International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

Denoising of EEG Signals For Analysis of Brain Disorders: A Review

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Abstract - The Electroencephalogram (EEG) signal is a biological non-stationary signal which contains important information about various activities of Brain. Analysis of EEG signals is useful for diagnosis of many neurological diseases such as epilepsy, tumors, and various problems associated with trauma. EEG measured by placing electrodes on scalp usually has very small amplitude, so the analysis of EEG signal and the extraction of information from this signal is a difficult problem. EEG signals usually were contaminated with unwanted artifacts that may hide some valuable information in the signals. EEG signal become more complicated to analyze by the introduction of artifacts such as line noise, eye blinks, eye movements, heartbeat, breathing, and other muscle activities. Proper diagnosis of disease requires faultless analysis of the EEG signals. The problem of denoising is quite varied due to variety of signals and noise. Therefore this paper presents a review on denoising of EEG signals and concludes that discrete wavelet transform provides effective solution for denoising non-stationary signals such as EEG.

Key Words: epilepsy,tumors, artifacts, diagnosis,EEG.

1.INTRODUCTION

Epilepsy is a neurological disorder with prevalence of about 1-2% of the world's population (Mormann, Andrzejak, Elger & Lehnertz, 2007). It is characterized by sudden recurrent and transient disturbances of perception or behaviour resulting from excessive synchronization of cortical neuronal networks; it is a neurological condition in which an individual experiences chronic abnormal bursts of electrical discharges in the brain Monitoring brain activity through the electroencephalogram (EEG) has become an important tool in the diagnosis of epilepsy. Epileptic people are two or three times more likely to die prematurely when compared to a normal person. Hence, study of epilepsy has always been an utmost importance in the biomedical field of research.
Epilepsy is a chronic brain disorder, characterized by seizures, which can affect any person at any age. The epileptic seizures occur because of the malfunctioning of the electrophysiological system of the brain, which causes sudden excessive electrical discharge in a group of brain cells (i.e. neurons)present in the cerebral cortex. Involvement of cerebral cortex leadsto abnormalities of motor functions causing jerky (tonic-clonic) spasms of muscles and joints.

Feature extraction is a process whereby the relevant information or characteristics from the signal is extracted so that the features can be easily interpreted. Therefore, it is a substantial process in interpreting an input signal. The information extract reflects the physiology and anatomy of the activity going on within the brain. It involved a number of variables in a large set of data, which require a large amount of memory or powerful algorithm to analyze the data. In this context, feature extraction method is needed in order to resolve these variables or information to be interpreted in a simple and accurate way.

Some of the techniques that can be used for the noise removal are ICA 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 . The aim of the paper is to review the de-noising signal processing techniques for the removal of artifacts in EEG signals.

Section II describes about Brain waves and EEG signals. Section III describes literature survey. Section IV describes the various de-noising techniques .Section V presents the conclusion.

I. BRAIN WAVE AND EEG SIGNALS

The analysis of brain wave plays an vital role in diagnosis of different brain disorders. Brain produces electrical signals which can be detected using EEG which is measured by electrodes placed over the scalp. This technique is non-invasive as no surgery is required. The one of the biggest challenge in using EEG is the very small signal-to-noise ratio of brain signals which is contaminated by various noise sources or artifacts.

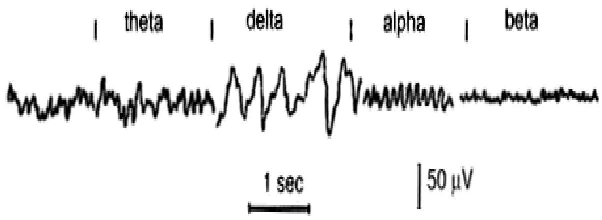

Figure 1: Various bands of EEG signal

The artifacts are caused by biological sources and external sources. The presence of artifacts in EEG signal attenuates the brain signals which could lead to misdiagnosis of brain disorder. Therefore the very first step in analyzing EEG signals is to remove the artifacts while enhancing the brain signals. Rejecting the artifacts may result in lose of data because EEG signals contain neural information below 100Hz frequency. The human EEG potentials are manifested as aperiodic unpredictable oscillations with intermittent bursts of oscillations which are typically categorized in specific bands such as 0.5-4 Hz (delta, δ), 4-8 Hz (theta, θ), 8-13 Hz (alpha, α), 13-30 Hz (beta, β) and >30Hz (gamma, γ).

Delta wave lies between the range of 0.5 to 4 Hz and the shape is observed as the highest in amplitude and the slowest in waves. It is primarily associated with deep sleep, serious brain disorder and in the waking state.

Theta wave lies between 4 and 8 Hz with an amplitude usually greater than 20 µV. Theta arises from emotional stress, especially frustration or disappointment and unconscious material, creative inspiration and deep meditation.

Alpha contains the frequency range from 8 to 13 Hz, with 30-50m µV amplitude, which appears mainly in the posterior regions of the head (occipital lobe) when the subject has eyes closed or is in a relaxation state. It is usually associated with intense mental activity, stress and tension. Alpha activity recorded from sensorimotor areas is also called mu activity.

Beta is in the frequency range of 13 Hz-30 Hz. It is seen in a low amplitude and varying frequencies symmetrically on both sides in the frontal area. When the brain is aroused and actively engaged in mental activities, it generates beta waves

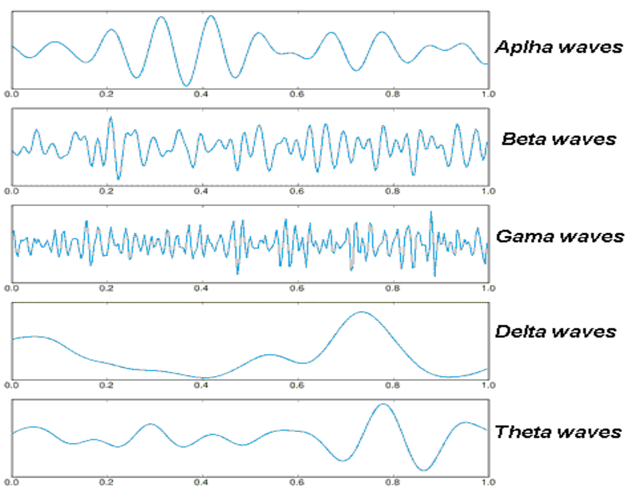

Figure 2: Example of different types of normal EEG rhythms

II. LITERATURE SURVEY

Electroencephalography (EEG) signals provide valuable information to study the brain function and neurobiological disorders. EEG signals recorded contains are contaminated by various noises which makes the signals analysis difficult. Therefore it is necessary to remove these noises from signals. The problem may also come in the database collection of patients. Different artifacts such as blinking of eyes, ocular artifacts, movements of eyeball create additional noise and hence becomes difficult. The various techniques and methods have been proposed to denoise the EEG signals.

Jeena Joy et al. [1] presented a comparative study of different denoising techniques. The denoising process rejects the noise by threholding in wavelet domain. Discrete Wavelet Transform has the benefit of giving a joint time-frequency representation of the signal and suitable for both stationary and non-stationary signals and is the most suitable method for signal detection. Discrete Wavelet Transform is a multiresolution analysis and provides effective solution.

Janett Walters-Williams et al. [2] proposed a new method for denoising artifacts in mixed EEG signals. To remove these artifacts the information theoretic concept of mutual information estimated using B-Spline was used for creating an approach for Independent Component Analysis (ICA) and tests showed that B-Spline Mutual Information Independent Component Analysis (BMICA) performs better.

Eleni Kroupi et al. [3] performed a comparative study on the performances of two methods namely, subspace projection and adaptive filtering using two measures mean square error (MSE) and computational time of each algorithm. ICA (independent component analysis) methods appear to be most robust but not the fastest one. Hence, they could be easily used for off-line applications. PCA (principal component analysis) is very fast but is less accurate so it could be used for real-time applications. Adaptive filtering appears to have worst performance in terms of accuracy but it is very fast.

Muhammad Tahir Akhtar et al. [4] proposed a framework based on independent component analysis and wavelet denoising to improve the preprocessing of EEG signals and employed a concept of spatially-constrained ICA (SCICA) to extract artifact only independent components (ICs) from EEG recording, used wavelet denoising to remove any bran activity from extracted artifacts and finally project back the artifacts to be subtracted from EEG signals to get clean EEG signal.

V.V.K.D.V.Prasad et al. [5] introduced a new thresholding filter for purpose of thresholding in denoising EEG signals using wavelet packets. Wavelet packets have been found to be effective in denoising of biological signals. Wavelet based denoising methods employ hard and soft thresholding filters for denoising the signals.

Haslaile.Abdullah et al. [6] proposed wavelet based image processing techniques known as 1-D Double Density and 1-D Double Density Complex for denoising EEG signals at various window sizes nad performance is compared and evaluated using Root Mean Square Error(RMSE).1-D Double Density Complex was outperformed 1-D Double Density and was effective in EEG signal denoising.

Geeta Kaushik et al. [7] describes the method of wavelet transform for the processing and analysis of biomedical signals.One of the most important applications of wavelets is removal of noise from biomedical signals and is called denoising which is accomplished by thresholding wavelet coefficients in order to separate signal from noise A biomedical signal is a non-stationary signal whose frequency changes over time and for the analysis for these signals Wavelet transform is used.

P.Ashok Babu et al. [8] proposed wavelet based threshold method and Principal Component Analysis (PCA) based adaptive threshold method to remove the ocular artifacts.In comparison to the wavelet threshold method, Principle component analysis based adaptive threshold method will give better PSNR value and it will decreases the elapsed time.

Patil Suhas S. et al. [9] discussed that denoising of EEG signals is performed using wavelet transform that are acquired during performing different mental tasks. Appropriate analysis of EEG signal requires the elimination of noise due to facial muscle movements, eye blinking ,heartbeats etc. The problem of denoising is varied due to variety of signals and noise. The results are evaluated using the signal-to-noise ratio of the denoised signals.

Priyanka Khatwani et al. [10] concludes that wavelet method of denoising and its enhancement wavelet packet is best. various techniques that can be used for noise removal in EEG signals are discussed. As EEG signal is contaminated by various type of noises so to diagnose various brain related diseases ,the signal should be free from noise.

Weidong Zhou et al. [11] introduced methods of wavelet threshold denoising and independent component analysis (ICA). ICA is novel signal processing technique based on higher order statistics and is used to separate independent components from the measurements. The extended ICA method does not need to calculate high order statistics. The experiment results indicate the electromyogram (EMG) and electrocardiograph (ECG) can be removed by a combination of wavelet threshold denoising and ICA.

The above various methods have been discussed and hence its is necessary to denoise the EEG signal effectively and We need to remove these noises from the original EEG signal for proper processing and analysis of the diseases related to brain. Therefore in this paper different methods and techniques are discussed for the removal of noise.

III. Different Methods For EEG Signal Denoising

The various methods of denoising for the removal of noise in EEG signal are

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.[2].

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[2][13] . 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.

C.WAVELET based De noising.

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. Wavelets 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

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. Wavelet transform is applied to low pass results (approximations) only From 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.

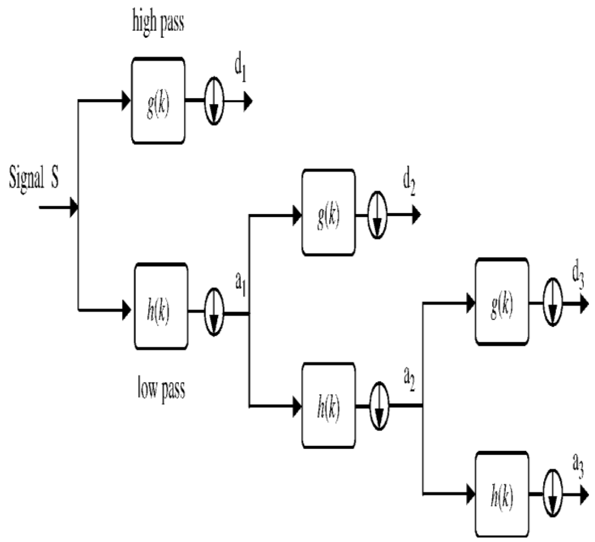

Figure 3: Block Diagram Representation of wavelet Denoising as Combination of Filter Banks

IV. CONCLUSION

Wavelet transform, compared to Fourier transform, has obvious advantages. Using wavelet transform for signal de-noising processing will reduce noise while improving SNR. Various methods have been studied for denoising of the EEG signal. 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 It is known that a denoised signal has high PSNR,SNR and low MSE .By taking into account various performance measures like SNR, PSNR, SDR, SIR calculated by various authors it is concluded that Wavelet based denoising gives better results.

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