ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 4, Issue 7, July 2015

Performance Comparison of Ocular Artifacts Removal from Electroencephalogram Signals using Different Techniques

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Abstract:* Electroencephalogram (EEG) signals are contaminated by different type of artifacts. The most common artifacts are ocular artifacts (OAs). To remove these artifacts different techniques have been used. In this paper comparison of ocular artifacts removal using five techniques: DWT, SWT, LMS Adaptive Filter, RLS Adaptive Filter and ICA are studied. Parameters used for comparison are SNR and FFT of cleaned signal after using above techniques and the comparison leads to two best techniques named as LMS and RLS for the removal of ocular artifacts.

***Index Terms*— Discrete Wavelet Transform, Stationary Wavelet Transform, Least Mean Square, Recursive Least Squares.**

I. INTRODUCTION:

EEG is defined as the signal that is used to measure the electrical activity of brain. Electro-encephalography waveforms can be categorized into four basic groups: delta (0.4-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), and beta (13-30 Hz). Sometimes one more wave may appear named as Gamma (above 30 Hz).While recording EEG signal these signals are contaminated by different type of artifacts [1].

Mainly artifacts are divided into two parts technical artifacts and physiological artifacts. Technical artifacts are those artifacts that arise due to electrode placement problems and body movements.

Most common physiological artifacts are due to movement of eye balls and eye lids, called as ocular artifacts. This paper is devoted towards removal of the ocular artifacts using five different techniques and their comparison by calculating SNR and plotting FFT plots. The purpose is to find out the best approach or technique out of these five techniques to deal with removal of ocular artifacts. Five different techniques used are DWT, SWT, LMS Adaptive Filter, RLS Adaptive Filter and ICA [2].

II. TECHNIQUES TO DEAL WITH OAs:

There are three methods to deal with ocular artifacts which are given as wavelet transform, adaptive filtering and ICA. In wavelet transform again there are two algorithms named as discrete wavelet transform (DWT) and stationary wavelet transform (SWT) [3]. In adaptive filtering there are again two algorithms named as least mean square (LMS) and recursive least square (RLS). Therefore there are five techniques to reduce the ocular artifacts.

A. Wavelet Transform:

Wavelet transform is tool that is used to deal with signal that are non stationary i.e. time varying frequency content. Wavelet transform decompose the signal into two parts first detail part which is given by high pass filter and approximation part which is given by low pass filter [4]. Wavelet transform is divided into two parts

1. Algorithm 1(DWT): It is discrete wavelet transform technique. It is designed to detect OA zones in the given EEG signal, so it can be called as detection technique the algorithm designed is given below in figure 1

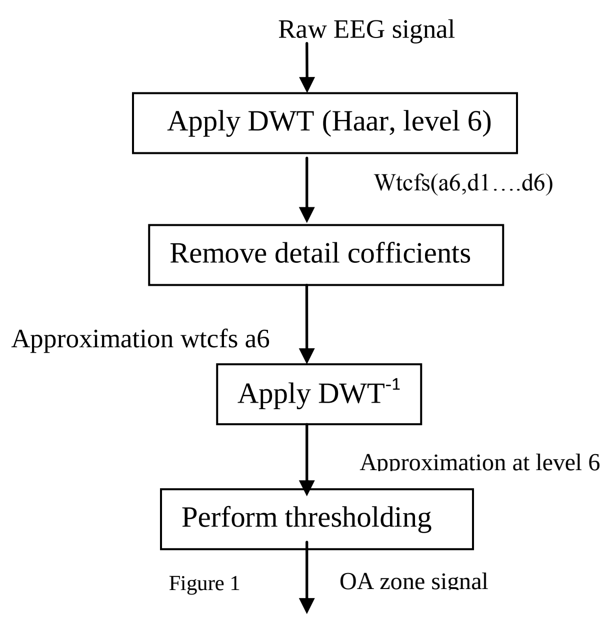

Figure 1

In this technique DWT is applied to the raw EEG signal with Haar mother wavelet of level 6. Because ocular artifacts lies in the range of [0-20] Hz range, so detail part is removed from the signal and after removing detail part approximation part is left and by applying inverse DWT signal is re- constructed. By performing thresholding signal with OA zone is detected [5].

2. Algorithm 2(SWT): This is the de-noising technique it reduces the OA from the signal. In this technique soft thresholding is used to eliminate the components that are below some threshold value T and reduce others magnitude by T. The algorithm designed for this technique is given in figure 2

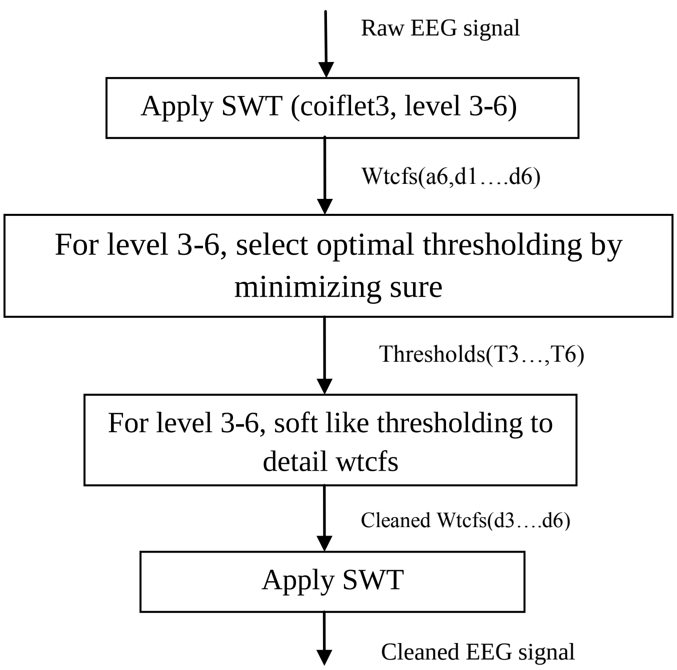

Figure 2

In this algorithm SWT is applied of coiflet3 then by applying thresholding all the components below threshold are eliminated then by soft like threshold is performed on the detail parts after that inverse SWT is applied to reconstruct the signal [6,7].

B. Adaptive Filtering:

Figure 2.2(a) shows the most common form of adaptive filtering. Here x[n] is the input y[n] is output and d[n] is desired input. The difference between d[n] and y[n] defines the error signal e[n].the value of signal at any particular time say n_0 is used to adjust vector wn of the adaptive filter at time n_0[8,9].

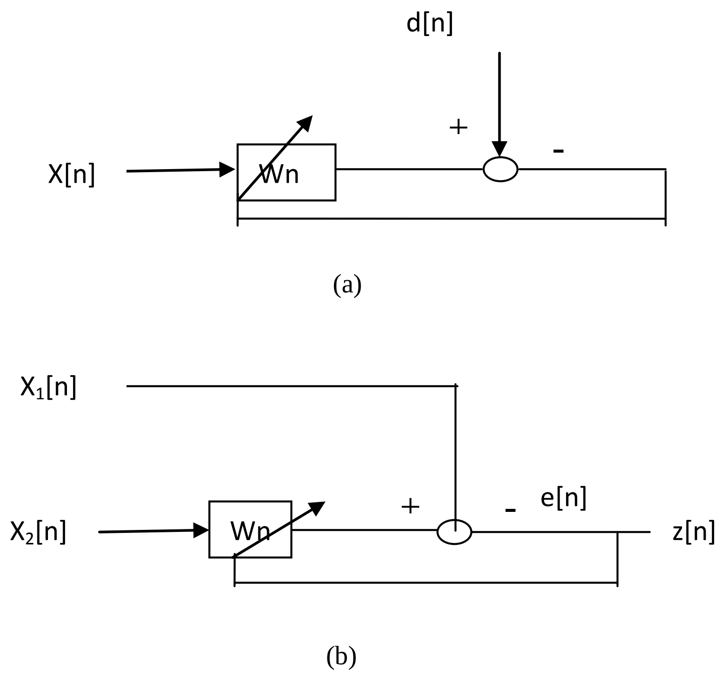

Figure 2.2(a) generic adaptive filter (AF) and (b) specific AF

Figure 3(b) shows the slight adaption of figure 3(a) in this x_2[n] is raw EOG signal where as desired signal x_1[n] is raw EEG signal .While output is still y[n] and e[n] will be new EEG signal with the effect of OAs reduced.

$$y[n] = w^t n \times x_{2n} \qquad (1)$$

The error signal e[n] is thus

$$e[n] = x_1[n]-y[n] = x_1[n]- w^t n \times x_{2n} \qquad (2)$$

the weight w_n is adapted linearly at each time step according to

$$w_{n+1} = w_n + e[n]g_n \qquad (3)$$

where g_n is vector of length l, the form of which depends upon particular type of generic adaptive filter used. Two types of adaptive filter considered are:

1) Least mean square error (LMS) algorithm which minimize the mean square error

2) Recursive least squares algorithm (RLS) which minimize the cost function

For LMS g_n is given by

$$g_n = \mu x_{2n} \qquad (4)$$

Where μ is the step size, for stability and convergence [13] $\mu = 10^{-6}$ as in [12] for RLS g_n is given by

$$g_n = \frac{P_{n-1}X_{2n}}{\lambda + X_{2n}^T P_{n-1} X_{2n}} \quad (5)$$

Where the L×L matrix p_n is recursively defined by

$$P_{L-1} = \frac{I}{\sigma},\ P_n = \frac{P_{n-1}}{\lambda} - \frac{g_n\, x_{2n}^T P_{n-1}}{\lambda} \quad (6)$$

Where λ is the forgetting factor here we take $\sigma = 10^{-2}$ and $\lambda = 9999\times10^{-4}$ as in [14].

C. Independent component analysis (ICA):

With the help of ICA [15], one can have access to different signals that are of one's interest which are unknown here; each signal of interest is called source signal or component signal

The fundamental ICA problem is formulated as follows. One assumes that one has access to K observations corresponding here to the available PSG channels and that these observations are, for simplicity, generated by the same number (i.e. K) of sources, and are each affected by noise. One models the underlying signals as random, and one deals here with random vectors (RVs), e.g. corresponding to an epoch, all of the same length N. The kth observation, source, and noise RVs are denoted by x_k, s_k, and n_k, respectively. For x_k and n_k, one can say that "k" corresponds to the kth observation channel, but this does not apply to s_k One assumes that the above RVs are linearly related by

$$\begin{pmatrix} x_1 \\ \vdots \\ x_k \end{pmatrix} = \begin{pmatrix} A_{11} \dots A_{1k} \\ \vdots \\ A_{k1} \dots A_{KK} \end{pmatrix} \begin{pmatrix} s_1 \\ \vdots \\ s_k \end{pmatrix} + \begin{pmatrix} n_1 \\ \vdots \\ n_k \end{pmatrix} \quad (7)$$

Or

$$(x_1 \ldots\ldots x_k)^T = \sum_{i=1}^{k} A_{11} s_1 + n_1 \ldots \sum_{i=1}^{k} A_{ki} s_k + n_k$$

Where the block matrix of the A_{kl}, denoted by A, is the mixing matrix and each nk is assumed to be the white noise

(WN) RV uncorrelated with each of the sk′s. One can compactly write (1)

$$x = As + n \quad (8)$$

as where all quantities should always be viewed as consisting of blocks of vectors or matrices, as appropriate.

III. METHODS FOR COMPARING AND EVALUATING RESULTS:

In this paper, SNR and FFT plots are used to compare the performance of above different techniques.

Since there is no way to find original ocular artifacts so we consider the signal as non OA zone signal and OA zone signal with the help first method that is detection method. In other methods we use the OA zone signal detected by the DWT.

Where SNR is given by

$$\text{SNR} = 20\log\frac{\text{rms (filtered signal)}}{\text{rms (noise)}} \quad (9)$$

IV. RESULTS:

This paper compares above mentioned five techniques using SNR values and FFT plots on 4 sets of data,taken from CSIO Chandigarh.
Below table gives the comparison of SNR values.

Data Set	DWT (db)	SWT (db)	LMS (db)	RLS (db)	ICA (db)
Data Set 1	13.152	-4.335	7.222	10.396	-10.363
Data set 2	15.912	-3.3149	9.315	11.551	-8.685
Data set 3	12.279	-3.6606	9.021	13.668	-19.513
Data set 4	13.633	-3.4812	7.521	12.536	-18.903
Average	13.744	3.6979	8.270	12.027	-14.366

Here four data sets are used for the analysis of above mentioned five techniques.
From the results it is clear that

1: DWT, which is a detection method for the visualization purpose.

2: SWT is unable to correct the signal.

3: LMS is able to correct the EEG signal with average value of 8.2700.

4: RLS is able to correct the EEG signal with average value of 12. 277.

5: ICA is unable to correct the signal.

Comparisons using FFT Plots

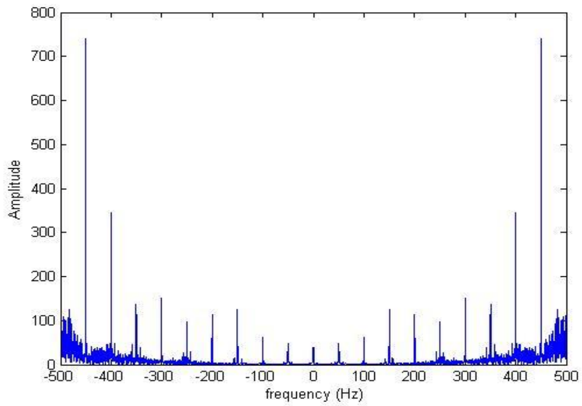

Figure 3.1 FFT of original signal

Figure 3.1 shows the FFT plot of original signal i.e. the raw signal having ocular artifacts,
FFT plots of cleaned signal using various techniques are as below:

Figure 3.2 is FFT plot of de-noised signal using DWT.

Figure 3.3 is FFT plot of de-noised signal using SWT.

Figure 3.4 is FFT plot of de-noised signal using LMS.

Figure 3.5 is FFT plot of de-noised signal using RLS.

Figure 3.6 is FFT plot of de-noised signal using ICA.

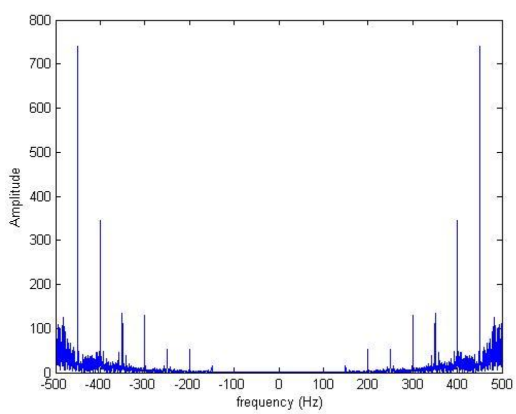

Figure 3.2 FFT after applying DWT

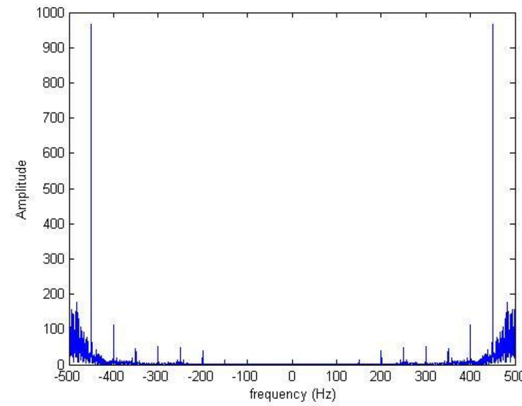

Figure 3.3 FFT after applying SWT

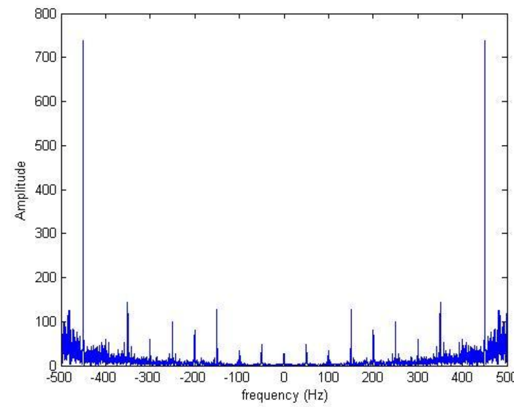

Figure 3.4 FFT after applying LMS

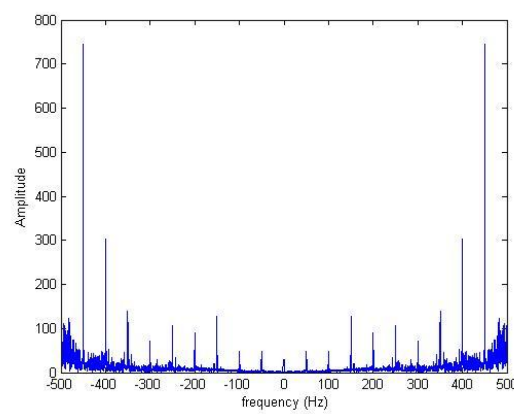

Figure 3.5 FFT after applying RLS

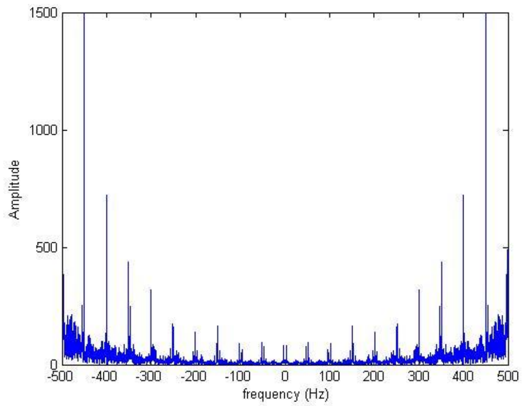

Figure 3.6 FFT after applying ICA

Again reminding DWT here used as detection method, after applying SWT and ICA the result shows that these techniques cannot be applied directly on the signal where RLS and LMS shows the positive results.

V. CONCLUSION:

Detecting and correcting of EEG signal is important aspect for the better analysis of the signal. So it is necessary to detect and correct the OA in the signal. This paper compares the performance of the five techniques on basis of SNR and FFT Plots. It is found that LMS and RLS are better techniques to reduce the noise.

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