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A Review of QRS Detection Algorithms

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ABSTRACT: Accurate QRS detection is the first step for analysis disease related to heart. We have studied and analyze Pan Tompkins algorithm for QRS detection. Mean RR interval were calculated for the ECG signal record from MITBIH Arrhythmia data base. The band pass filter used is IIR 4th order Butterworth filter having bandwidth of 5-15 Hz. For Moving average filter the choice of the window width N is to be made with the following considerations: too large a value will result in the outputs due to QRS and T waves being merged, where too small a value could yields several peaks for a single QRS.

KEYWORDS: QRS detection, IIR Butterworth filter, Pan Tompkins algorithms, Moving average filter

I. INTRODUCTION

The QRS complex is the most striking waveform within the ECG signal. It serves as the basis for the automated determination of the heart rate, as well as the benchmark point for classifying the cardiac cycle and identifying any abnormality. Over the last few decades, the QRS complex detection has been extensively studied. In 1984, Pahlm and Sormmo discussed the QRS detection methods developed before 1984 in the aspects of digital preprocessing and detection rule, which is a very early paper for systematically analyzing the QRS detection methods [4]. In 2002, Köhler et al. reviewed and compared the great variety of QRS detection algorithms [5]. They grouped all the algorithms into four categories, respectively, based on signal derivatives, wavelet, neural network, and additional approaches. The algorithmic comparisons with respect to the computational load and detection accuracies were carried out to rate the algorithms. This literature was the most cited review paper about QRS detection algorithms. In 2014, Elgendi et al. investigated the existing QRS detection methodologies to target a universal fast-robust detector for portable, wearable, battery-operated, and wireless ECG systems [6]. This study compared the different QRS enhancement and detection techniques based on three assessment criteria: (1) robustness to noise, (2) parameter choice, and (3) numerical efficiency. However, the review [4] did not compare the performances of different QRS detectors. In the review [5], the computational load and detection accuracies of QRS detection algorithms were not based on a standard database, and the comparison results were not given quantitatively. In the review [6], the comparison results were only based on the MIT-BIH arrhythmia database, but these results were from different literatures. In these literatures, some investigators have excluded some records [7] from the MIT-BIH arrhythmia database or excluded some segments with ventricular flutter [8] for the sake of reducing noise in the processed ECG signals. In 1990, the noise sensitivities from nine different QRS detection algorithms were evaluated on a normal, single-channel lead, synthesized ECG database corrupted with five different types of synthesized noise [9]. In 2006, three methods were quantitatively compared using a similar algorithm structure but applying different transforms to the differentiated ECG [10]. The three transformations used were the Hilbert transformer, the squaring function, and a second discrete derivative stage. In 2008, the traditional first-derivative based squaring function method [11] and the Hilbert transform-based method [12], as well as their modifications with improved detection thresholds, were analyzed in the literature [13]. In 2013, Álvarez et al. analyzed the performances of three algorithms [14], Pan and Tompkins algorithm [15], Hamilton and Tompkins algorithm [11], and a phasor transform-based algorithm [16]. However, some studies [9, 10, 13, 14] quantitatively compared different QRS detection algorithms based on the same database, that is, the MIT-BIH arrhythmia database. The MIT-BIH arrhythmia database was widely used to evaluate QRS detection algorithms as it includes different shapes of arrhythmic QRS complexes and noise. As shown in many literatures, majority of the QRS detection algorithms had high detection sensitivity

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and positive predictivity on the MIT-BIH arrhythmia database (>99%) [1, 6]. However, performances of multiple algorithms on multiple source ECG databases lack. For example, the evaluation on ECG signals monitored by portable devices has not been systematically studied, which also challenges the current signal processing algorithms. The ECG signals recorded from the dynamic and mobile equipment are inevitably noise corrupted, consisting of more uncontrollable aspects, such as physiology, pathology, and artificial effects [17]. Therefore, the performance comparison of the commonly used algorithms should be extended to multiple source ECG databases[18,19]. In this paper a review of QRS detection by pan Tompkins method is done through MITBIH arrhythmia database.

II. DATA

ECG test signal taken from physionet database details: MITBIH arrhythmia database with sampling frequency of 360 Hz.

ECG Signal Characteristics

- Relative power spectrum of QRS complex, P and T waves, muscle noise and motion artifacts.

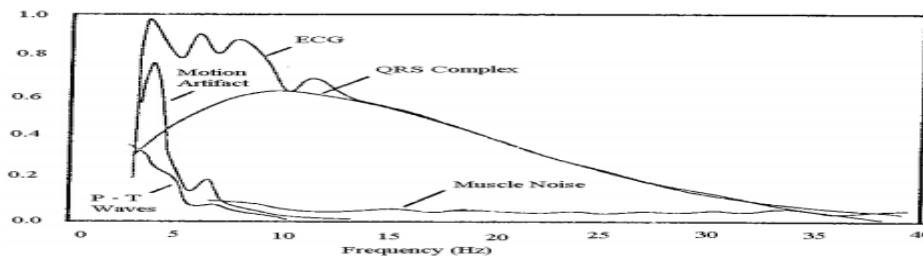


Figure 1 ECG signal characteristics

III. METHODOLOGY

Record mitdb/114 lead II used for QRS detection by pan Tompkins method.

QRS Detection Algorithm

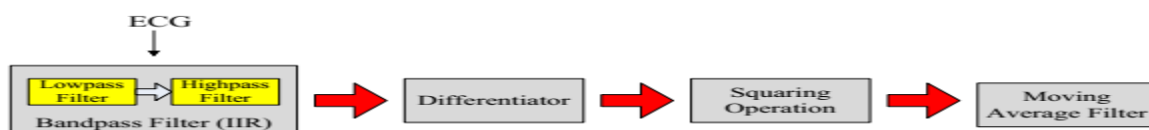


Figure2 block diagram of Pan Tompkins algorithms.

Band pass filter is a cascaded low pass filter and high pass filter to isolate the predominant QRS energy entered at 10 Hz. Energy of QRS is between 5Hz-15H. Low pass filter eliminate noise such as the EMG and 50Hz power line noise
Cutoff frequency=11Hz $y[n] = 2y[n-1] - y[n-2] + x[n] - 2x[n-6] + x[n-12]$
High pass filter eliminate motion artifacts, P wave and T wave
Cutoff frequency = 5Hz $y[n] = y[n-1] - x[n]/32 + x[n-16] - x[n-17] + x[n-32]/32$

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Differentiation is used to obtain information on slope and overcome the baseline drift problem.

Accentuates QRS complexes relative to P & T wave.

$$8y[n] = 2x[n] + x[n-1] - x[n-3] - 2x[n-4]$$

3.1 BAND PASS FILTER:

The band pass filter reduces the influence of muscle noise, 50 Hz interference, baseline wander, and T-wave interference. The desirable pass band to maximize the QRS energy is approximately 5-15 Hz.

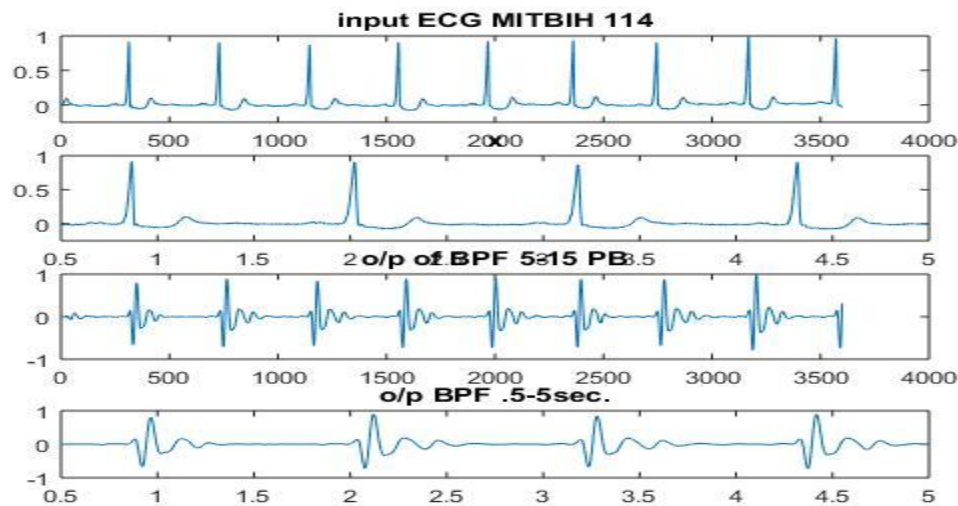


Figure 3: output of Band pass filter iir Butterworth order-4

3.2 DERIVATIVE FILTER AND SQUARING:

It is differentiated for finding the slopes that are associated with QRS complex. Each point in the sequence is squared will make all sample positive and also lead to consolidation of higher frequencies in the signal due to differentiation process. These frequencies are characteristics of QRS wave. The squaring operation makes the result positive and emphasizes large differences resulting from QRS complexes, the small differences arising from P and T waves are suppressed. Emphasizes higher frequency component and attenuates lower frequency component. The high frequency components in the signal related to QRS complex are further enhanced.

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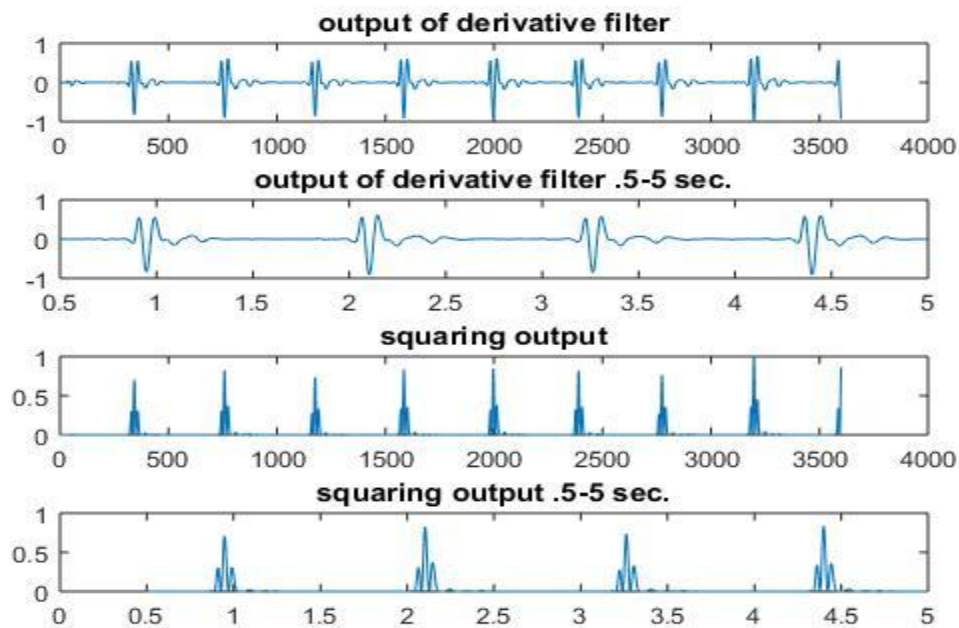


Figure 4 output of derivative filter and squaring output

3.3 MOVING AVERAGE FILTER:

The smoothed final output obtained by passing square output through Moving Average filter. The smoothed final output contains four pulses over the duration of corresponding QRS complex.

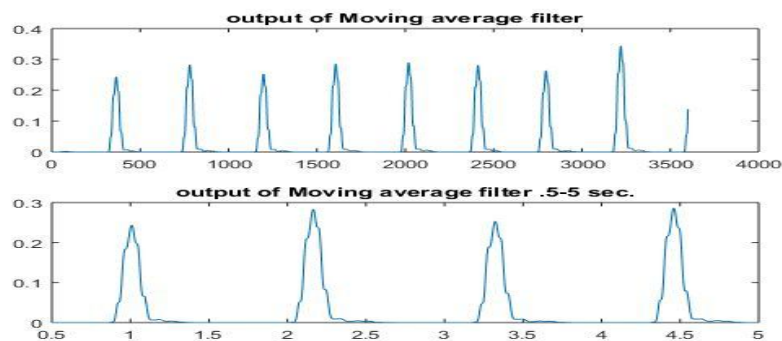


Figure 5 output of moving average filter

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IV. RESULTS

mean RR interval were calculated for the ECG signal record from MITBIH Arrhythmia data base.

ECG SIGNALS	MEAN RR-INTERVAL(ms)
100	290.4167
101	318.9091
103	308.9091
105	258.8333
106	350.9000
108	350.1000
109	230.9167
111	307.7273
112	250.3333
113	385.1250
114	395.1111
115	360.5556
116	269.9167

V. CONCLUSION

We have studied and analyze Pan Tompkins algorithm for QRS detection. Mean RR interval were calculated for the ECG signal record from MITBIH Arrhythmia data base. The band pass filter used is IIR 4th order Butterworth filter having bandwidth of 5-15 Hz. For Moving average filter the choice of the window width N is to be made with the following considerations: too large a value will result in the outputs due to QRS and T waves being merged, where too small a value could yields several peaks for a single QRS.

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