Removal of ECG Noise Artifacts Using Signal Processing Techniques

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Abstract- *ECG is considered to be the most vital physiological parameter for examining the anatomic and physiologic facets of the heart muscles. It is a graphical trace providing the electrical activity of the heart and is thus keenly used for clinical diagnosis. But over time, the ECG signals tend to change their statistical properties and hence are referred to have non-stationary behavior. Since the tools used in ECG recordings are based on analog circuitry, in certain exhausting and peripatetic conditions, the recorded ECG is contaminated with various types of noise artifacts. The main artificial artifacts include power-line interference, baseline drift and electrode contact noise. The main biological artifacts are motion artifacts and muscles artifacts (EMG noise). This paper presents an approach to filter the noise artifacts in the ECG signal and thus facilitate the detection of the QRS complex using the adaptive threshold. The experimental results also present the evaluation parameters before and after filtering of the ECG signal.*

Keywords- ECG; MIT-BIH; Baseline Drift; SNR

I. INTRODUCTION

The Electrocardiogram (ECG) is the electrical manifestation of the contractile activity of the heart that can be recorded rapidly and automatically. The ECG signals can be measured painlessly, using 12 lead or 3 lead electrode system. This is a non-invasive procedure that is used to record the electrical activity of heart.

The contraction and relaxation of heart muscles causes the blood to flow in and out of the heart. During each cardiac cycle, electrical impulses are generated by a group of tissues in the heart called as the sino atrial node also known as the pacemaker of the heart [2]. This electrical activity impulses spread all through the heart and causes rhythmic contraction and relaxation of the heart muscles. By placing electrodes at specific points on the body these electrical impulses can be detected. The electrocardiogram signal is characterized by six peaks and valleys labeled with successive letters of the alphabet: P, Q, R, S, T and U [8].

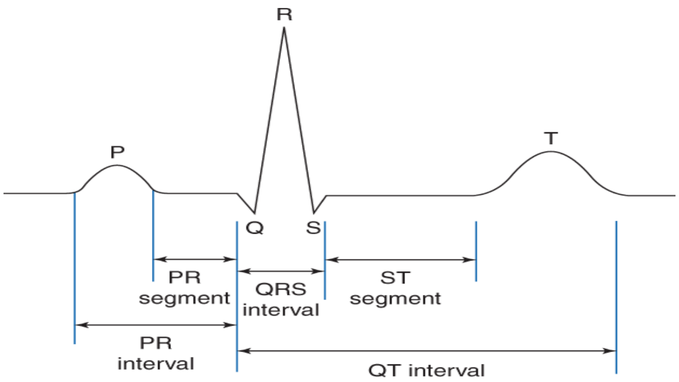

Figure 1: ECG Waveform

The tools of ECG recording procedure are non-invasive and hence are based on analog circuitry and manual handling. Therefore a typical ECG is invariably corrupted by electrical interference from surrounding equipment (effects of the electrical mains supply), movements artifacts, baseline drift and instrumentation noise which are the major noise sources contaminating the raw ECG. It is necessary to analyze the ECG signal correctly and remove the processing techniques which include digital filter and adaptive filter approaches have been proposed by the authors for the same [7]. This paper presents the filtering strategy for noise removal from the raw ECG and thus facilitates the detection of QRS complex using thresholding rules. It also shows a table depicting the evaluation parameters before and after filtering highlighting the fact that noise removal and baseline cancellation is necessary for processing the ECG signal.

II. DATABASE COLLECTION

For this paper, MIT-BIH Arrhythmia Database directory of ECG signal from physionet is used [6]. Total 48 files of 10 sec recording each in raw unit are utilized out of which 22 are females and 26 are males. This database is divided into two parts, first 23 files (numbered from 100m to 124m with some numbers missing) and second part of 25 files (numbered from 200m to 234m again with some numbers missing). The ECG waveform from MIT-BIH Database contains – a text header file, a binary file and a binary annotation file. The ECG signals are stored in 212 format, which means each one sample imposes number of leads times 12 beats to be stored and binary file contains beat annotations.

III. METHODOLOGY

The raw ECG signal may be contaminated with various types of noise artifacts like baseline drift, power-line interference, muscles noise, electrode contact and polarization noise. In most of the ECG recordings the respiration and body movements can give rise to baseline drift in the signal.

Thus, the common problem in ECG signal is the elimination of baseline drift and suppression of other noise artifacts.

A. Removal of baseline drift

The most common noise artifact responsible for contaminating the ECG signal is the Baseline Drift. It generally results from respiration, motion and changes in electrode impedance and lies between 0.15Hz and 0.3Hz. It can actually mask the necessary information from the ECG and cause irregularities in beat morphology. In this paper, the baseline drift of the ECG signal is eliminated by using the moving average filter to achieve the smoothed signal. Then the smoothed signal is subtracted from the original signal to get rid of the baseline drift from the ECG signal. Hence the signal thus obtained is free from baseline drift.

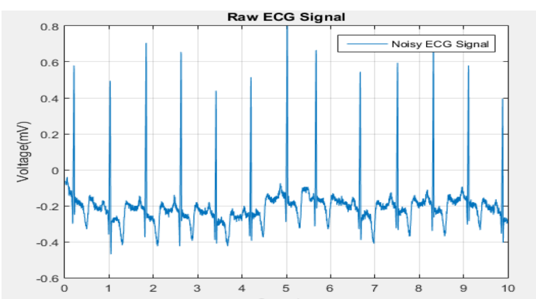

Figure 2: Raw ECG signal

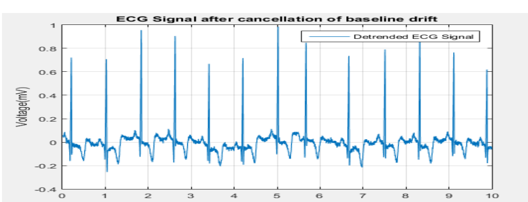

Figure 3: ECG signal with baseline drift removal

B. Removal of noise artifacts

With the eradication of baseline drift the ECG signal is free from DC offset but still contains some noise. To get rid of this noise various schemes have been proposed earlier like digital filtering technique and use of adaptive filters. In this paper we try to implement band-pass filtering approach for noise rejection as it improves SNR and reduces influence of these noise sources. It also permits the use of lower thresholds that would be possible on filtered ECG signal and thus reduces the noise caused due to false positives that mimic the QRS complex.

The approach involves linear as well as nonlinear filtering for noise rejection. Since the desired pass band 5-15 Hz cannot be achieved using bandpass filters directly for our chosen sample rate, we use the cascade of low pass and high pass filters to achieve 3dB pass band from 5-12 Hz.

- Bandpass Filtering:

It is the cascade of low pass filter and high pass filter. The low pass filter eliminates 50 Hz power line noise and electromyogram noise, having cutoff of 11 Hz, with the gain 36 and a delay of 6 samples.

The difference equation for low pass filter is:

$$y(nT)=2y(nT-T)-y(nT-2T)+x(nT)-2x(nT-6T)+x(nT-12T) \quad ...(1)$$

The high pass filter eliminates lower frequency components which are motion artifacts, P wave and T wave.

The difference equation for high pass filter is:

$$y(nT)=32x(nT-16T)-[y(nT-T)+x(nT)-x(nT-32T)] \quad ....(2)$$

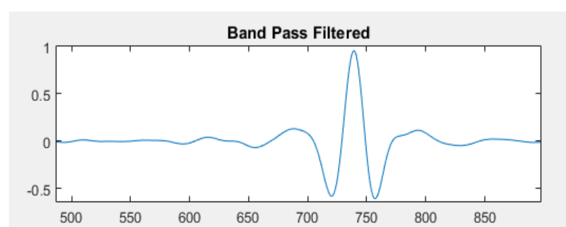

Figure 4: bandpass filter output

- Derivative Operator:

The next step is differentiation. After filtering, the signal is differentiated to provide QRS slope information. Five point derivative is been implemented as it approximates ideal derivative over dc and 30 Hz with delay of two samples.

The difference equation for derivative operation is:

$$y(nT)=(1/8T)[-x(nT-2T)-2x(nT+T)+2x(nT+T)+x(nT+2T)] \quad ......(3)$$

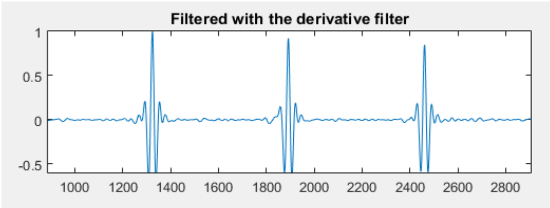

Figure 5: Derivative operator output

- Squaring:

After differentiation the signal is squared point by point. This emphasizes the higher frequency components and attenuates the lower frequency components.

The equation for squaring operation is:

$y(nT) = [x(nT)]^2$ ………………………………. (4)

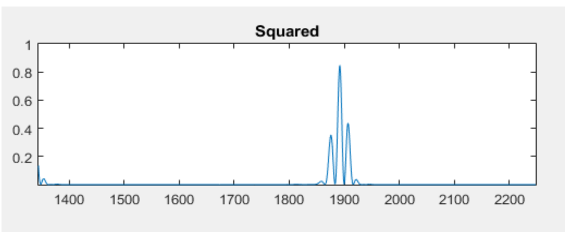

Figure 6: Squared output

- Integration:

The squared signal is then passed through moving window integrator. It acts as a smoother and performs as a moving window integrator, with sample rate of 200 samples/sec and window width of 30 samples (150ms).

The equation for moving average integration is:

$y(n) = (x[n-(N-1)]) = x[n-(N-2)]+\ldots+x[N]/N$………….... (5)

Where N is length of Moving Average Filter.

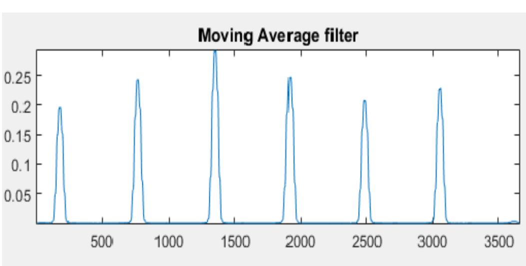

Figure 7: Integration output

C. Evaluation Parameters before and after filterating

SNR		Cross Correlation		Peak signal to noise ratio	
Before Filtering	After Filtering	Before Filtering	After Filtering	Before Filtering	After Filtering
-0.959dB	0.1988dB	-0.05218	0.006686	2.43306dB	7.3583dB

IV. CONCLUSION

This paper presents a filtering approach to cope up with the noise artifacts affecting the ECG. Three evaluation parameters were compared for their values before and after filtering the ECG signal. The procedure of bandpass filtering, finding the derivative, squaring and integrating was found to significantly improve the signal in terms of the signal to noise ratios with the improved SNR of 0.1988dB and peak SNR of 7.3583dB and cross correlation of 0.006686.

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