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Removal of Flicker noise from ECG Signal Using Wavelet

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Abstract: An electrocardiogram ECG signal of the human heart shows the reflection the cardiac health by any of the disorder in heart rhythm, change in the morphological pattern of ECG signal. Accurate analysis of ECG signals becomes difficult if it is corrupted by noise during acquisition. Some primary source of noise are power line interference, external electromagnetic field interference, noise due to random body movements and respiration movements, electrode contact noise, electromyography (EMG) noise, and instrumentation noise. In this paper, 20 ECG signal is taken from standard MIT-BIH Arrhythmia database and Flicker noise is generated and added with original ECG signals which corrupt the signal. Noisy ECG signals is Filtered using different Wavelet function and different thresholding methods. Quantitative measurement has been done based on Signal to Noise Ratio (SNR).

Keywords: ECG, Flicker, SNR, Wavelet.

INTRODUCTION

To measures bioelectrical activity of the heart, electrocardiogram (ECG) is a best diagnostic tool which provides a wide range of cardiac conditions. To achieve precise ECG analysis, noise free ECG signal is essential. Unfortunately, the ECG generally infected by different artifacts and noises that corrupt the morphologies of ECG signal. It is very essential to get the important parameters of ECG signal without noise. Some primary sources of noise are power line interference, external electromagnetic field interference, noise due to random body movements and respiration movements, electrode contact noise, electromyography (EMG) noise, and instrumentation noise.

Denoising is a process to remove noise that is present in the signal. A denoising algorithm must eliminate all noises present in the ECG signal and preserve all present important signal information regardless of the spectral content of the noisy signal. It has been shown in several works that wavelet transform has been proven as a powerful tool for signal analysis, and it is widely used in denoising applications. Large numbers of ECG denoising methods have been implemented by the researchers [1] - [7]. Wavelet based ECG denoising method has been widely used. Wavelet is an important tool to analysis bio medical signals.

Recently many researchers have been done in ECG denoising methods. Chouakri et al. suggested Wavelet Denoising of the Electrocardiogram Signal Based on the Corrupted Noise Estimation in this paper an algorithm of filtering the noisy real ECG signal Patil et al. suggested wavelet based ECG denoising, in which they used both hard and soft thresholding for the denoising of the ECG signal cantaminatated by different noises. Performance is evaluated in terms of SNR. Aouinet et al. suggested Electrocardiogram Denoised Signal by Discrete Wavelet Transform and Continuous Wavelet Transform, by a denoising technique based on discrete wavelet transform (DWT) has been developed. Mehmet et al. presented the Performance comparison of wavelet thresholding techniques on weak ECG signal denoising. Wavelet transformed based denoising of ECG have be widely used because it provide wide range of application.

Signals are generally affected by instrumentation noise; flicker noise is a kind of instrumentation noise which has low frequency noise signal properties. In this paper, noisy ECG signal which is corrupted by flicker noise is filtering by using discreet wavelet transform. DWT denoising based on Haar, Daubechies, symlet, biorthogonal, coiflet wavelets function and Rigrsure, Sqwrlog, Heursure, Minimaxi thresholding. We are computing best combination of mother wavelet function and thresholding for removal of flicker noise and to improve SNR.

ECG Morphology

ECG signal is an electrical impulse generated by the heart muscle result in time-varying potentials on the surface of the human body. To diagnosis of cardiovascular diseases electrocardiogram is widely used. The electrical impulse generated by the heart of standard ECG signal has 12 views. The 6 views are generated by the electrodes on the arms and legs on the left half of ECG (called I, II, II, aVR, aVL and aVF). The 6 views are generated by the electrodes on the chest on the right half (V1through V6). It consists of a set of P, Q, R, S, and T successive waves a great intention has been paid to the adequate and accurate analysis of the ECG signal that would lead to cardiac anomalies diagnosis [5]. The dominant morphologies are the P, QRS and T waves. Sometimes a U-wave may be present immediately after the

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T-wave, the genesis of which is uncertain. The atria activation is represented by P-wave; the ventricular activation or depolarization is represented by QRS complex. The first downward deflection after the P-wave is called as, 'Q', the dominant upward deflection is the 'R' and the terminal part is denoted as 'S'. The T-wave represents ventricular recovery or depolarization. The total duration of ventricular recovery is represented by the T-wave and the U-wave together represents the greater part of ventricular depolarization is represented by ST segment.

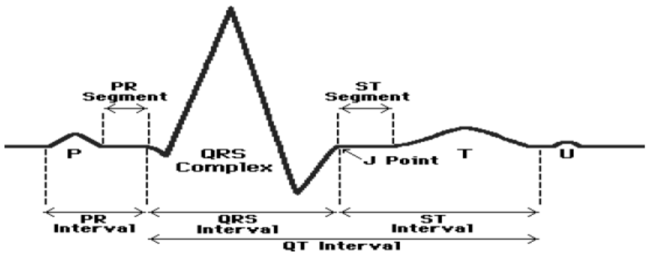

Figure-1: Morphology of ECG

ECG parameters

Amplitude	Duration
P wave : 0.25mV	R-T interval : 0.12-0.20sec
R wave : 1.60mV	Q-T interval : 0.35-0.44sec
Q wave : 25% of R wave	S-T interval : 0.05-0.155secc
T wave : 0.1-0.5mV	P wave interval : 0.11sec
	QRS interval : 0.09sec

Recently, a number of techniques are used to detect their features. In ECG pattern QRS detection is one of the fundamental issues in the analysis of ECG signal

Noises in ECG

Biomedical signal processing various types of noise which contaminate ECG signals. Interference caused by them may have technical sources,

Power line interference: This PLI noise consists of sinusoidal signal of 50-60 Hz harmonics. Properties of PLI noise are Amplitude is 50% of peak-to-peak ECG amplitude, Frequency content 50 Hz with harmonics,

Electrosurgical noise: This noise completely corrupt the ECG signal because it has large amplitude Properties of Electrosurgical noise are , Frequency is 100 kHz to 1 MHz, Amplitude is 200 % peak-to-peak and Duration is 1 to 10s.

Electrode contact noise: This noise is generated by loose contact between the electrode and, which skin which effect the morphology of signal. Properties of Electrode contact noise are: Frequency is 50 HZ, period is 1s, and Time constant is about 1s.

Muscle contraction noise: The baseline of ECG is generally in the micro volt range which makes it insignificant to measurement of signal. Properties of Muscle contraction noise are: period is 50ms, Standard deviation is 10% of peak-to-peak ECG amplitude and Frequency is 10000 Hz.

Patient movement: Patient movements are also considered therefore variations in the electrode skin impedance, baseline changes with the. Properties of Patient movement noise are Amplitude is 500% peak-to-peak. Duration is 100 to 500ms. [9]

METHODOLOGY

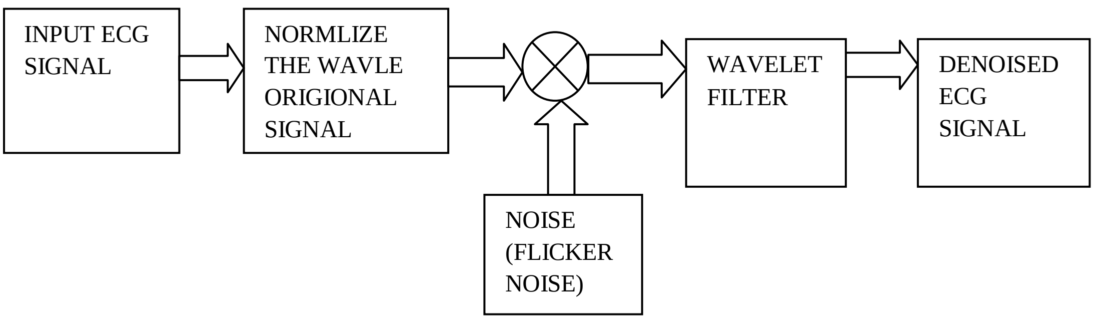

Figure-2: block diagram

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Flicker Noise

The various types of noise which contaminate ECG signals one of them is Flicker noise also known as pink noise. Flicker noise generated due to instrument. It arises in practically all electronic components as well as in many other physical objects in everyday life from the earth's rotation to undersea currents and many other objects. Generally, Flicker noise is having relation to semiconductor devices such as diode, transistors and MOSFET devices. It may show variety of effects, but generally takes place in a resistance fluctuation.

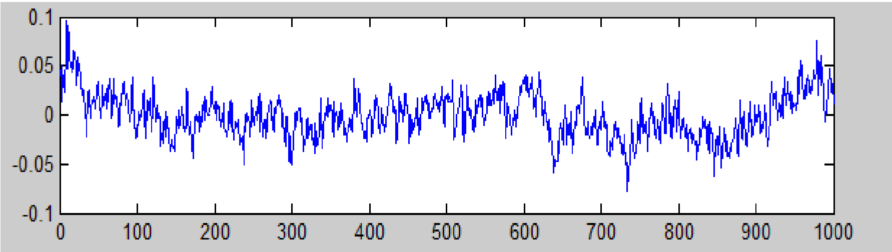

Figure- 3 Flicker Noise

Wavelet Filtering

Wavelet denoising has different steps by decomposing, thresholding, and reconstruction. Wavelet transform has the characteristics of multi-resolution and time-frequency analysis method of signal. It has the ability of presenting the character of signal in time field and frequency field. The wavelet transform decompose ECG signal in a set approximation coefficients and detailed coefficients and analysis those coefficients. Location frequency band and time periods are analysis by wavelet. The coefficient generated from the wavelet transforms is due to computation of the ECG components in the frequency band and time periods. There are two methods of wavelet transform first is in continuous domain and second is in Discrete domain. Continuous Wavelet Transform (CWT) the signals are analyzed using a set of basis function, which are related to each other by simple scaling and translation. CWT is a wavelet transform with a continuous mother wavelet, continuous dilation parameter and a discrete translation parameter [4].
Discrete Wavelet Transform (DWT) as a wavelet transform with a discrete-time mother wavelet, integer dilation parameter and a discrete translation parameter. The discrete wavelet transform, which is based on sub-band coding, is found to yield a fast computation of wavelet transform. It is easy to implement and reduce the computation time. In the case of DWT, a time-scale representation of the digital signal is obtained using digital filtering techniques [7].
The signal to be filtered is passed through sets of filters with different cut off frequencies at different scales. Electrocardiogram signals were decomposed into the detailed (high frequency component) and approximate (low frequency component) information. Every stage consists of two set of digital filters and two down samplers. The first filter, h[n] is the low pass filter and g [n] is the high pass filter. The down sampled output of low pass filter is the approximation coefficients (A1). And output of first high pass filter is called detail coefficients (D1). The first approximation (A1) is further decomposed and this process is continued.

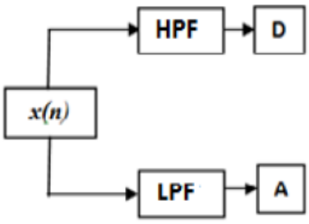

Figure-4: one dimensional wavelet filter

Thresholding methods are classified into two set: soft thresholding and hard thresholding. In the given application performance of the filtering process depends on the type of thresholding technique and thresholding rule. After decomposition in the each level thresholding is founded through the loop, and this threshold value is applied to the detailed coefficient value of the both noise and original signal [10]. Thresholding Let T denotes 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. Wavelet provide four types of soft thresholding techniques are following.

1. Rigrsure- Stein's Unbiased Risk Estimate principle is used in selection rigrsure threshold or we can say quadrature loss function. We can calculate approximately of the risk for every threshold value. Reducing the risks will provide a choice of the threshold value for the thresholding process.

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2. Sqwrlog- It is normally equal to sqrt (2* log (length (s)).) It is type of fixed threshold giving maximum result when multiplied by a factor proportional to log (length(s)) of very small quantity.
3. Heursure- This thresholding method is combination of previous rigrsure and Sqwrlog thresholding methods, normally heursure thresholding is selected but as a result, if the SNR comes very small, so it is considered as a very noisy. Hence, if this condition is present, fixed form threshold is used instead of Heursure.
4. Minimaxi -This technique is also a kind fixed thresholding method, it is selected to provide minimax performance for mean square error against an ideal procedure [11].

Signal reconstruction generally means that the determinations of an original continuous signal from an order of equally spaced samples. Reconstructing the original sequence from the thresholded wavelet detail coefficients leads to a denoised (smoothed) version of the original sequence. Inverse Discrete Wavelet Transform (IDWT) is used to reconstruct the original signal. Calculate high resolution log-spectral features of the input noise signal to reconstruct the signal

Results
In this paper, denoising of electrocardiogram (ECG) signal based on the Discrete Wavelet Transform multilevel decomposition analysis and thresholding. The performance is evaluated in terms of the SNR.

Signal to noise ratio (SNR)

$$SNR_{DB} = 10\log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) \quad (1)$$

Here, 20 ECG/BIH ECG 1 minute records are taken and each is added with flicker noise figure-5 is show 100m.mat ECG signal and figure-6 shows noisy ECG signal which has been corrupted by flicker noise. Flicker noise having the property of low frequency signal. It completely destroys P-wave and changed shape of QRS wave of ECG Signal.

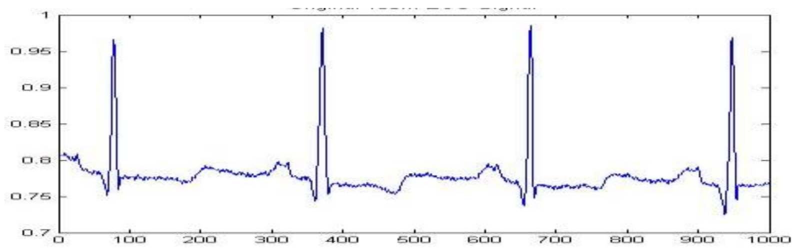

Figure- 5 !00m.mat ECG signal

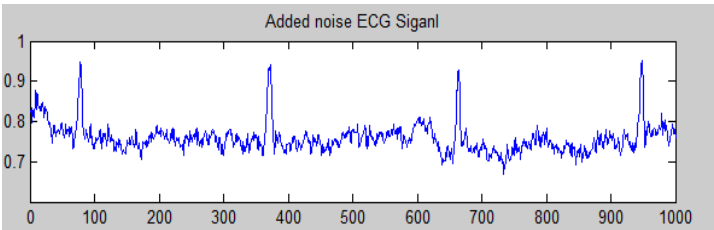

Figure-6 ECG signal Corrupted with Flicker Noise

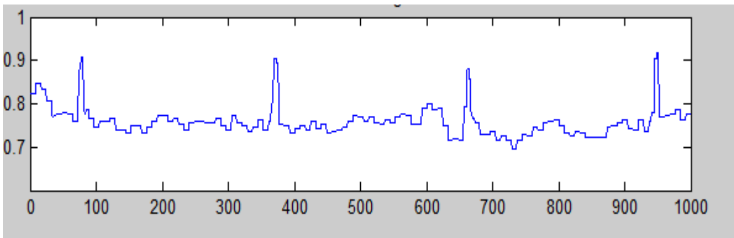

Figure- 7 Filtered ECG Signal

Denoising based on Haar, Daubechies, symlet, biorthogonal, coiflet wavelets function and Rigrsure, Sqwrlog, Heursure, Minimaxi thresholding. Different filter (haar, db2, db6, db10, sym4, sym20, bior2.2, bior3.3, coif1, coif2) is applied and result is obtained shown in table-1.

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Table-1: Flicker noise added with signals & average output SNR with different filters

	HAAR	DB2	DB6	DB10	SYM4	SYM20	BIOR1.1	BIOR2.4	COIF1	COIF2
AVGof 20 signal	**38.136 48**	**39.09 739**	**39.42 064**	**39.4001 2**	**39.397 4**	**39.4539 6**	**38.13648**	**39.1883 7**	**39.120 79**	**39.416 58**

From table-1 it can be concluded that after taking average of 20 signals, Symlet20 is giving best result so we applied four thresholding (rigrsure, Heursure, minimaxi, sqwrlog) to sym20's output signal. From table-2 it can be concluded that after taking average of 20 signals, rigrsure thresholding giving best result. Improvement of SNR in output is shown in table-3

Table-2: Symlet 20 result with all thresholding

	RIGRSURE	MINIMAXI	HUERSURE	SQWRLOG
AVG	**39.45396**	**38.36001**	**39.30831**	**37.65108**

Table-3: Calculation of average SNR I/P & O/P for combination of sym20 with rigrsure thresholding.

	SNR I/P	SNR O/P
AVG	34.00604	**39.45396**

CONCLUSION

Noise removal of ECG signal has always been a interested subject in research field. ECG signals from MIT-BIH database is taken and added with flicker noise. The noisy ECG signal x (n) passing it through a series of high-pass and low-pass filters with different cut-off frequencies. Different wavelet filter and thresholding methods are applied 5 filters (debuncies, Haar, Biorthogonal, Symlet, coif let) and 4 types of thresholding (rigrsure, Heursure, minimaxi, sqwrlog) using scaling function and mother wavelet function. At the end after taking the average of all 20 signals SNR improvement, rigrsure with combination of symlet20 got the best result among this four filters and thresholding.

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