Comparison of Wavelet and FIR Filter for Removing Flicker Noise from ECG Signal

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ABSTRACT

This paper presents efficient denoising schemes for electrocardiogram (ECG) signals based on wavelet filter algorithm and FIR Filter algorithms. We have used a previously introduced denoising of flicker noise using different wavelet filter banks and found that the Sym20 mother wavelet is best with rigrsure thresholding which gives highest improvement of SNR. Our study reveals that best SNR improving denoising algorithm for ECG signal. The difference between FIR and Wavelet filter is time taken is less for removal in FIR filter as compare with wavelet filter. But wavelet is better in terms of removing Flicker noise and improvement of SNR of ECG Signal

Keyword: Wavelet transforms, Fir filter, thresholding, flicker noise,

INTRODUCTION

The electrocardiogram (ECG) is the recording of the cardiac activity and it is widely used for diagnosis of diseases of heart. It is also an important device to permit monitoring patients at home, thereby advancing medical applications. The electrocardiogram (ECG) is extensively used for diagnosis of diseases of heart [19]. Good quality ECG is used by doctor for identification and interpretation of pathological and physiological phenomena. However, in real situations, ECG recordings are often affected by artifacts. Two foremost noises present in ECG recordings are: 1.) Power Line interference Noise and 2.) Flicker Noise. These noises harshly limit the use of recorded ECG signal and thus it must be removed for better medical assessment. Several methods have been developed for ECG enhancement.

During past few years, various contributions have been made in literature regarding noise removal, beat detection and classification of ECG signal. Most of them use either time or frequency domain representation of the ECG waveform. Akram et al. presented Electrocardiogram Denoised Signal by Discrete Wavelet Transform and Continuous Wavelet Transform. In this paper they proposed a denoising technique based on discrete wavelet transform (DWT) has been developed and they compare it to continuous wavelet transform (CWT). Patil et al. present approach of threshold estimation for denoising ECG signal using wavelet transform. Their threshold estimation is simple and faster compared to all existing threshold calculation methods namely VisuShrink, SureShrink, BayesShrink, and leveldependent threshold estimation and gives better SNR and RMSE. Mikhled et al. presented ECG Signal Denoising by Wavelet Transform Thresholding and they compare compared with the Donoho's method for signal denoising meanwhile better results are obtained for ECG signals by the proposed algorithm. Omid Sayad et al. presented Multiadaptive Bionic Wavelet Transform: Application to ECG Denoising and Baseline Wandering Reduction they proposed standard. BWT a mechanism that adjusts the center frequency of every analyzing scale in a signal-adaptive fashion Nagendra et al. presented Application of Wavelet Techniques in ECG Signal Processing” ECG signals are non-stationary, pseudo periodic in nature and whose behavior changes with time. The proper processing of ECG signal and its accurate detection is very much essential since it determines the condition of the heart. Awal et al. presented Wavelet Based Distortion Measurement and Enhancement of ECG signal. They eliminate the noise found in ECG signal and cardiac rhythm using Coiflet wavelet since its scaling function is closely related to the shape of ECG and suited for denoising for many applications. Different adaptive and soft threshold functions are used to enhance the ECG signal. Seema et al. presented Simulink Model to denoise ECG signal using various IIR & FIR fiters, In this paper the design of various FIR fiters like Kaiser, Rectangular, Hamming, Hanning, Gaussian and Bartllet window techniques and FIR Equiripple Filter. IIR fiters like Butterworth, Chebychev I & II and Elliptic Filters are also explored to remove the artifacts in ECG signal.

In the present study we seek to improve the denoising procedure of Wavelet Domain and FIR Filter. We compare thresholding technique among four thresholding method in wavelet domain and best windowing technique in FIR Filter. We also compare best denoising of method between FIR and Wavelet filter in terms of SNR for flicker noise. Flicker noise are mostly corrupt the ECG signal and have different properties. Some noise has high frequency artifacts, but they are easy to remove but flicker noise has low frequency artifacts which it difficult to remove however both needs to be removed from ECG signal for proper medication. In this paper we removed Flicker noise from ECG signal using FIR and wavelet filter and compare their performance in terms of SNR.

METHOD

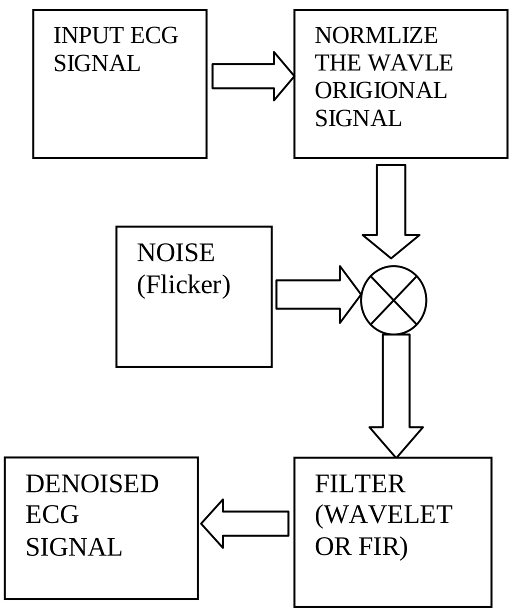

Figure-1: Block diagram

ECG Morphology

The morphology of ECG signal has been used for recognizing much variability's of heart activity, so it is very important to get the parameters of ECG signal clear without noise. it consists of various points in it and those are P-QRS-T. One period of the ECG waveform represents one cycle of the blood transform process form the heart of arteries. QRS complex is the largest amplitude portion of the ECG caused by vertical depolarization [19].

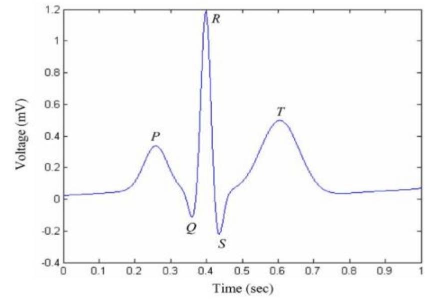

Figure-2: Morphology of ECG

Noises

While filtering a biomedical signal care should be taken because no any of the information altered. These abnormalities decreases the signal quality, strongly affects the ST segment, frequency resolution, produces large amplitude signals in ECG that can resemble PQRST waveforms and masks small features that are important for clinical diagnosis. There are various kinds of noises which corrupt ECG signal, in this paper low frequency Flicker noise is analyzing [9]. Naturally precautions should be taken to keep power lines as far as possible or shield and ground them, but this is not always possible. Flicker noise occurs in virtually all electronic components as well as in many other physical items in everyday life from the earth's rotation to undersea currents and many other items

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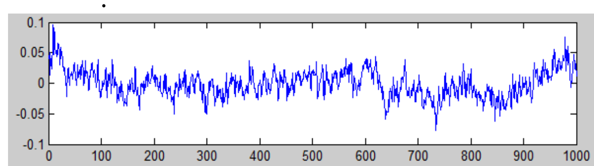

Figure-3: Flicker noise

Wavelet Denoising

The wavelet transform is an efficient technique for such a non-stationary signal processing. The signal is decomposed into time- frequency scale in the wavelet transform. The wavelet transform can be used as a decomposition of a signal in the time-frequency scale plane. There are many uses of wavelet transform such as data compression, sub-band coding, noise reduction and characteristic points detection. There are many techniques are available such as FIR or IIR digital filters and wavelet transform thresholding methods. It has been proven that wavelet transform is a use full tool for analysis of non-stationary signal.

The continuous filtering of the input signal through a pair of filters known as and high pass filter (HPF), and low pass filter (LPF) and the middle of input signal frequency is their cutoff frequency. Low pass filter coefficient is known as Approximation Coefficients (CA) and high pass filter coefficient is known as Detailed Coefficients (CD). Furthermore, the Approximation Coefficients is again passes through pair of filter which generate new approximation and detailed coefficients. This decomposition process is continuous until the required frequency response is accomplished from the given input signal [14].

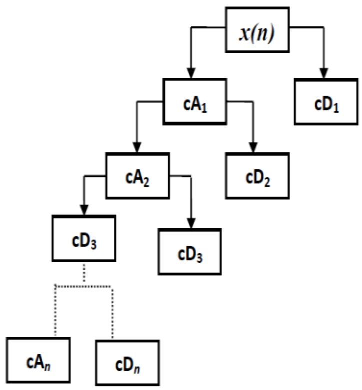

Figure-4: Multi stage wavelet decomposition

Thresholding is used in wavelet domain to smooth out or to remove some coefficients of wavelet transform sub signals of the measured signal. The noise content of the signal is reduced, effectively, under the non-stationary environment. Thresholding methods are classified into two groups: hard thresholding and soft thresholding[15]. Let T denote the threshold. The hard threshold signal is x if $x > t$, and is 0 if $x < t$. The soft threshold signal is sign(x)(|x|-T)if $x > t$, and is 0 if $x < t$. Performance of the denoising process depends on the type of thresholding method and thresholding rule used for the given application. There are 4 kind of soft thresholding techniques in wavelet transform known as rigrsure, sqwrlog, heursure and minimaxi. All those four thresholding techniques have its own function to select best possible threshold value[16].

FIR Filter

According to unit pulse response of the system, digital filters can be into classified either as Infinite Impulse response (IIR) filters or Finite Impulse Response (FIR) filters. The impulse response is of finite duration in the FIR system, while the impulse response is of infinite duration in the IIR system. Feedback structures is used in IIR filters, hence present and past values of the excitation as well as the past value of the response is used to generate present response of IIR filter is a function. But Feedback structures are not used in FIR filters; hence FIR response only depends on present excitation. Non-recursive structure is used to implement FIR filter which guarantees a stable filter. FIR filter design mainly consists of two parts: (a) Approximation part, (B) Realization part. In the approximation stage, specifications of the filters are taken and a transfer function is generated. In approximation, first an ideal frequency response is taken of length N where N represents here 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[6].

The equations below show the input output relation of the filter and transfer function of the filter. where x[n] is the input of the signal, y[n] output of signal

$$Y[n]= \sum_{k=0}^{N-1} bk. x[n-k] \qquad (1)$$

The window method uses following functions and parameters.

[b, a] = fir1(N, Wn, type)   (2)

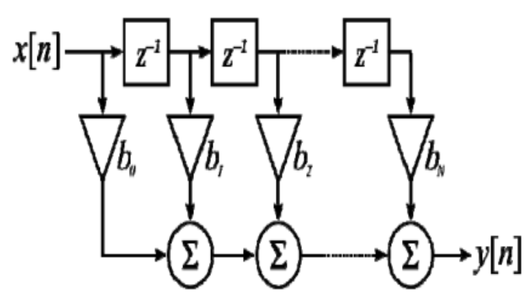

Figure-5: structure of FIR filter

RESULT

The performance is evaluated in terms of the SNR,.

Signal to noise ratio in db(SNR)

$$SNR=\left(\frac{p_{signal}}{p_{noise}}\right)=\left(\frac{A_{signal}}{A_{noise}}\right)^{2} \quad (3)$$

$$SNR_{DB}=10\log_{10}\left(\frac{p_{signal}}{p_{noise}}\right) \quad (4)$$

$$SNR_{IMPROVEMENT} = (SNR)_{OUTPUT} - (SNR)_{INPUT} \quad (5)$$

The original ECG waveform of MIT-BIH arrhythmia database 100m.mat is in normalized form is shown in Fig.

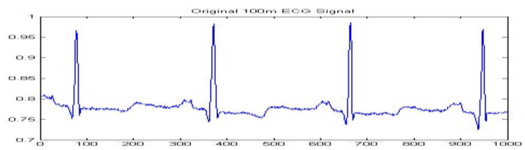

Figure-6: 100m.mat ECG signal Wave Form

Analysis of Removal of Flicker Noise

We generated the Flicker noise by adding random signal with low frequency sinusoidal signal which is shown in figure-x. Flicker noise has a properties of low frequency component is added with original ECG signal. Corrupted ECG signal via Flicker noise mostly effect low frequency component of ECG signal like P, Q, S wave and R wave of is Less affected by it. Corrupted ECG signal waveform shown in figure-y. Input average SNR of corrupted signal is 27.191 db.

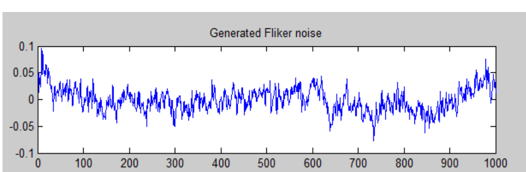

Figure-7: Morphology of ECG

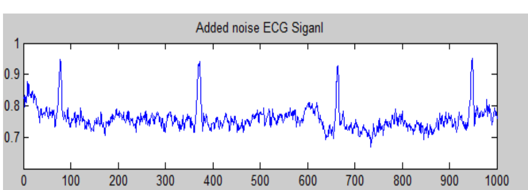

Figure-8: Corrupted ECG signal by flicker noise

a) Wavelet Analysis

Wavelet filter bank based denoising applied for different thresholding. 20 signals from MIT-BIH database are added with flicker noise and 4 different types of soft thresholding (rigrsure, Heursure, minimaxi, sqwrlog) are applied to all corrupted ECG Signal with symlet-20 mother wavelet function. It has been that after removal of noise from ECG Signal all four thresholding gives different SNR improvement. Average output SRN of rigrsure, Heursure, minimaxi and sqwrlog thresholding is 28.22065 db, 27.98608 db, 28.07267 db and 28.00584 db respectively. Rigrsure thresholding Gives highest output SNR but lowest output SNR is given by sqwrlog thresholding. Filtered ECG signal and residual signal after denoising are shown in figure-2 and figure-3 respectively.

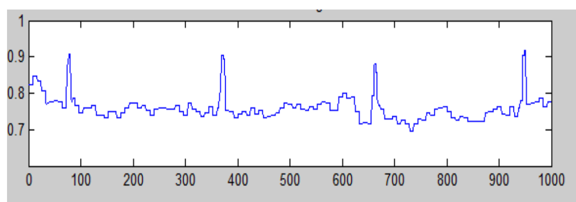

Figure-9: Flirted ECG signal by Wavelet transform

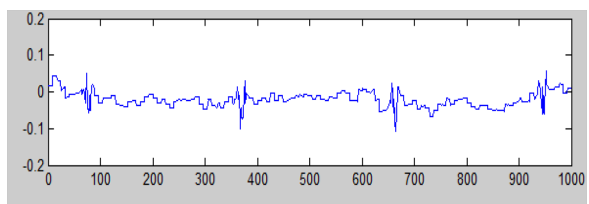

Figure-10: residual noise after denoising

b) FIR Analysis

FIR filter bank based denoising applied for different windowing technique. 20 signals from MIT-BIH database are added with flicker noise and 3 different kind of windowing techniques (hamming, hanning, blackman) are applied to all corrupted ECG Signal. It has been that after removal of noise from ECG Signal all three windowing techniques give different SNR improvement. Average output SRN of hamming, hanning, and blackman windowing techniques is 27.68564db, 27.72998db and 27.77818db respectively. Blackman windowing technique Gives highest output SNR but lowest output SNR is given by hamming windowing technique. Filtered ECG signal and residual signal after denoising are shown in figure-2 and figure-3 respectively.

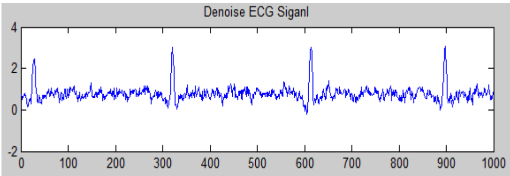

Figure-11: Flirted ECG signal by FIR Filter

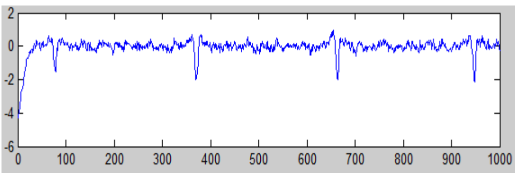

Figure-12: residual noise after denoising

Wavelet transformed is an efficient technique for non-stationary signal processing. Wavelet filter gives better SNR improvement of signal as we compare with FIR filter. Rigrsure is the best thresholding technique of wavelet transform gives output SNR 28.22065db while FIR filter's best windowing technique is blackman which gives SNR output 27.68564db and visualization of output filtered signal is much better in wavelet domain over FIR filter.

CONCLUSION

We have validated affect of flicker noise on ECG signal and removal of flicker noise using wavelet domain and FIR filter domain. A novel method for ECG denoising based on the wavelet thresholding for flicker noise is presented. First part wavelet filter bank based denoising algorithm is analyzed. The noisy ECG signal x (n) passing it through a series of high-pass and low-pass filters with different cut-off frequencies. This is achieved by using mother wavelet function and scaling function. In the DWT, wavelet filter and thresholding methods are applied and average of all 20 signals SNR improvement, rigrsure thresholding got the best result among this four thresholding. In the second part, we present FIR Filtering Techniques of ECG Signal Using Various Window Techniques algorithm. In this we have compare the results of ECG signal filtered by FIR filter with three windows Hamming and Blackman and rectangular hanning window. The best signal to noise ratio was carried out in Blackman window. SNR improvement of wavelet filtering, FIR filtering, under which wavelet filtering is giving better result for denoising i.e. better SNR improvement and simplicity of circuit FIR is giving better

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