An Algorithm for Extraction of Heart Rate Variability from ECG Signal

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Abstract

Nowadays, for the diagnosis of several diseases and to limit some dangerous diseases to spread up, can be easily done with the help of physiological signals of human beings, such as temperature, blood pressure, heart rate, respiratory rate etc. For example, Heart rate precisely and reliably plays a significant role in the primary recognition of heart attack and several heart rate associated syndromes. The electrocardiogram (ECG) is an outstanding strategy that can be utilized to measure Heart Rate Variability (HRV). This paper depicts a strategy for handling electrocardiogram signals (ECG) to recognize Heart Rate Variability (HRV). The HRV gives data about the thoughtful parasympathetic autonomic dependability and subsequently about the danger of unpredicted heart demise. We have actualized our technique utilizing MATLAB on ECG signal which is gotten from MIT/BIH arrhythmia database. In this strategy, first the ECG signal is pre-processed by band-pass filter; later the Hilbert Transform is applied on filtered ECG signal to improve the nearness of QRS peak. By computing Hilbert transform and applying moving window integration R-Peaks are identified. R-Peaks are detected by setting a threshold and after that RR-intervals are calculated to determine Heart Rate. Our MATLAB implementation results in the detection of QRS Complexes in ECG signal, locate the R-Peaks, computes Heart Rate (HR) by calculating RR-internal and plotting of HR signal to show the information about HRV.

Keywords: *- Physiological signal, ECG, QRS Complex, R Peaks, Heart rate, Hilbert transform, MIT-BIH Arrhythmia, MATLAB*

INTRODUCTION

The electrocardiogram (ECG) signal is the recording of the electrical activity of the heart which provides the clinical information about the condition of heart [1]. The investigation of ECG signal plays a significant role in the diagnosis of heart diseases. Detection of ECG arrhythmias is necessary for the treatment of patients for diagnosing the heart disease at the early stage. Different types of artefacts like power-line

Interference, Baseline artefact and muscle artefact affects the originality of the ECG signals [2]. Therefore, to enhance the quality of ECG signals, the digital filters and adaptive filters are employed.

ECG signal is identified by electrical activity during a cardiac cycle named as P wave, QRS complex and T wave [3]. Detection of QRS complex and R peak is one of the most important parts of the ECG signal analysis. The cardiovascular arrhythmias are distinguished by choosing the exact QRS complex. The fundamental parts of ECG waveform are the P wave, PR interval, QRS complex, ST section, T wave and QT interval which represents to polarization of atria and ventricles in a consecutive way. These parts are appeared in the Figure-1. The frequency range of ECG signal is from 0.05 to 100 Hz.

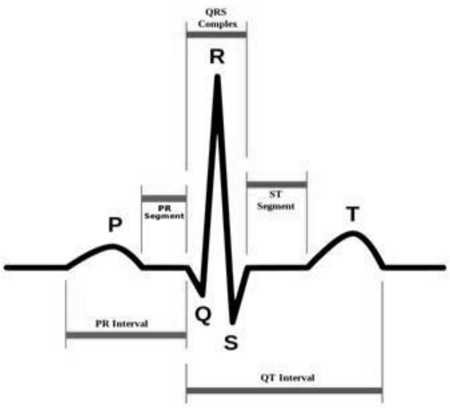

Figure 1 ECG Waveform

This paper depicts a use of Hilbert change with versatile Thresholding for QRS complex and R-peak identification by utilizing recorded signs from the MIT-BIH database. The noisy ECG signal is filtered with a windowing task utilizing wavelet change to save the data of QRS complex. The executed outcomes are assessed both quantitatively and subjectively to test the execution of the calculations.

PRE-PROCESSING

ECG signal can be analysed and processed in two domains, Time and frequency [7]. Here, we have used Hilbert Transform to analyse ECG signal.

Hilbert Transform is used to rectify the phase in order to create a signal with peaks in the location of the R peaks [8]. To use Hilbert transform, first the ECG signal is band-pass filtered, then Hilbert transformed, followed by Thresholding operation.

In Pre-processing operation, different types of noises like Baseline, muscle movement and power line interference is removed from ECG signal by applying Band pass filter. The digital low-pass and high-pass filters are used to realize band-pass filter [9].

A. Low-Pass Filter

The low-pass filter is used to remove high frequency noise present in the signal and it is derived by following difference equation [11]:

$$y(n)= 2y(n-1)-y(n-2)+x(n)-2x(n-4)+x(n-8)$$

B. High-Pass Filter

The High-pass filter is used for removing a very low dc Frequency noise of baseline wandering by the movement of patient and it is derived by following difference equation [11]:

$$y(n)=0.0303[\, y(n-1)-x(n)+x(n-33)]+x(n-16)-x(n-15)$$

HEART RATE DETECTION

To find heart rate (HR), detection of QRS complex, in turnIdentification of R-Peaks is essential. Any automated QRSDetection algorithm structure involves QRS enhancement and QRS detection [12]. The QRS enhancement stage is used to enlarge the QRS complex compared to the other ECG features (P, T, and noise). The QRS enhancement stage is occasionally called pre-processing or feature extraction, which we have done already under pre-processing section. If the R-Peak is required to be detected, an extra step is needed to determine the maximum amplitude value within the detected QRS complex. Since R-wave is positive waveform and highest peak in ECG signal, the time interval between two successive R-wave peaks is used to calculate HR (beats/minute) as follows [13]:

$$HR = \frac{60}{RR - Interval} \; Beats/minutes$$

Hilbert transform is used to identify the R-wave peaks. Hilbert Transform of a real signal is defined as:

$$X_h(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{x(\tau)}{t-\tau}\, d\tau$$

$$= X(\tau) * \frac{1}{\pi t}$$

And the envelop Xe(n) of ECG signal, x(n), is as,

$$X_e(n) = \sqrt{x^2(n) + x_h^2(n)}$$

$$= |\, x(n)| + |x_h(n)|$$

After the ECG signal is filtered in a band-pass filter, the envelop of this ECG signal is computed with help of the above equation. Using the following algorithm R-Peaks from the Hilbert Transformed ECG signal are located and separation between consecutive R-Peaks are calculated. Figure 2 shows that Flow Diagram of R-Peak Detection using Hilbert Transform.

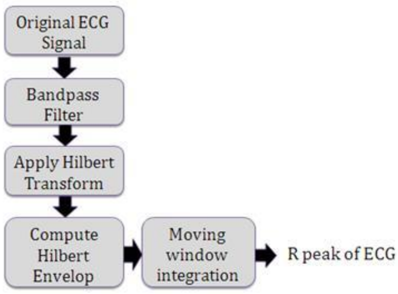

Figure 2 Flow Diagram of R-Peak Detection using Hilbert Transform

RESULT

We have applied this algorithm on ECG signal that is obtained from the MIT/BIH database. As per our algorithm, first the signal is passing through the low-pass filter and then high-pass filtered to cancel out the noise due to baseline wander, other physiological signals, to attenuate the low frequencies characteristics of P and T waves, to isolate and also enhance the predominant QRS energy centered at 10 Hz.

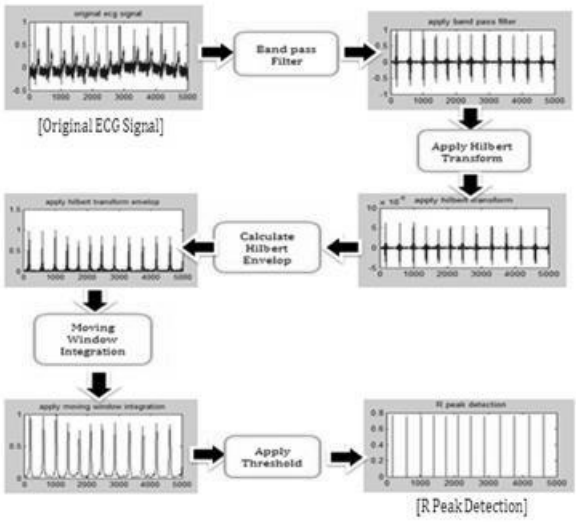

Figure 3 Flow Diagram of R-Peak Detection using Hilbert Transform

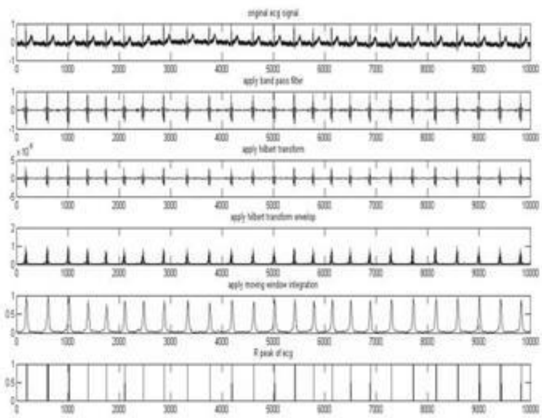

Figure 4 Heart rate detection by using Hilbert transform: (a) original ECG Signal (b) apply Band pass filter on original ECG (c) apply Hilbert Transform (d) Calculate Hilbert Envelop (e) apply Moving window integration and (f) apply threshold for R peak detection

Table 1 Correlation between Heart Rate and RR-Interval by using Hilbert Transform

SUBJECT	HR BY HILBERT TRANSFORM	RR INTERVAL BY HILBERT TRANSFORM
f1o01	89	0.67
f1o02	87	0.69
f1o03	92	0.65
f1o04	71	0.85
f1o05	83	0.72
f1o06	70	0.86
f1o07	87	0.69
f1o08	79	0.76
f1o09	60	1.00
f1o10	97	0.62
f1y01	130	0.46
f1y02	110	0.55
f1y03	115	0.52
f1y04	78	0.77
f1y05	109	0.55
f1y06	100	0.60
f1y07	95	0.63
f1y08	95	0.63
f1y09	103	0.58
f1y10	130	0.46

Table 2 Statistical Analysis (Mean, Standard Deviation, Correlation coefficient and MSE of Heart Rate and RR Interval) using Hilbert Transform

Sr. No.	Methods	Mean & Std. of HR	Mean & Std. of RR Interval	Correlation Coefficient	MSE
1.	Hilbert Transform	94	0.663	85.40%	331.6
		18.683	0.137		

CONCLUSIONS

We have applied Hilbert transform on ECG for the detection of R peak. This method gives correlation coefficient 85.40%. This method provides a feedback control to slow down or speed up breathing rate to resonant frequency. The current work is used in biomedical signal processing shows the validity of the affirmation in academic and professional aspects in medical field.

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