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ECG Real Time Feature Extraction Using MATLAB

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Abstract — **An Electrocardiogram signals change their statistical property over time and ECG signals are highly non-stationary signals. Growing of embedded technology has provided powerful tools to analysis of ECG. ECG is advanced recording method of bioelectric signal which is originated in the heart and it provides valuable information about the activity of human heart. Different types of features of the ECG can be extracted from the intervals and amplitudes of ECG waves at different parts. The accuracy of the QRS interval detection defines the accuracy of locating all remaining waves and their intervals. For the ECG signals analysis wavelet transform is a more useful tool. In this paper, we are propose implementation of an ECG feature extraction system based on DWT for detection of P wave, QRS interval, total number of heart beats in one minute. The performance of algorithm will test using MATLAB routine and validated our results based on the MITBIH arrhythmia database.**

Index Terms — **DWT, ECG signal, HPF, LPF, MITBIH**

I. Introduction

An electrocardiogram is a graphical representation of the small electric waves being generated during heart activity [1]. It provides information about the heart rate, rhythm, and morphology. Fig.1 shows the basic shape of a healthy ECG heartbeat signal with P, Q, R, S, T and U characteristics and the standard ECG intervals QT interval, ST interval and PR interval [1][3].

The ECG is distinguished by a recurrent wave sequence of P, QRS, T and U wave associated with each beat. The QRS complex is the most extreme waveform, caused by ventricular depolarization of the human heart. A typical ECG wave of a normal heartbeat consists of a P wave, R peak (i.e. QRS complex), and a T wave [4] [7] [8].

In fact, R peak is necessary to determine the heart rate, and several related arrhythmias like as Tachycardia, Bradycardia and Heart Rate changes [4].

ECG signal analysis was previously based only on time domain method. But this is not sufficient way to study all the features of ECG signal. So we need the frequency representation of signal. To overcome this, FFT (Fast Fourier Transform) technique was applied. But the FFT is failed to provide the information regarding the exact location of frequency components in time. While STFT (Short Time Fourier Transform) compromise between time and frequency information, the drawback is that it use in particular window that window frequency is same for all time. Several algorithms suggested in literature [1][2][3].

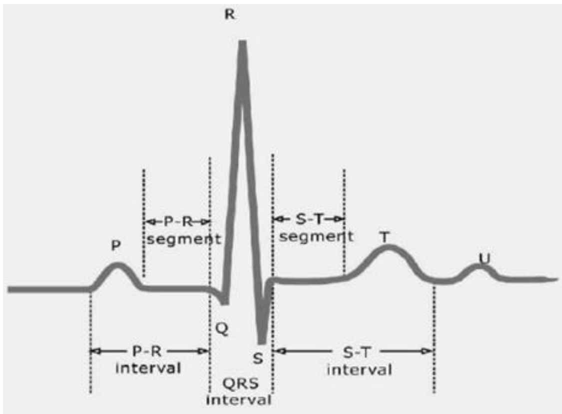

Fig.1: An ECG waveform with the ECG intervals [1]

The Wavelet Transform (WT) method gives information for the signal simultaneously in both time and frequency domain. In wavelet transform, a linear operation transforms the signal by decomposing it into various levels. The signal is passed through a number of series of high pass and low pass filters in order to analyze both high as well as low frequency components. The wavelets closely resembling the signal are generally selected for the analysis. There are several wavelet families [2].

In this paper we are proposing implement an ECG signal feature extraction based on discrete wavelet transform (db4).

II. Mitbih Database

ECG signals required for analysis are collected from Physionet MIT-BIH arrhythmia database where annotated ECG signals are described by a text header file (.hea), a binary file (.dat) and a binary annotation file (.atr).Header file consists of detailed information such as number of samples, sampling frequency, format of ECG signal, type of ECG leads and number of ECG leads, patients history and the detailed clinical information. In binary data signal file, the signal is stored in 212 format which means each sample requires number of leads times 12 bits to be stored and the binary annotation file consists of beat annotation. MATLAB and its wavelet toolbox is used for ECG signal processing and analysis [7] [10].

III. 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 [7].

A) *Preprocessing*

ECG signal contains noises due to baseline drift, frequency interference, polarization noise, electrode contact first page footnote as an example. Muscle noise, internal amplifier noise. 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 [1][4][7][8].

The simple waveform without preprocessing shown in Fig.2

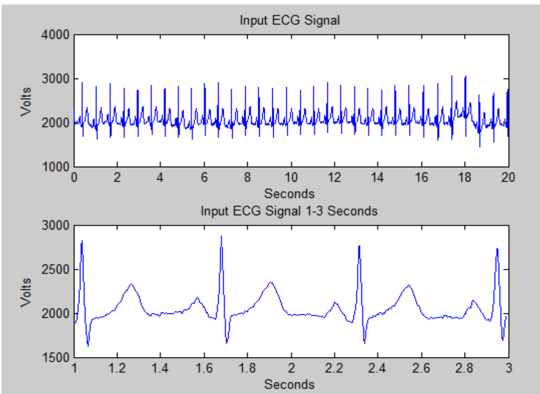

Fig. 2: (a) Sample ECG4.dat signal from MITBIH database (b) ECG4.dat signal for 1-3 seconds.

1) *Removal of the baseline drift*

Baseline wandering is the noise artifacts that affect ECG signals. Removal of baseline drift is therefore required in the analysis of the ECG signal to minimize the changes in beat morphology with no physiological counterpart. Respiration and electrode impedance changes due to perspiration are main sources of baseline wander in most types of ECG recordings. This baseline wandering can be eliminated without disturbing the ECG waveform characteristics. For the elimination base line drift we are used maxima and minima principal [1] [7].

Output after the removal of baseline drift is shown in Fig.3.

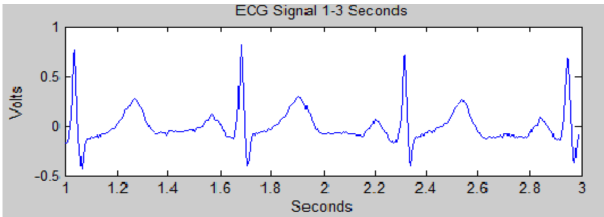

Fig.3 ECG signal after DC drift removal and normalization

2) *Removal of noise*

After removal of baseline drift the ECG signal is stationary and contains some noise .To reduce the noise number of techniques digital filters, adaptive filtering methods. We use Band pass filter to noise rejection.

For our chosen sample rate we were not able to use band pass filter directly, for the desired pass band 5-15 Hz using the specialized designed technique. Therefore we cascade the low pass and high pass filter t achieve 3 dB pass band from about 5-12 Hz [3].

We use second order low pass filter and the design of high pass filter is made by subtracting the output of first order low pass filter from an all pass filter.

$$H(z) = (1 - z{-}12)^2 / (1 - z{-}1 + z{-}2)^2 \qquad (1)$$

Output after LPF and HPF shown in Fig.4 and Fig.5 respectively.

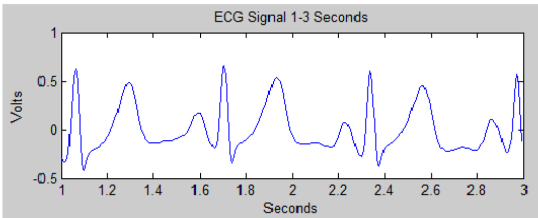

Fig. 4: ECG signal after passing through LPF

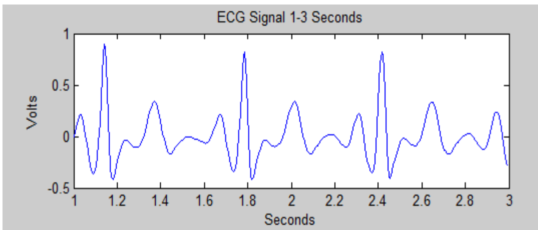

Fig. 5: ECG signal after passing through HPF

B) *Feature Extraction*

The purpose feature extraction process is to retain information from original ECG signal. Fig 4 shows the general block diagram for ECG feature extraction.

First we detect the R peak i.e. QRS complex which is the highest amplitude in the ECG signal. Then Q and S waves are detected. Then detected two zero crossing of the signal before the Q and after the S waves are selected. And at last P and T waves are detected [7].

a. QRS detection

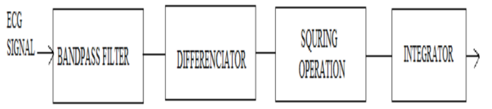

Fig. 6: Block Diagram for QRS detection Algorithm [2]

After the band pass filter the output is given to differentiator.

Differentiation: After the signal has been filtered; it is then differentiated to provide information about the slope of the QRS complex [9]. A five-point derivative has the transfer function

$$H(z) = 0.1 (2 + z^{-1} - z^{-3} - 2z^{-4}) \quad (2)$$

This derivative is implemented with the difference equation

$$y(nT) = 2x(nT) + x(nT - T) - x(nT - 3T) - 2x(nT - 4T) /8 \quad (3)$$

Squaring Operation: The squaring function that the signal now passes through is a nonlinear operation [9]. The equation that implements this operation is

$$y(nT) = [x(nT)]^2 \quad (4)$$

After squaring operation makes all data points in the processed signal positive, and it amplifies the output of the derivative process nonlinearly. It emphasizes the higher frequencies in the signal, which are mainly due to the QRS complex [9]

$$y(nT) = 1 N [x(nT - (N - 1)T) + x(nT - (N - 2)T) + \ldots + x(nT)] \quad (5)$$

Where N is the number of samples in the width of the moving window

Integrator: The slope of the R wave alone is not a guaranteed way to detect a QRS event. Many abnormal QRS complexes that have large amplitudes and long durations (not very steep slopes) might not be detected using information about slope of the R wave only. Thus, we need to extract more information from the signal to detect a QRS event. Moving window integration extracts features in addition to the slope of the R wave [9].

Threshold: Signal peaks are defined as those of the QRS complex, while noise peaks are those of the T waves, muscle noise, etc. After the ECG signal has passed through the band pass filter stages, its signal-to-noise ratio increases. This permits the use of thresholds that are just above the noise peak levels. Thus, the overall sensitivity of the detector improves [9].

Then we use Search back technique. To implement the search back technique, this algorithm maintains two RR-interval averages [9]. We use DWT algorithm to check high frequency and low frequency component.

Output after the DWT shown in Fig. 7 and Fig. 8 respectively

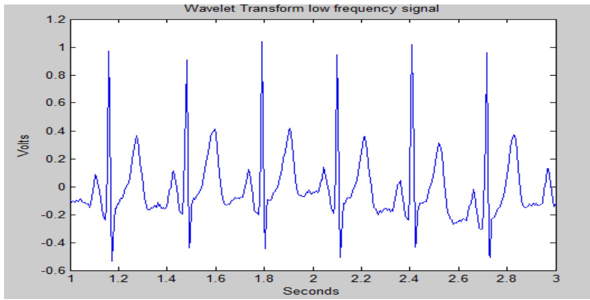

Fig. 7: Using DWT shows the low frequency ECG signal

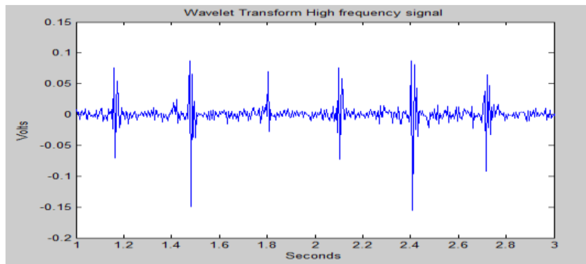

Fig. 8: Using DWT shows the high frequency ECG signal

Results

MATLAB and its wavelet toolbox is used for ECG signal processing and analysis. By using MITBIH database we are taken sample ECG4.dat file.

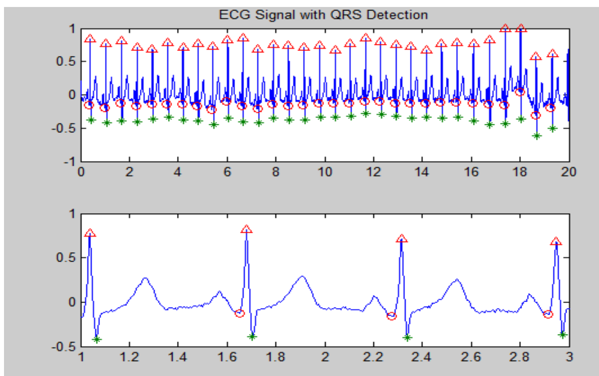

Fig. 9: Final detection of QRS complex.

From the detection of RR interval or QRS complex we make calculation of heart rate .like for 3 seconds 4 RR interval then for 60 seconds it is how much is the Heart Rate using MATLAB itself. From that data we conclude patient is normal or not.

Conclusions

An algorithm for R Peak and QRS complex detection using Wavelet Transform technique has been developed. The information about the R Peak and QRS complex obtained is very useful for ECG Classification, Analysis, Diagnosis Authentication and Identification performance. The QRS complex is also used for beat detection and the determination of heart rate through R-R interval estimation.

Amplitude of P wave remains constant throughout the life and other amplitude features are changes on small scale. Future work is to calculate the amplitude distance between ECG features and comparison will be made for Identification.

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