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# Wavelet Transform Based Electroencephalogram (EEG) Signal Enhancement and Critique

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***Abstract*: In this paper, EEG signals are the signatures of neural activities. There have been many algorithms developed so far for processing EEG signals. The analysis of brain waves plays an important role in diagnosis of different brain disorders. Brain is made up of billions of brain cells called neurons, which use electricity to communicate with each other. The combination of millions of neurons sending signals at once produces an enormous amount of electrical activity in the brain, which can be detected using sensitive medical equipment such as an EEG which measures electrical levels over areas of the scalp. The electroencephalogram (EEG) recording is a useful tool for studying the functional state of the brain and for diagnosing certain disorders. The combination of electrical activity of the brain is commonly called a Brainwave pattern because of its wave-like nature. EEG signals are low voltage signals that are contaminated by various types of noises that are also called as artifacts. Statistical method for removing artifacts from EEG recordings through wavelet transform without considering SNR calculation is proposed. This paper proposes time-frequency analysis of EEG spectrum and wavelet analysis in EEG de-noising. In this paper, the basic idea is to use the characteristics of multi-scale multi-resolution, using four different thresholds to wipe off interference and noise after decomposition of the EEG signals. By analyzing the results, understanding the effects of four different methods, it comes to a conclusion that the wavelet de-noising and soft threshold is a better conclusion.**

**Key Words: EEG, Discreet Wavelet Transform, EOG, SNR, MSE**

## 1. Introduction

The human brain is one of the most complex systems in the universe. Nowadays various technologies exist to record brain waves and electroencephalography (EEG) is one of them. This is one of the brain signal processing technique that allows gaining the understanding of the complex inner mechanisms of the brain and abnormal brain waves have shown to be associated with particular brain disorders.

The analysis of brain waves plays an important role in diagnosis of different brain disorders. Brain is made up of billions of brain cells called neurons, which use electricity to communicate with each other. The combination of millions of neurons sending signals at once produces an enormous amount of electrical activity in the brain, which can be detected using sensitive medical equipment such as an EEG which measures electrical levels over the areas of the scalp.

The electroencephalogram (EEG) recording is a useful tool for studying the functional state of the brain and for diagnosing certain disorders. The combination of electrical activity of the brain is commonly called a Brainwave pattern because of its wave-like nature.

Electroencephalographic (EEG) signals are the realizations of brain electrical activities recorded from multiple electrodes located on the scalp. Analysis of EEG signals has led to an interdisciplinary field of research called EEG signal processing.

EEG signals are the signatures of neural activities. There have been many algorithms developed so far for processing EEG signals. The application of these algorithms to analysis of the normal and abnormal EEGs.

## 2. Literature Review

The detection of neuro-physiological features by means of electroencephalogram (EEG) is one of the most recurrent medical exams to be performed on human beings. As it is noticed, EEG trials are not always sufficient to deliver a clear and precise diagnosis for many pathologies. Hence it must be integrated with other exams. But we can use all additional instrumental exams to improve the quality of the diagnosis since there are other constraints, namely, financial, medical and individual. This work presents an original implementation of EEG signal processing [2].

Different state of mind and the cause of the cerebral cortex in different locations reflect the different EEG. Therefore, the electro encephalogram contains plentiful physical, psychological and pathological information, analyzing and processing of EEG both in the clinical diagnosis of some brain diseases and treatments in cognitive science research field are very important [4].

EEGLAB provides visualization, analysis and processing for EEG signals. For analysis of EEG signal EEGLAB is interactive menu-based [9] and scripting software for processing EEG signal data based under the Matlab interpreted programming script environment. EEGLAB implements common methods of electroencephalographic data analysis and time/frequency analysis. EEGLAB has become a widely used platform for applying and sharing new techniques for biophysical signal processing [10].

Time-frequency analysis is a nonlinear quadratic transformation. Time-frequency analysis is an important branch to process non-stationary signal, which is the use of time and frequency of joint function to represent the non-stationary signal and its analysis and processing. Wavelet transformation is a time-scale analysis method and has the capacity of representing local characteristics in the time and scale (frequency) domains. In the low frequency, it has a lower

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time resolution and high frequency resolution, the high frequency part has the high time resolution and lower frequency resolution, it is suitable for detection of the normal signal, which contains transient anomalies and shows their ingredients. Wavelet de-noising is the most important aspect in signal processing [5].

A wavelet is a small waveform which has its energy concentrated in time. Wavelet Transforms [8] are used to convert a signal into a series of wavelets. The wavelet transform is an important tool for analysis of EEG signals. One of the primary benefits of the wavelet transform is that it is localized in both time and frequency, whereas other classical methods like the Fourier transform are localized in frequency, only. DWT (Discrete Wavelet Transform), being non-redundant, is a very powerful tool for many non-stationary Signal Processing applications. The key point is that it gives a better approximation than the discrete wavelet transform (DWT) since, it is redundant, linear and shift invariant [8].

Applying Stationary wavelet transforms to the contaminated EEG signals and decomposes it up to six levels as a basis function. The denoising technique employed at this

Stage is sure by fixing a threshold value and thresholding function. The last stage is to obtain the de-noised EEG signal. Apply inverse stationary wavelet transform to the threshold wavelet coefficients to obtain the de-noised EEG signal [8].

### *A. Denoising EEG Signal using Wavelet Transform*

R. Princy, P. Thamarai, B.Karthik, given various ideas for Electroencephalogram (EEG) signal is the recording of spontaneous electrical activity of the brain over a small interval of time. Signals are produced by bombardment of neurons within the brains which are measured and evaluated by EEG. EEG signals are low voltage signals that are contaminated by various types of noises that are also called as artifacts. As these signals are used to diagnose various types of brain related diseases like narcolepsy, Sleep apneasyndrome, Insomnia and parasomnia it becomes necessary to make these signals free from noise for proper analysis and detection of the diseases [1].

### *B. Wavelet Time Frequency Analysis of Electro encephalogram (EEG) Processing*

Zhang xizheng, Yin ling, Wang weixiong, In this paper, the basic idea is to use the characteristics of multi-scale multi-resolution, using four different thresholds to wipe off interference and noise after decomposition of the EEG signals. By analyzing the results, understanding the effects of four different methods, it comes to a conclusion that the wavelet de-noising and soft threshold is a better conclusion [2].

### *C. Topics in Brain Signal Processing*

Justin Dauwels_ and Franc¸ois Vialatte,this paper provides an introduction to the area of brain signal processing, and also serves as an introductory presentation for the special session entitled Advanced Signal Processing of Brain Signals: Methods and Applications at APSIPA 2010. Several topics related to the processing of brain signals are discussed: preprocessing, inverse modeling (a.k.a. source modeling), and signal decoding. The papers in the special session are centred around those three topics [3].

### *D. EEG Purging using Labview Based Wavelet Analysis*

Jigar D. Shah, M. S. Panse, this paper provides the removal of artifact from scalp EEGs is of considerable importance for analysis of underlying brainwave activity. The presence of artifacts such as muscle activity, eye blinks, pulse signals and line noise in electroencephalographic (EEG) recordings obscures the underlying processes. These artifacts sources increase the difficulty in analyzing the EEG. For this reason, it is necessary to design a procedure to decrease such artifacts in EEG [4].

### *E. Subtraction using Linear Regression*

When dealing with predictable noise that can be recorded independently on a separate channel, it is possible to remove the noise from the data by estimating the amount of noise transtered to data using linear regression and then subtracting it. A typical example is the noise produced by blinks and eye movements. To remove such noise, linear regression is computed between each data channel and nuisance channels used to record horizontal (HEOG – difference between voltages recorded above and below eyes), vertical (VEOG – difference between voltages recorded at the left and right outer canthi of the eyes) and radial (REOG – difference between average voltage at the eyes and EEG reference) movement. The estimated ß coefficients are then used to subtract values from each nuisance channel multiplied with corresponding ß coefficient from the measured data channel [5].

### *F. Subtraction using Adaptive Filtering*

As EOG signals are mostly of lower frequency than the cerebellar signal of interest, the problem of EOG signals contamination by signal of interest can be somewhat reduced by low-pass filtering the EOG channels before applying subtraction using linear regression, problem of removing cerebellar signal of interest along with EOG in subtraction using linear regression [6].

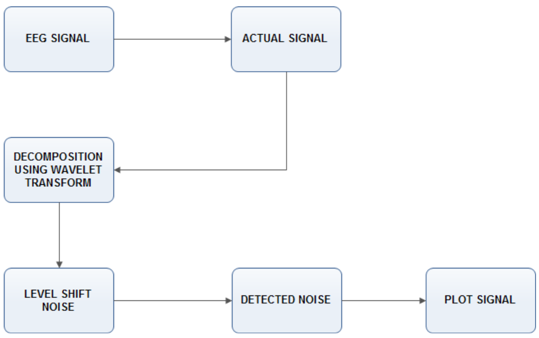


Fig. 1. Block diagram of proposed system

*Steps involved:*

1. Get the EEG signals in the database
2. Extract the actual signal by demodulates the signal to remove the carrier.
3. Decompress the signal to perform level shifting.
4. Split the level of the EEG signal based on the factor PRST.
5. Identify the peak and minimum value in each level.
6. Set up the EEG amplitude as threshold value.
7. Identify the noise.

8. Perform denoising using wavelet transform.
9. Plot the signal

*G. EEG Theory*

EEG is normally used to record the brain wave in medical treatment. The recording is usually taken by electrodes (small metallic discs) pasted by an electricity conducting gel to the surface of the scalp.

In EEG recording, a powerful electronic amplifier increases several hundreds or thousands of times the amplitude of the weak signal (less than a few micro volts) which is generated in this place. In the past, a device called galvanometer, which has a pen attached to its pointer, writes on the paper strip, which moves continuously at a fixed speed past it. In the present time, with the advent of powerful electronic computer and very high storage, we can use A/D device to transform signal between electrode and computer. A lot of data can be recorded and easily analysed and printed. One pair of electrodes usually makes up a channel. Since earlier times, it is known that the characteristics of EEG activity change in many different situations, particularly with the level of vigilance: alertness, rest, sleep and dreaming. The frequency of wave change can be labelled with names such as alpha, beta, theta and delta. Particular mental tasks also alter the pattern of the waves in different parts of the brain.

## 3. Experimental Results

This is a spectrogram analysis of EEG data. From the experimental results, it can be seen that there were many time-domain waveform pulse signal, but we cannot determine the frequency range, we also cannot rule out the interference caused by transient pulse. From the EEG signal spectrogram, it can be seen mainly in the 10 Hz or so, but still not make sure the exact range. Therefore, we calculated this spectrogram as shown in Fig. 4 and Fig. 5 to show transient pulses existing in the 0.9s to 1.1s and 1.4s to 2.0s. So we can better extract the pathological information from the transient pulse signal.

Following the results of wavelet de-noising analysis, four de-noising methods are used in this paper. Fig. 2, is original EEG waveform, in order to comparing with the filtered signals.

Wavelet de-noising is the most important aspect in signal processing. From Fig. 3, it can be seen that EEG signals largely restore the original shape, and obviously eliminates noise cause by interference. However, compared with original signal, the restored signal has some changes. This is mainly not appropriate to choose wavelet method and detail coefficients of wavelet threshold.

*Output:*
Sample
Gamma: Maximum occurs at 40.69 Hz.
Frequency Range of gamma is: 32Hz-100Hz
Beta: Maximum occurs at 22.56 Hz.
Frequency Range of Beta is: 15 Hz to about 30 Hz
Alpha: Maximum occurs at 17.437500 Hz.
Frequency Range of Alpha is: 7 Hz to 14 Hz
Theta: Maximum occurs at 5.187500 Hz.
Frequency Range of Theta is: 4 Hz to 7 Hz
Delta: Maximum occurs at 1.687500 Hz.
Frequency Range of Delta is 0.5-4 Hz
1.6875 epilepsy

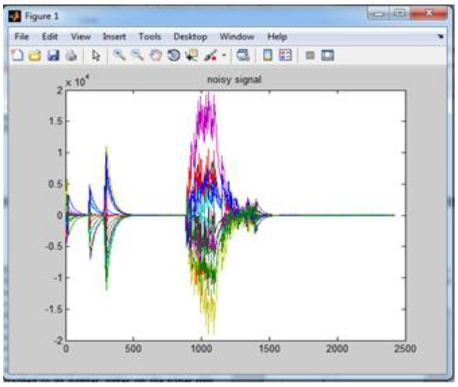


Fig. 2. Noisy signal

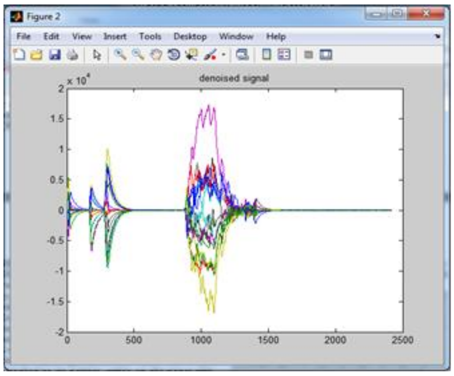


Fig. 3. Denoised signal

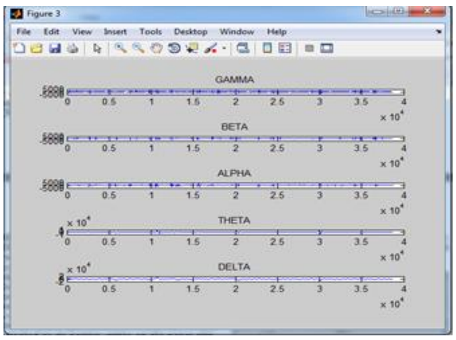


Fig. 4. Output-1

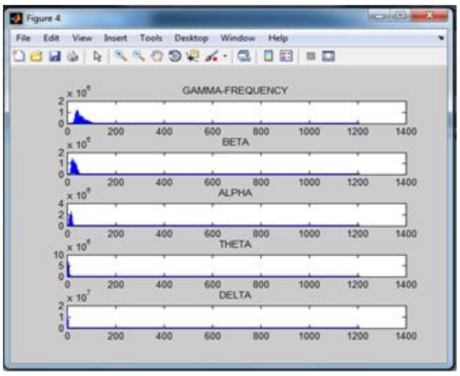


Fig. 5. Output-2

## 4. Conclusion

In this paper, time-frequency analysis toolbox function TFRSP is used in analysis spectrogram of EEG. As can be seen from the spectrum and spectrogram, analyzing spectrogram can be known the specific time period of useful transient information. Thus, it can be very easy to extract useful diagnostic information through the analysis of pathological in medicine. There are four de-noising methods, including wavelet de-noising, default threshold, hard threshold and soft threshold, wavelet de-noising is to choose wavelet function db5 and the level of decomposition-3. To ensure signal without distortion, it is better to choose wavelet de-noising and soft threshold de-noising. So, they are widely used in signal processing. Wavelet transform analyses the signals in both time and frequency domain and also signals with low noise amplitudes can be removed from the signals by selecting the best wavelet to decompose the signal. In wavelet transform we decompose only the low pass components of the signals.

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