COMPARATIVE STUDY OF QRS COMPLEX DETECTION BY THRESHOLD TECHNIQUE

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ABSTRACT

An ECG (Electrocardiogram) is used to measure the heart's electrical conduction system. ECG's are performed for diagnostic or research purposes of human heart. For ECG signal analysis QRS Complex plays an important role. I compare three techniques of QRS Complex detection in this paper. Detection techniques are based on thresholding. De-noising is also important part in ECG signal analysis. In this paper I compare wavelet families for de-noising. I compare those methods on the basis of performance parameters. The comparison of wavelet family gives best one with detection error rate (DER) 0.278, Positive Predictivity 99.83% and sensitivity 99.80% using Sym8. Method 3 gives the best result for QRS-Complex detection. The results have been concluded using MATLAB software and MIT-BIH database.

KEYWORDS: *ECG (Electrocardiogram), MIT-BIH database, QRS complex, Threshold, Wavelet.*

I. INTRODUCTION

ECG is a valuable technique that has been in use for over a century for clinical applications. The electrocardiogram is a graphic record of the direction and magnitude of electrical activity of the heart that is generated by polarization and depolarization of the atria and ventricles. ECG machines record changes in electrical by drawing a trace on a moving paper strip [1]. The ECG noises are due to several interferences like electrode contact, motion artefacts, base-line drift and instrumentation nose generated by electronic devices, electrosurgical noise, and muscle contraction. Among this noises power line interference and base-line drift are the most significant and can strongly affect the ECG signal analysis [2].

The MIT-BIH database is preferable to other ECG data base because of reasons as follows. The MIT-BIH data contains 30 minute, 1 minute, 30 second and 10 sec recording for each patient which is considerably longer than the records in other database. The CSE database for example contains 10 seconds recording only. The MIT-BIH database contains records of normal ECG signals as well as records of ECG signals that are affected by non-stationary effects, low signal to noise ratio, premature atria complexes, left bundle blocks and right bundle blocks. This provides the opportunity to test the robustness of the QRS Complex detection method [3].

Any QRS detection algorithm accuracy depends on the frequency range ECG being processed. The QRS-Complex has different morphology and frequency band for different arrhythmias and noises in ECG signal. Band-pass filtering is an essential first step of nearly all QRS detection algorithms. The purpose of band-pass filtering is to remove the Base-line wander and high frequencies which do not contribute to QRS complexes detection [3]. Base-line wandering can mask some important features of the electrocardiogram signal hence so it is desirable to remove this noise for proper analysis and display of the ECG signal [4]. The wavelet transform allows processing non-stationary signals such as ECG signal. A wavelet is simply a small wave which has energy concentrated in time to give a tool for analysis of transient non stationary time-varying phenomena [6].

The most important characteristic of the classification sub module is its ability to distinguish between normal and abnormal (i.e. abnormal heart rhythm or ECG shape) Heart beats. The classification made based on evaluation of Heart rhythm and amplitude of the R wave peak [7]. As ECG signal being non-stationary signal. The arrhythmia may occur at random in the time scale. This means, the arrhythmia symptoms may not show all the time but would manifest at certain irregular intervals during the day [8].

The organization of this paper is as follows. Section II provides Aim of the project. Section III gives information about morphology of ECG signal. Section IV provides a detailed description of the methodology. Section V provides the results and discussion of the various dataset. In section VI Future work of project is described. Overall conclusion of the study is summarized in section VII.

II. AIM

The aim of this paper is to compare QRS Complex detection based on thresholding. Compare wavelet family for de-noising the ECG signal and choose the best one. Compare QRS Complex detection using performance parameter accuracy, positive predictivity, and sensitivity and Detection error rate.

III. MORPHOLOGY

Most of the cardiac diseases classification algorithms begin with the separation or delineation of the individual ECG signal main waves. The ECG signal of a single cardiac cycle consists of the QRS complexes, P and T waves as shown in fig.1 [1]. QRS complex is the most noticeable part in the ECG because of its high amplitude compared to the P and T waves. P wave represent depolarization and contraction of the right and left atria. QRS complex represents the depolarization of the ventricles of the heart which have grater muscle mass and therefore its process consumes more electrical activity. T wave represents ventricle re-polarization. The main difficulties in QRS complexes detection can be summarized as follows: 1) negative QRS polarities, 2) low SNR (noisy ECG signal), 3) non-stationary (statistical properties of signal change with time), 4) low QRS amplitude, and 5) ventricular ectopic [10].

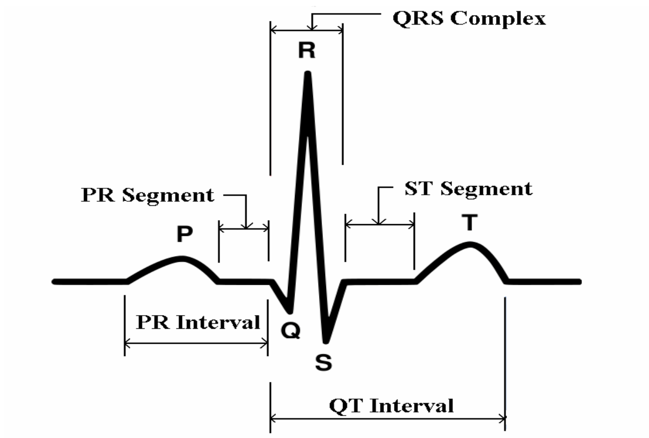

Figure 1. A single cardiac cycle

IV. METHODOLOGY

4.1 Method 1: Adaptive Threshold

In this method the process of analysis is as follows band pass filter, differentiation, squaring, moving window integration and adaptive thresholding. The desirable pass band to maximize the QRS energy is approximately 5-15 Hz. Use Butterworth band-pass filter 5-15 Hz. The band pass filter reduces the influence of muscle noise, 60 Hz interference, base-line wander and T wave interference. The signal is differentiated to provide the QRS complex slope information. After differentiation signal is squared. The purpose of moving window integration is to obtain waveform feature information in addition to the slope of the R wave. Adaptive threshold technique is used for threshold. Fined the temporal location R peak can be determined. The thresholds are automatically adjusted to float over the noise [5].

4.2 Method 2: Dynamic quantized Threshold

In this QRS detection method based on an dynamic quantized thresholding. In this method Butterworth filter with pass band of 1-13 Hz, for remove all frequencies which are not necessary to detect the region of QRS complex. The mean is subtracted from the signal for base line wandering removal. Square the signal then four components are detected by gradient and moving average integrator. The desired final QRS feature is derived by retaining the amplitude values of G4 exceeding dynamic threshold THR1 rather than of 5% of the maximum peak amplitude and reducing the remaining to zero. Threshold 1 equals to the mean of G4 plus standard deviation of G4. Then apply dynamic thresholding. Then I get window of QRS complex [10].

4.3 Method 3: Wavelet based

The presented method based on the de-noised by wavelet and find QRS complex using threshold and window. Below fig 3 shows the process involved in this method.

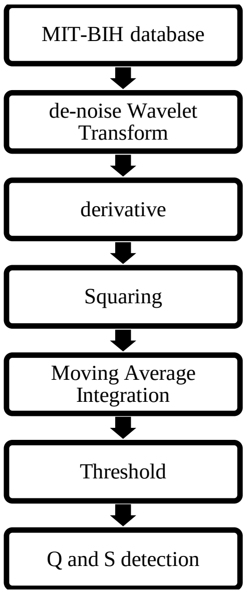

Figure 2. Block Diagram of Method 3

4.1.1 Wavelet Transform

A wavelet is simply a small wave which has energy concentrated in time to give a tool for the analysis of transient, non-stationary or time-varying phenomena. In the wavelet transform the original signal is transformed using predefined wavelets. The wavelets are orthogonal, ortho-normal or bi-orthogonal scalar or multi-wavelets. In discrete case, the wavelet transform is modified to a filter bank tree using the decomposition or reconstruction [6]. To implement the discrete wavelet transform, we need to use a discrete filter-bank and make use of equation scale to two.

$$\varphi(2^j t) = \sum_k h_{j+1}(k)\varphi(2^{j+1}t - k) \quad (1)$$

Where $\varphi(2^j t)$ is the scaling function, the two state relation states that the scale function$\varphi(2^j t)$, at a certain scale can be expressed in terms of translated scaling functions at the next smaller scale. Where j indicate the resolution level associated to the frequency, k indicates the localization and t is the translation variable. De-noising is an interesting application of wavelet transform. The process of filtering by wavelet is using wavelet de-noise function in MATLAB. We de-noised the signal up to level 3 and 5. In level 3 all characteristics points of ECG is clearly visible but in level 5 only P and T wave is remain in the signal. So by taking the differences between these two signals we obtain QRS point.

4.1.2 Derivative

$$x_d(n) = x(n) - x(n-1) \tag{2}$$

Where x (n) is the input signal at time n, and $x_d(n)$ is difference output signal at time n.

4.1.3 Squaring

This makes all the result positive and emphasizes the QRS complex because the amplitude of signal is increases. The squaring function that the signal now passes through is a nonlinear operation.

$$y(n) = [x_d(n)]^2 \tag{3}$$

4.1.4 Moving average integrator

A moving window integrator is used because there are multiple peaks within the duration of a single QRS, the integrator takes an average of N samples, where N is window width and this is done by using a FIR filter. Moving average integration extracts feature in addition to the slope of the R wave. It is implemented by the equation (4).

$$y(nT) = (1\,/\,N)[x(nT - (N-1)T) + x(nT - (N-\ 2)T) + \cdots + x(nT)\ ] \tag{4}$$

The width of the window should be approximately the same as the widest possible QRS complex. For a sample rate of 200 samples per second, the window chosen for this was 30 samples wide.

4.1.5 Thresholding

For the R wave detection a new approach was used since the R wave detection logic used in method 1 [5] was too complicated for implementation. So we used $threshold = \max(y(n)) * mean(y(n))$. Rectangular pulses are formed where the output of the moving window was higher than the threshold. This window shows the QRS complex then we easily detect the R peak. Look for points Q and S based on point R. S and Q point detection - if we calculate R point then it is easy to calculate other points.

The comparisons of three method and wavelet family are described by following parameters:

Sensitivity = $\mathrm{TP}/(TP + FN)$

Positive Predictitivity = $TP/(TP + FP)$

Accuracy = $(TP + TN)/(TP + FP + FN)$

DER = $TP/(TP + FP + FN)$

Where: TP = number of actual beat detected, FP = Number of false beat detected and FN = Number of time fail to detect actual peak.

V. RESULT AND DISCUSSION

In order to evaluate the performance 48 MIT-BIH database were tested and annotation indicates the position of beats. The project implemented in MATLAB (R2010a).

Table1: Comparison of Wavelets

Wavelet	**Sensitivity (%)**	**Positive Predictivity (%)**	**Detection Error Rate (%)**
db4	99.57	99.82	0.597
db6	99.39	99.59	1.000
db10	99.28	99.65	1.051
dmey	99.28	99.65	1.052
bior6.8	99.17	99.57	1.247
coief5	99.52	99.27	1.195
haar	97.95	98.89	3.100
rbio6.8	99.44	99.19	1.360
sym4	99.07	99.52	1.361
sym8	99.80	99.83	0.278

Above table shows the comparison of wavelet for de-noising. Above table summarizes that sym8 performance is best hence I use this for further detection technique.

Table 2: Comparison of QRS complex detection Methods

METHODOLOGY	SE%	P+%	AC%	DER%	Time elapsed (second)
Method 1	99.77	99.09	98.87	1.123	0.33399
Method 2	97.74	99.14	98.89	1.102	0.98158
Method 3	99.80	99.83	99.47	0.278	0.60615

By above table, see that third method gives the best performance among all hence it would be desirable to use this method in feature for further extension of this project. There is trade off between computational time and detection error rate between method 1 and method 3. Method 3 has more computational time because wavelet was used for de-noising. Below figure shows the result of project in MATLAB.

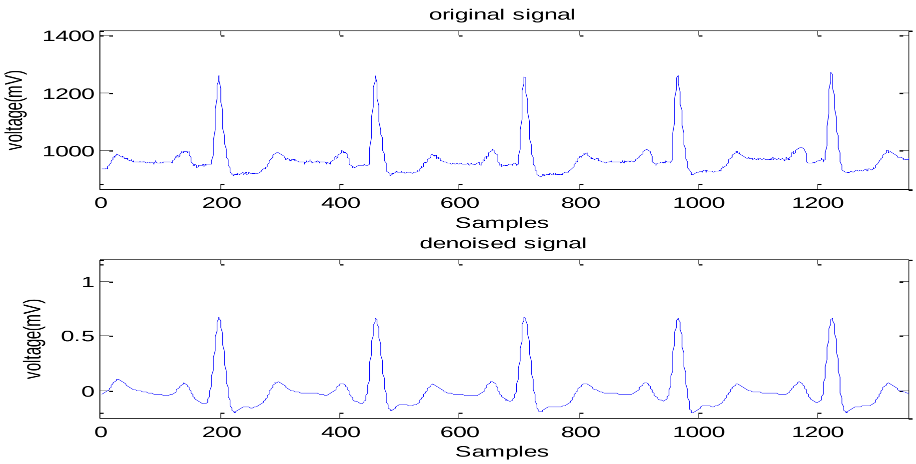

Figure 3. Original signal and Pre-processed Signal

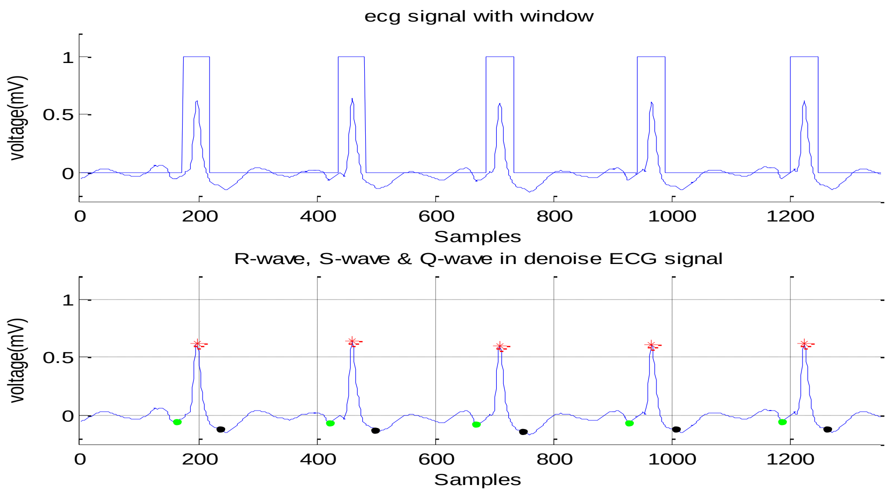

Figure 4. QRS Window and QRS peak of database 105.

VI. FUTURE WORK

Computerized ECG diagnostic system is an important tool for clinical practice today. Heart rate variability, feature extraction, P and T wave detection are very important for abnormality detection of ECG signal. For robustness of the algorithm it will be tested for the other database also. Wavelet transform is very important technique for research in other biomedical signal processing also. Hence future work will be concentrate on feature extraction and classification of ECG signal.

VII. CONCLUSIONS

In order to evaluate methods I use MIT-BIH database of one minute. It can be concluded from table that wavelet based threshold method gives better result for QRS complex detection. The wavelet transform allows processing of non-stationary signal such as Electrocardiogram. Sym8 gives the better result for de-noising as shown in table. The technique used here detect QRS complexes records with low amplitude, inverted amplitude and ventricular ectopic. By analyzing the methods last method gives the better performance. The values are 99.80% sensitivity, 99.83% positive predictivity, 99.47% accuracy and 0.278 detection error rate.

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