Forward Artificial Neural Network Classifier, Ventricular Fibrillation are classified. Conventional segmentation methods present some limitations such as, need of definition of large number of parameters and lack of obvious way to tune all these parameters. Optimization is used to adjust the parameters of the delineator in order to minimize the cost function and it is able to find global solution in high dimensional search space. Particle Swarm Optimization is defined as (PSO) and Artificial Bee Colony Optimization is defined as (ABC) are used here. The databases are extracted by using these databases MIT-BIH, EURO VFDB, SVDB, MIT ST Change, CUVTDB databases. The dataset is involved by first trained, validated and tested after that it is analyzed by using the Pattern Recognition Toolbox in MATLAB. The Artificial Neural Network achieved 81.1% accuracy in its training phase before optimization and 90.5% with ABC and 92.9% with PSO.

Index terms: ECG, PSO, ABC and Wavelet Transform.

1. INTRODUCTION
ECG is the recording of the electrical activity of heart. The information obtained from the ECG signals is used to identify different heart abnormalities. An ECG represented by the cardiac physiology, which can be used in diagnosing cardiac disorders [1], ECG is a main way of collecting information from a body in order to better analyze the hearts activities.

MIT/ BIH is defined as (Massachusetts institute of technology / Beth Isrel hospital) Data bases [2] are used to verify the various algorithms and implemented by MATLAB software. Several approaches to Classification were proposed. Artificial Neural Networks have often been used as a tool for realizing classifiers that are capable for dealing with non-linear differentiation between classes and to accept insufficient or ambivalent input patterns. Back Propagation algorithm is used which performs gradient descent algorithm to reduce yocard the mean square error between adjusting the weights in the actual output and the desired output. In our previous paper study the Wavelet algorithm and Neural network is used to identify and categorized by Premature Ventricular Contraction, Myocardial infarction, ventricular Tachycardia, Supra - Ventricular Arrhythmia, ST deviation, Ischemia Change. Optimized features using PSO and ABC optimizations are used to achieve more accurate classification.

2. PROBLEM FORMULATION
2.1 Cardiovascular Diseases
Cardio vascular disease (CVD) causes the death of over 17 million people worldwide each year. The cause of CVD is due to heart attacks, strokes heart valve problems and abnormal heart rhythm [3].MI, PVC, VT, LTSV arrhythmias are the dangerous Cardiac disorders. The classification of ECG (electro Cardiogram) into these different types of cardiac diseases is a difficult task. Therefore the characteristic shapes of ECG need to be found for the successful classification. In this analysis, Discrete Fourier Transform (DFT) is low efficient when compared to the wavelet transform algorithm, whether not the patient
will lose the chance of treatment. Hence ECG detection should be reliable in both an ECG monitoring system or else a defibrillator. So cardiac arrhythmias are classified like atrial flutter, atrial fibrillation, ventricular flutter, ventricular fibrillation etc. By using these many databases are used to making this project possible. In which finding the quality ECG signal, which does not require filtering and relatively clean signals are desired. NEXT the signals are analyzed using Artificial Neural Networks (ANN).

ECG is a non-invasive technique. By using an ECG that is simple to analyze and record the electrical activity of heart. From the leads that are analyzing the heart are to be known. In which to understand better about ECG, Knowledge about the signal outputted. Each heart beat signal is analyzed by the ECG. Certain properties help us to determine which cardiac abnormality, if any is occurring in the heart. For the abnormalities in this paper most of them can be analyzed using the differences in the QRS part of the signal. Duration and amplitude of ECG is used to determine the difference in the heart.

Myocardial Infarction (MI) is a type of heart abnormality which occurs when part of the heart muscle, called myocardium, is deprived of oxygen and nutrients. Common causes of ischemia are Narrowing of coronary artery or presence of blocks in coronary artery, causing an imbalance in supply and demand for energy [4]. The heart muscle cells die when the ischemia lasts for a longer period of time. This is commonly called a heart attack or myocardial infarction. This is the reason why it is critical to recognize ischemia on the ECG in an early stage. Within in few minutes severe ischemia results variations in ECG signals. Duration of the ischemia on the ECG, in some situations it is difficult to estimate. which is crucial for adequate treatment [5]. Ischemia episodes have been performed on the ST-T European database [6].

PVCs are premature heart beats that originates from the ventricles of the heart. They are premature because they occur before the normal heart beat. This early heart beat can happen in either atria or ventricles. The heart is filled with more blood during the pause time following the PVC giving the next beat with extra force. This pattern may occur randomly or at regular intervals. Many studies have shown PVCs, when accompanied with myocardial infarction, can be linked to mortality. Consequently their sudden detection and treatment is essential for patients with heart diseases. PVCs are performed with MIT-BIH Arrhythmia database [2].

Ventricular Tachycardia (VT) is nothing but a fast heart rhythm that occurs in one of the ventricles of the heart. It has a pulse rate of more than 100 beats per minute. It is a tough problem for the physicians as it often occurs in life threatening situations. The symptoms of VT are angina, palpitations, shortness of breath etc. [7].

Supra Ventricular Tachycardia (SVT) is also a sudden heart rate variation with a heart rate above 100 beats per minute. It starts and ends quickly. It originates above the heart’s ventricle. This is also called Paroxysmal Supra ventricular Tachycardia. The symptoms of SVT are palpitations, Dizziness etc.

ST Segment depression is determined by measuring the vertical distance between the patient’s trace and the isoelectric line. It is a sign of myocardial ischemia. Long term ST is to detect the transient ST segment changes in the ECGs.

Ventricular Fibrillation (VF) is a condition. In Ventricular fibrillation condition having uncoordinated contraction of the cardiac muscles of the ventricles in the heart, It is making them quiver rather than contract properly [8]. Finally results occur in cardiogenic shock and cessation of powerful blood circulation. As a consequence, Sudden Cardiac Death (SCD) will result within few minutes.

3. METHODS
3.1 De-noising
The ECG signal may have noises like base line wandering, power line interference etc. These noises are to be removed since they are not required for the analysis [9], [10].Wavelet transform is used for noise cancellation. The de-noised ECG signals are then segmented and delineated using stationary wavelet transform [11].

3.2 Feature extraction
3.2.1 Wavelet Transform Algorithm
Wavelet transform algorithm [9] is used to decomposition of the signal. In which combination of a set of basis function obtained by Dilation and Translation.  

\[
w_a(x) = \frac{1}{a^{0.5}} \sum_{b} \langle x \ast [-b]/a \rangle dt, a > 0 \quad (1)\]

The ECG wave has to be detected for extracting the
features. In this paper 15 features are extracted from each sample [12]. These features may be either Statistical or Morphological. Morphological features are QRS interval, T wave interval, P wave interval, R amplitude, S amplitude, QRS delineation interval, T wave delineation interval, P wave delineation interval, Slope of ST interval and Statistical features are Mean, Variance, Standard deviation, Skewness, Kurtosis, Spectral entropy.

3.3 Classification
3.3.1 ECG Classification Flow
This stage consists of the Segmentation, Extraction and classification process. The heart beat finishes at the next P wave from the beginning of P wave of the following heart beat [13]. After this process feature extraction was done for extracting the significant features of ECG (15 features) mentioned above was extracted, after which the classification [14] was done using the ANN classifier. The classification algorithm checks for any abnormalities in the heart beat [15].

3.3.2 Classification of Arrhythmias using artificial Feed Forward neural network
Feed forward networks continuously having one or more hidden layers of sigmoid neurons followed by an output layer of linear neurons. When nonlinear relationships between input and output vectors [16] multiple layers of neurons with nonlinear transfer functions allow the network to learn. A network can have several layers. Each layer has a weight matrix W, a bias vector b, and an output vector a.

It consists of three layers the first layer is the input layer which takes the input and middle layer is the hidden layer, which has no connection with the other layers. In Back propagation algorithm the inputs and outputs are fed into the network for many cycles, by which the network clearly learns the relationship between the input and the output, in this when every time the input vector is given for training the output is compared with the target called the error, which is calculated by

\[
\text{Error} = \text{Target} - \text{output}^2
\]

The goal is to minimize the error with minimum iteration. The weights between the processing units are iteratively adjusted, in the Back propagation algorithm. So that the overall error is minimized for classifying first the samples are trained then check the validity and finally tested. The Arrhythmias considered are, 1) Myocardial Infarction, 2) Premature Ventricular Contraction, 3) Ventricular Tachycardia Supra Ventricular Tachycardia, 4) ST depression and 5) Ventricular Fibrillation.

![Figure 1: Feed Forward Neural Network with Back Propagation Algorithm](image)

![Figure 2: Setup for the beat analysis of ECG signals using Feed forward artificial neural networks.](image)

3.3.3 Classification using Particle Swarm Optimization
PSO is an Optimization algorithm that is inspired from nature. The particles move around the space to obtain optimum solution. In PSO Each and every particle in the swarm represents a point in the solution space. The main operators of the PSO algorithm are the velocity and the position of each particle. In each iteration the particles evaluate their positions according to their fitness function. Then the velocity and position of each particle are updated depends upon the equation,
\[
v_{i}(t + 1) = w_{i}v_{i}(t) + c_{1}\phi_{1}x_{i}(t) - x_{i}(t) + c_{2}\phi_{2}p_{g} - x_{i}(t)
\]

where \(v_i(t)\) represents the current velocity and \(v_i(t+1)\) represents the next velocity, which controls the movement direction of the \(i^{th}\) particle and \(x_i(t)\) and \(x_i(t+1)\) represents the current and next position of the \(i^{th}\) particle[17]. The above equations are used to optimize the selected features of ECG signal and these optimized features are used for classification.

3.3.4 Classification using Artificial Bee Colony

Artificial Bee Colony algorithm (ABC) was proposed by Karaboga. It is modeled based on two processes, sending of bees to nectar (food source) and desertion of a food source [18]. Here bees act as variation agents which are responsible for generating new sources of food. There are three types of bees in ABC algorithm. They are employed bees, onlooker bees and scout bees. These bees obtain the optimal solution. This algorithm is very simple when compared to existing swarm algorithms. The action of employed bees is mathematically given by [19],

\[
v_{ij} = x_{ij} + \phi_{ij} x_{ij} - x_{ij}
\]

Where, \(x_g\) is the current solution in which the bee is located, \(X_{ij}\) is randomly generated food source and \(\phi_{ij}\) is the real random number between [-1 1]. Features are optimized using the above algorithm and then used for classification.

4. RESULTS AND DISCUSSIONS

Fifteen samples are taken from each database with a total of 62 samples for training and 14 samples for testing and validation. The datasets are trained several times to minimize the error. The overall classification error is 11.1%. In Medical statistics Sensitivity (S), Positive predictivity (+p) and Specificity has to be evaluated [12].

\[
S = \frac{TP}{TP+FN}
\]

\[
+p = \frac{TP}{TP+FP}
\]

Where TP is True Positive, FP is False Positive, FN is false negative. BP performs the gradient search for reducing the mean square error, which is obtained from training the network.

From the table given below it is clear that we obtain a better classification using PSO and ABC algorithms. Without optimization the maximum training accuracy is only 81.1%. But if the features are optimized using PSO the training accuracy is improved to 92.9% for four classes and using ABC it is improved to 90.5% for six classes. The MSE in the training, validation and testing phase of ANN is reduced by using PSO and ABC optimized features.

<table>
<thead>
<tr>
<th>Iterations</th>
<th>MSE Training</th>
<th>MSE Validation</th>
<th>MSE Testing</th>
<th>Training Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Optimization</td>
<td>28 2.141e-2 2.929e-2 6.758e-2</td>
<td>76.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1.044e-1 1.425e-1 4.302e-1</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>1.731e-1 1.593e-1 1.44e-1</td>
<td>81.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With ABC 6 classes</td>
<td>43 3.281e-3 2.379e-3 1.084e-3</td>
<td>90.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6.4527e-6 1.2072e-1 8.885e-6</td>
<td>83.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>1.3421e-7 1.5167e-1 4.897e-7</td>
<td>85.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With PSO 6 classes</td>
<td>35 6.4527e-6 1.2072e-1 8.885e-6</td>
<td>83.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>1.3421e-7 1.5167e-1 4.897e-7</td>
<td>85.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 classes</td>
<td>34 1.613e-5 7.645e-5 1.097e-2</td>
<td>88.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>2.651e-5 1.468e-5 1.284e-5</td>
<td>92.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1 shows the classification results of the data using Feed Forward neural network classifier with Back Propagation algorithm before and after optimization. Fig 3 shows the Confusion Matrix of Classification of ECG beats into six and four abnormalities. The Confusion matrix having information about actual and predicted classifications done by using system. In the training phase classification error is 7.1% for PSO (for 4 classes) and 9.5% for ABC (for 6 classes).

Figure 3: Confusion matrix of classifier using ANN with PSO and ABC optimized features for 4 and 6 classes.

Table 2: Comparison of Sensitivity, Positive Predictivity, Specificity and Accuracy before and after Optimization

<table>
<thead>
<tr>
<th>Performance Evaluation (%)</th>
<th>Without Optimization</th>
<th>With ABC</th>
<th>With PSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Classes</td>
<td>4 Classes</td>
<td>6 Classes</td>
<td>4 Classes</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>84.12</td>
<td>92.126</td>
<td>62.97</td>
</tr>
<tr>
<td>Positive Predictivity</td>
<td>81.65</td>
<td>90.47</td>
<td>66.46</td>
</tr>
<tr>
<td>Specificity</td>
<td>94.35</td>
<td>98.145</td>
<td>87.812</td>
</tr>
<tr>
<td>Training Accuracy</td>
<td>81.1</td>
<td>90.5</td>
<td>62.3</td>
</tr>
<tr>
<td>Overall Accuracy</td>
<td>71.3</td>
<td>78.3</td>
<td>53.3</td>
</tr>
</tbody>
</table>

Table 2 shows that after optimization the percentage of sensitivity, positive predictivity and accuracy is increased.
Fig 5 shows the error histogram of the classifier. This gives the error in the training, validation and testing stages at various instances.

5. CONCLUSIONS
The Feed Forward neural network classifier with back propagation algorithm using optimized features performs better than other networks in terms of Sensitivity, Positive Predictivity, Specificity and Accuracy. In this study the cardiac arrhythmias such as MI, PVC, VT, VF and SVT has been detected and classified using six different types of databases. Similarly, large number of arrhythmias can be classified using other databases. ECG signal is first de-noised and then segmented. Selected features are extracted from the segmented ECG. Using these features the ECG classification is done without optimization and with PSO and ABC algorithms. The optimization is used to adjust the parameters of the delineator in order to minimize the cost function and it is able to find global solution in high dimensional search space.

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REFERENCES


[16] Roland Adams,Anthonychoi, “Neural network to predict cardiac arrhythmias”, 2012 florida conference on recent advances in robotics”.

