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# A survey on different noise removal techniques of EEG signals

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ABSTRACT**: 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 lowvoltage 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. Variousnoise removal techniques are available and can be implemented in mat lab. The methods that are discussed in this paper are: ICA,PCA, WaveltTransform and WaveletPacketTransform. All the above methods can be implemented for EEG signal denoising.Various methods of denoising are studied and considering advantages and disadvantages of all the methods it is concluded that wavelet method of denoising and its enhancement wavelet packet is best.**

**Keywords**: **EEG, PCA, ICA, Wavelt Transform and Wavelet Packet Transform.**

## I. INTRODUCTION

Electroencephalography (EEG) signal is the recording of spontaneous electrical activity of the brain over a small period of time [1][2] The language of communication with the nervous system is electric.The neurons of the human brain process information, by changing the flow of electrical currents across their membranes. These changing currents generate electric and magnetic fields that can be recorded from the surface of the scalp by placing electrodes on the scalp [3]. The potentials between different electrodes are then amplified and recorded as the Electroencephalogram (EEG); which means the writing out of the electrical activity of the brain (that which is inside the head). EEG recordings therefore, complete knowledge aboutoverall activity of the millions of neurons in the brain. Brain is one of the most important organs of humans, for controlling the coordination of human muscles and nerves. The EEG is the recording of brain's electrical activity. EEG is one commonly used non-invasive facility to investigate the intricacy of human brain. The EEG is used in the evaluation of brain disorders. It is also used to evaluate people who are having problems associated with brain. An EEG is also used to determine brain death.

The analysis of continuous EEG signals is complex. Different types of EEG waves are categorized by the frequency namely Alpha waves (7.5-14 Hz), Beta waves (14-40 Hz), Gamma waves (above 40 Hz), Theta waves (4-7.5 Hz), Delta waves (0.5-4 Hz)[2].All the waves represents different mental states of the patient.

EEG signals are having very small amplitudes and because of that they can be easily contaminated by noise [3][4]. The noise can be electrode noise or can be generated from the body itself. The noises in the EEG signals are called the artifacts and these artifacts are needed to be removed from the original signal for the proper analysis of the EEG signals [5]. The various types of noises that can occur in the signals during recordings are the electrode noise, baseline movement, EMG disturbance and so on [5]. We need to remove these noises from the original EEG signal for proper processing and analysis of the diseases related to brain.

Various denoising techniques have been implemented for removal of the artifacts from the EEG signals . Some of the techniques that can be used for the noise removal areICA denoising [2] PCA method of denoising [4], Wavelet based denoising [5] , Wavelet packet based denoising and so on. All the above methods can be implemented for the denoising of the EEG signals and their performance evaluation can be done by measuring the parameters like SNR,PSNR,and MSE etc.

## II. MOTIVATION.

Electroencephalography (EEG) signals provide valuable information to study the brain function and neurobiological

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disorders. But EEG recordings are contaminated by various types of noises which creates problems in the proper analysis of the brain signals. As the EEG recordings of patients are very important for analysing any kind of diseases related to brain so it is necessary to remove these noises from the signals and various approaches for removal or suppression of the noise will be help full in analysing the signals in a proper manner. The EEG recordings too contain that data in which it becomes difficult to find out the noisy signals as the voltage level is considered while checking the waveforms and to detect any ellepsy in the patients .Because of this it becomes necessary to remove noise from the EEG signals. The problem also comes in the data base collection of the various patients. Various artifacts such as the blinking of eyes , ocular artifacts , movement of eyeballs extra create noise and so to detect such noises becomes difficult. So because of all the reasons mentioned above becomes very necessary to implement various denoising methods to make the EEG signals free from noise.

## III. DIFFERENT METHODS FOR EEG SIGNAL DENOISING.

The various methods of denoising that can be implemented for removal of noise available in the EEG signals are discussed below.

### *A. PCA based denoising.*

Principal component analysis (PCA) involves a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number Of uncorrelated variables called principal components[4]. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. Principal components are guaranteed to be independent only if the data set is jointly normally distributed. PCA is sensitive to the relative scaling of the original variables. Depending on the field of application, it is also named the discrete Karhunen–Loève transform (KLT), the Hotelling transform or proper orthogonal decomposition (POD). The mathematical technique used in PCA is called Eigen analysis: we solve for the Eigen values and eigenvectors of a square symmetric matrix with sums of squares and cross products. The eigenvector associated with the largest Eigen value has the same direction as the first principal component. The eigenvector associated with the second largest Eigen value determines the direction of the second principal component. The sum of the Eigen values equals the trace of the square matrix and the maximum number of eigenvectors equals the number of rows (or columns) of this matrix.[6].

PCA is sensitive to the scaling of the variables. If we have two variables and they have the same sample variables and are positively correlated, then the PCA will tend to rotate by 450 and the loadings for the two variables with respect to the principal components will be equal .PCA is mathematically defined as an orthogonal linear transformation that transforms the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on[6][7].

### *B.ICA based denoising*

Another important approach for denoising the EEG signal is the ICA method of denoising. An ICA based denoising method has been developed by Hyvarinen and his CO-workers[8][9] **.** The basic motivation behind this method is that the ICA components of many signals are often very sparse so that one can remove noises in the ICA domain. The ICA model assumes a linear mixing model x= AS, where x is a random vector of observed signals, A is a square matrix of constant parameters, and s is a random vector of statistically independent source signals. Each component of *s* is a source signal. Note that the restriction of A being square matrix is not theoretically necessary and is imposed only to simplify the presentation. Also in the mixing model we do not assume any distributions for the independent components.
Suppose we have *n* observedsignals xi where i= 1,,2….n from mixing m source signals yi, where,i=1,2,…….m we want to find such a transformation Matrix W that for a given number of dimensions d Y'=W*X, where Y' is a dx1 vector. The transformed variable yi is considered the component explaining the essential structure of the observed data. These components should contain as much as possible information of the observed data.[10][11]

ICA usually carries all the information in a single component and most of the times this component carries non- artifactual information which may lead to information loss . Also ICA performance depends on the dataset size. Another limitation which arose in this method is that the signals can be analysed only in time domain not in the frequency domain as the artifacts in EEG have a typical frequency range and are overlapped with the spectrum of the EEG data this becomes one of the disadvantage of this method [11].

### *C.WAVELET based denoising.*

The term 'wavelet' refers to an oscillatory vanishing wave with time-limited extend, which has the ability to describe the time-frequency plane, with atoms of different time supports Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. They represent a suitable tool for the analysis of non-stationary ortransient phenomena [12][13]. Wavelets

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are a mathematical tool, that can be used to extract information from many kinds of data, including audio signals and images. Mathematically, the wavelet , is a function of zero average, having the energy concentrated in time[14][15]:

$\int_{-\infty}^{+\infty} \varphi(t)dt = 0$( 1)

In order to be more flexible in extracting time and frequency information's, a family of wavelets can be constructed from a function (t), also known as the 'Mother Wavelet', which is confined in a finite interval. 'Daughter Wavelets', are then formed by translation with a factor u and dilation with a scale parameter s:$\varphi u, s(t) = (1/\sqrt{s})$* $\varphi$(t)(t-u)/s (2)

In wavelet denoising we decompose the signals in to high frequency components and low frequency components using the threshholding method and apply wavelet transform to the low frequency components.The two threshholding methods available are hard threshholding and soft threshholding. And then we select the best wavelet from the wavelet families which can best decompose the noisy signal and again we reconstruct the signals.The flow chart of the methodology that can be implemented is shown in the below figure[5].

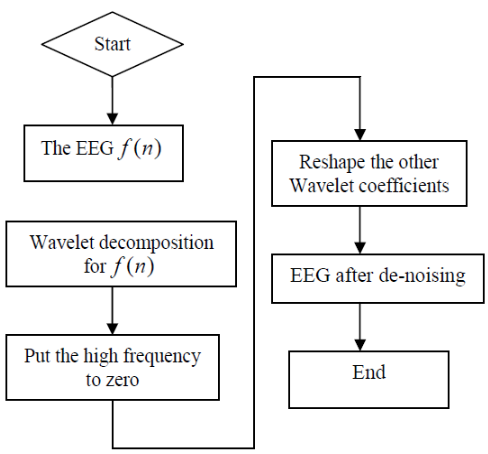


Fig. 1 Flow Chart for EEG denoising using Wavelet transform

*D. WAVELETPACKET based denoising.*

The wavelet transform is actually a subset of a far more versatile transform, the wavelet packet transform. Wavelet packets are particular linear combinations of wavelets. They form bases which retain many of the orthogonality, smoothness, and localization properties of their parent wavelets.[16]Wavelet transform is applied to low pass results (approximations) onlyFrom the point of view of compression, where we want as many small values as possible, the standard wavelet transform may not produce the best result, since it is limited to wavelet bases (the plural of basis) that increase by a power of two with each step. It could be that another combination of bases produce a more desirable representation. Wavelet packet transform is applied to both low pass results (approximations) and high pass results (details).The EEG signal can be decomposed in to both the high pass and the low pass components called the approximations and detail[17][18][19][20][21][22].

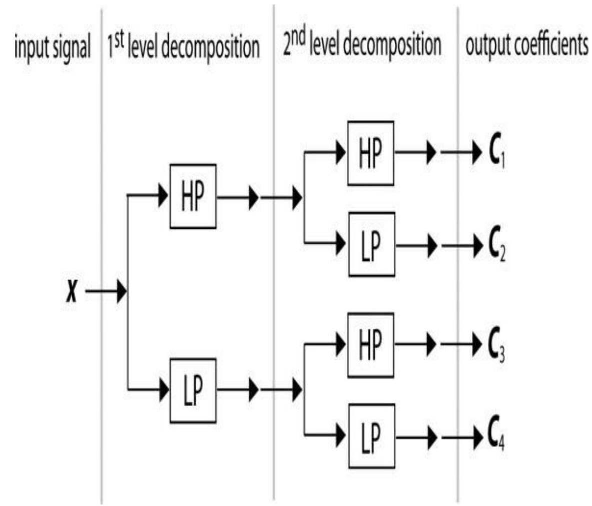


Fig. 2Stationary wavelet transformation and decomposition into stationarywavelet packets. LP and HP denote low-pass and high-pass filters,respectively.

Michal Kubinyi et.al in 2011 proposed wavelet packet denoising method which was implemented for EMAT noise suppression .The method was evaluated on signals measured with EMAT probes and under various SNR conditions; it outperforms the wavelet transform with the Stein unbiased risk estimate (SURE) threshold estimation method and split-spectrum processing (SSP). The results indicate SNR enhancement of 19 dB with real EMAT data.[22].

### III. CONCLUSION

Various denoising methods were studied for EEG denoising. The signals were denoised using PCA,ICA, and Wavelet method. It is known that signals with higher PSNR and SNR and low MSE are less noisy signals. By looking at the various evaluation parameters like MSE, PSNR, SNR calculated by different authors it is concluded that wavelet method gave the best denoising result with its multiresolutional capacities.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

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wavelet transform we decompose only the low pass components of the signals.Wavelet Packet transform was used for EMAT noise suppression which decomposes the signal in both low pass and high pass component and shown SNR improvement of 19 dB[22]. ICA method was based on the blind source separation and it could analyze the signals only in time domain the frequency components of the signal therefore could not be analyzed. In PCA method the correlated values are transformed in to uncorrelated smaller values called the principal components for signal denoising. The PCA and ICA can analyze the signal only in time domain and also PCA method depends on the size of data set of the signal which is to be denoised[23][24].

TABLE I

PERFORMANCE OF DIFFERENT DENOISING TECHNIQUES FOR DENOISING SIGNALS.

| S. No | Author | Year | Method | ParameterE valuated | Values |
|---|---|---|---|---|---|
| 1 | Majkowski | 2005 | PCA | MSE | 3.55e-004 |
| 2 | Lanlan Yu | 2009 | WT | SNR | 38.96 db |
| 3 | Suyi Li | 2009 | WT | SNR | 4.493 db |
| 4 | GirishaGarg | 2010 | WT | SNR | 26.872db |
| 5 | Janett Walters-Williams | 2011 | WT | MSE | 1.00e+03 |
| 6 | Janett Walters-Williams | 2011 | ICA | MSE | 2.50e+03 |
| 7 | Jannetwalters | 2012 | ICA | MSE | 1.66e+03 |

From the literature survey it is beinginferred that wavelets gave the best result for denoising .Till now only simple wavelet transform is implemented for EEG denoising in future its advancement wavelet packets can be used for denoising EEG signals which will give better results.

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## Biography

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