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An EMD Based Approach for the Detection of Premature Ventricular Contraction

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Abstract**: This paper gives a novel method for detection of Premature Ventricular Contraction (PVC) based on Empirical Mode Decomposition(EMD) of Electrocardiogram (ECG) signal. Four linear and one nonlinear feature are used for ECG classification. The features used are RR ratio, QRS area, Sum of trough, Sum of R peak with minimum, and IMF entropy. For classifying the beats in to normal and PVC an SVM classifier is used. To evaluate the proposed method MIT-BIH arrhythmia database is used.***

Keywords: Arrhythmia, Premature Ventricular Contraction, EMD, IMF, SVM, QRS area, Sum of Trough.

I. INTRODUCTION

Electrocardiogram (ECG) is a diagnosis tool that plots the electrical activity of heart on a paper. Electrodes are placed on the skin to measure the ECG. Any problem with human heart can be analysed by the analysis of the ECG morphology and heart rate. [1]. It is normally a noninvasive technique. The signal is measured on the surface of human body. Any variation in the normal heart rate or rhythm, or change in the morphological pattern, is an indication of cardiac arrhythmia. An ECG signal of a human heart has the following entities. A P wave, QRS complex, and T wave. (Figure.1). If we can extract the information about intervals, amplitudes, and waveform morphologies of the different P-QRS-T waves, the onset of the arrhythmia can be detected.

The normal rhythm of the heart where there is no disease or disorder in the morphology of ECG signal is called Normal sinus rhythm (NSR). The normal heart rate of a human being is 60 to 100 beats per minute. There will be a slight variation in the regularity of the R-R interval with the breathing cycle. When the heart rate is more than 100 beats per minute, the rhythm is known as tachycardia. If the heart rate is too slow (less than 50) then this condition is known as bradycardia and this can badly affect vital organs.

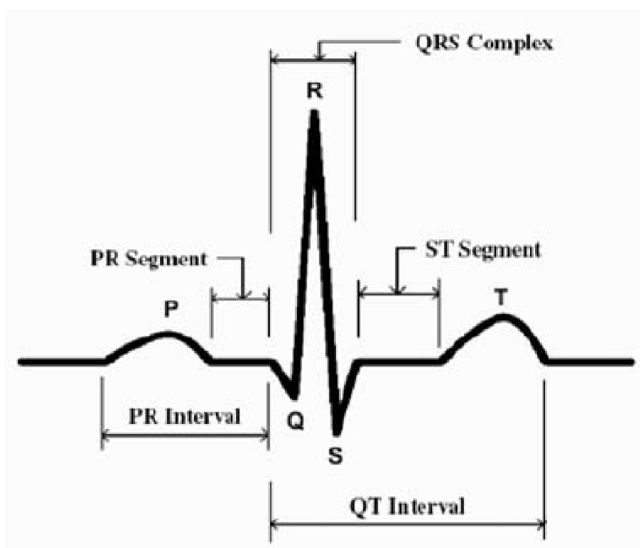

Figure 1. ECG signal.

The different types of arrhythmia related to human heart are Atrial arrhythmia, Junctional arrhythmia, Ventricular arrhythmia, Atrioventricular block, and bundle branch block. In this paper mainly the ventricular arrhythmia is discussed. Ventricular arrhythmias normally originate from the bottom chambers of the heart called the ventricles.

Ventricular arrhythmias can be divided in to Premature Ventricular Contraction (PVC), Ventricular Tachycardia, and Ventricular Fibrillation. In this paper the method to detect PVC is discussed. PVC results from the early depolarization of the myocardium

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originating in the ventricular area and is a widespread form of arrhythmia in adults [2]. PVC is common, with an estimated occurrence of 1 to 4% in the general population. It is often seen along with structural heart disease and increases the risk of sudden death. The main characteristics of PVC are: wide QRS complex, a missed P- wave and a T- wave which is longer than the normal one. An SVM classifier is employed for classifying the beats in to normal and PVC.

A lot of studies are already done on arrhythmia detection. A QRS image based geometrical features are used for detection of arrhythmia. [3] An SVM –KNN hybrid classifier is used for classification. In another work ECG beats are classified using S-transform and Genetic algorithm [4]. An MLP neural network is also used for classifying ECG beats for arrhythmia detection [5].

In the proposed method ECG beats are classified based on a nonlinear feature extracted using EMD and four linear features. The linear features that are used here are RR ratio,QRS area, Sum of trough, Sum of R peak with minimum.

II. MATERIALS AND METHODS

A. ECG Data Base

The MIT-BIH arrhythmia data base is used for validation in this study. [6] The MIT-BIH Arrhythmia Database contains 48 half-hour extracts of two-channel ambulatory ECG recordings, obtained from 47 subjects studied by the BIH Arrhythmia Laboratory between 1975 and 1979. The recordings were digitized at 360 samples per second per channel with 11-bit resolution over a 10 mV range. The QRS complex of each beat is detected as a first step. After detecting the QRS complex it is easy to detect the P wave and T wave. The database contains approximately 109,000 beat labels. In MIT-BIH Database ECG signals are described by- a text header file (.hea), a binary file (.dat), a binary annotation file (.atr) and (.mat) a mat lab file. Header file describe the detailed information about the ECG like number of samples, sampling frequency, format of ECG signal, type of ECG leads and number of ECG leads, patients history and the detailed clinical information.

B. Discrete Wavelet Transform

Discrete wavelet transform is used to detect the Rpeak. The discrete wavelet transform (DWT) is an implementation of the wavelet transform which uses a discrete set of the wavelet scales and translations. The original signal is divided in to a set of approximation and detail coefficients. The sub band decomposition of DWT is shown in Figure.2. The details are the low-scale, high-frequency components of the signal. Approximations are the high-scale, low frequency components of the signal. The main advantage of DWT is that different band of frequency can be analysed. For DWT analysis first a mother wavelet has to be selected. The selection of mother wavelet depends upon the type of signal which has to be analysed. The analysed signal which is similar to the wavelet function is usually selected. Haar, daubechies, biorthogonal, coiflets, symlets, morlet, Mexican hat etc. are different wavelet functions. Here DB4 wavelet is used for R peak detection because it has a shape similar to the Qrs complex.

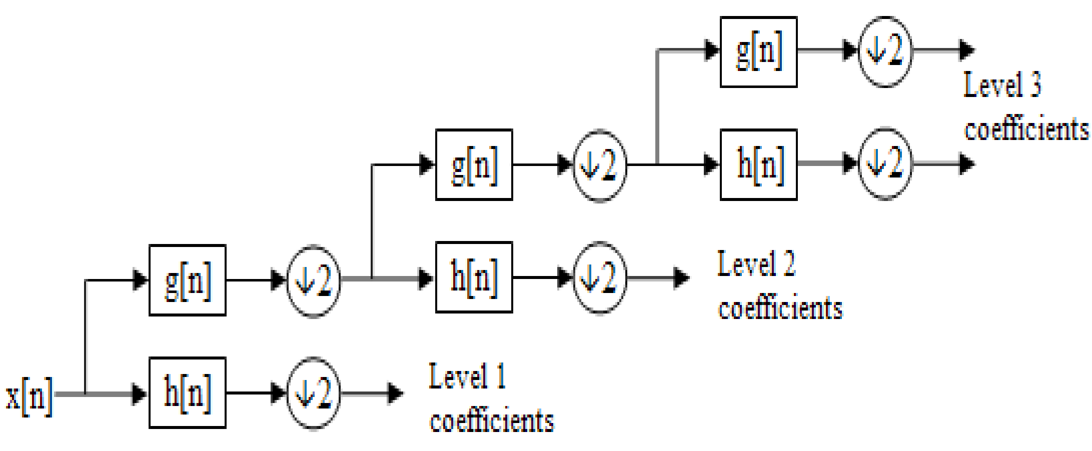

Figure 2. Subband Decomposition of DWT

C. Empirical Mode Decomposition

The Empirical mode decomposition is an algorithm used to decompose a signal in to a series of intrinsic mode functions (IMF).EMD is mainly used to analyse non stationary and non linear signals. The main advantage of using EMD compared to other transformation techniques like wavelet transform is that, for EMD no prior knowledge about the signal is required. An IMF is defined as a function that satisfies the following requirements:

1) In the whole data set, the number of extrema and the number of zero-crossings must either be equal or differ at most by one.

2) At any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima is zero.

The EMD can decompose a signal x(t) in to a series of IMFs and a residue signal r. x(t) can be represented as

$$x(t)= \Sigma\ imf+r \qquad (1)$$

The algorithm for extracting IMFs is given below.

Given an input signal x(t), take r(t)= x(t), n=0.

Step 1: Find local maximum and local minimum of x(t) .

Step 2: Find the upper envelope emax(t) by connecting all local maxima. This procedure is repeated for the local minima to produce the lower envelope emin(t).

Step 3: The mean value at every point of the envelopes [m(t)=(emax(t)+emin(t))/2] is calculated.

Step 4: h(t)=x(t)-m(t). If h(t) satisfies the IMF condition, then n=n+1, imfn=h(t) and Step 5 is performed.

Otherwise, x(t)=h(t), and Steps 1 to 4 are repeated.

Step 5: Let r(t)= r(t)-imfn; if r(t) is a monotonic function, the process is terminated. Otherwise, x(t)= r(t), and Steps 1 to 4 are repeated.

At the end of the decomposition process, the EMD expresses the signal x(t) as the sum of a finite number of IMFs and a final residual r (Equation 1).

D. SVM Classifier

SVM is one of the most popular classifier used for ECG-based arrhythmia detection methods [7].SVM is a binary classifier. An SVM classifies data by finding the best hyper plane that separates all data points of one class from those of the other class. The best hyper plane for an SVM means the one with the largest margin between the two classes. Margin means the maximal width of the slab parallel to the hyper plane that has no interior data points. The support vectors are the data points that are closest to the separating hyper plane; these points are on the boundary of the slab. An SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall. In addition to performing linear classification, SVMs can efficiently perform a non-linear classification using what is called the kernel trick, implicitly mapping their inputs into high-dimensional feature spaces.

III.PROPOSED METHOD

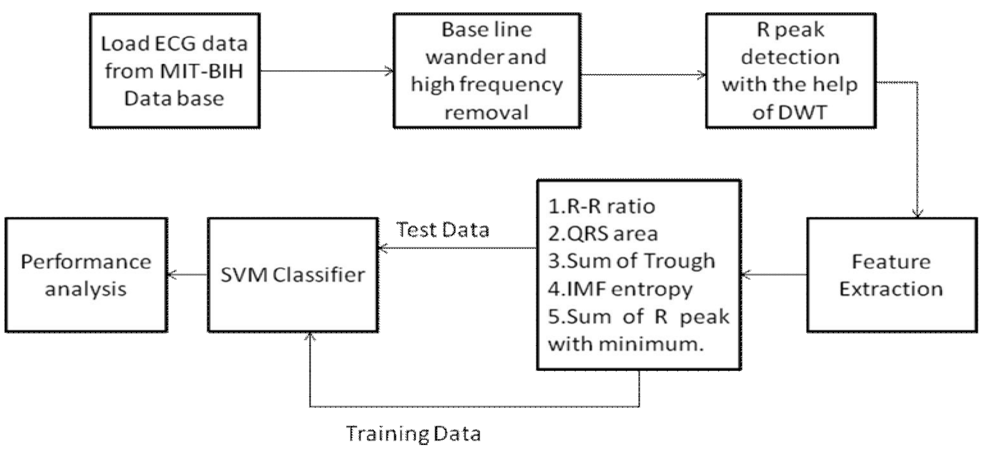

Figure.3. Flow diagram of proposed method.

All the physiological signals will be having lot of noises and artefacts associated with it. So the first step in analysing any signal is to remove these artefacts, ie .preprocessing of the signal. The main artefacts are base line wandering and power line interference.

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The signal is detrended to remove baseline wander and the high frequency component can be removed by Savitzky-Golay least-squares polynomial filters. Discrete wavelet transform is used for detecting the R peaks. DWT will also help in removing the high frequency components. A Db4 mother wavelet is used for decomposition. Wavelet transform will decompose the signal in to approximation and detail coefficients. The details from 2 to 5 are used for detecting the R peak. Once the R peak is detected correctly then P, Q, S and T location can easily be determined with respect to R peak.

Once the morphological values are determined correctly then we can go for feature extraction. Here four linear features and one nonlinear feature are used for classification. The features extracted are RR ratio, Sum of trough, Sum of R peak with minimum, QRS area and IMF entropy. Normally the width of QRS complex for PVC beat will be more than that of normal beat. So here QRS area is used as a feature. RR ratio is found as the ratio of post PVC RR interval to pre PVC RR interval. Whenever PVC beat happens this ratio will be high. To calculate Sum of trough equation 2 is used.

$$Sum\_trough=\Sigma y(Rloc(i)+n) \quad (2)$$

Where Rloc(i) is the location of R-peak, n is the number of samples from the R peak of PVC, y is the amplitude of the original signal. Next feature is Sum of R peak with minimum. It is calculated as

$$\text{Sum of R peak with minimum}=min + y(Rloc) \quad (3)$$

Here min is the minimum value between two R peaks. y is the amplitude of R peak. R peak location is given by Rloc. An EMD based feature is also used for classification. The IMF entropy is the fifth feature used here. To measure the IMF entropy second IMF to fifth IMF are used.

After extracting these five features the feature set is given to an SVM classifier. SVM is a binary classifier which classifies the data into two categories. Here the classifier classifies the beats in to normal and PVC. A 10 fold cross validation is done on the classifier training set.

IV. RESULTS

To evaluate the proposed method MIT-BIH arrhythmia database is used. First the preprocessing of the signals are done to remove any noises and artefacts. The original noisy signal is given in figure.4. Noise removed signal is given in figure.5

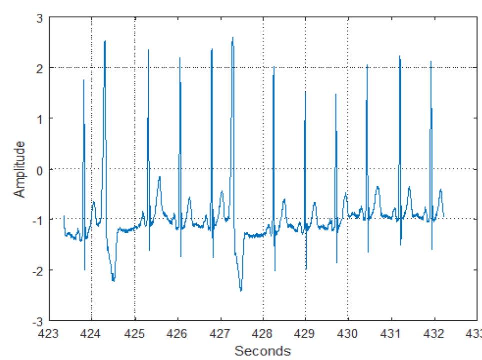

Figure. 4. Original ECG signal with noise

The signal is detrended to remove baseline wander and the high frequency components are removed by Savitzky-Golay least-squares polynomial filters.

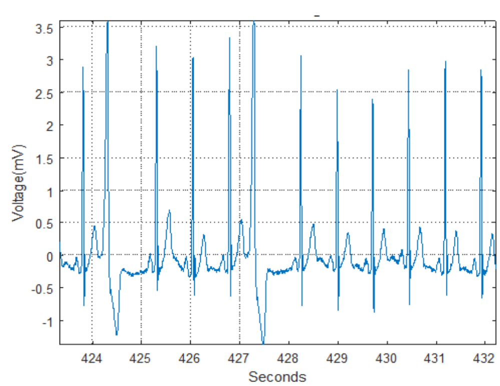

Figure.4. The signal after preprocessing

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R peak detection is done with the help of discrete wavelet transform. The details from level 3 to level 5 are used. From the detected R peak Qlocation and S locations are found out.the detected beats are shown in figure .5.

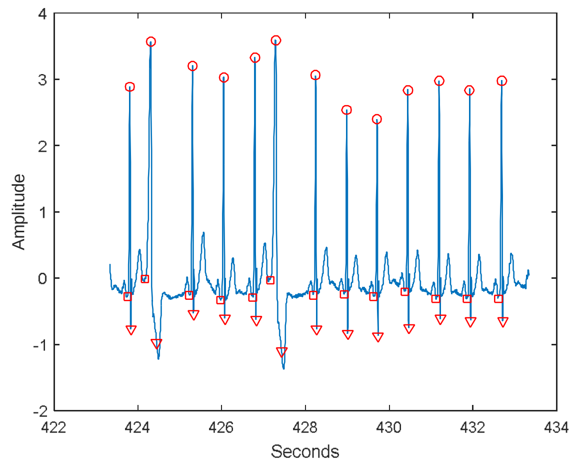

Figure.5.QRS detection.

An SVM classifier is used to classify the beats in to normal and PVC.421 beats are used for evaluating the proposed method. There are 365 normal beats and 56 PVC beats. 200 beats are used for training the classifier, and then it is tested with 221 beats. Proposed method gives an accuracy of 100%.

V. CONCLUSION

In this paper a method for detection of Premature Ventricular Contraction is discussed. The results shows that this method gives a better accuracy compared to other PVC detection methods.. The algorithm can be used to detect arrhythmia in more number of ECG records. The proposed method can be further extended to detect the other ventricular arrhythmias like Ventricular Fibrillation and Ventricular Tachycardia.

VI. ACKNOWLEDGMENT

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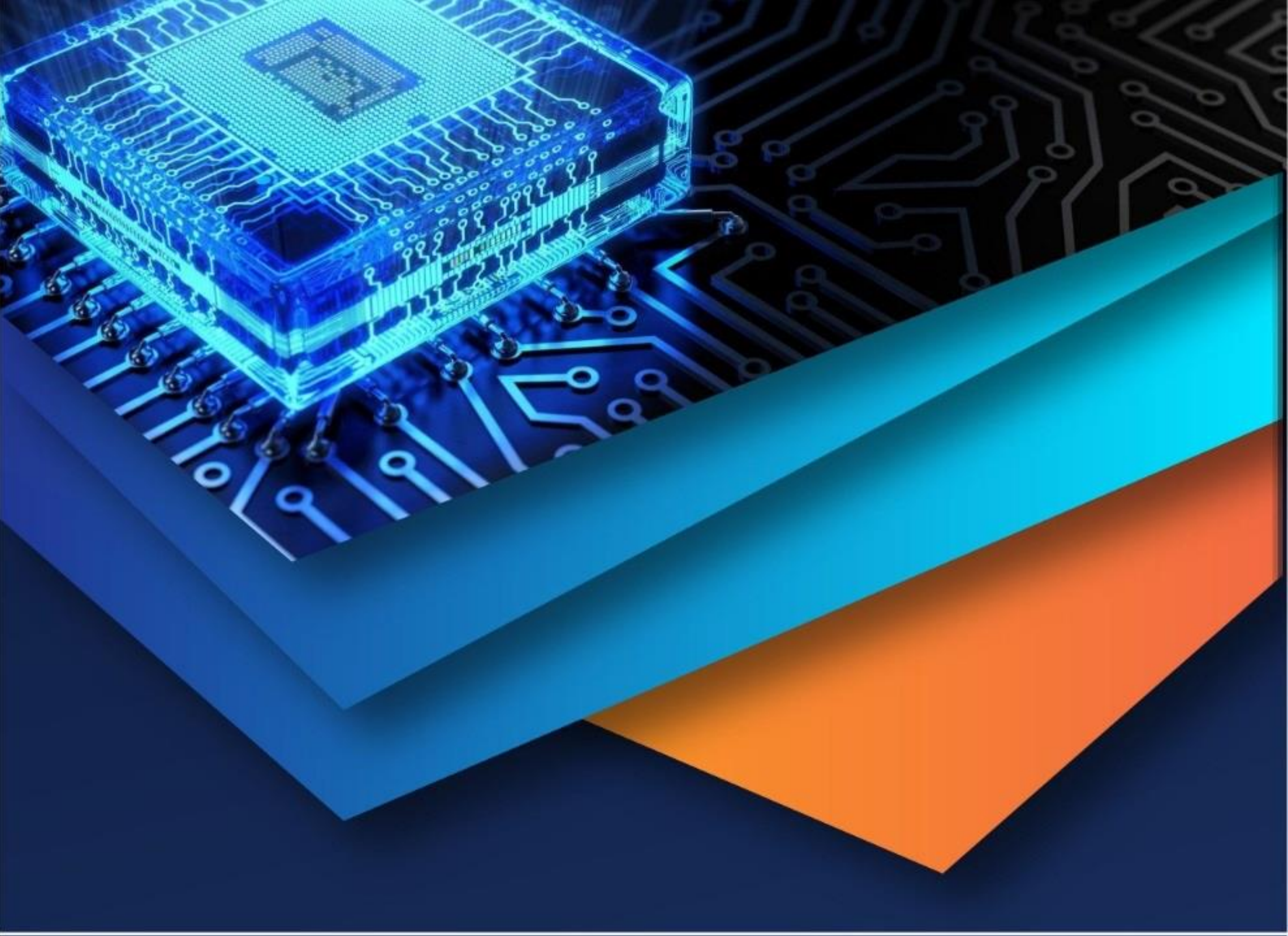

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