

Denoising of EEG Signals using Wavelets and SIMULINK Techniques



B. Krishna Kumar

Abstract: The Electroencephalogram (EEG) is the standard technique for investigating the brain’s electrical activity in different psychological and pathological states. Analysis of Electroencephalogram (EEG) signal is a challenging task due to the presence of different artifacts such as Ocular Artifacts (OA) and Electromyogram. Normally EEG signals falls in the frequency range of DC to 60 Hz and amplitude of 1-5 μv . Ocular artifacts do have the similar statistical properties of EEG signals, often interfere with EEG signal, thereby making the analysis of EEG signals more complex. In this research paper, removal of artifacts was done using both matlab coding as well as SIMULINK DWT and IDWT blocks by setting the various parameters of the blocks. The implementation of denoising of EEG signal using SIMULINK DWT and IDWT blocks is explained in detail in the paper under the methodology heading. In this paper the collected EEG signal is normalized and later linearly mixed with the normalized EOG signal resulting in a noisy EEG signal. This noisy EEG signal is decomposed to 4 levels by using different wavelets. This decomposition of EEG signals yields approximate and detail coefficients. Later different thresholding techniques were applied to detail coefficients and estimated the Signal to Noise Ratio of it.

Keywords: WT, DWT, Ocular Artifacts

I. INTRODUCTION

Electroencephalogram (EEG) has been long utilized to diagnose different disorders of the nervous system such as epilepsy, classifying stages of sleep in patients, seizures and brain damage. EEG is the brain’s electrical activity recorded from the scalp surface, which is picked up by conductive media and electrodes [1-2]. EEG has been performing a vital role to investigate brain activities in clinical application and scientific research for several years [3-5]. The EEG signals can be contaminated by various artifacts, of which the major noise source is ocular artifact. Eye-movement and eye-blink artifacts are the major sources of ocular artifacts [6]. However, artifacts are the major enemies of high-class EEG signals. The mixing up of these ocular artifacts with the EEG

signal at the time of recording causes the problems in the precise estimation of EEG signal. These artifacts will plunge into either of the 2 categories namely, technical and physiological artifacts. Power line noise 50/60Hz falls into technical artifact category while the artifacts that crop up because of ocular(EOG), heart(ECG) and muscular activity(EMG) falls into physiological artifacts category respectively [7]. Regression in the time domain and frequency domain [8-10] methods were proposed in removing eye blinks artifacts. These methods require a reliable reference channel. This channel can be contaminated by EEG. So, EEG has to be removed from the reference channel by regression techniques. Hence, the regression methods are not the finest to remove EOG artifacts.

In this research paper, noisy EEG signal is decomposed to four levels using different wavelets. This decomposition gives low frequency and high frequency components of noisy Electroencephalogram signal. The high frequency components contain more noise information than low frequency components, hence are processed with various thresholding techniques.

The above mentioned procedure has been carried out both in matlab and SIMULINK.

II METHODOLOGY

EEG signal that is collected from Physionet data base[11] is normalized by using the following formula:

$$\text{Normalized EEG signal} = \frac{\text{Collected EEG Signal} - \text{Mean (Collected EEG Signal)}}{\text{Std (Collected EEG Signal)}}$$

The collected and normalized EEG signals are shown in Figure 1.

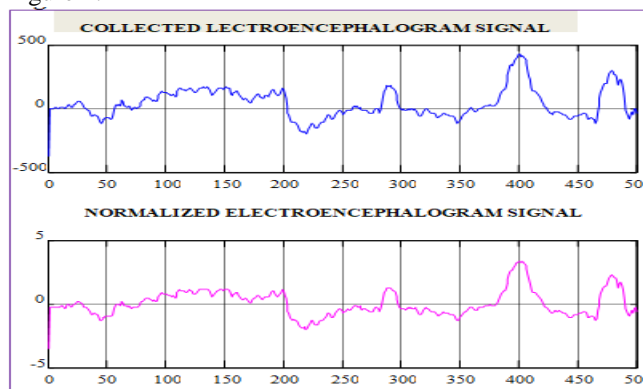


Fig 1: Collected EEG Signal and the Normalized EEG Signal

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* Correspondence Author

Dr.B.Krishna Kumar, Professor, Methodist college of Engineering and Technology Hyderabad, INDIA.

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Denosing of EEG Signals using Wavelets and SIMULINK Techniques

The normalized EEG signal from matlab workspace is taken to SIMULINK, using signal from work space block and the output of this block is connected to scope to view the signal and the normalized EEG signal from the scope block of SIMULINK is shown in the Fig.2.

For convenience sake, normalized signal both from matlab and as well as SIMULINK are shown in Fig.2

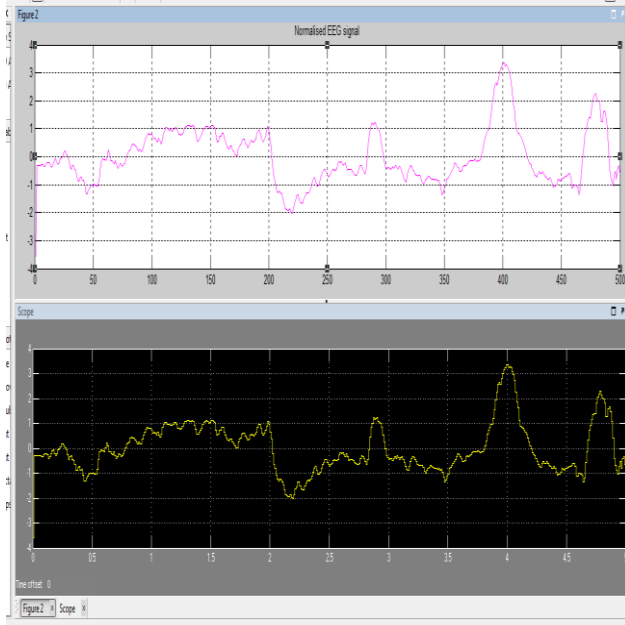


Fig 2: Normalized EEG Signal using matlab and SIMULINK

The EOG signal that is collected from Physionet data base is normalized by using the following formula:

$$\text{Normalized EOG signal} = \frac{\text{Collected EOG Signal} - \text{Mean (Collected EOG Signal)}}{\text{Std (Collected EOG Signal)}}$$

The collected and normalized EOG signals are shown in Figure 3.

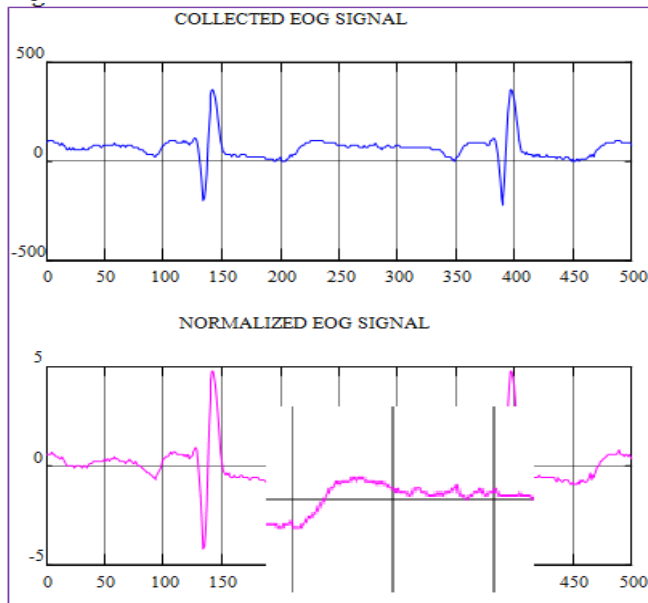


Fig 3: Collected ElectroOculoGram Signal and Normalised EOG signal

The normalized EOG signal from matlab workspace is taken to SIMULINK, using signal from work space block and the output of this block is connected to scope to view the signal. The normalized EOG signal from the scope block of SIMULINK is shown in the Fig.4.

For convenience sake, the normalized signal both from matlab and SIMULINK are shown in Fig.4.

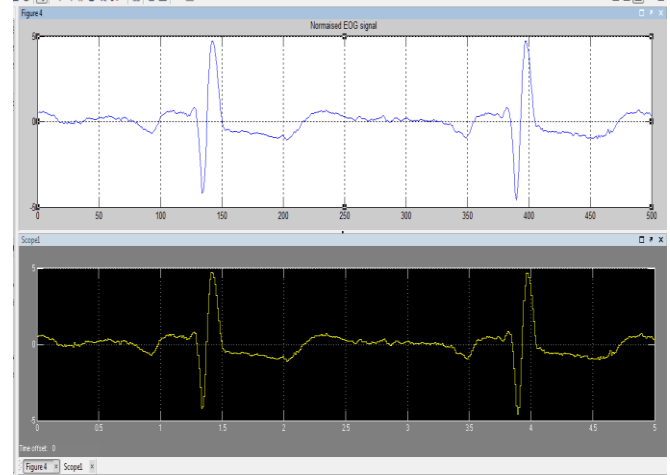


Fig 4: Normalized EOG Signal using matlab and SIMULINK

The corrupted EEG (observed) signal can be modeled in the following manner:

$$y(n) = x(n) + \sigma e(n)$$

Where, $x(n)$ is the original Electroencephalogram signal, $e(n)$ is the ElectroOculoGram signal, σ is the noise variance and $y(n)$ is the Noisy EEG signal

To achieve the noisy EEG signal, the normalised Electroencephalogram signal is mixed with the ElectroOculoGram signal with noise variance of 0.4, [12] and is shown in the Figure 5.

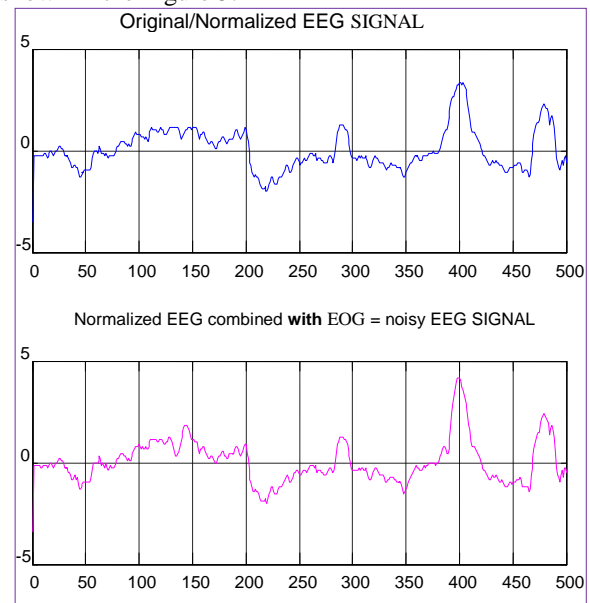


Fig 5: Normalized EEG combined with EOG- noisy EEG

The normalized EEG signal combined with EOG from matlab workspace is using signal from work space block and the output of this block is connected to scope to view the signal and the normalized EEG signal combined with EOG signal

from the scope block of SIMULINK is shown in the Fig.6. For convenience sake, both the normalized EEG signal combined with EOG signal from matlab and SIMULINK are shown in Fig.6.

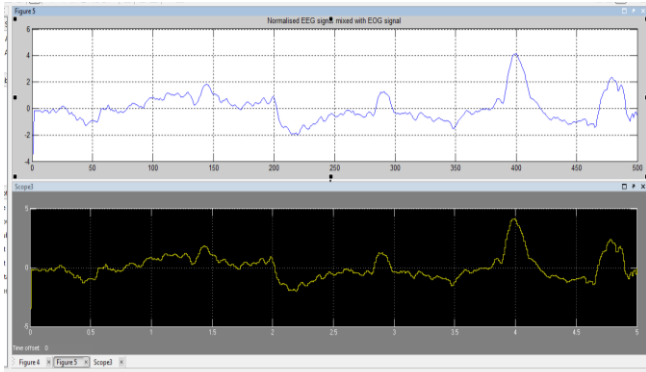


Fig 6: Normalized EEG combined with EOG- noisy EEG using matlab and SIMULINK

The decomposition of noisy EEG signal is done to four levels by dB4 wavelet. This decomposition gives Approximate and Detail coefficients of noisy Electroencephalogram signal. Soft Thresholding is applied to Detail coefficients. The wave reconstruction was done using threshold coefficients and approximate coefficients and is shown in Fig 7.

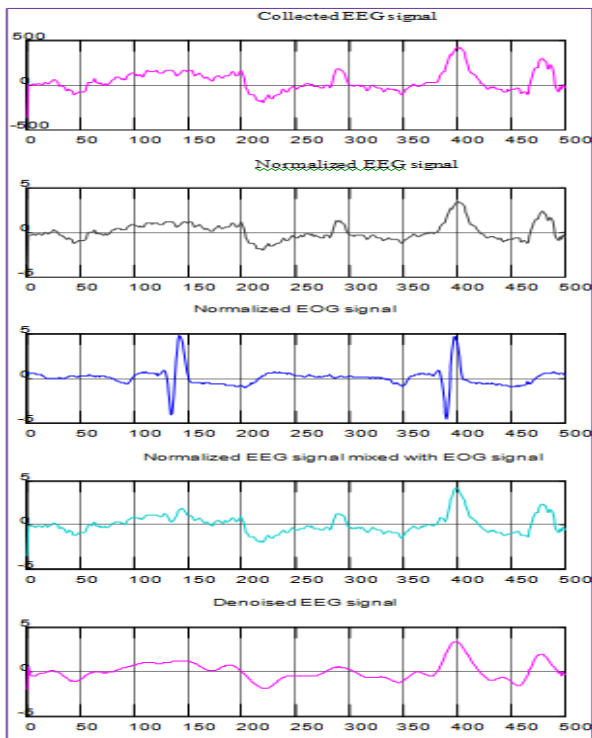


Fig 7: COLLECTED, NOISY and DENOISED EEG Signal Using Soft Thresholding Using dB-4 Wavelet

The overall set up of denoising of EEG signal using SIMULINK is shown Fig 8.

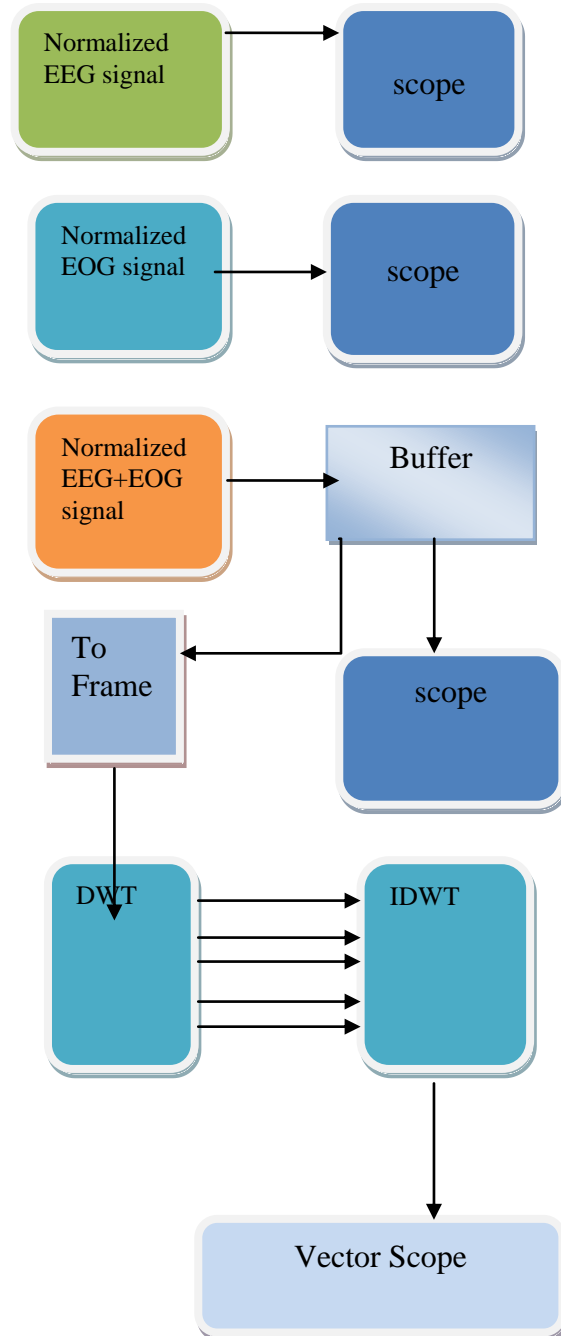


Fig 8 : Over all set up of Denoising of EEG Signal Using SIMULINK

The noisy EEG signal consisting of 500 samples is provided to a buffer block. Using this Buffer block these samples are converted into frames and the output buffer size per channel is considered as 16. The samples in the form of frames are provided to DWT block[13]. This block is the same as the Dyadic Analysis Filter Bank block. Basically this block computes the discrete wavelet transform (DWT). Uses a filter bank with specified highpass and lowpass FIR filters to decompose the input into subbands that have smaller bandwidths and slower sample rates.

Denoising of EEG Signals using Wavelets and SIMULINK Techniques

The filters can be user-defined or wavelet-based (use of wavelets requires the Wavelet Toolbox). Usually, the highpass and lowpass filters should be half-band filters designed to complement each other.

When 'Output' is set to 'Multiple ports' the block outputs each subband from a different port as a frame-based vector or matrix (the topmost port outputs the subband with the highest frequency band). When 'Output' is set to 'Single port' the block outputs one sample-based vector or matrix of concatenated subbands.

Inputs must be frame-based with a frame size a multiple of 2^n , where n is the value entered in the 'Number of levels.' To create a filter bank that accepts sample-based inputs and inputs of other sizes, use Two-Channel Analysis Subband Filter blocks in the Multirate Filters library.

The parameters of this block are set in the following manner: The type of wavelet chosen was Daubechies and wavelet order is 4. The number of levels of decomposition was set to 4, the type of tree was chosen as asymmetric and the output of DWT block is taken to multiple ports. Since the number of levels of decomposition is taken as 4, then the frame size becomes 16 and the total number of frames will be $32(500/16)$. The samples are thresholded using ode 45 solver and later provided as input to IDWT block for the reconstruction of the signal. When 'Input' to this block is set as 'Multiple ports', one must input each subband through a different input port as a frame-based vector or matrix (the topmost input port should receive the subband with the highest frequency band). The parameters of this block were set as same as DWT block. The output of IDWT block is given to vector scope to view the denoised signal and is shown in the Fig 9.

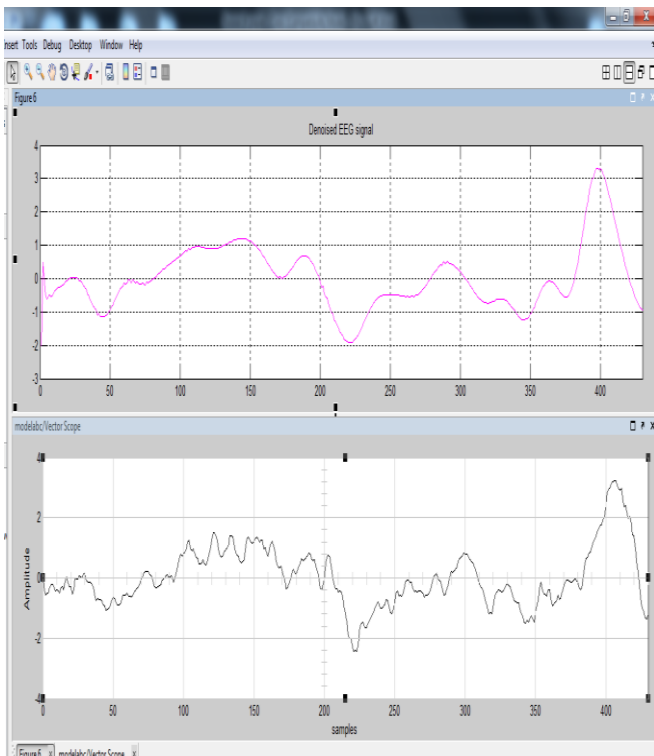


Fig 9: Denoised signal using matlab and SIMULINK

III . RESULTS

The estimation of SNR of denoised signal using different wavelets was presented against method of implementation (MATLAB OR SIMULINK) in Table 1.

Table 1: SNR in dB using MATLAB and SIMULINK

NAME OF WAVELET	SNR IN dB	
	MATLAB	SIMULINK
DB4	5.625	11.8644
DB10	6.302	11.7018
Sym8	5.6658	11.5744
Haar	5.5616	11.4650

IV CONCLUSION

From the above results, it is observed that the signal denoising using SIMULINK techniques are providing better results than MATLAB based wavelet coding.

Compliance with Ethical Standards

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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AUTHORS PROFILE



B.Krishna Kumar holds PhD degree in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Hyerabad. He also has M.Tech degree in Digital Systems and Computer Electronics from JNTU, Hyderabad and B.Tech degree in Electronics and Communication Engineering from S.V.University, Tirupathi. He has more than 15 publications to his credit. He has written a book on Estimation of statistical parameters of EEG signals using wavelets. He is a member of INSTITUTE OF RESEARCH ENGINEERS AND DOCTORS and also International Association of Engineers. His fields of interest are biomedical signal processing and image processing.