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Detection of Characteristic Points of ECG Signal

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ABSTRACT: ECG's are continuous record of electrical activity of heart. Automatic and accurate detections of ECG signal characteristic points play a vital role in ECG signal analysis and diagnosis of arrhythmia. This paper presents an algorithm for removal of noise, detection of QRS complex, P and T wave detection and Heart rate. For QRS complex, P and T wave detection methods based on finding features of signal and thresholding. By calculating Heart Rate we define the signal as Normal, Bradycardia and Tachycardia. The performance of the algorithm was tested on MIT-BIH database and using MATLAB software for implementation. The performance of QRS complex detection error rate (DER) 0.305%; Positive Predictivity 99.88% and sensitivity 99.80% using Sym8 for de-noise. T wave detected with 98.71% sensitivity and P wave with 96.02% sensitivity.

KEYWORDS: ECG (Electrocardiogram), MIT-BIH database, QRS complex, P and T wave, 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 aim of this paper is to compare QRS Complex detection based on thresholding. Compare wavelet family for de-noising the ECG signal. Compare QRS Complex detection using performance parameter accuracy, positive predictivity, and sensitivity and Detection error rate. Detect P and T wave and Heart rate. Feature extraction depends on amplitude and interval. Most of the cardiac diseases classification algorithms begin with the separation or delineation of the individual ECG signal main waves.

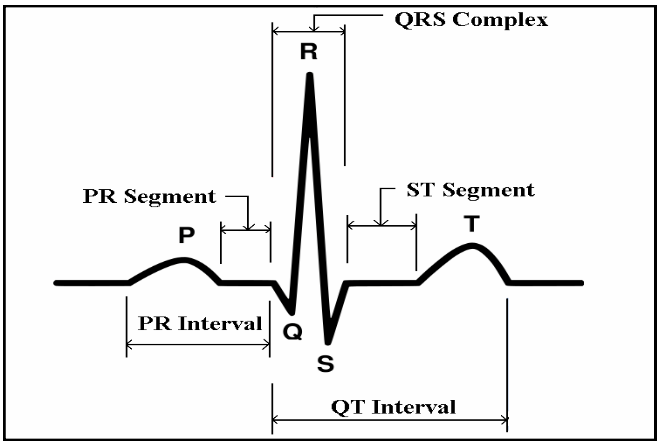

Fig. 1. Single cardiac cycle of ECG [2]

The ECG signal of a single cardiac cycle consists of the QRS complexes, P and T waves shown in fig 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

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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].

The organization of this as follows. Section I describes the aim of project and morphology of ECG. Section II related works are presented. Section III provides a detailed description of the methodology. Section IV provides the results and discussion of the various dataset. Section V provides the future scope of project and overall conclusion of the study is summarized.

II. RELATED WORK

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. 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 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 detection of P and T wave is an important part in the analysis and interpretation of ECG. Determining the position of the T wave and P wave is complicated due to the low amplitude, the ambiguous and changing form of the complex. A wavelet transform approach handles these complications therefore a method based on wavelet transform is used [10].

The multi-resolution, threshold, minima/maxima pairs with window searching feature of wavelet transform has been used for the implementation of the algorithm. The measured values of characteristic wave of ECG are validated for European ST-T database records [11]. P and T wave detection using threshold has been developed to detect and feature signal is employed for distinguishing P and T waves. A robust and numerically efficient method base on two moving average filters followed by a dynamic event duration threshold has been developed to detect P and T waves in ECG signal [14].

III. ALGORITHM OF METHOD

A. *Design Considerations:*

- Initially load the MIT-BIH data base from Physio.net. Database is one minute long.
- Preprocessing removing baseline wandering and power line interference. Then normalize the signal.
- QRS complex detection, three methods are compared here.
- P and T waves are detected for non-QRS part and Feature extraction.
- Heart rate detection and case identification.

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B. *Description of the Algorithm:*

Step 1: Preprocessing:

The dataset includes 48 complete two lead ECG records with arrhythmia reference annotations from the MIT-BIH arrhythmia DB (physio.net). The records have a diagnostic bandwidth of 0.1-100 Hz with 12 bit resolution and were digitized at 360. Take an ECG signal of MIT-BIH database and denote as ECG signal. Effects of artifacts are removed in pre-processing. Normalize the signal by divide it by maximum of signal.

Step 2: QRS complex detection:

In this paper I compare three methods for QRS complex detection. Method 1 is Adaptive Thresholding based, 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. Adaptive threshold technique is used for thresholding. Find the temporal location of R peak. The thresholds are automatically adjusted to float over the noise.

Method 2 is Dynamic quantized threshold, this method based on a 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 for QRS complex.

Method 3, fig 3 shows the block diagram of QRS detection. In this method we find the best wavelet for denoising by comparing wavelet family. Thresholding is based on maximum and mean values of signal after moving average filter. 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.

Step 3: P and T wave detection:

Threshold detection method is used for P and T wave detection in ECG signal using new feature signal. A band-pass filter is used for baseline removal which is a typical bidirectional Butterworth implementation. The main frequencies of the P and T waves lie in the range of o.5-10 Hz [14]. For this the QRS complex detected first. Already detected QRS become a reference for detection of P and T waves. The proposed algorithm first extracts non-QRS features Fnq for detection of P and T waves (non QRS wave component). The present work has been tested for dataset of MIT-BIH database.

Step 4: Heart Rate:

Detect RR interval then find BPM (Beat per Min) and classify the signal as Bradycardia and Tachycardia. Bradycardia is slow heart rate under 60 beat per minute and Tachycardia is fast heart rate above 100.

IV. RESULT AND DISCUSSION

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

$$\text{Sensitivity} = \text{TP}/(TP + FN)$$
$$\text{Positive Predictitivity} = TP/(TP + FP)$$
$$\text{Accuracy} = (TP + TN)/(TP + FP + FN)$$
$$\text{DER} = TP/(TP + FP + FN)$$

Where: TP = number of actual beat detected, FP = Number of false beat detected and FN = Number of time fail to detect actual peak. TN = number of false beat not detected.

In order to evaluate the performance, 48 MIT-BIH databases were tested and annotation indicates the position of beats. Below table 1, shows the comparison of wavelet for de-noising. Below table summarizes that sym8 performance is best among all. Sym8 have better sensitivity, positive predictivity and detection error rate.

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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**	**0.305**

By table 2, see that third method gives the best performance among all hence it would be desirable to use this method in feature extraction stage of this project. There is tradeoff 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.

Table 2: Comparison of QRS complex detection Methods

Methodology	**Sensitivity%**	**Positive Predictivity%**	**Accuracy%**	**Detection Error Rate%**	**Time elapsed (second)**
Method 1	99.61	99.30	98.92	1.070	0.33399
Method 2	99.63	98.98	98.62	1.370	0.98158
Method 3	99.80	99.88	99.69	0.305	0.60615

Table 3 shows the result of P and T peaks annotation. T wave detected for 46 and P wave detected for 42 databases. See here detection error rate is very les. P and T point detection is helpful for other feature extraction.

Table 3: P and T wave annotation result

Parameter	**T wave**	**P Wave**
True Positive	3396	2871
False Negative	44	119
Total	3440	2986
Sensitivity	98.71%	96.02%
Detection Error Rate	0.0128	0.0418

We see here P wave is detected with less sensitivity and QRS complex detected with high sensitivity. This result because of QRS has high amplitude and P and T wave have low amplitude. The case detection depends on heart rate BPM (beats per minute). Bradycardia is slow heart rate (less than 60 beats per minute) and tachycardia is fast heart rate (more than 100 beats per minute). Out of 48 signal 37 normal, 7-Bradycardia and 4-techycardia.

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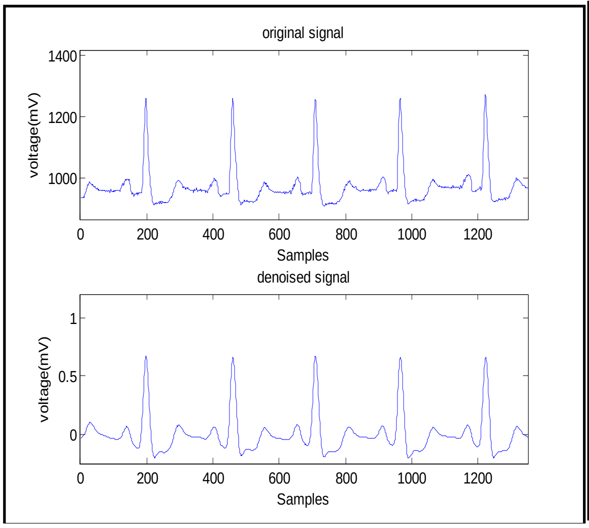

Fig. 2. Original and denoised signal

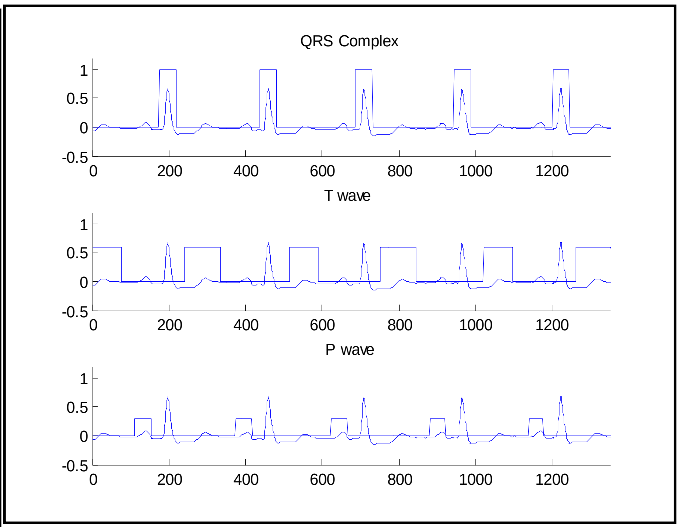

Fig. 3. P, QRS complex and T wave

Figure 2, 3 and 4 shows the result of project for database 105. Original signal is loaded from Physionet and then pre-processing. Pre-processing include baseline wandering, normalization and denoising of signal by wavelet-sym8. Figure 2 present the result of QRS detection, P and T wave detection by thresholding window technique. Each wave presented in window.

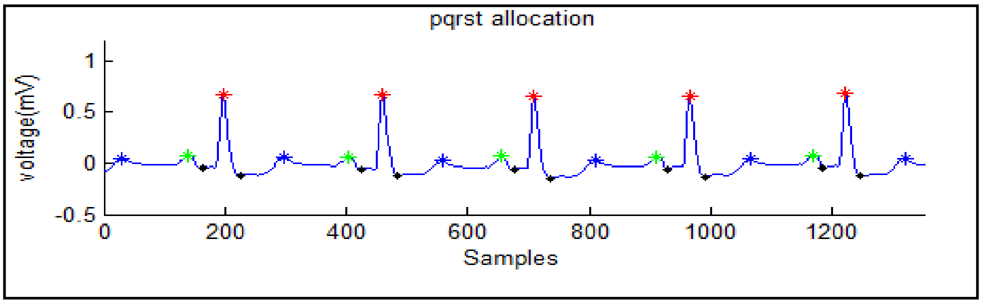

Fig. 4. PQRST point allocation

Figure 4 shows the annotation of characteristic points – P-Q-R-S-T. Fiducial points in an Electrocardiogram are the location of peaks, onset and offset of waveform which have clinically useful information for physician.

V. Conclusion and Future Work

In order to evaluate algorithm, 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. By analyzing the methods, method3 gives the better performance. The values are 99.80% sensitivity, 99.88% positive predictivity, 99.69% accuracy and 0.305% detection error rate. P and T wave detected with 96.02% and 98.71% sensitivity. It has been concluded from the results that the allocation and delineation errors of ECG characteristic waveform, especially for P and T wave is due to their morphological variations.

ECG signal is a diagnostic tool for arrhythmia detection. This research should be helpful for classification of ECG signal. The measures of the features amplitude, interval, and heart rate can be used to assess the present or likelihood of cardiovascular diseases. An automated ECG delineation system may provide an easy means of ECG interpretation using pattern recognition.

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REFERENCES

1. Sameer K. Salih, S. A. Aljunid, Abid Yahya and Khalid Ghailan, "A Novel Approach for Detecting QRS complexes of ECG Signal", International Journal of Computer Science Issues 6, No. 3, pp1694-0814, November 2012.
2. Sibushri.G, "Analysis of ECG Signals for Arrhythmia Using MATLAB", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 2, Special Issue 1, 2320-9801, March 2014.
3. Mohamed Elgendi, Mirjam Jonkman and Friso DeBoer, "Frequency Bands Effects on QRS Detection", Conference: Biosignals 2010 - Proceedings of the Third International Conference on Bio-inspired Systems and Signal Processing, Valencia, Spain, January 20-23, 2010.
4. Manpreet Kour, Birmohan Singh and Seema, "Comparisons of Different Approaches for Removal of Baseline Wander from ECG signal", International Journal of Computer Applications. Artical 5, pp 30-34, 2011.
5. Jiapu Pan and Willis J.Tompkins, "A Real Time QRS Detection Algorithm", IEEE Transactions on Biomedical Engineering, VOL, BME-32, NO. 3, pp 230-23, March 1985.
6. Mikhled Alfaouri and Khaled Daqrouq, "ECG Signal Denoising by Wavelet Transform Thresholding", American Journal of Applied Sciences, Vol. 5(3), pp 276-281, 2008.
7. Barbara Mali, Sara Zulj, Ratko Magjarevic, Damijan Miklavcic and Tomaj Jarm, "MATLAB-Based Tool for ECG and HRV Analysis", Biomedical Signal Processing and Control, Vol. 10, pp 108-116, 2014.
8. Jayalaxmi C Mannurmath, Prof. Raveendra M, "MATLAB-Based ECG Signal Classification", International Journal of science,Engineering and Technology Research, Vol. 3, Issue 7, July 2014.
9. Wen Zhu, Nancy Jang and Ning Wang, "Sensitivity, Specificity, Accuracy, Associated Confidence Interval and ROC Analysis with Practical SAS Implementation", Health Care and Life Sciences, 2010.
10. Mohamed Elgendi, Mirjam Jonkman and Friso DeBoer, "Improved QRS detection Algorithm Using Dynamic Thresholds", International Journal of Hybrid Information Technology, Vol. 2, No. 1, January2009.
11. V.Viknesh & P. Ram Prashanth, "MATLAB Implementation of ECG Signal Processing", IOSR Journal of VLSI and Signal Processing (IOSR-JVSP), VOL. 3, Issue 1, PP 40-47, Sep-Oct. 2013.
12. Sreenivasan Baduru, Dr. S.N. Raddy, P.Jagdamba and Dr. P. Satyanarayanan, "Noise Cancellation on ECG and Heart Rate Signals Using the Undecimated Wavelet Transform", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 1, Issue 4, pp. 1962-1970, 2009.
13. Namitha Thomas and D.J.Jagannath, "Detection of Peak and Boundaries of P and T waves in ECG signals", International Journal of Electronics Signals and Systems (IJESS), ISSN: 2231- 5969, Vol-3, Iss-1, 2013.
14. Mohamed Elgendi, "P and T wasves annotation and detection in MIT-BIH arrhythmia database", 2009.
15. V. S. Chouhan and S.S. Mehta, "Threshpld-based detection of P and T wave using new feature signal", International Journal of Computer science and Network Security, VOL. 8No.2, February 2008.

BIOGRAPHY

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