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# Wavelet Based Method for Denoising of Electroencephalogram

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***Abstract: Electroencephalograph (EEG) gives an electrical representation of biosignals to determine the different rhythms of the brain. EEG signal plays an important role to diagnosis the diseases related to brain such as brain injury, coma, head injury, stroke, sleep disorder, sleeping test as well as brain machine interface and anesthesia . During the recording, EEG signal acquires the different types of artifacts such as 50Hz noise, EMG noise, Electrode noise, eye blink, Electrocardiogram (ECG) signal. Distorted signal makes the clinical analysis and information retrieval difficult therefore it is necessary to remove all such disturbances in EEG signal and improve the accuracy and quality of the signal for proper diagnosis. In this paper, these algorithms (IIR low pass filter, FIR low pass filter and Wavelet method) were applied on the distorted EEG signal. The mother Wavelet (sym22) has been most compatible with EEG signal founded by determines the higher Signal to Noise ratio (SNR) and minimum Mean Square Error (MSE) than the all other filters and wavelets.***

***Keywords:- Electroencephalography(EEG) ,Finite Impulse Response (FIR), Infinite Impulse Response (IIR), Fast Fourier Transform (FFT), Signal to Noise Ratio (SNR).***

## I. INTRODUCTION

Electroencephalography (EEG) is the biomedical device that measures the electrical activity of the brain using electrodes placed along the scalp. EEG measures voltage differences producing ionic current flow within the neurons of the brain. Normal human brain shows different rhythmic activity but some disorder in brain can change the rhythmic pattern. Brain clinical experts are familiar with the rhythmic activity of the EEG signals. The electrical activity of the brain is recorded over a short time period, generally 20–40 minutes. The brain signals ranges from 0.5μV to 100μV in amplitude, which is about 100 times lower than ECG signal. EEG signals are classified based on their frequency range: alpha (α), theta (θ), beta (β), delta (δ), and gamma (γ) [1]. Small Amplitude (μv) of the EEG signal is contaminated by various artifacts that recorded in the signal and changed the originality of the signal [2]. Artifacts are divided into two group;1) physiologic signals are generated by sources external to the brain such as; heart, eyes, muscles, tongue etc. 2) Non- physiologic signals are produced by electrical equipment such as power line interference 50 Hz [3].In this paper, different types of filters and wavelet methods were used to find the best method and most compatible wavelet with the EEG signal.

## II. DENOISING ALGORITHMS

In Fig 1 shown the denoising process of EEG signal discussed below:

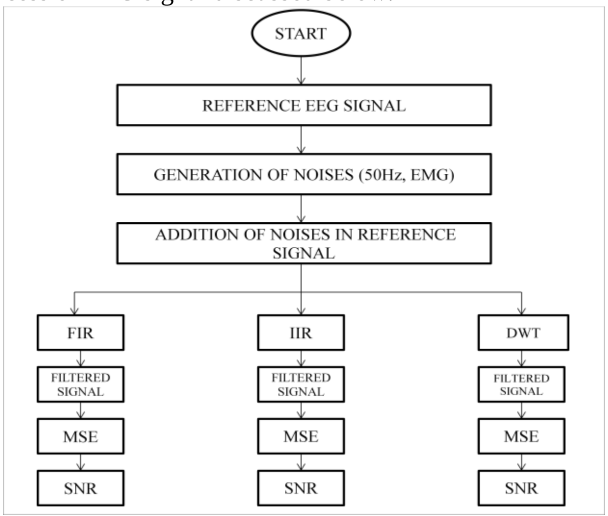


Fig 1 EEG Noising Flow Process

In first step, Reference EEG signal was taken from the patient having 250 sampling rate with time duration of 5 seconds. In next step, Generation of power line interference (50Hz) and high frequency signal (>70Hz) using matlab code and then add the generated noises to reference EEG signal to get the distorted EEG signal Appling these algorithms (IIR low pass filter, FIR low pass filter and Wavelet (Haar, db10, coif5, dmey, sym22) on the distorted EEG signal and obtained filtered EEG signal. Calculating the Mean Square Error (MSE) and Signal to Noise Ratio (SNR) values of the filtered EEG signal

### *A. FIR FILTERING*

Finite impulse response (FIR) filter is a filter whose impulse response (or response to any finite length input) is of finite duration, because it settles to zero in finite time. The response of the FIR filter is executed using structures having no feedback system. The output of the system is depends only on the present and past values of the input only. The impulse response of an Nth-order discrete-time FIR filter is lasts exactly N + 1 samples before it then settles to zero. For a causal discrete-time FIR filter of order N, each value of the output sequence is a weighted sum of the most recent input values [4].

$$y[n] = b_0 x[n] + b_1 x[n-1] + \cdots + b_n x[n+N] \quad (2.1)$$

Where x[n] is the input signal, y[n] is the output signal, $N$ is the filter order and $bi$ is a coefficient of the filter [5].

### *B. IIR FILTERING*

Infinite impulse response (IIR) filter is a filter whose impulse response does not become exactly zero as past certain point, but continues indefinitely. The response of the IIR filter is usually implemented using structures having internal feedback system. The output of the filter at any given time depends upon the present inputs and past IIR filter is recursive in nature and equation is [6]:

$$y[n] = \sum_{k=0}^{M} b_k\, x[n-k] - \sum_{k=1}^{N} a_k\, y[n-k] \quad (2.2)$$

Where: N is the filter order, which corresponds to the number of delay elements an implementation of the filter would require. The filter coefficients are $a_k$ and $b_k$. IIR filters have coefficients $a_k$, k >0 that are nonzero, which implies that the impulse response of an IIR filter has infinite length.

### *C. WAVELET TRANSFORM*

The wavelet transform is same as the Fast Fourier transform. In the FFT, the basic functions are sines and cosines, but in wavelet transform, the basic functions are more complex called wavelets, mother wavelet, analyzing wavelets and scaling function [7]. Wavelet is a wave-like oscillation with an Amplitude that begins at zero, increases, and then decreases back to zero. In wavelet analysis, the signal is divided into small parts and shifted to different scale. The fact that wavelet transform is a multi resolution analysis makes it very suitable for analysis of non-stationary signals such as the EEG signal [8].

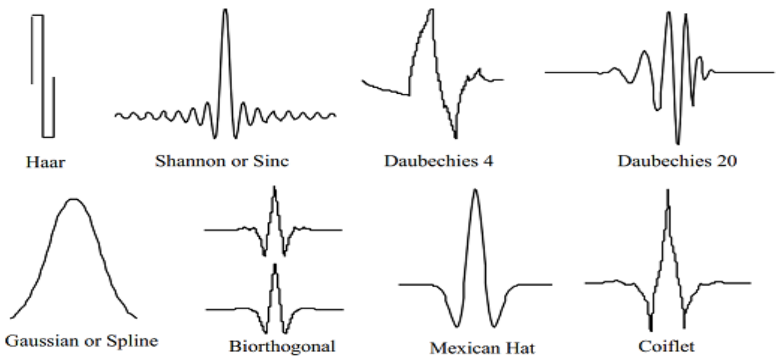


Fig 2 Different Types of Wavelet

## III. RESULTS AND DISCUSSIONS

Reference EEG signal has recorded for duration of 5 seconds at sampling rate of 250 Hz. The Reference EEG waveform is shown in Fig 3.

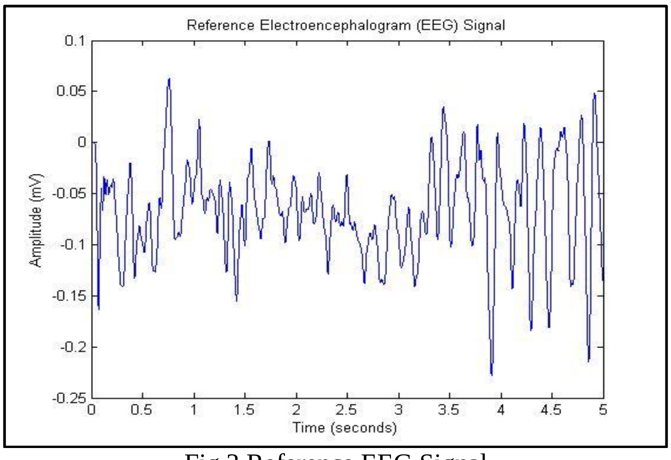


Fig 3 Reference EEG Signal

The artifacts in EEG can be described by the different frequency range. Adding High frequency signal (EMG noise) whose frequency is more than (>70Hz) and power line interference of 50 Hz. These noises are generated in MATLAB based on their frequency content. Generated noise signals are added with the reference EEG signal to get the distorted EEG signal. Distorted EEG signal is shown in Fig 4. Reference EEG signal has recorded for duration of 5 seconds at sampling rate of 250 Hz. Four EEG reference signals have been taken from EEG database and then add the generated noises in the reference EEG signal to get the distorted signal.

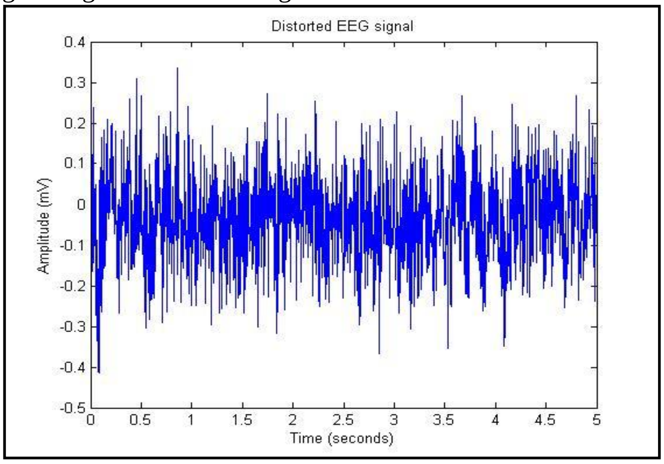


Fig 4 Distorted EEG Signal

FIR low pass filter based Kaiser window with cutoff frequency 40Hz, Buffer IIR low pass filter with cut off frequency 40Hz whose order of the filter was found out with ripple varies from .01 to 40 were applied to distorted EEG signal. DWT has been applied to decompose the distorted EEG signal up to level 2 using (haar,db10,coif5,dmey,syml22) mother wavelet function with soft thresholding. After that, inverse wavelet transform (IDWT) has been applied to reconstruct the signal by the modified coefficients. Sym22 wavelet was selected because its shape just like EEG signals. It has concentrated energy spectrum around the low frequencies. To evaluate the performance of IIR, FIR Filter and Wavelet by the SNR values were calculated through the different signals listed in the Table 1

Table 1 SNR Values of Applied Algorithms

| S. NO | SNR (INPUT) (db) | SNR(OUTPUT) (db) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | IIR | FIR | DWT | | | | |
| | | | | Haar | db10 | Coif5 | Dmey | Sym22 |
| 1. | 67.2832 | 69.5859 | 69.2560 | 73.4399 | 73.9547 | 73.8648 | 73.9309 | 74.0849 |
| 2. | 67.2512 | 70.3272 | 69.9091 | 73.4981 | 74.0687 | 73.9259 | 73.9875 | 74.1436 |
| 3. | 67.2376 | 70.6120 | 70.4341 | 73.7082 | 74.0698 | 73.9907 | 74.0500 | 74.1690 |
| 4. | 67.2081 | 71.2501 | 70.5056 | 73.9281 | 74.3308 | 74.2717 | 74.2904 | 74.3576 |
| avg | 67.2450 | 71.1010 | 70.5720 | 73.6577 | 74.1051 | 74.0136 | 74.0648 | 74.1891 |

The performance of wavelet (sym22) mother is better than the rest of wavelets and filters. Filter has sharp attenuation and pulsation present in the stop band. Average SNR (decibel) value of sym22 is 74.18 that higher than the all other filters and wavelet used is shown in Fig 5.

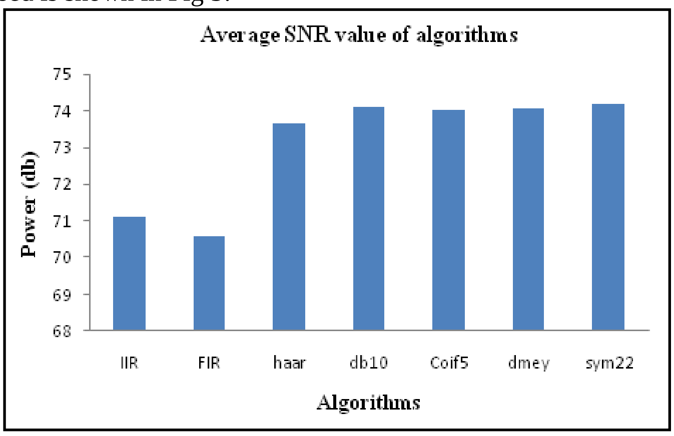


Fig 5 Average SNR value of Applied Algorithm

 

To calculate the performance of IIR, FIR Filter and Wavelet by the MSE values were calculated through the different signals listed in the Table 2

Table 2 MSE Values of Applied Algorithms

| S. NO | MSE (INPUT) (db) | MSE(OUTPUT) (db) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | IIR | FIR | DWT | | | | |
| | | | | Haar | db10 | Coif5 | dmey | Sym22 |
| 1. | 27.20 | 21.90 | 22.67 | 12.90 | 11.85 | 12.05 | 11.90 | 11.54 |
| 2. | 26.35 | 19.27 | 20.23 | 11.96 | 10.65 | 10.98 | 10.84 | 10.48 |
| 3. | 25.08 | 17.30 | 17.72 | 10.18 | 9.35 | 9.53 | 9.39 | 9.12 |
| 4. | 22.37 | 12.96 | 14.68 | 6.80 | 5.87 | 6.00 | 5.96 | 5.81 |
| avg | 25.25 | 17.85 | 18.82 | 10.46 | 9.43 | 9.64 | 9.52 | 9.23 |

The performance of wavelet (sym22) mother is better than the rest of wavelets and filters. Filter has sharp attenuation and pulsation present in the stop band. Average MSE (decibel) value of sym22 is 9.23 that lesser than the all other filters and wavelet used is shown in Fig 6.

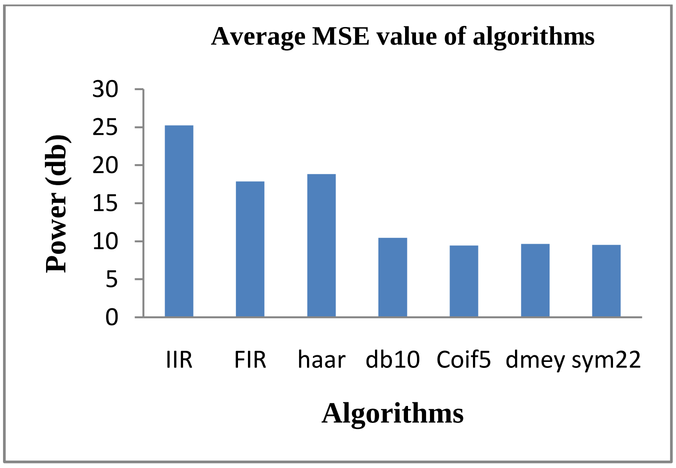


Fig 6 Average MSE value of Applied Algorithm

It shows symlets (sym22) mother wavelet has a most compatibility with the all tested EEG signals. Sym22 mother wavelet has given larger SNR (decibel) values and lower MSE values for all tested EEG signals. Sym22 is a best function for denoise the distorted EEG signal and it gives the filtered signal closer to original signal.

## IV. CONCLUSION & FUTURE WORK

Three techniques have been successfully applied to distorted EEG Signal. These algorithms were applied to signals having 250 sampling rate with time duration of 5 seconds. Power line noise of 50Hz and muscular artifacts were easily removed by the techniques used in this paper. Higher SNR and minimum MSE values of the filtered EEG signals showed the mother wavelet sym22 has a most compatibility with EEG signals. Implementation of wavelet based denoising for the removal of EOG noise, eye blink noise. ICA technique can be used to improve the quality of the signal.

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