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Study and Review of the Biomedical Signals With Respect To Different Methodologies

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Abstract-- **Biomedical signals are described as the collection of electrical signal acquired from any organ that represents a physical variable of interest. This signal is normally a function of time .It is described in terms of its amplitude, frequency, and phase. The analysis of these signals is important both for research and for medical diagnosis and treatment. If the signals are not properly diagnosed and analyzed it will lead to wrong diagnosis and can be fatal to life. Biomedical signals such as ECG, EMG, and EEG are extremely important in the diagnosis of patients. These signals have noise as well as artifacts which have to be removed for proper treatment of a patient. Different methodologies are used to remove noise and artifacts .This paper describes the different filtering techniques like IIR, FIR and Wavelet.**

Keywords: *ECG, EEG, EMG, artifact, noise, IIR, FIR, and Wavelet*

I. INTRODUCTION

Heart diseases, which are one of the death reasons of men/women, are among the important problems on this century. Early diagnosis and medical treatment of heart diseases can prevent sudden death of the patient. One of the ways to diagnose heart diseases is to use electrocardiogram (ECG) signals. ECG signals are formed of P wave, QRS complex, and T wave [8][9] .They are designated by capital letters P, Q, R, S and T figure 1 shows the sample ECG signal with P-QRS-T wave. In the normal beat phase of a heart, the main parameters, inspected include the shape, the duration, and the relationship with each other of P wave, QRS complex and T wave components and R-R interval. In today's growing age the eating habits are posing a great problem on human health therefore the use of new technology is must. The computer aided ECG signal analysis is a popular research in today's world.

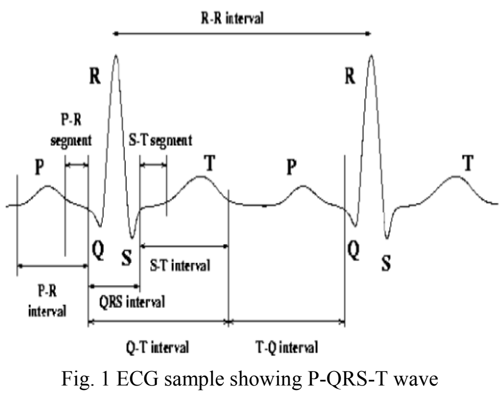

Fig. 1 ECG sample showing P-QRS-T wave

For ECG the process of automated analysis the noises present in signal are needed to be considered and eliminated for the accurate signal analysis and diagnosis. Electrocardiogram (ECG) can be corrupted by various types of noise such as power line interference, electrode contact noise, motion artifacts, EMG noise, instrumentation noise, muscle tremor, wandering baseline [9].The ECG signal embedded in these noises is very difficult to correctly interpret for diagnosis. To obtain a distortion less, accurate & error free signals we uptakes a filtering techniques by using several filters.

II. ECG FILTERING: A REVIEW

The filtering techniques are primarily used for pre-processing of the signal and have been implemented in a wide variety of systems for ECG analysis. To reduce and remove the noises, digital software filters are widely used in biomedical signal processing. [3]. Analog filters can deal with the noises, but they introduce nonlinear phase shifts and depend on the instrumentation such as resistance, temperature and design. Analogue filter characteristics are typically fixed by the circuit design and component values. If we wish to change the filter characteristics we would have to make major modifications to the circuit. In comparison digital filters' characteristics can be changed very easily by simply changing the algorithm that the processor was running. Digital filters are more precise and less error with more advantages over analog filters. Filters have two uses: signal separation and signal restoration. Signal separation is needed when a signal has been contaminated with interference, noise, or other signals. For example, imagine a device for measuring the electrical activity of a baby's heart (EKG) while still in the womb. The raw signal will likely be corrupted by the breathing and heartbeat of the mother. A filter might be used to separate these signals so that they can be individually analysed [6][7]. Digital filters are classified either as Finite Impulse Response (FIR) filters or Infinite Impulse response (IIR) filters, depending on the form of unit pulse response of the system. In the FIR system, the impulse response is of finite duration whereas in the IIR system, the impulse response is of infinite duration. IIR filters are usually implemented using structures having feedback, that's why the present response of IIR filter is a function of present and past values of the excitation as well as the past value of the response. But the response of the FIR filter usually implemented using structures having no feedback so the response depends only on the present and past values of the input only [6].

A. Design Techniques of FIR & IIR Filters

The FIR filter is implemented in a non-recursive way which guarantees a stable filter. FIR filter design mainly consists of two parts

i. Approximation part
ii. Realization part

In the approximation stage, the specifications of the filters are taken and a transfer function is generated. In approximation, first an ideal frequency response is taken of length *N* (*N* represents the order of the FIR filter). Then a method or algorithm is selected for the implementation of the filter transfer function. In the realization part, a structure is chosen to implement the transfer function i.e. in the form of circuit diagram or a program.

There are essentially three well-known methods for FIR filter design namely:

i. The window method
ii. The frequency sampling technique
iii. Fourier series method

The equations below show the input output relation of the filter and transfer function of the FIR filter.

$$y[n] = \sum_{k=0}^{N-1} b_k \cdot x[n-k]$$

$$H(z)\big|_{z=e^{j\omega}} = H(e^{j\omega}) = \sum_{n=0}^{N-1} h[n] e^{-jn\omega}$$

The first filter designed for the task of removing the noise from original signal is an IIR notch filter. A notch filter lends itself quite well to this task considering that we are interested in removing a very specific, narrow band of frequencies [7].

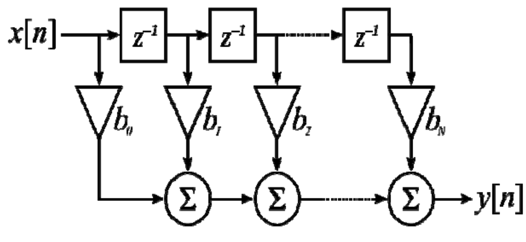

Fig. 2 FIR Filter Structure

The center frequency of the filter, F_0 was chosen to be at exactly 60Hz and the bandwidth ΔF=4Hz.

$$H_{notch}(z) = \frac{b_0\left(z^2 - 2\cos(\theta_0)z^{-1} + z^{-2}\right)}{1 - 2r\cos(\theta_0)z^{-1} + r^2 z^{-2}}$$

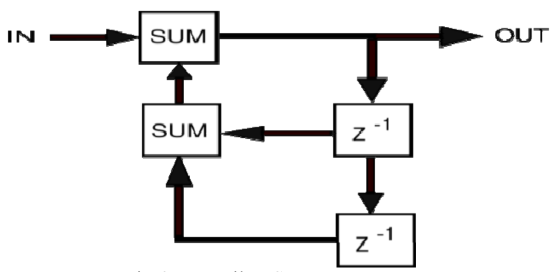

Fig-3: IIR Filter Structure

An IIR notch filter offers the very best of what IIR filters have to offer; very high attenuation with a low order. The notch filter presented is of order two and has only one coefficient. These properties lend themselves to being a light computational load.

III. IIR AND FIR FILTERS: A COMPARISON

IIR filters are not linear phase filters there is severe phase shift around the stop band of the filter. This could pose a problem for this application given the importance of maintaining meaningful timing data. After all, the physician is primarily concerned with the time at which different peaks and waves occur at within the ECG. Looking at the notch filtered ECG signal time domain plot in the beginning there is some oscillation which settles in the first half second or so [3][6].

After closely examining an IIR notch filter and FIR band-stop filters of varying order, we found the IIR to perform best overall [4]. Although the IIR filter's phase response is non-linear, almost all of the non-linearity occurs within the stop-band. This would seem to indicate that it's shifting the phase of frequencies we're not interested in anyway. The IIR's low computation cost is also of importance especially if you're looking at implementing some sort of noise filter for an actual piece of medical equipment. This implies finite computational resources and keeping costs down. The IIR filter achieves both of these goals while still delivering a high quality filtered signal [7].

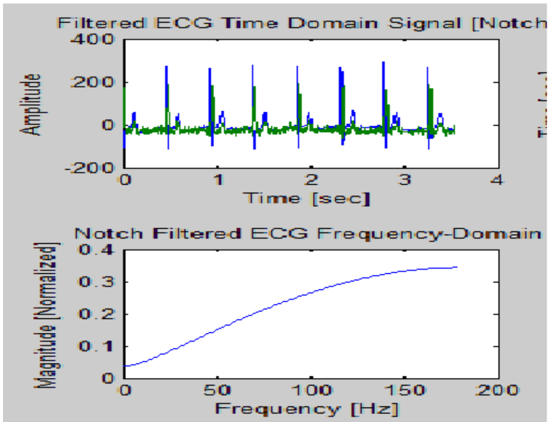

Fig-4: Notch Filter Response

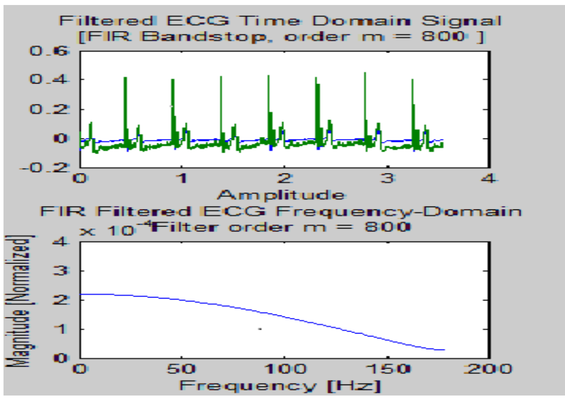

Fig-5: FIR Filter Response

The comparison of the two waveforms show that the IIR filter is much better than the FIR filter in the preprocessing technique. Noises and artifacts play a vital role in the processing of ECG signal. It becomes difficult for the physicians to diagnose the diseases if the artifacts are present in the ECG signal. For artifacts like power line interference, digital notch filters were implemented and the amplitude spectra were compared for the evaluation of their performance. FIR filters have important property of linear phase. This property plays a vital role for ECG signal analysis. In addition, the mean square error is estimated for the performance of digital filters quantitatively. The mean square error of IIR notch filter is lower than that of FIR digital notch filter. Therefore, due to the low computational cost of IIR notch filter, the IIR notch filter is suitable for the real-time implementation in hardware. For the baseline wonder removal due to its lower frequency characteristics, FIR and IIR high-pass filters were implemented. The performance of the filter was up to an acceptable extent and no information of ECG signal was lost during analysis. FIR filters are preferred for ECG signal processing due to the property of linear phase but the major drawback is the higher orders of filters are required and the signal was delayed proportionally to the orders of filter. IIR filters need only a few filter orders at the same time less hardware is required and complexity and computational cost is reduced .On the basis of above discussion it is found that IIR filters can be preferred over FIR filter .

IV. Wavelet Transform

The wavelet transform is similar to the Fourier transform. For the FFT, the basis functions are sines and cosines. For the wavelet transform, the basis functions are more complicated called wavelets, mother wavelets or analyzing wavelets and scaling function. [1] In wavelet analysis, the signal is broken into shifted and scaled versions of the original (or mother) wavelet. The fact that wavelet transform is a multiresolution analysis makes it very suitable for analysis of non-stationary signals such as the ECG signal.

The Fourier transform is useful tool to analyze the frequency components of the signal. However, if we take the Fourier transform over the whole time axis, we cannot tell at what instant a particular frequency rises. Short-time Fourier transform (STFT) uses a sliding window to find spectrogram, which gives the information of both time and frequency. [2] But still another problem exists i.e. the length of window limits the resolution in frequency. Wavelet analysis is originally introduced in order to improve seismic signal analysis by switching from short time Fourier analysis to new better algorithms to detect and analyze abrupt changes in signals. Wavelet transform seems to be a solution to the problem above. Wavelet transforms (WT) are based on small wavelets with limited duration. In WT both the time and frequency resolutions vary in time-frequency plane in order to obtain a multi resolution analysis. In the wavelet transform we do not lose the time information which is useful in many contexts. [5] The ECG signals contains information both in time and frequency domain hence using wavelet transform the minute details can be analyzed and after reconstruction of the data no information is lost as is the case with other filtering techniques.

V. Conclusion

The new technological advance in the biomedical engineering has led to development of better, safer ECG devices with a capacity to incorporate the latest diagnostic features. But the sensitivity of ECG signal getting distorted by even a small noise makes the study of ECG filtering along with the various types of filters very significant. A study reveals there are various techniques for feature extraction, QRS complex detection, noise and artifact removal .This paper reveals the advantages of the various filtering techniques over the other. The paper gives the brief idea on which filter to be used from the above explained filter bank. The wavelet transform based approach is better than the existing minutiae based method and it takes less response time which is more suitable for online verification with high accuracy.

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