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Feature Extraction and Classification of ECG Parameters

Phadte Sneha Kisan[1], Amita Dessai[2]
[1] Goa College of Engineering, Electronics Communication and Instrumentation, Ponda, India
Email: snehakphadte20@gmail.com
[2] Goa College of Engineering /Electronics and Telecommunications, Ponda, India
Email:amitachari@gec.ac.in

***Abstract*— Electrocardiogram (ECG) is a diagnosis device which reports the electrical activity of heart. An ECG comprises of a P-QRS-T waves. There is a complete dissimilarity in extracted features of the ECG between Normal Heart rhythm and Cardiac Arrhythmia. Cardiac arrhythmia is a set of conditions in which the heartbeat is irregular, too slow, or too fast. The accurate detection of arrhythmia is difficult process for the cardiologist because ECG signals get contaminated due to noise and coexistence of two or more arrhythmic events in one irregular cardiac rhythm. Hence for the reliable detection and interpretation of Arrhythmia an artificial neural network based on feature extraction of ECG signal with the help of signal processing algorithms is required. ECG waveform intervals and ECG peak amplitudes are used as inputs to an Artificial Neural Network.**

Index Terms— **Artificial Neural Network, ECG analysis, ECG Morphology, Feature Extraction, Arrhythmia.**

I. Introduction

The electrocardiogram is a vital tool which provides the information about the proper functioning of the heart. Many Heart diseases are diagnosed by the investigation of ECG. ECG features include wave peaks and wave intervals, which contain most of the clinically useful information [1].ECG records the heart's electrical activity versus time .The ECG signal can be measured on the surface of the human body therefore it is called as a noninvasive device. It is the most important data to study cardiac diseases and conditions. The early discovery of heart diseases is vital for patients. The Sinoatrial (SA) node, which is the natural pacemaker of the heart, gives out the signals which cause the heart's muscle fibers to contract [2].

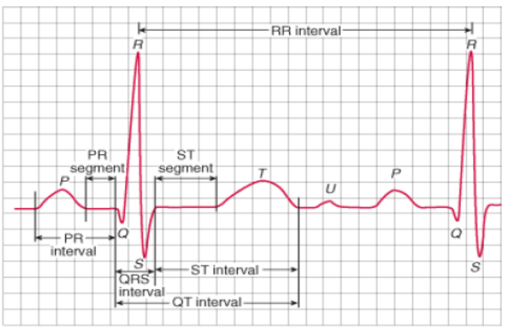

Fig 1. The normal ECG signal

The study of ECG is very useful in the detection of heart diseases which is the major cause of deaths in many countries. The P-QRS-T waves comprise one cardiac cycle of an ECG [3]. The Q, R and S wave of ECG signal follow in rapid sequence. QRS complex is a result of ventricular depolarization of human heart. A Q wave is a downward going wave after the P wave [4].A R wave is an upward going wave after the Q wave. S wave is the downward going wave after the R wave.

When the electrical activity of the heart is irregular, which causes the heartbeat to be slow or fast is called as Cardiac Arrhythmia [5]. They indicate serious cardiac health problems which may lead to a heart stroke or sudden death [6].

II. Propossed System

The proposed system consists of four steps: step i, pre-processing of the ECG signals for noise removal; step ii, segmentation of ECG signal; step iii, Feature Extraction of ECG; step iv, classification of ECG signal.

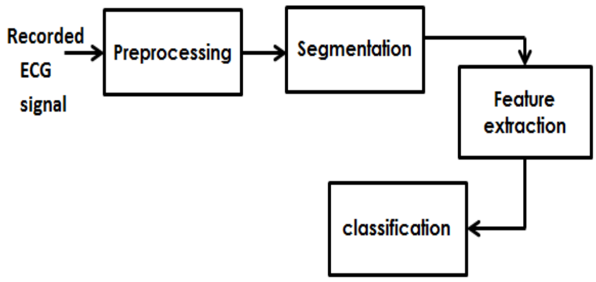

Fig 2. Block diagram of the proposed system

A. Database

The ECG signals used in this paper are found from the Physionet MIT-BIH Arrhythmia database [7] .The database contains of 48 records. Each of the record is over 30 minutes long. Sampling is done at 360 Hz frequency with the resolution of 11 bits. The first set contains 23 records which run from 100 to 124 with particular numbers missing. The second set contains of 25 records which run from 200 to 234 with certain numbers omitted. The first set consists of most common records selected from routine ambulatory practice. The second set contains supraventricular arrhythmias, junctional arrhythmias and complex ventricular arrhythmias.

B. Preprocessing

Signal Averaging: Signal averaging is required because two signals are available from the MIT-BIH Arrhythmia database namely modified limb lead II and modified lead V2. The QRS complex is more prominent in the modified limb lead II signal. Both

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the signals are obtained by placing the electrodes on the chest.

Powerline noise filtering: Noise components appear at the powerline frequency (60 Hz) due to Electromagnetic fields originating from power lines. The interpretation of low amplitude waveforms get mostly affected by these noise components. Power line interference was eliminated by using a notch filter centered at 60Hz.

Baseline drift filtering: The amplitudes of the ECG waveform changes due to baseline drift [8]. Baseline drift occurs due to body breathing which causes the ECG waveform wandering. The measuring electrodes impedance is modulated. Baseline drift is removed by subtracting the mean of the signal from signal itself.

Low pass and High pass filter: The low pass filter and high pass filter are designed with the help of Transfer functions. Low frequency and high frequency noises are eliminated with the use of Low pass filter and high pass filter.

The low pass filter (LPF) is represented by the transfer function:

$$\mathrm{H}(z) = .0002 * \frac{(z^{-1}+1)^2}{(1-z^{-1})^2}$$

The high pass filter is represented by the transfer function:

$$\mathrm{H}(z)= \frac{(z^{-17}-z^{-16}-.01z^{-1}-.01)}{(-z^{-1}+1)}$$

C. Segmentation

Segmentation is done for the determination of R peaks. The following steps are implemented for the determination of R peaks.

Differentiation: The filtered ECG signal is differentiated to obtain the slope information. Differentiation is done to find the maximum slope of the ECG. QRS complexes have highest slopes. The P wave and T wave have small slopes. The P wave and T wave which have low frequency components are suppressed by differentiation. It emphasizes the high frequency components of the QRS complex slopes. The derivative is represented by the transfer function:

$$\mathrm{y(mT)}= 0.125 * [-x(-4T+mT) - 2x(-3T+mT) + x(mT) + 2x(-T+mT)]$$

Squaring: Squaring is done to make the ECG result non negative. The large differences from the QRS complex, with high frequency are enhanced. The differences of the P wave and T waves are compressed which are very small in magnitude. The squaring function is represented by:

$$\mathrm{y\ (mT)} = [\mathrm{x(mT)}]^2$$

Thresholding: Thresholding is done to determine the R peaks. From these R peaks we further determine the RR intervals in the feature extraction stage. If a peak is above the threshold than it is marked as an R peak. If the peak is below the threshold than it is not an R peak.

D. Feature Extraction

In feature extraction stage we need to find out the QRS complex onset and offset. Q peak or the S peak is the other maximum slope of the R wave. In a window backward search is carried out from the R position. If a zero crossing is detected it is marked as Q wave. Q wave is said to be lacking if there is no zero crossing inside the window. Forward search from R position is carried out and the detected zero crossing is marked as QRS offset. S wave is said to be lacking if there is no zero crossing inside the window.The onset of QRS complex is called as the Q wave and the offset of QRS complex is called as the S wave. From this procedure two more features were extracted namely the amplitude of Q wave, amplitude of S wave.

The fourth feature is the RR interval. It is the distance between two subsequent R peaks .It is found by calculating the mean of the detected R peaks.

Also the heart rate is calculated from the RR interval. Heart rate = $\frac{(60 * fs)}{(\mathrm{RR\ interval})}$; where fs is the sampling rate.

E. Artificial Neural Network

ANN architecture is the interconnection of processing elements called as neurons. It comprises of an input neuron layer, output neuron layer and hidden layers. The weights define the strengths of these connections.

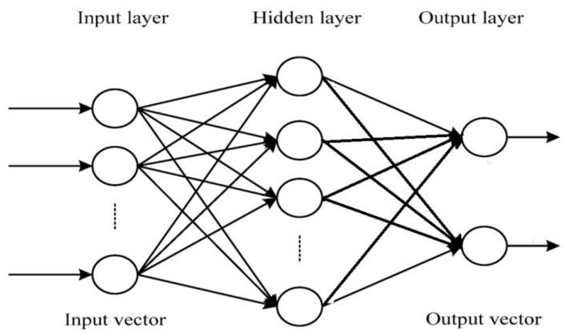

Fig 3. Artificial Neural Network Architecture

The network contains two output neurons. Hidden layers represent the intermediate layers which do not mix with outside environment. Trial and error method is used to find the number of hidden layers. The time required to train a network is directly proportional to the number of hidden layers.

The neural network uses back-propagation algorithm. Each node of the back-propagation algorithm contains a nonlinear threshold element and hence it is a nonlinear method. The layered structure makes it very complex. Nodes are divided into layers which run from 0 to L. The length of node from the input nodes signifies the layer number.

The training function used is traingd; it updates weight and bias values according to gradient descent. For the proper network development, number of training cycles and network size must be carefully selected. The network does not learn the examples presented to it if the training is inadequate. The network memorizes the training examples if the network is trained excessively. The Artificial neural network classifies the ECG based on

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the four features into two different classes namely Normal Sinus Rhythm and Cardiac Arrhythmia.

III. Results

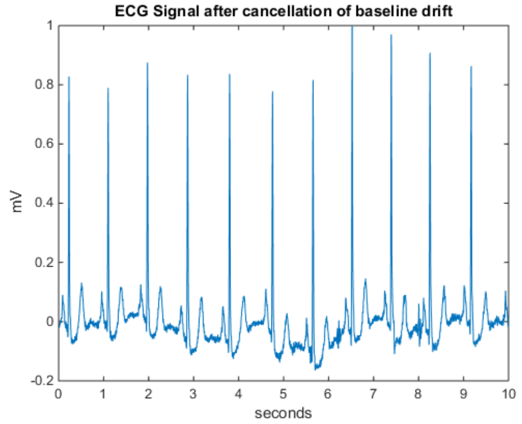

Fig 4. ECG signal after cancellation of Baseline drift

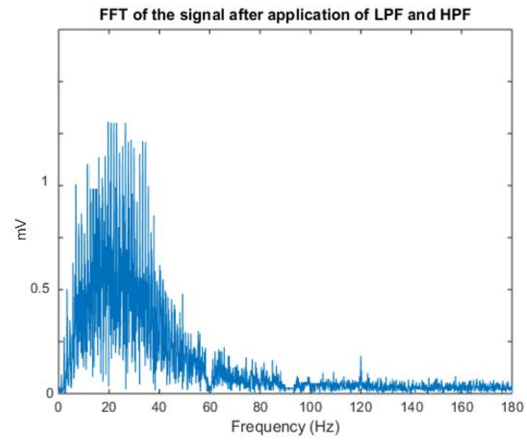

Fig 5. Pre-processed ECG signal in frequency domain

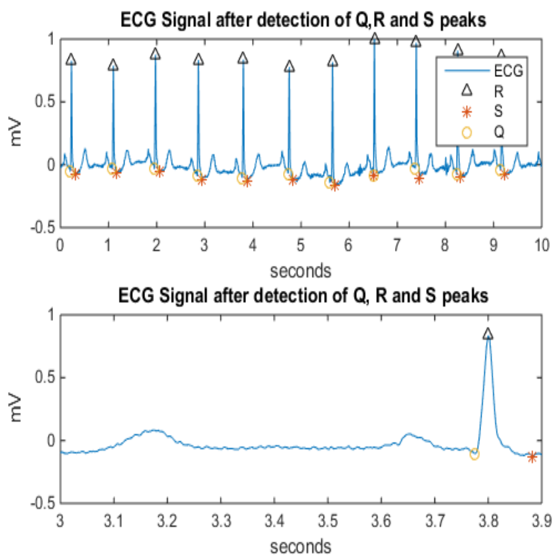

Fig 6. Detected Q peak, R peak and S peak after Segmentation and Feature Extraction of ECG signal

Fig 7. Confusion plot of Artificial Neural Network

Conclusions

The Morphological features of the ECG signal are extracted from the ECG using signal processing algorithms. Features like amplitude of Q wave, amplitude of S wave, amplitude of R wave and RR intervals are used to differentiate between the various ECG signals into two classes namely normal sinus rhythm and Cardiac Arrhythmia. The procedure is implemented on MATLAB platform with the intension to extract the ECG features in best possible way.

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