Cardiac Arrhythmia Detection By ECG Feature Extraction

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ABSTRACT

Electrocardiogram (ECG) is a non-invasive technique used as a primary diagnostic tool for detecting cardiovascular diseases. One of the important cardiovascular diseases is cardiac arrhythmia. Computer-assisted cardiac arrhythmia detection and classification can play a significant role in the management of cardiac disorders. This paper presents an algorithm developed using Python 2.6 simulation tool for the detection of cardiac arrhythmias e.g. premature ventricular contracture (PVC), right bundle branch block (R or RBBB) and left bundle branch block (L or LBBB) by extracting various features and vital intervals (i.e. RR, QRS, etc) from the ECG waveform. The proposed method was tested over the MIT-BIH Arrhythmias Database.

Keywords - Cardiac Arrhythmia, ECG, left bundle branch block (L or LBBB), premature ventricular contracture (PVC), right bundle branch block (R or RBBB).

1. INTRODUCTION

An ECG is a graphic representation of the electrical activity of the heart muscle. ECG is the main diagnostic approach for cardiac rhythm evaluation. Cardiac arrhythmia is the disturbance in the regular rhythmic activity of the heart. Different characteristics such as shapes, interval and amplitudes of ECG reflect different arrhythmias. Arrhythmia may be caused by irregular firing patterns from the SA node or due to abnormal activity from other parts of the heart and indicates a serious problem that may lead to stroke or sudden cardiac death. The vital and weight bearing types of arrhythmia are ventricular tachycardia ventricular fibrillation, premature ventricular contracture (PVC), right bundle branch block (R or RBBB) and left bundle branch block (L or LBBB).

In the past few years, a lot of research has been carried out on the automatic classification of ECG. These attempted to characterize arrhythmia using various features, including waveform shape features i.e. using ECG morphology and heartbeat interval [3], in [2] a set of discrete wavelet transform (DWT) coefficient, which contain the maximum information about the arrhythmia, is selected from the wavelet decomposition. These coefficients are fed to the back-propagation neural network which classifies the arrhythmias, [8] presents the classification of cardiac arrhythmia based on the signal variation characteristic of each beat type. Using the principal component analysis estimation, the detection selects the class by searching the minimal norm of the error vector obtained by basis of each type, Autoregressive modeling (AR) has been applied to ECG signals and the AR coefficients have been used for classification into arrhythmias in [4], and in [9] the estimation of instantaneous frequency (IF) of an ECG signal is used as a method for carrying out detection of cardiac disorder. Based on IF estimates, a classifier has been designed to differentiate a diseased signal from a normal one.

This paper presents a method for the recognition of various categories of cardiac arrhythmias based on their characteristics features extracted from ECG signals. For PVC beat detection RR interval ratio and energy of beat is calculated. Dominant (slurred) or notched (M-shaped) R wave, dominant (slurred) S wave, QRS duration and direction of T wave are used for the detection of LBBB and RBBB.

The rest of this paper is organized as follows: Section 2, presents the ECG signal processing. Section 3 describes the detection of arrhythmia. Finally, the section 4 & 5 summarizes the result & conclusion of this work.

2. ECG SIGNAL PROCESSING

The proposed method includes processing and parameter calculation of ECG and then detection of cardiac arrhythmia using an algorithm developed in Python 2.6 simulation tool. The algorithm is tested over MIT-BIH Arrhythmia database.

2.1 ECG Denoising

ECG signals are usually corrupted by several noises like 50 Hz power line interferences, baseline wander and electro mayogram (EMG). Therefore, the signal needs to be preprocessed before applying any detection algorithm. Wavelet denoising and S- Golay Filter is used for removal of baseline wander and high frequency noise. ECG unfiltered data is passed through baseline wandering removal function, followed by wavelet based high frequency noise removal. The data is then smoothed further using S-Golay filter. All the modules are implemented and simulated in python.

2.2. ECG Parameter Calculation

The purpose of the feature extraction process is to select and retain relevant information from original signal. The Feature Extraction stage extracts diagnostic information from the ECG signal. In order to detect the peaks, specific details of the signal are selected. The detection of R peak is the first step of feature extraction. R peak is detected by using Pan-Tompkins algorithm [1].

The intervals QRS, PR and QT are calculated by searching for corresponding onset and offset points in the wave. The separate logic was implemented for identifying P-onset, Q and S points, once R-peak was located using Pan-Tompkins algorithm. The window is selected around R-wave and the minimum of the points within this window are declared as Q and S points. In the differentiated signal ECGDER, a window of 155 ms is defined starting 225 ms before R-peak position. In this window, we search for maximum and minimum signal value. The P-wave peak is assumed to occur at the zero-crossings between maximum and minimum values within the selected window. Once P-wave peak is found, we proceed to locate waveform boundary-P-wave onset. Similarly T wave peak is obtained by changing the window size.

3. DETECTION OF ARRHYTHMIA

3.1 Detection of PVC

A premature ventricular contraction (PVC), also known as a premature ventricular complex, ventricular premature contraction (or complex or complexes) (VPC), is a relatively common event where the heartbeat is initiated by the heart ventricles rather than by the sinoatrial node, the normal heartbeat initiator.

ECG Characteristics of PVC patient

1. Broad QRS complex (≥ 120 ms) with abnormal morphology.
2. Premature — i.e. occurs earlier than would be expected for the next sinus impulse.
3. Discordant ST segment and T wave changes.

There are five different types Of PVC, first Bigeminy every other beat is a PVC, second Trigeminy every third beat is a PVC, third Quadrigeminy every fourth beat is a PVC, forth Couplet two consecutive PVCs and last Triplet three consecutive PVCs.

The main characteristic of PVCs is its premature occurrence. This characteristic is measured by relating the RR interval lengths of heart cycles adjacent to the PVC. In case of a PVC, these lengths should be notoriously different .The method for classifying the abnormal complexes from the normal ones is based on the concepts of RR interval ratio of detected R peaks and energy analysis of ECG signal [7]. The total energy in a discrete time signal x[n] over the time interval $n1 \le n \le n2$ is defined as $E = \sum_{n1}^{n2} |x[n]|^2$ .The energy of ECG signal is calculated for each beat and RR interval ratio is also calculated. The threshold for energy is taken as 65% of maximum energy and for ratio 70% of maximum ratio value. If RR interval ratio and energy is less than threshold PVC beat is detected. Figure 1 shows the detection of PVC bigeminy and couplet. In Figure 2 PVC trigeminy is detected.

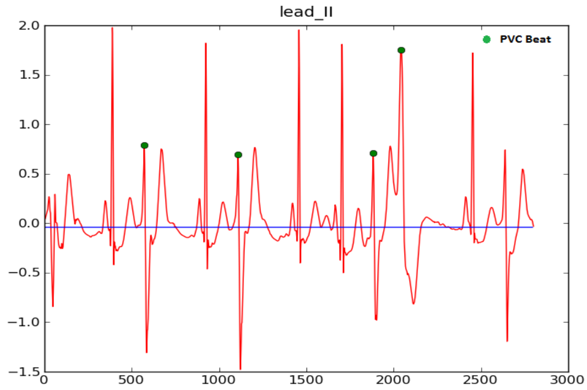

Figure 1.Detection of PVC Bigeminy and couplet

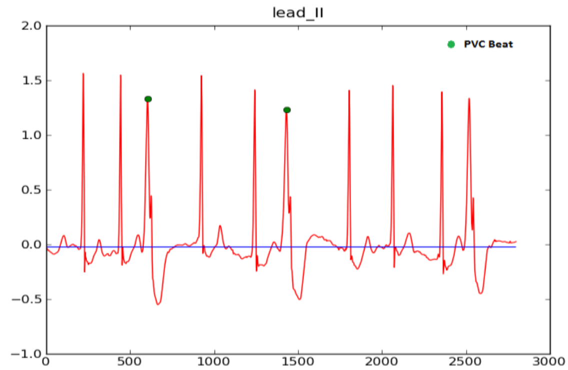

Figure 2.Detection of PVC Trigeminy

3.2. Detection of LBBB

Normally the septum is activated from left to right, producing small Q waves in the lateral leads. In LBBB, the normal direction of septal depolarisation is reversed (becomes right to left), as the impulse spreads first to the RV via the right bundle branch and then to the LV via the septum. This sequence of activation extends the QRS duration to > 120 ms and eliminates the normal septal Q waves in the lateral leads. As the ventricles are activated sequentially (right, then left) rather than simultaneously, this produces a broad or notched ('M'-shaped) R wave in the lateral leads [6] [11].

ECG Characteristics LBBB patient:

1. QRS duration greater than or equal to 120 ms in adults

2. Broad notched or slurred R wave in leads I, aVL, V5, and V6 and an occasional RS pattern in V5 and V6 attributed to displaced transition of QRS complex.
3. Absent q waves in leads I, V5, and V6, but in the lead aVL, a narrow q wave may be present in the absence of myocardial pathology.
4. T wave usually opposite in direction to QRS.
5. Dominant S wave in V1

Two leads lead V6 and lead V1 are mainly considered for detection of LBBB.

3.2.1. Processing of lead V6

Lead V6 is processed for detection of dominant (slurred) or notched (M-shaped) R wave, QRS duration and direction of T wave.

- The dominant R wave is detected by checking each point between Q and S is greater than minimum value of S point for every beat.

QS6[i] >smin

- QRS duration is calculated by taking difference between S point and Q point and then averaging the difference. It should be greater than 120 ms.

QRS>120

- To detect M-shaped R wave array of points between Q and R is obtained for every beat. If the difference between every point and previous point is greater than zero it is normal R wave else notched R wave.

QR6[i]-QR6[i-1]<0

- If the average value of T peak is less than zero then direction of T wave is opposite to QRS complex of lead V6.

Avg(T peak6)<0

M-shaped and dominant Rwave is shown in Figure 3 and 4.

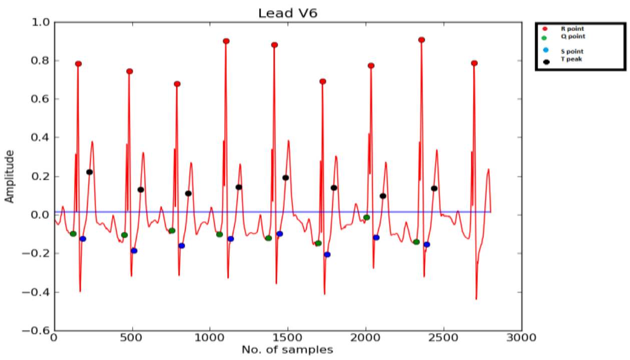

Figure 3.M-shaped Rwave in LBBB

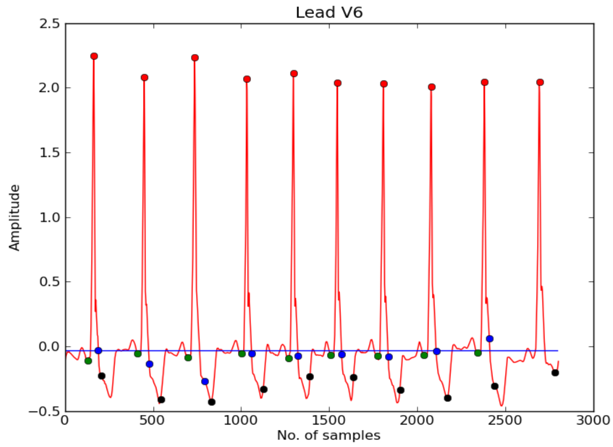

Figure 4.Dominent Rwave in LBBB

3.2.2. Processing of lead V1

Lead V1 is processed for detection of dominant (slurred) S wave, QRS duration and direction of T wave.

- The dominant S wave is detected by checking each point between Q and S is less than minimum value of S point for every beat.

QS1[i] <smin

- QRS duration is calculated by taking difference between S point and Q point and then averaging the difference. It should be greater than 120 ms.

QRS1>120

- If tiny R wave is present then Rwave i.e duration between Q and R and Swave i.e. duration between R and S is obtained. For dominant S wave Rwave duration is less than Swave.

Swave>Rwave

- If the average value of T peak is greater than zero then direction of T wave is opposite to QRS complex of lead V1.

Avg(T peak1)>0

Figure 5 and 6 shows dominant Swave and Swave with tiny Rwave in LBBB.

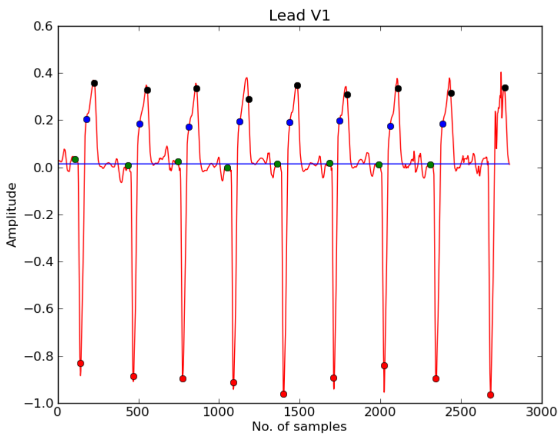

Figure 5.Dominent Swave in LBBB

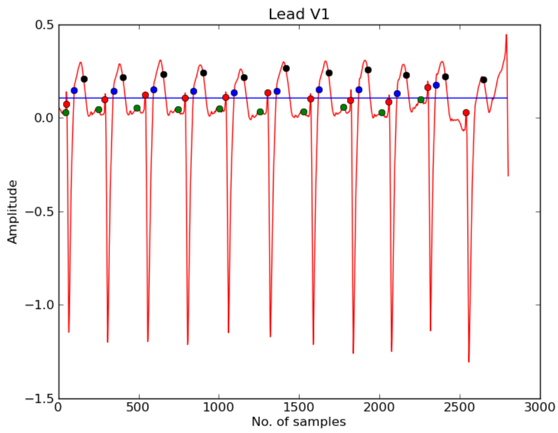

Figure 6.Dominent Swave with tiny Rwave in LBBB

3.3. Detection of RBBB

In RBBB, activation of the right ventricle is delayed as depolarisation has to spread across the septum from the left ventricle. The left ventricle is activated normally, meaning that the early part of the QRS complex is unchanged. The delayed right ventricular activation produces a secondary R wave (R') in the right precordial leads (V1-3) and a wide, slurred S wave in the lateral leads [6] [11].

ECG Characteristics RBBB

1. QRS duration greater than or equal to 120 ms in adults
2. RSR' pattern in V1-3 ('M-shaped' QRS complex)
3. S wave of greater duration than R wave in the lateral leads (I, aVL, V5-6)

Two leads lead V6 and lead V1 are mainly considered for detection of LBBB.

3.3.1. Processing of lead V6

Lead V6 is processed for detection of dominant (slurred) S wave, QRS duration and direction of T wave.

- Rwave i.e duration between Q point and point of intersection of signal with isoelectric line and Swave i.e. duration between point of intersection of signal with isoelectric line and S point is obtained. For dominant S wave Rwave duration is less than Swave.

Swave>Rwave

- QRS duration is calculated by taking difference between S point and Q point and then averaging the difference. It should be greater than 120 ms.

QRS>120

- If the average value of T peak is greater than zero then there is no T wave inversion.

Avg(T peak6)>0

Figure 7 and 8 shows dominant Swave in RBBB.

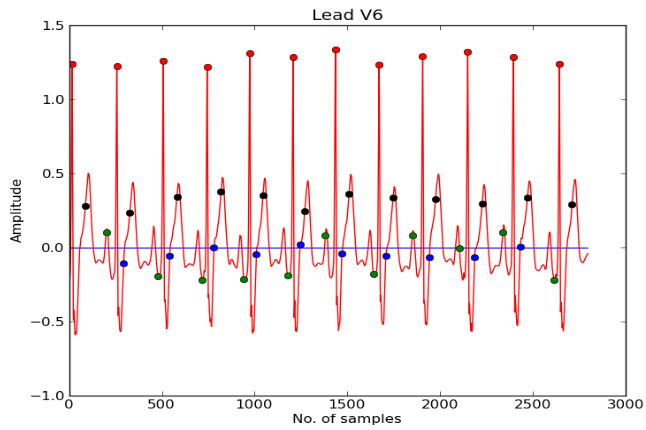

Figure 7.Dominent Swave in RBBB

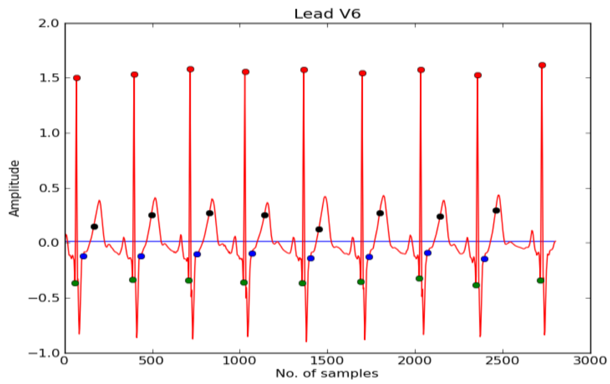

Figure 8.Dominent Swave in RBBB

3.3.2. Processing of lead V1

Lead V1 is processed for detection of dominant (slurred) or notched (M-shaped) R wave, QRS duration and direction of T wave.

- The dominant R wave is detected by checking each point between Q and S is greater than minimum value of S point for every beat.

QS1[i] >smin

- QRS duration is calculated by taking difference between S point and Q point and then averaging the difference. It should be greater than 120 ms.

QRS1>120

- The notched R wave is detected by detecting number of zero crossing between Q and S point. If it is greater than 3 R wave is notched [5].

No. of zero crossing between Q and S >3

- If the average value of T peak is less than zero then it is T wave inversion.

Avg(T peak1)<0

In Figure 9 dominant Rwave is shown. Figure 10 gives notched Rwave in RBBB.

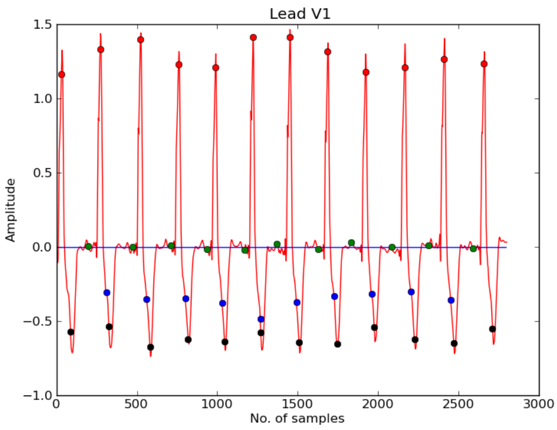

Figure 9.Dominant Rwave in RBBB

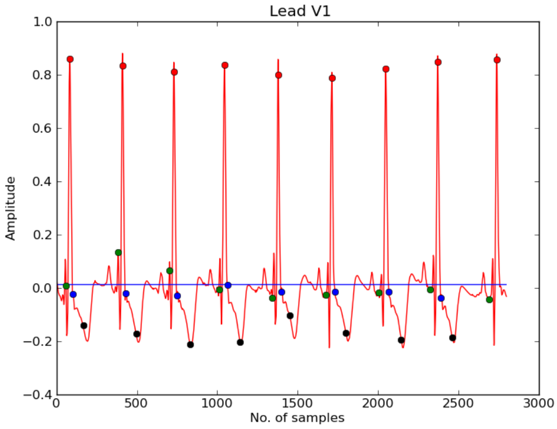

Figure 10.Notched Rwave in RBBB

4. RESULT

The applicability and efficiency of this algorithm has been tested using ECG signals from MIT-BIH database which is developed with the aim to be benchmarking references for automated analysis of ECG [10]. The MIT-BIH arrhythmia database contains 48 records (each 30 minutes long) with a sampling frequency of 360 Hz among which 32 records exemplifies PVC beats. Data of length 7.778sec is taken from PVC records and tested. Two parameters - sensitivity and specificity are calculated to evaluate the detection performance. Sensitivity measures the accuracy in detecting PVC beats whereas specificity depicts performance in rejecting normal beats as non-PVC beats. These two parameters are calculated using the following equations:

$$S_e = \frac{TP}{TP + FN}$$

$$S_p = \frac{TP}{TP + FP}$$

Where, TP, FP, FN denote for true positive, false positive and false negative respectively. True positive is that tests positive for a condition and is positive (i.e; have the condition). False positive is that tests positive but is negative. False negative is that tests negative but is positive. Similarly specificity and sensitivity are calculated for LBBB and RBBB. The final result of detection is provided in Table1.

Arrhythmia	Sensitivity	Specificity
PVC	96.15%	92.59%
LBBB	91.66%	95.65%
RBBB	96.15%	96.15%

Table 1.Result of classification

5. CONCLUSION

This paper presents an efficient and simple detection algorithm based on feature extraction of ECG signal. The efficiency of detection depends on the proper extraction of P-Q-R-S and T points for ECG signal. The overall specificity above 92% and sensitivity above 91% is obtained, which is satisfactorily high considering simplicity. Because of its simplicity it can be a better choice in clinical field of cardiac arrhythmia detection. The efficiency can be further improved by using higher order statistics and support vector machine.

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