ANALYSIS OF ECG SIGNALS USING WAVELETS AND IIR FILTER FOR DENOISING

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ABSTRACT: Electrocardiograms (ECG) play a vital role in diagnosis, and providing information about heart diseases. The electrocardiogram is commonly used to detect abnormal heart rhythms, while recording noise, sources like the power line interference and other noise sources distorts the original ECG signal. In this paper, we propose a new method for removing the noise interferences, based on discrete wavelet transform and IIR notch filter. Our proposed method is a hybrid technique, which combines Daubechies wavelet decomposition and notch filter .Wavelets are mathematical functions that cut up data into different frequency components, and then analyse each component with a resolution. Filtering is done for improved denoising performance. Here quantitative study of result evaluation has been done in MATLAB environment using wavelet and signal processing toolbox.

Keywords: *Electrocardiogram, Denoising, power line interference, Decomposition, Notch filter*

I INTRODUCTION

An ECG is used to measure the heart's electrical conductivity system. It takes electrical impulses produced by the polarization and depolarization of cardiac tissue and translates into a wave-form. This waveform is then used to measure the rate of heartbeats, and also the size and position of the chambers of the heart, the presence of any kind of damage to the heart, and the various drugs or devices used to control or regulate the heart functioning, like pacemaker.The majority of useful information in the ECG is originated in the intervals and amplitudes defined by its morphological features the QRS complex. The ECG signal is usually contaminated by baseline wandering which is caused due to respiration, power line interference due poor-electrode contact, muscle contraction noise and due to the movement of patient . Thus removal of these noises is required for obtaining correct result in ECG analysis. Baseline wander's frequency range is usually below 0.5Hz which appears as similar to the ST segment frequency range. The measurement of ST wave becomes difficult due to baseline wander. ECG wave can be decomposed in to various components, named P, Q, R, S and T waves. Each of components of ECG signal has its own typical behavior. A typical one-cycle ECG tracing is shown in Fig.1.

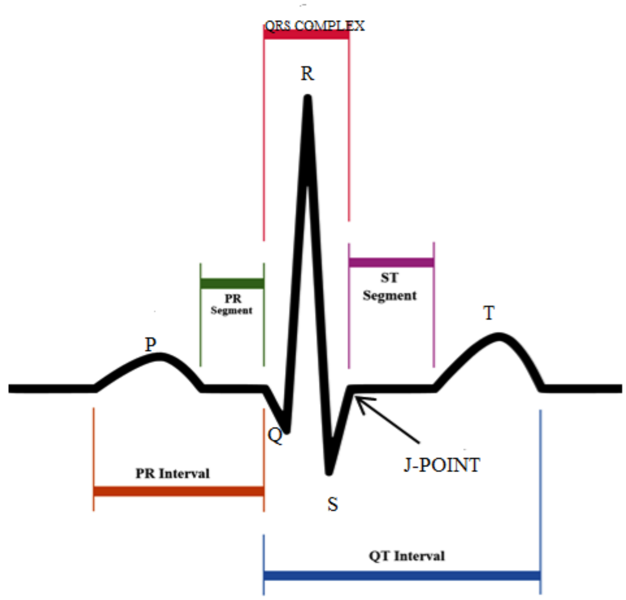

Figure 1: ECG Waveform

It is therefore important to be aware of most common types of noises and artifacts in the ECG tracing and find a method which can compensate for their presence before proceeding to the future extraction step .Wavelet based QRS detection methods usually utilize a band-pass filter or a combination of low-pass and high-pass filter to filter out noise in the ECG first. Then the transform is applied and the QRS complexes are detected by finding local maxima. Wavelet QRS detectors based on discrete wavelet transform (DWT) are given in [1] and [2], and those based on continuous wavelet transform (CWT) can be found in [3] and [4]. Mali eta al. [5] provides for reliable and effective detection and classification of heartbeats and for calculation of ECG parameters.

Till now many methods of removing the baseline wander are proposed. A classical method using high pass filter removes very low frequency component from ECG recording [6]. Linear filtering is also performed for removing baseline wander from ECG signals in the frequency range of 0.5Hz [7]. A ringing effect (Gibbs phenomenon) is introduced by this method on the ECG signal analysis [8]. The polynomial fitting (PF) or cubic spline filter came in to existence in order to overcome this limitation . This method includes cubic spline approximation and subtraction technique, which consists off baseline estimation with polynomial or cubic spline and then subtracting it from disturbed signal. [9]. Adaptive filtering proposed by Windrow can also be used to remove baseline wander. Reference signal is needed in this method, which adds to complexity of hardware and software adaptive filter etc. [10-11]. In this work DWT based denoising is performed. Daubechies wavelet function (db4) with notch filter is used to analyse the efficiency of noise removal from ECG signals.

II NOISES IN ECG WAVEFORM

ECG data consists noise and artifact components that change the waveform of the ECG trace from the ideal structure described earlier and render the clinical observation inaccurate and misleading. Consequently, a pre-processing step to improve the signal quality is recommended. It is therefore important to be aware of most common types of noises and artifacts in the ECG tracing and find a method which can compensate for their presence before proceeding to the future extraction step.

ECG is a typical non-stationary and random signal. ECG signals contain limited information above 100 Hz in which 90% of the ECG spectral energy concentrated in the 0.25 Hz to 20 Hz. ECG inevitably influenced by various kinds of noise interferences, can be summed up in the following:[15]

A. Baseline Wander

It is extraneous noise in the ECG trace that may be caused from a variety of noise sources including perspiration or respiration and any kind body movements, or poor electrode contact. The magnitude of this wander may exceed the amplitude of the QRS complex by many times, but spectral content of it is usually confined to an interval below 1Hz.

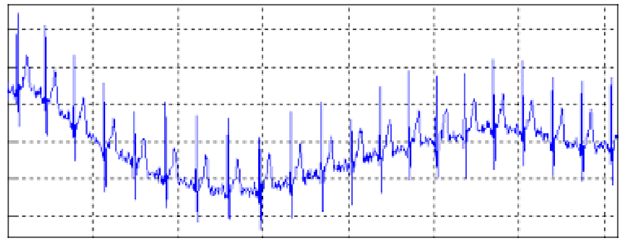

Figure 2: Baseline drifts in ECG signal.

B. Power line Interference (50/60 Hz)

It is high frequency noise caused by interferences from nearby devices as a result of improper grounding of the ECG equipment. It appears as a spike at 60 Hz/50 Hz harmonics, and will appear as additional spikes at integral multiples of the fundamental frequency whose amplitude is up to 50 percent of peak-to-peak ECG signal amplitude.

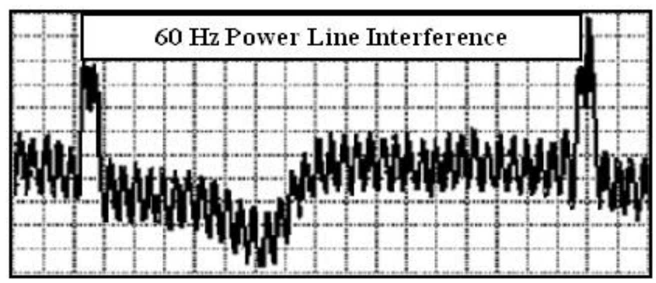

Figure3:60 Hz Power line interference

C. Motion artifacts

These are transient baseline changes caused due to electrode skin impedance with electrode motion. It can cause larger amplitude signal in ECG waveform. The peak amplitude of this artifact is about to 500 percent of Peak to Peak ECG amplitude and its time duration is about 100 – 500 ms. An adaptive filter can be used to remove the interferences due to motion artifacts.

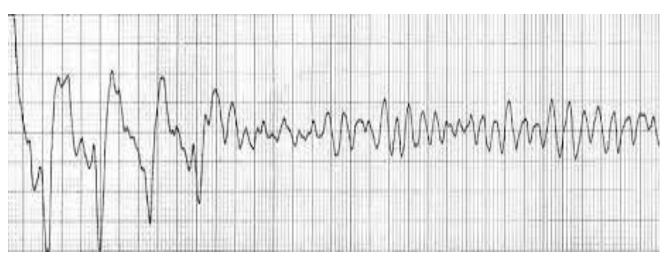

Figure4: Motion artifacts in ECG signal

III DATA BASE

MIT-BIH Arrhythmia Database, is available on-line is used as a data-set. The recordings were obtained by the Beth Israel Hospital Arrhythmia Laboratory between 1975 and 1979; approximately 60% of the recordings were obtained from patients. The 10 records (numbered from 100 to 110) were chosen from the same set. By placing the electrodes on the chest, we can obtain limb lead II (MLII) that is the upper signal in most of the records. A modified lead V1 is usually the lower signal; the recordings were digitized at 360 samples per second per channel with 11-bit resolution over a 10 mV range**.**

IV WAVELET TRANSFORM

Wavelet transform is used for removing base line wander and other high frequency noises from the ECG signal.

A multiresolution property is associated with wavelet transform to give both time and frequency domain information in a simultaneous manner through variable size window. The DWT of a signal "x" is calculated by passing it through a series of filters i.e low pass and high pass filters. The inner product of the signal x (t) and the wavelet function ψ (m,k) provides a set of coefficients X_{DWT} (m,k), for m and k by applying DWT on signal x(t). DWT can be considered as one of the multi-rate signal processing systems that use multiple Sampling rates in the processing of discrete time signals. The DWT of a signal x (t) is given by eqn:1

$$X_{DWT\,K} = \int_{-\infty}^{\infty} x(t) 2^{m/2} \psi(2^m t - k)\, dt \qquad (1)$$

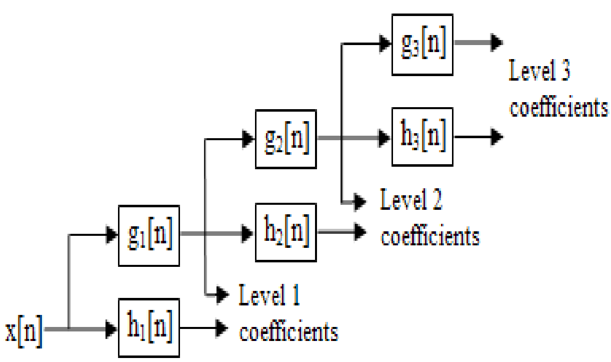

Figure5 : Wavelet Decomposition

V FILTERING TECHNIQUES FOR REMOVAL OF POWER LINE INTERFERENCE (PLI) USING. *IIR NOTCH FILTER*

The extraction of cardiac signals from a noisy electrocardiogram (ECG) is an important problem for the biomedical engineering community. The numerous non cardiac ECG contaminants, such as electromyography noise, overlap with the cardiac components in the frequency domain, particularly in the 0.01 Hz to 100 Hz range.

Notch filters are kind of the band stop filter which can be used to reject a single or very small band of frequencies. These are simple filter which can remove power line interference .A notch filter has higher attenuation level, thus it can able to remove PLI noise to a greater extent from ECG signal. It eliminates power line interference at 50Hz frequency. The ideal response of the filter is shown in fig.

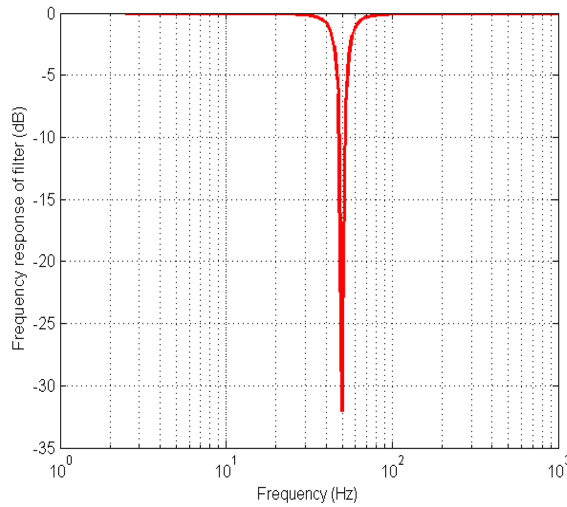

Figure6: Frequency response of Notch filter

VI PROPOSED DENOISING METHODS

The Data which is collected from Physionet is considered to be as the research resource for complex physiologic signals. The pre-processing of ECG signal is done to remove the base line wander, motion artifacts and other interruptions of original recorded signal. ECG signal are recorded with many noise such as muscle noise, grid noise, base line drift, power line interference, motion artifacts which are not avoidable. These noises must be detected and removed in order to get useful information from the signal [4].

In this paper Daubechies wavelet (db4) with a decomposition tree of level 4 is used because it can provide a well orthogonality to high frequency noise with a given number of vanishing moments. Filtering is also done by notch filter which removes the power line interference more accurately.

VII MATLAB SIMULATION RESULT

The response of the filters are stable but containing some ripples. The phase is also linear which indicates that if a multiple frequency signal is applied to it there will be no phase shift and hence no distortion. The implementation of filter results in removal of the noise specifically meant for it.

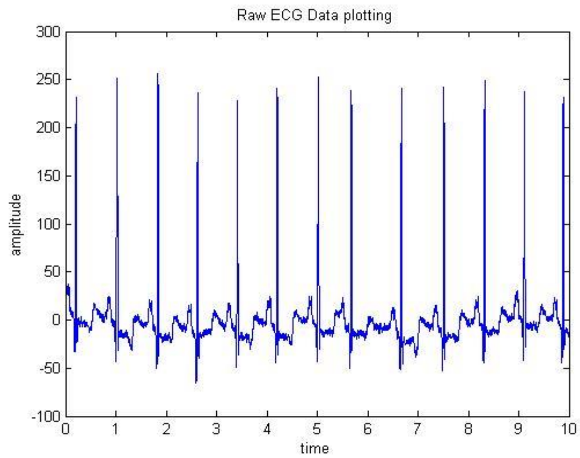

Figure7: Raw ECG signal

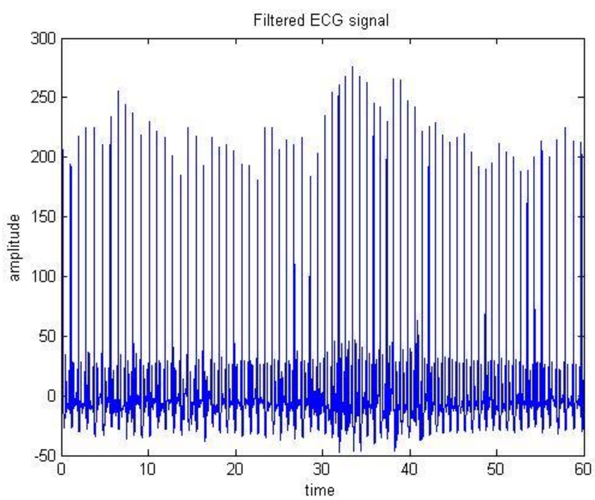

Figure8 : Filtered ECG signal

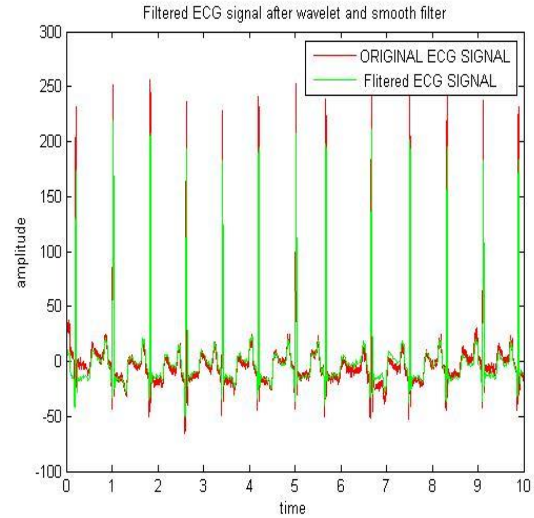

Figure9: Filtered ECG signal after wavelet and smooth filter

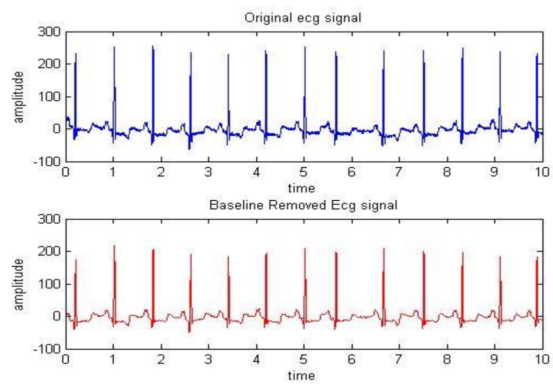

Figure10: Removal of Baseline wander

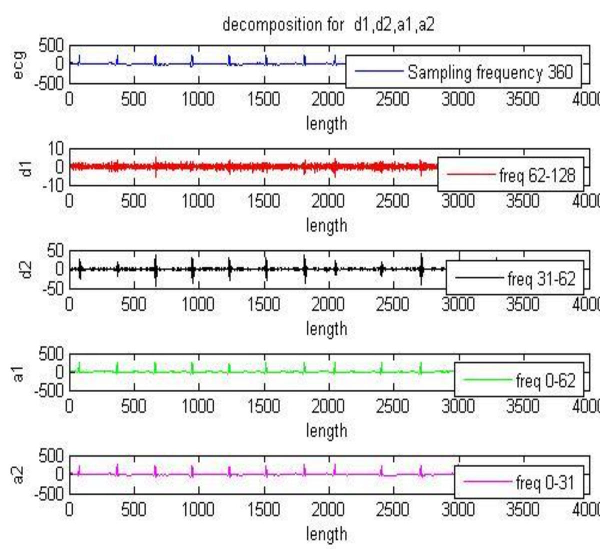

Figure11 : Wavelet decomposition

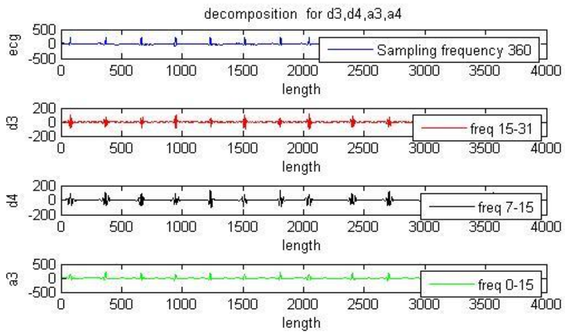

Figure 12: Wavelet decomposition

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