Survey on Filtering Techniques Applied to ECG Signal

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Abstract: This Analysis of ECG signals is crucial for early detection of cardiac ailments. With the sensors becoming more and more predominant and available in all wearable forms for measuring multiple physiological parameters, the importance of algorithms to detect the abnormalities are also gaining importance. The physiological signals are measured through noninvasive means unless very critical and hence are very weak in nature. Bio-amplifiers are applied during signal acquisition. The signals are weak and hence susceptible for the electrical disturbances in the environment. Selection of Filtering techniques is very important and is decided by many factors. This paper is a survey which presents digital filtering techniques the researchers have applied in the last decade. The study reveals the different types FIR/IIR filters the researchers have worked and also the performance metrics adapted by the researchers electronic document is a “live” template and already.

Keywords: FIR, IIR, De-noising, ECG, Noise, Power line interference

I. INTRODUCTION

World over heart related disease are the major causes of human deaths. Therefore, it is necessary to understand the functional and physiological status of heart, clinicians require efficient methods and tools for effective diagnosis of the heart disease. Electrocardiography (ECG) is a widely used tool to understand the condition of the heart. In recent years, computerized ECG analysis is considered as a primary and reliable technique for the diagnosis of cardiac related disease [1].

The ECG signal peak value is normally about 1 mV. The clinical ECG signal is usually filtered to a bandwidth of about 0.05 – 100Hz, with a recommended sampling rate of 500 Hz for diagnostic ECG is shown in Fig. 1. ECG for heart rate monitoring could use a reduced bandwidth 0.5 – 50 Hz. High resolution ECG requires a greater bandwidth of 0.05 – 500Hz.

When R-R intervals of heart rate are collected over long periods of time (several Hours), expected signal could be of non-stationary. PSDs of R-R interval are analyzed for the following frequency bands: low-frequency (LF) band in the range 0.18-0.4Hz related to respiration and vagal activity; very-low- frequency (VLF) band in the range 0 – 0.03Hz related to humoral and thermoregulatory factors.

II. DIFFERENT TYPES OF NOISES IN ECG SIGNAL

A. Power Line Interference (PIL)

Power Line Interference is main source of noise and is introduced due to dirty electrodes or loose contacts, stray alternating current looped wires, electromagnetic interference from the power lines, improper grounding of ECG machine or the patient. The frequency component of power line interference is from 50 to 60 Hz whereas the frequency range of ECG signal is from 0.5 to 80 Hz and this will corrupt the ECG signal. The PIL can be introduced on account of badly grounded equipment, leakage of electrical power or due to of another instrument in the recording room of ECG signal [2] & [4].

B. Electrode Motion Noise

Good Electrode motion noise is due to the changes in electrode skin impedance which in turn affect the transient baseline. The changes in electrode skin impedance is caused by the sudden body movement of patients while recording the ECG signal. Frequency range of EMG signal is in the range of 5 to 450Hz which will overlaps with ECG frequency range 0.5 to 100Hz. EMG signal is non-stationary and is difficult to suppress or remove these signals [5] & [6].
C. Baseline Wandering

While walking, running, pull-up or push-up or patient is not still or restless if ECG signal is acquired then different shapes of baseline wandering is added to ECG signal [7].

III. DENOISING TECHNIQUES

The different filtering techniques are employed for signal preprocessing and have been implemented in the ECG signal analysis system. Nature of ECG signal is quite sensitive, even if a small noise is mixed with an original ECG signal that will changes in the characteristics of signal. The corrupted signal that is due to noise must either be filtered or disposed [2].

In biomedical signal processing digital filters play a crucial role. A digital filter refers to a mathematical algorithm executed in hardware/software which works on a corrupted digital input signal to generate a desired digital output signal so as to achieve a filtering objective [1].

[1] In this paper the analysis of FIR and IIR filter is done to remove the Baseline noise from ECG signal and the analysis show that using of IIR filter is better than FIR filter as it removes Ringing effect which is small oscillation at the starting of the ECG signal. Also the analysis shows that IIR filter requires less computation-power and their implementation is easy.

[2] In this paper, the authors compare the different methods using Normalized Least Mean Square (NLMS) filter, Discrete Wavelet Transform (DWT), FIR and IIR filters were used. The different metrics used were Signal to Noise ratio (SNR), Mean Square Error (MSE), Mean Absolute Error (MAE), and peak signal to noise ratio (PSNR). Here the authors have made a comparison of IIR and FIR in terms of the order while removing the power line interference. The FIR of order 40 gives the desirable performance.

Filters are used for selectively classifying heart beat rhythm for detection of cardiac abnormalities. This can be done through supervised and unsupervised classification. Alternate ECG model based classification technique [3] using Kalman filter. The authors adapt Kalman filter for classification of heart beat using prior knowledge and also detection of noisy beats as unknown morphologies. As 3% of the beat in this case were discarded as unknown or X factor. The authors here carried out the classification of MIT-BIH arrhythmia data sets.

Different IIR filters performance is examined using ten datasets and found Chebyshev type I is the best for ECG denoising and its SNR average value is higher among the other filters [5].

The paper analyses several modes of high pass & low pass filters to arrive at a hybrid filter model [8]. An FIR filter of high order up to 400 is used and a Chebyshev low pass filter Mean Square Error (MSE) is used as the performance metric for comparing the different signals. The authors applied this for filtering EMG signal from the ECG.

[10] This paper observed and compared different digital filters and found that Chebyshev window give better signal-to-noise ratio and remove approximate 50Hz power line interference (PLI).

Various IIR and FIR filters are compared for different orders [11]. Power spectrums density (PSD), Mean Square Error (MSE) and signal to noise ratio (SNR) of various filtered are compared and found that Kaiser Window order 56 of FIR filter is better than other filters. The SNR values of Equiripple FIR filter of 3rd order and Elliptic IIR filter of 1st order are compared and the result shows that Equiripple FIR will be the best filter [12].

SSRLS adaptive filter is proposed for tracking of accurate PLI and its harmonics [13]. The proposed filter is able to self-adjust its tuning frequency for highly precise filtration of 1st, 3rd, and 5th harmonics of PLI.

The Daubechies (DB) technique is used to reduce the noise in ECG signal and to improve the SNR upto value of 52.07374 dB [14].

Comparison between Kaiser Window filter and Bartlett window filter analysis has been done using SNR and PSD confirms the denoising of PLI [15].

[16] In this paper, IIR wavelet filters and FIR wavelet filters are compared and demonstrated that IIR filter is better for frequency selectivity with lesser arithmetic operations and is better filter than to denoising the ECG signal.

Comparative study of side-lobe roll-off ratio and ripple ratio of the FIR filter window and concludes that the proposed window is better than the adjustable window for removing high frequency noise which corrupt the ECG signal [17].

[18] This paper describes IIR filter will reduce number of multiplications and additions within the process of various filters. The paper shows the achievement of low power consumption in filters.

[19] This paper discuss various types of IIR filter and algorithm is presented to find appropriate filter. The result shows that algorithm is efficient in determining the apt filter for the parameters generated.

Comparison of SNR performance is done with different filter techniques and is observed that increase in filter order rises SNR and in some cases decreases with increasing filter order [20]. The study shows to choose the right filter for ECG denoising.

IV. CONCLUSION

A survey of different filtering techniques for removing of various types of noise in ECG signal is presented in this paper. We find that Baseline noise from ECG signal is removed by IIR filter. Comparison of FIR and IIR filter is done using DWT, NLMS methods for removing Power Line Interference and found FIR of order 40 gives the desirable performance. Different IIR filters and their algorithm are observed based on the observation appropriate filter can be adopted.

REFERENCES


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