Q Onset And P Onset Detection For ECG PR_Interval Measurement

Thandar Nwet Htun, Aung Soe Khaing, Hla Myo Tun

Abstract: Electrocardiogram (ECG) is a graphical record of bioelectrical signal generated by the human body during cardiac cycle. The duration, slope and amplitude between characteristic points of ECG signal are important for diagnosing of heart problems. In this paper, onset points of Q and P waves are detected for automatic diagnosis. These two points are critical points to get the important parameters such as PR_interval, PR segment, QRS complex and QT interval for analysing of ECG signal for medical doctors. Pan Tompkins algorithm is used for accurate detection of R peak position in normal ECG signal. In this paper, characteristic points of normal ECG signal are detected to provide the information of heart diseases.

Keywords: Electrocardiogram, Pan Tompkins algorithm, QRS Complex, Q onset and P onset detection, PR_interval

I. Introduction

ECG is a repetitive waveform that comprises several waves distinguished each other by frequencies and amplitudes. Under normal conditions, ECG tracings have a very predictable direction, duration and amplitude. They are the most important parameters for aiding the clinical staff to get information about the patients' states and diagnosing the cardiac abnormalities**.** Detection of characteristic points is an essential step to get these important factors of ECG signal. ECG waves and intervals are shown in Fig. 1 and characteristics of normal ECG is shown in TABLE I [4], [5].

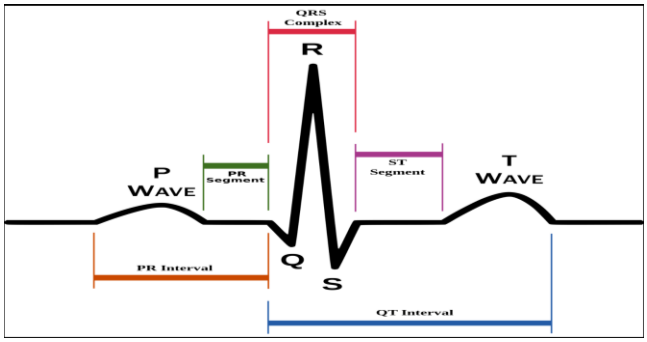

Fig. 1 *ECG waves and intervals [9]*

TABLE II
CHARACTERISTICS OF NORMAL ECG

Segment	Duration in seconds
P wave	0.12
PR segment	0.05-0.12
PR interval	0.12-0.2
QRS complex	0.06-1
QT interval	0.3-0.4
ST segment	0.08

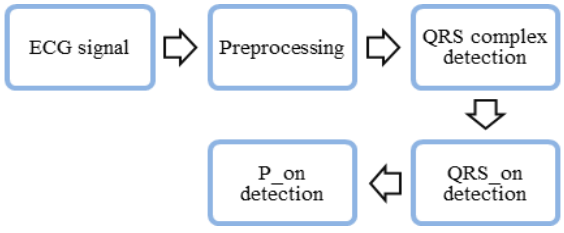

Fig. 2 *Block diagram of Q onset and P onset Detection for ECG PR-interval measurement*

General block diagram of Q onset and P onset Detection for ECG PR_interval Measurement is shown in Fig. 2. Firstly, ECG signals are downloaded from the Massachusetts Institute of Technology/Beth Israel Hospital (MIT-BIH) arrhythmia database. Before analyzing the ECG signal, noise of the low and high frequency components was removed through preprocessing. After preprocessing, QRS complex detection i.e. locating the R point for each beat of the signal is implemented by using Pan-Tompkins algorithm. Once R point is determined, all other characteristic points on the wave such as P onset and QRS onset are determined with reference to the R point.

II. Methodology

A. MIT-BIH Arrhythmia Database

The MIT-BIH Arrhythmia Database contains 48 half-hour excerpts of two-channel ambulatory ECG recordings. The recordings were digitized at 360 samples per second per channel with 11-bit resolution over a 10mV range [3].

B. Preprocessing

ECG signals can be contaminated with several types of noise which may affect the accuracy of the main events detection and overall diagnosis. Among various types of noises, baseline wandering and power line noises are the most significant and can strongly affect the ECG signal analysis. ECG preprocessing removes the noises from the raw ECG signal and process the signal before extracting the information. Baseline wandering is an effect which shifts the position of signal base. In an ECG, this can be caused due to respiration, perspiration or physical activity. The frequency of baseline drift is 0.5 Hz. ECG signal with baseline drift is shown in Fig. 3. To get rid of baseline wander, IIR Butterworth second order high pass filter with cut off frequency of 0.5 Hz is used. Fig. 4 shows the baseline drift filtered signal of ECG signal [1].

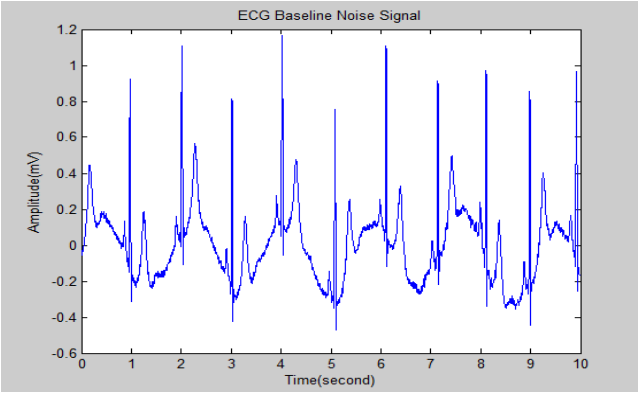

Fig. 3 *Baseline noise ECG signal*

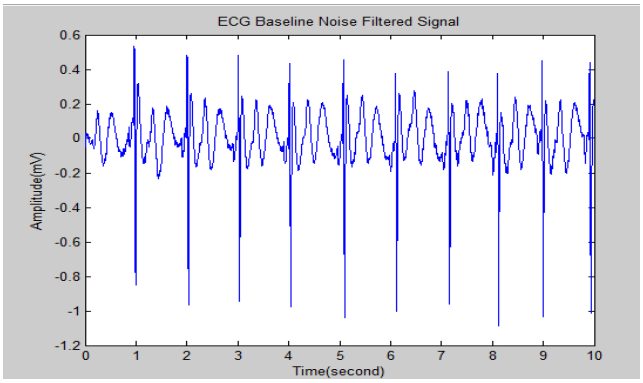

Fig. 4 *ECG baseline noise filtered signal*

Power line interference can be caused due to the power supply component of the device. Power line interference is a significant noise with frequency of 60 Hz in ECG signal. Power line noise of ECG signal is shown in Fig. 5. For sampling frequency of 360 Hz in ECG signal, IIR filter with notch frequency 60 Hz is used for removing of power line noise [1].

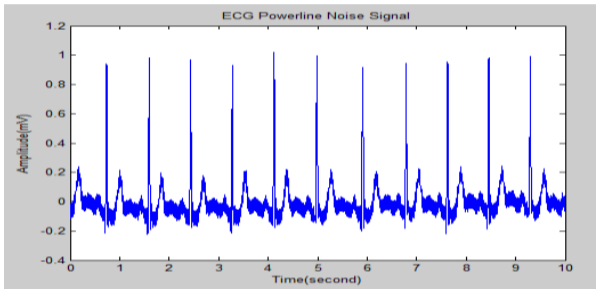

Fig. 5 *Power line noise of ECG signal*

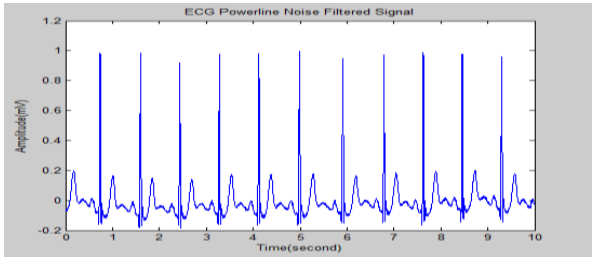

Fig. 6 *ECG Power line noise filtered signal*

C. QRS Complex Detection

Pan Tompkins algorithm is used because it gives a higher accuracy for various beats than other traditional real-time methods. Various steps of Pan Tompkins algorithm is shown in Fig. 7.

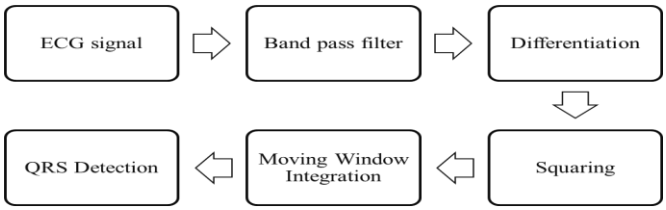

Fig. 7 *Block diagram of Pan Tompkins algorithm*

In Pan Tompkins algorithm, band pass filter is used to reduce the influence of muscle noise, 60 Hz interference, baseline wander, and T wave interference. The desirable pass band to maximize the QRS energy is approximately 5-15 Hz. This pass band filter was constructed using both low pass filter and high pass filter in cascade, to achieve the 3 dB band pass of 5-11 Hz [2].

1) Low pass Filter: A second order low pass filter is used to suppress high frequency noise. The cut off frequency of the filter is 11 Hz and delay is 25ms [2].

The transfer function is:

$$H(z) = \frac{(1-z^{-6})^2}{(1-z^{-1})^2} \qquad (1)$$

The difference equation is given by:
y(nT)=2y(nT-T)-y(nT-2T)+x(nT)-2x(nT-6T)+x(nT-12T)

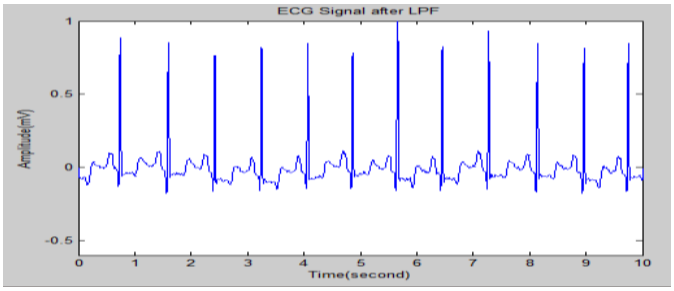

Fig. 8 *ECG signal after low pass filter*

2) High pass Filter: High pass filter can reduce baseline noise. The high pass filter is implemented by subtracting a first order low pass filter from an all filter with delay. The low cut off of frequency of the filter is about 5 Hz and delay is 80ms. The gain of this filter is 1 [8].

The transfer function of the low pass filter is shown in equation (2)

$$H_{lp}(z) = \frac{(1-z^{-32})}{(1-z^{-1})} \qquad (2)$$

The difference equation is:
y(nT) = y(nT-T)+x(nT)-x(nT-32T)

The transfer function of subtracting the output of a first order low pass filter from an all pass filter is shown in equation (3)

$$H_{hp}(z) = z^{-16} - \frac{H_{lp}(z)}{32} \quad (3)$$

The difference equation of the high pass filter is:
y(nT)=x(nT)-16T)-1/32[y(nT-T)+x(nT)-x(nT-32T)]

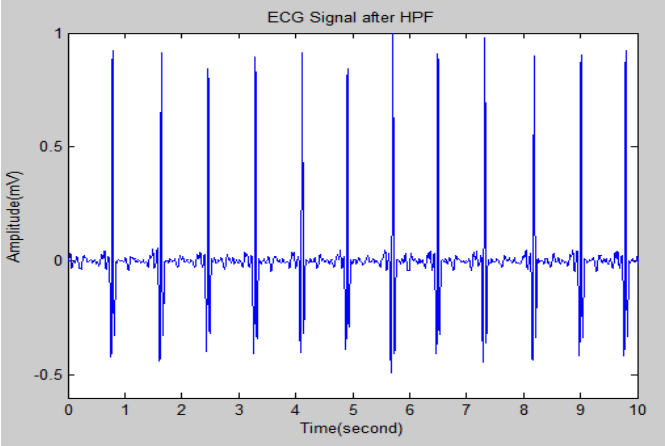

Fig. 9 *ECG signal after high pass filter*

3) Differentiation: After the band pass filter was applied, the signal was differentiated to provide the slope information. A five point derivative is implemented.

The transfer function is shown in equation (5):

$$H(z) = \left(\frac{1}{8}\right)\left(2 + z^{-1} - z^{-3} - 2z^{-4}\right) \quad (4)$$

The difference equation is:
y(nT)=(1/8)*[2x(nT)+x(nT-T)-x(nT-3T)-2x(nT-4T)]

The fraction 1/8 in equation (5) is an approximation of the actual gain of 0.1.

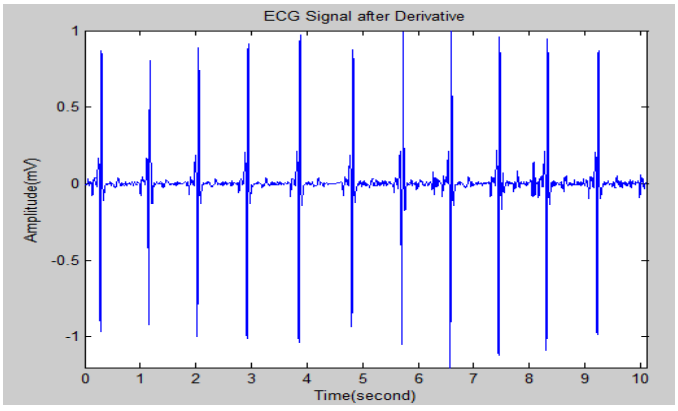

Fig. 10 *ECG signal after derivative filter*

4) Squaring: The squaring function makes all data points to be positive and to make nonlinear amplification of the output of the derivative, emphasizing the higher frequencies [2].

It can be written as:

$$y(nT) = [x(nT)]^2 \quad (5)$$

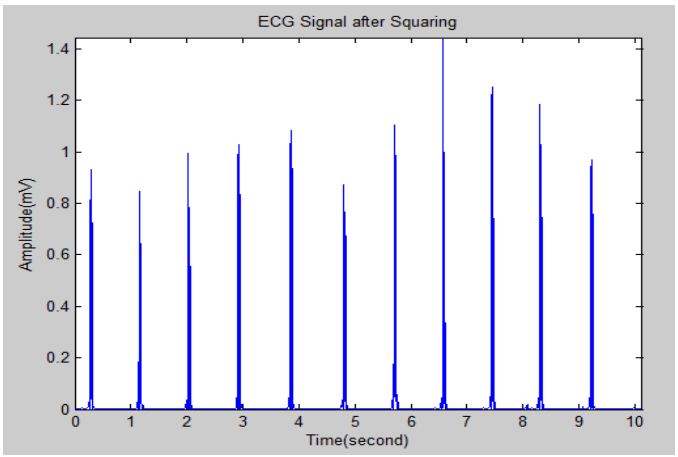

Fig. 11 *ECG signal after squaring*

5) Moving Average Integration: Once the signal was positive and the higher frequencies were emphasized, a moving-window integration was applied to the signal. This integration was applied to obtain waveform feature information.

It can be expressed as:
y(nT)=(1/N)[x(nT)-(N-1)T+x(nT-(N-2)T)+……+x(nT)]

Where N is the number of samples in the width of the integration window. The efficiency of the QRS complex detector depends on the correct implementation of this function. If N is too large, the waves could be mixed, and if it is too narrow, the information of the R wave would be lost. For sample rate of 360 samples /s, the window is 54 wide [2].

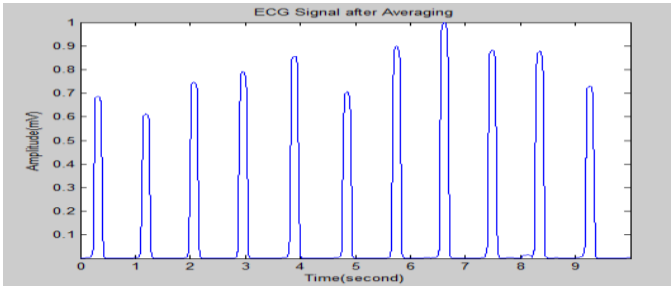

Fig. 12 *ECG signal after moving average filter*

6) Thresholding: The mean and the maximum value of the output of the Moving-Window integration have been stored. With this information, a threshold comparison has been performed. If the signal was greater than the product of the maximum value and the mean then it was considered to be a QRS complex, and the position stored [2].

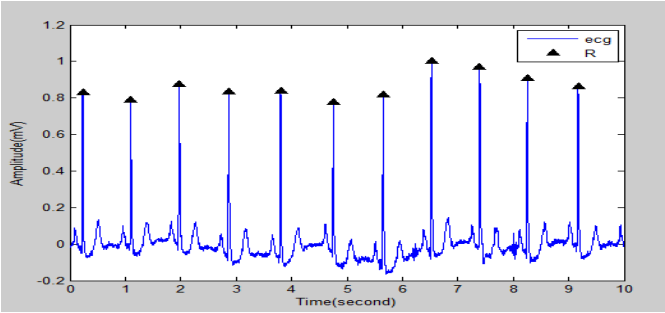

Fig. 13 *ECG signal with R peak detection of MIT-BIH record 101*

C. Other Points Detection

Once the R peak is defined in the original signal, other peaks location can be detected by establishing search windows on either side of the R peak. Search windows are selected based on their position from the R peak.

1) Q Wave Detection: After R peak detection, Q peak points are determined by finding a minimum value on Q period. Q period means 55ms before each R peak position [7].

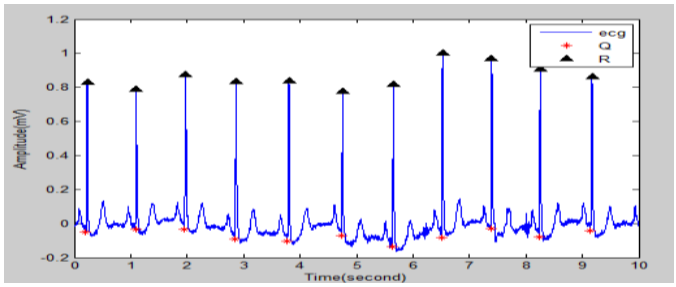

Fig. 14 *Q wave detection of MIT-BIH record 101*

2) P Wave Detection: Apply a search window from 60_250ms to the left of the R peak is established. This window provides the P peak by searching the highest positive point [1].

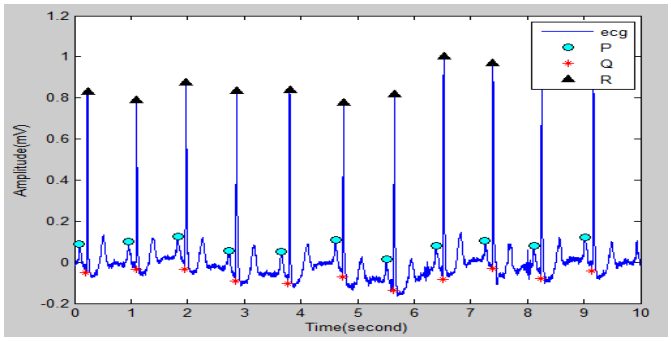

Fig. 15 *P wave detection of MIT-BIH record 101*

3)Q Wave Onset Detection: The onset of Q wave is detected by creating a search window of 20ms before Q peak position. The least minimum value point is searched within the search window and the point is defined as Q onset point of Q wave [1].

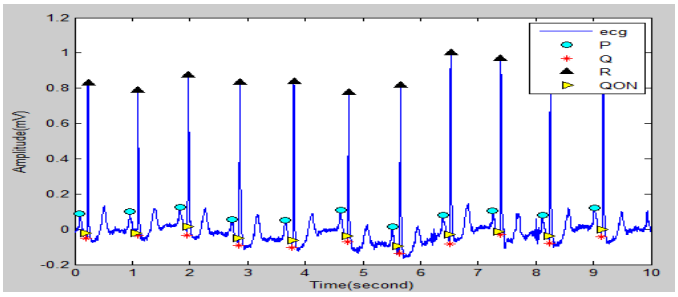

Fig. 16 *Q onset detection of MIT-BIH record 101*

4) P Wave Onset Detection: P onset range is located from 70ms of search window to the left of P peak position. The maximum value point within P onset range gives the onset point of P wave [7].

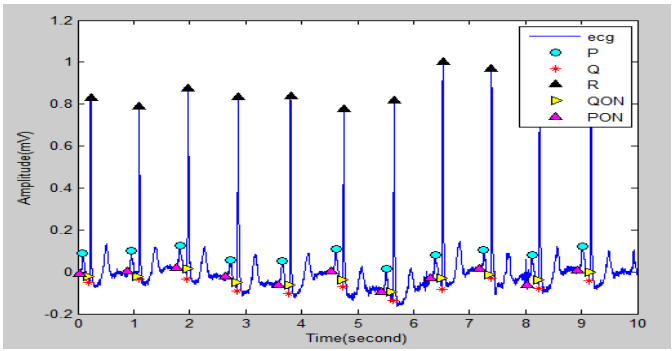

Fig.17. *P onset detection of MIT-BIH record 101*

III. Discussion

Raw ECG signal is preprocessed to reduce the noises that can strongly affect the signal analysis. Baseline noise and power line noise are successfully removed by applying digital filters. With the help of FDA Tool in MATLAB, filters are designed to remove the noises. In order to obtain the best extraction of the QRS complex of an ECG signal, digital filters are applied in all 48 records of MIT-BIH database. Among various QRS detection methods, Pan Tompkins algorithm is used because it can provide accurate R peak detection for MIT-BIH database records of 10 seconds. The P and Q waves in the MIT-BIH Arrhythmia Database are not fully annotated; this makes testing and evaluating developed algorithms quite difficult.P and Q wave detection is affected by the quality of the ECG recordings and the abnormalities in the ECG signals. Onset points of Q and P waves are only detected only when the signal is normal and cannot be detected when it is abnormal, arrhythmia conditions.

IV. Conclusions

The electrocardiogram (ECG) representing the electricity activity of the heart is the key bio-signal for aiding the clinical staff in disease diagnosis. Generally the characteristic points of ECG signal are detected for extracting important parameters and used for automatic diagnosis. Firstly, original ECG signal is downloaded from MIT-BIH database. Preprocessing is used to eliminate the noises from the raw ECG signal. Pan Tompkins algorithm is used to detect the location of the QRS complex. P wave and Q wave are detected from the R peak location. Q onset and P onset points

of ECG signal are detected with reference to the peak of Q and P waves. These points play a very important role in determining of cardiac heart diseases. In future work, PR_interval can be calculated from the difference of Q onset and P onset points.

Acknowledgment

The author is greatly thankful to her supervisor, Dr. Aung Soe Khaing, Associate Professor, Department of Electronic Engineering, Mandalay Technological University, for his excellent supervision, true guideline and valuable suggestion in writing this paper. The author is grateful to Dr. Hla Myo Tun, Associate Professor and Head, and all teachers from Department of Electronic Engineering, Mandalay Technological University, for sharing technical knowledge and supporting.

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