Effect of Different Windowing Techniques on the QRS Detection of ECG Signals using Short Time Fourier Transformation

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Abstract— Though various techniques have been used for the detection of QRS peak of ECG signals so far, attempts are still going on for further improvement. In the present work, the authors used Short Time Fourier Transform (STFT) technique together with different types of window functions for this purpose. For this, not only the most widely used rectangular windowing technique is utilized in STFT for QRS detection, but also the Hamming Windowing and Blackman Windowing technique are also implemented. A comparative study using STFT technique with different windows are also focused.

Keywords— ECG signal; QRS detection; Short Time Fourier Transform, Windowing Techniques.

I. INTRODUCTION

An electrocardiogram (ECG) signal is the definition of the myocardium electrical activity on the body surface, which appears as a nearly periodic signal [1]. Traditionally, the ECG cycle is labeled using the letters P, Q, R, S, and T for the individual peaks of the whole cycle waveform which is depicted in Figure 1. The electrocardiogram provides essential and relevant information about the status of the heart [2].

There are many expediencies for a reliable QRS peak detection of an ECG signal. QRS detection is troublesome, not only because of the physiological instability of the QRS complexes, but also because of the various types of noise that can be present in the ECG signal [3]. Noise sources include muscle noise, artifacts due to electrode motion, power-line interference, baseline wander and T waves with high-frequency characteristics similar to QRS complexes. In most QRS detection algorithms there are two differentiated stages: preprocessing and decision [4].

In the pre-processing stage different techniques are applied to the signal, such as linear and nonlinear filtering or smoothing, to attenuate P and T waves as well as the noise. While in the decision stage the most important task is the determination of thresholds and in some cases the use of techniques to discriminate T waves. Some algorithms include another decision stage to reduce false positives.

There are various techniques that have been employed to detect the QRS complex of the ECG, like power spectrum of the ECG signal, Fourier Transformation, Short Time Fourier Transformation techniques etc. [6]. The earlier method of ECG signal analysis was based on time domain method. But this is not always sufficient to study all the features of ECG signals. So, the frequency representation of a signal is required.
To accomplish this, FFT (Fast Fourier Transform) technique is applied. But the unavoidable limitation of this FFT is that the technique failed to provide the information regarding the exact location of frequency components in time. As the frequency content of the ECG varies in time, the need for an accurate description of the ECG frequency contents according to their location in time is essential. This justifies the use of time frequency representation in quantitative electro cardiology [5]. The immediate tool available for this purpose is the Short Term Fourier Transform (STFT). The STFT is equivalent to windowing the signal \( x(t) \) with a finite width window function \( w(t) \) in to different segments and perform the Fourier transform on each segment.

Window functions can be divided into two categories; Fixed and Adjustable window functions. Mostly used fixed window functions are; Rectangular window, Hanning window, Hamming window and Blackman window etc. A novel window function yielding suppressed main lobe width and minimum side lobe peak.

The database has been taken from [13], [14] when twenty young (21 - 34 years old) and twenty elderly (68 - 85 years old) rigorously-screened healthy subjects underwent 120 minutes of continuous supine resting while continuous electrocardiographic (ECG), and respiration signals were collected; in half of each group, the recordings also include an un calibrated continuous non-invasive blood pressure signal. Each subgroup of subjects includes equal numbers of men and women. All subjects remained in a resting state in sinus rhythm while watching the movie Fantasia (Disney, 1940) to help maintain wakefulness. The continuous ECG, respiration, and (where available) blood pressure signals were digitized at 250 Hz. Each heartbeat was annotated using an automated arrhythmia detection algorithm, and each beat annotation was verified by visual inspection.

II. Methodology

The raw ECG signal may contain different type of noises, so ECG signal should be processed. There are mainly two parts for ECG signal Feature extraction. First is preprocessing and second one is feature extraction [10]–[12]. Detail structure of ECG Signal Processing shown in Fig 2.

![Block Diagram of the proposed work](image)

In the Pre-processing section, the ECG signal which contains noises due to baseline drift, frequency interference, polarization noise etc. are processed. In most of the ECG recordings the respiration, electrode impedance change and increase body movements creates baseline drift. The common problem in ECG signal processing is base line drift removal and noise suppression .This two problems are eliminated in the pre-processing stage. After pre-processing the signal is periodically divided, using auto-correlation method in the feature extraction section for the QRS peak detection.

In the feature extraction stage, STFT (Short Time Fourier Transformation) is computed on the filtered data [7]–[9]. A smaller window length yields a high time resolution and low frequency resolution and vice-versa. Based on this, one need to choose an optimum window length. After computing STFT, one can estimate how much each frequency component have contributed to the total energy of the signal over certain interval of time. In the computation of STFT, different windowing techniques have been applied to analysis the performances of different windows. In this work, the responses of Rectangular, Hamming and Blackman windows are being compared.
III. RESULT AND ANALYSIS

In this work, there are mainly three steps. Firstly the pre-processing of the raw ECG signal is done. Secondly, the signal is periodically divided to get the proper QRS peaks. This is done by the auto-correlation method and the signal obtained after auto-correlation is depicted in Fig 3.

![ECG signal after auto-correlation]

Fig. 3. ECG signal after auto-correlation

After getting those periodical signals, by using the STFT technique QRS peak of the ECG signal is detected. In this STFT method different windowing techniques are used. The response of STFT using Rectangular windowing technique is shown in Fig 4.

It is found that for the fixed length, the Rectangular window provides smallest main lobe width but the highest peak of side-lobe among them. So Rectangular window is not widely used in digital signal processing.
Next the response of STFT using Hamming window is shown in Fig 5. It was analyzed that Hamming Window provides good side lobe attenuation compare to rectangular window, so these window is commonly used in different DSP applications.

Lastly, in the detection of QRS by STFT, Blackman window is used whose response is depicted in Fig 6.

For higher side lobe attenuation Blackman window is used but the Blackman window has a wider main lobe width compare to Rectangular and Hamming window. So the response of Blackman windowing STFT is better among the two.
Fig. 5. STFT using Hamming Windowing

Fig. 6. STFT using Blackman Windowing
IV. CONCLUSION

This paper shows that the STFT technique do have the potential to improve the performance of QRS peak detection. Further improvements can be possible by using STFT technique with different windows. In this work the frequency-time response using STFT of ECG signal, using three different windows are analyzed. It is found that Blackman Window gives better response over Rectangular and Hamming Window signal. Using Blackman Windowing the signal extraction was nearly perfect. Other types of windows may also be used to have the better response.

REFERENCES


