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Performance Comparison of Denoising Methods of Electroencephalogram

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***Abstract*--Electroencephalograph (EEG) is the recording of electrical activity of neurons of the brain along the scalp. EEG signal is contaminated by various kinds of artifacts when it travels from different layer of brain. It is necessary to eliminate all such disturbances in EEG signal for proper diagnosis. In this study, mainly two types of artifacts such as 50Hz and Electromygram (EMG) artifact have been removed using three different algorithms. These algorithms (Finite impulse response (FIR) filter, Infinite impulse response (IIR) filter and discrete wavelet transform) have been applied to remove the above mentioned artifacts from the EEG signal. The filtered out signals from the IIR low pass filter, FIR low filter and Wavelet (sym29) are compared with their Signal to Noise Ratio (SNR) values. About 28 epochs of the signal were studied and the performance analysis was done. The result showed that the compatibility of mother wavelet symlets (sym29) for denoising is better than the rest two.**

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 measuring of electrical impulse of the neurons along the scalp. EEG measures voltage differences producing ionic current flow within the neurons of the brain [1]. The electrical activity of the brain is recorded over a short time period, generally 20–40 minutes. The amplitude of the brain signals ranges from 0.5μV to 100μV, which is about 100 times lower than ECG signal [3]. EEG signals are classified based on their frequency range: alpha (α), theta (θ), beta (β), delta (δ), and gamma (γ). Small Amplitude (μv) of the EEG signal is contaminated by various artifacts that recorded in the signal and changed the originality of the signal. 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 [4]. This contaminated signal makes the clinical analysis difficult therefore it is necessary to remove all such disturbances in EEG signal for proper diagnosis. Many methods have been implemented to eliminate the artifacts from original EEG signal. The aim is to find a best method to denoise the EEG signal. These algorithms (IIR low pass filter, FIR low pass filter and Wavelet method) are applied successfully in this paper. Performance analysis has been done by SNR value of the filtered EEG signal.

II. DENOISING ALGORITHMS

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

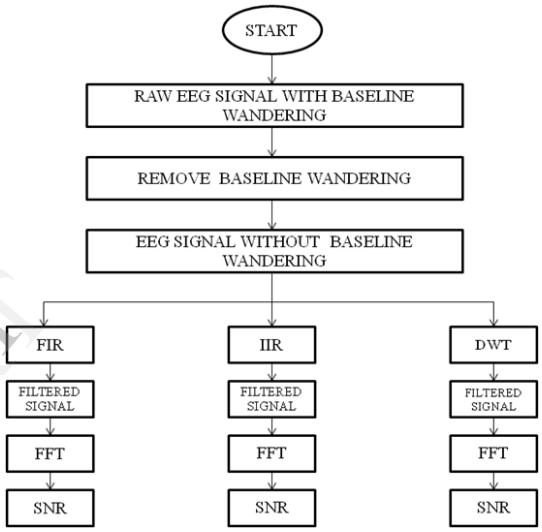

Fig. 1- EEG Noising Flow Process

In first step, Raw EEG signal was taken from the patient having 256 sampling rate with time duration of 4 seconds. In next step, removing baseline wandering from the EEG signal by taking average of the EEG signal and making it at the ground level. Appling IIR notch filter, FIR notch filter and Wavelet (symelets) on the EEG signal and obtained filtered EEG signal. Later, the calculation of Signal to Noise Ratio (SNR) values of the filtered EEG signal is obtained.

A. FIR Filtering

Finite impulse response (FIR) filter is a filter whose impulse response 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 depends only on the present and past values of the input only. The output sequence is a weighted sum of the most recent input values [5]

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

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.

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 system at any given time depends upon the present inputs and past outputs [7].

$$y[n] = \sum_{k=0}^{M} b_k\, x[n-k] - \sum_{k=1}^{N} a_k\, y[n-kN \quad ..(2)$$

N is the filter order, a_k and b_k are filter coefficients. 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. 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. In WT both the time and frequency resolutions vary in time-frequency plane in order to perform a multi resolution analysis [8]. It is shown below in Figure 2

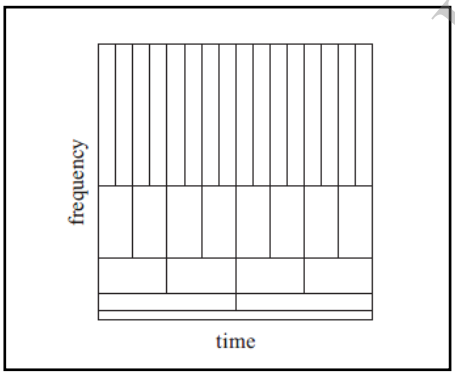

Fig. 2 Multi Resolution Time Frequency Plane [8]

III. Results and Discussions

Raw EEG signal has recorded for duration 4 seconds at sampling rate of 256Hz. During the recoding of the signal some artifacts can added in the signal. In Figure 3 shows raw EEG signal containing power line noise of 50Hz, EMG artifact and baseline wandering is shown in blue signal and Red signal. Red signal shows EEG signal after Removal of baseline wandering. DC component from the raw signal was removed and it was shifted at the ground (zero) level.

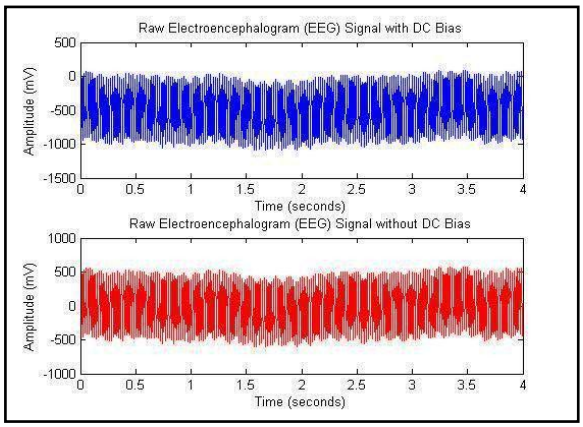

Fig.3 Raw EEG signal and EEG signal without DC shift

After removed the baseline wandering, algorithms (IIR filter, FIR filter and wavelet (sym29)) were applied on the EEG signal which were recorded for duration of 4 seconds and 256 Hz sampling rate and each recorded movement is called epoch. Seven epochs have been taken from each patient (number of patients were four) and applied above algorithms on total 28 epochs. These Algorithms gave the filtered signals which were used to calculate the Signal to Noise Ratio SNR values to quantify the most effective algorithm for the denoising. The comparison was done by calculating the SNR values of the filtered signal. It showed wavelet method was better from the rest of two. In Table 1 shows the SNR values of 28 epochs were calculated through above algorithms.

Table 1: SNR Values of Applied Algorithms

Sr. no.	Patient	IIR Filter	FIR Filter	Wavelet(sym29)
1.	P1.1	39.97	41.25	42.14
2.	P1.2	44.12	46.98	47.90
3.	P1.3	43.27	45.42	47.27
4.	P1.4	44.33	47.01	48.78
5.	P1.5	41.22	42.77	43.45
6.	P1.6	38.93	39.68	40.23
7.	P1.7	42.19	44.01	44.95
8.	P2.1	38.75	39.72	40.43
9.	P2.2	40.70	42.01	43.52
10.	P2.3	35.21	35.42	36.16
11.	P2.4	39.45	40.64	41.31
12.	P2.5	38.76	39.74	40.73
13.	P2.6	35.97	36.58	37.38
14.	P2.7	34.93	35.28	35.53
15.	P3.1	34.31	37.19	38.70
16.	P3.2	24.37	24.39	24.85
17.	P3.3	28.14	28.97	29.69
18.	P3.4	26.62	27.10	27.39
19.	P3.5	28.44	29.25	29.99
20.	P3.6	35.76	39.02	41.45
21.	P3.7	23.59	25.23	27.25
22.	P4.1	21.75	23.06	24.60
23.	P4.2	20.68	21.86	23.29
24.	P4.3	21.30	21.89	23.12
25.	P4.4	20.66	21.50	22.68
26.	P4.5	21.30	21.89	23.12
27.	P4.6	20.17	21.35	22.38
28.	P4.7	19.63	20.33	20.49

Average SNR values of filtered signals (**32.30, 33.55** and **34.59**) through the applied algorithms are shown in Figure 4. Average SNR value of Sym29 wavelet showed larger for all tested epochs. IIR filter and FIR filter showed lower bar because of main signal was attenuated and other artifacts were present in the filtered signal. Higher Bar showed wavelet has Higher SNR value because of less attenuation in the main signal and preserved more EEG signal than the other methods. The study shows the performance of symlets (sym29) mother wavelet has a most compatibility with the all tested EEG signals. Sym29 mother wavelet has gave larger SNR (decibel) values of all EEG signals.

Sym29 is a best function for denoising the raw EEG signal and it give the filtered signal closer to original signal.

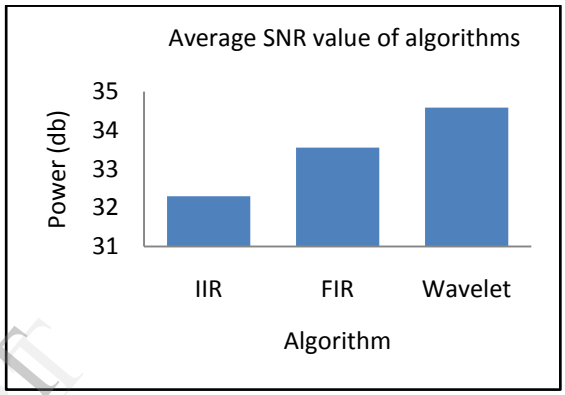

Figure 4: Average SNR value of Applied Algorithms

IV. Conclusion & Future Work

These methods were successfully removing the artifacts from the EEG signal. These algorithms were applied to signals having 256 sampling rate with time duration of 4 seconds (i.e. 1024 samples). The target artifacts were power line noise of 50Hz and muscular artifacts (energy resides mostly between 50-150Hz). The filtered signal was limited upto 35Hz as energy of EEG signal resides upto 35Hz. The results from these algorithms were compared. Wavelet analysis could remove noise above 40Hz and desired frequency was achieved. The comparison was done by calculating SNR. Using wavelet sym29 mother technique, the desired frequency was preserved and the artifacts were also removed. Implementation of wavelet based denoising for the removal of EOG noise, eye blink noise. Wavelet technique and ICA technique can be used to improve the quality of the signal.

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