Denoising and Eye Movement Correction in EEG Recordings using Discrete Wavelet Transform

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Abstract — We present an algorithmic approach to correct the eye movement artifacts in a simulated ongoing electroencephalographic signal (EEG). The recorded EEG data set is obtained from the neuro lab where a realistic model of the human head is used, collectively with eye tracker statistics, to generate a information set in which potentials of ocular and cerebral foundation are simulated. This method bypasses the common trouble of brain-potential contaminated electro-oculographic signals (EOGs), whilst monitoring or simulating eye movements. The statistics are simulated for five specific EEG electrode configurations mixed with four extraordinary EOG electrode configurations. In order to objectively compare correction overall performance of the algorithms, we determine the signal to noise ratio, Power spectral density(PSD) of the EEG before and after artifact correction.

Index Terms — **EOG, DWT, Eye movements, Electroencephalography.**

1. INTRODUCTION

This paper introduces a method to objectively assess the performance of eye movement artifact removal algorithms used in electroencephalographic (EEG) measurements. The EEG is a recording of potential changes on the scalp caused by human brain activity. It is often used in clinical situations, for instance to identify sleep disorders or epilepsy or brain related disease, because it reveals important information about a person's mental condition. The EEG can be distorted by numerous other sources of electrical activity, called artifact sources. Before the information in the EEG can be retrieved, however, any artifacts should be removed. Eye movement artifacts can have a large disturbing effect on EEG recordings because the eyes are located close to the brain.
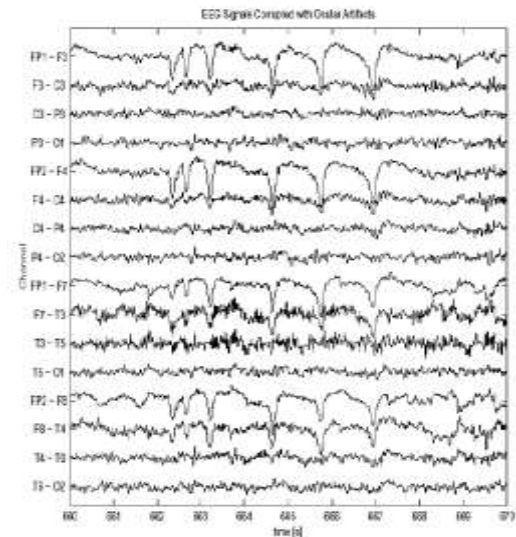

Fig-1: EEG recording by ocular artifacts

2. METHODOLOGY

The EEG recordings are contaminated by EOG signal. The EOG signal is a non-cortical activity. The eye and brain activities have physiologically separate sources, so the recorded EEG is a superposition of the true EEG and some portion of the EOG signal [1]. It can be represented as,

$EEG_{reco}(t) = EEGorg(x) + \alpha.EOG(x)$

$EEG_{reco}(t)$ – Recorded affected EEG,

$EEG_{org}(x)$ – EEG due to cortical activity

$\alpha.EOG(x)$–Recorded ocular artifact with EEG.

$EEG_{org}(x)$ is to be estimated from $EEG_{reco}(x)$ by removing the $\alpha.EOG$ at the same time retaining the EEG activity.

The Algorithm proposed in this paper involves the following steps:

i) Apply Discrete Wavelet Transform to the contaminated EEG with Haar wavelet as the basis function to detect the Ocular Artifact zone [8].

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ii) Apply Stationary Wavelet Transform with Coif 3 as the basis function to the contaminated EEG with OA zones identified for removing Ocular Artifacts.

iii) For each identified OA zone, select optimal threshold limit at each level of decomposition based on minimum Risk value and apply that to the soft-like thresholding function [7] which best removes noise.

iv) Apply inverse stationary wavelet transform to the thresholded wavelet coefficients to obtain the de-noised EEG signal.

2.1 Artifact zone identification using wavelet transform:

By analyzing the frequency spread of the EEG data that contained the Ocular Artifacts, researchers found that the difference in the frequency of the spikes caused due to rapid eye blink and the EEG signal could be used along with a simultaneous recording of the EOG to detect and remove these artifacts. In [8] Haar wavelet is used to decompose the recorded EEG Signal to detect the exact moment when the state of the eye changes from open to closed and vice versa. Decomposition of the EEG data with the Haar wavelet results in a step function with a falling edge for a change in the state of the eyes from open to close and a step function with a rising edge for a change in state of the eyes from close to open. The same technique is used to detect the ocular artifacts zones in the contaminated EEG. Once the patterns are identified, the time instants at which the artifacts occur can be obtained and the OA zone can be identified.

2.2 Correction of EOG using Adaptive DWT:

A nonlinear time-scale adaptive denoising system proposed in [7] is based on wavelet compressed scheme and has been used for removing the identified ocular artifacts from EEG. A soft-like thresholding function is used which searches for best thresholds using gradient based adaptive algorithms.

3. Conclusions

In this paper, we initially done the filtering process of the noise affected EEG signal, since the EOG artifacts are very low frequency signal and completely mixed with the EEG signal and hence the normal filtering process will leads to loss of essential data in EEG. So we proposed a adaptive thresholding method to identify the artifacts zone by having the knowledge about the EOG artifacts (normally it's like a short spike) and then applying the suitable filtering on the corresponding zone will give a improved result. Further it is our considered opinion that a suitable performance metric for validating the de-noised EEG

signals should be devised for quantitatively comparing the algorithms for ocular Artifacts spike removal.
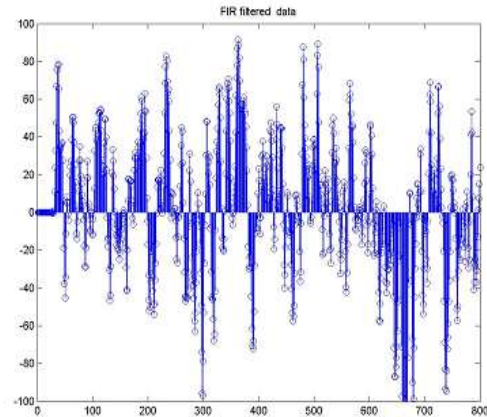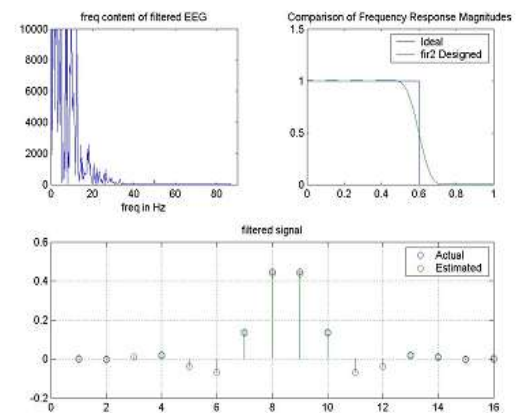

Fig- 2: Filtered Data (FIR)
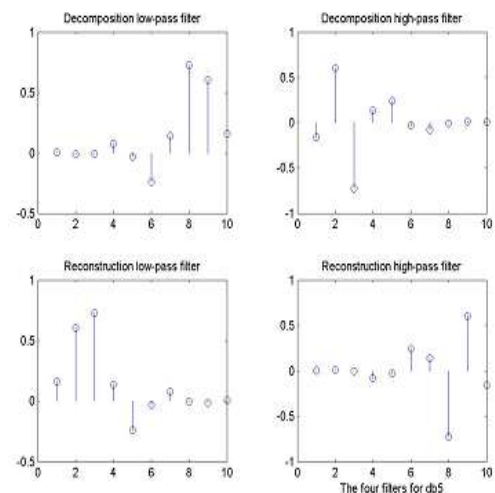

Fig -3: Filtered & Reconstructed signal
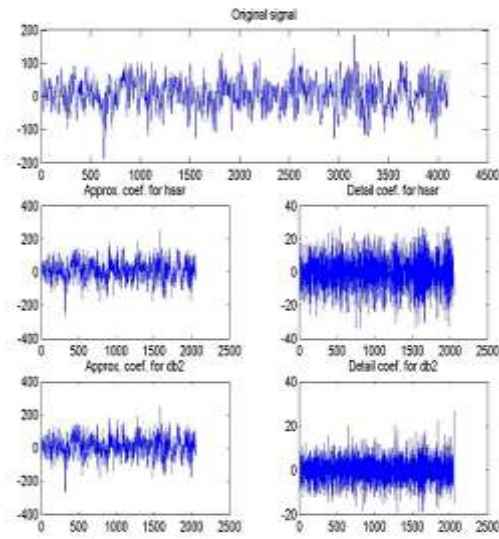

Fig- 4: Decomposed & Reconstructed signal

Fig- 5: Approximation Coef for Haar Transform

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