Review On Different Artifact Removal Techniques

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Abstract- *EEG is a medical imaging technique that records the electrical activity of the brain. It is mainly used for the diagnosis of neurological disorder which is characterized by sudden and nonstop firing in the brain. When EEG signals are contaminated by non-neuronal signals then these contaminations are called artifacts. Several methods and techniques have been reviewed in this survey paper to remove these artifacts automatically as well as manually. The methods discussed in this paper are ICA, WICA, AWICA and wavelet transform. Considering all the given method it is concluded that wavelet transform is the best method.*

Keywords- EEG, ICA (Independent component analysis), AWICA (Automated Wavelet independent component analysis) and Wavelet transform.

I. INTRODUCTION

Electroencephalogram (EEG) analysis is the most challenging field in biomedical engineering and psychophysiological research. It is a medical imaging technique which is used to archive the electrical activities of brain through electrodes placed over scalp using internationally recognized standards. It is often employed for the diagnosis of various brain conditions like location of epileptic activity, analyzing sleep disorders, neurological infections, dementia etc. [1]. Generally 10-20 system is employed forelectrode arrangement in EEG. Various others internationally recognized arrangement systems include 5 -10 electrode system for recording EEG signals [2].EEG signal is characterized by mainly five rhythm waveforms viz delta (0-4Hz), theta (4-7 Hz) alpha (7-12 Hz), beta (13-30 Hz) and gamma (>30 Hz) as shown in fig 1[3]. An automated system for analysis of EEG signal has merits such as low cost, non-invasion, high temporal and spatial resolution.

The efficiency of such system gets severely affected by the quality of input signal. Normally EEG signal get interfered by various non-neuronal signals. These signals are termed as “artifacts” in literature. These artifacts may be biological or non-biological in nature. Biological artifacts are such as eye blinking and eyemovements (EOG) known as ocular artifacts, Muscles artifacts (EMG), and Cardiac artifacts (ECG).The waveforms of these artifacts are shown in figure 2. Every automated system used for classification of disease uses pre-processing stage at the front-end of system. Pre-processing system is designed to remove artifacts from the EEG signal, and hence improve the overall efficiency of the classifier. Various artifact removal techniques exist in literature. This paper is aimed to review various existing denoising techniques. This paper is organized as follows: section 2 represents the standardized database. Section 3 describes denoising techniques or methods. Discussion of the survey is described in section 4. Finally the paper is concluded in section 5.

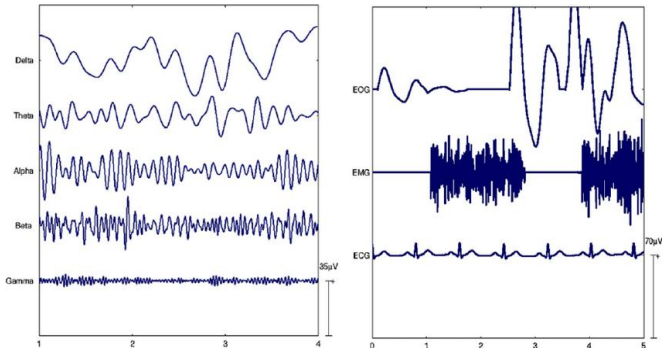

Fig1: Five normal brain rhythms and Different artifacts waveforms [4]

II. EEG DATA BASE

Many standardized databases exist for analyzing the performance of Automated EEG system namely CHB-MIT database, MMG database and EHG databases [5] .CHB-.MIT database is used in epileptic or non-epileptic seizure detection [6]. MMG (Magnetomygraphic) database provides methods for the prediction of labor [7]. Despite of wide availability of databases, researchers working over artifact removal techniques, face difficulty while evaluation of such techniques. Sweeney et. al. [8] resolved the issue and proposed methodology to validate artifact removal techniques. Improvement in SNR and correlation parameters of EEG signal can be considered for analysis of technique, however it require knowledge of original i.e. noiseless signal and noisy signal both. Motion artifact contaminated FNIRS & EEG data [8], is a database available at Physiobank, having data collection of fNIRS (function near-infrared spectroscopy) and EEG signals. It provides 23 trials of two channel recording of EEG signals. One of these channels, provide the ground truth or noiseless signal. So, with the knowledge of noiseless signal

and noisy signal contaminated by motion artifact, artifact removal techniques can be analyzed. Both channels are sampled at 2048 Hz.

III. DENOISING TECHNIQUES

A. Filter Based Technique

a) Adaptive filtering:EEG signal possesses overlapping spectra so that the conventional filters do not give optimized performance, and hence, adaptive filtering technique is used. It adjusts its parameters according to the selected features of the signals being analyzed. When the input signal is given into adaptive filter, the coefficients will adjust themselves to obtain desired results of the linear filter, and then its frequency response will generate a signal which is similar to noise component present in the signal to be removed. SNR for EEG data it is 5.1 dB [12].

b) Kalman filtering: Kalman filter is based on the linear quadrature estimation algorithms which use a series of measurements. It implements a mathematical predictor corrector type estimator that uses feedback control to estimate a process. Firstly it estimates the process state at a time and then obtains feedback in the form of noisy measurement. Unlike the adaptive filter, it does not need any reference signal to be capable of removing the contaminating artifact. Artifacts are easily removed but sometimes the physiological information can be lost [13].

c) Wiener filtering: Wiener filters are linear least square estimators for stationary stochastic process. It does not tell how to estimates statistics if the interference and signal of interest are Gaussian then wiener filter is optimal.It requires large no of computation i.e. complexity and the cost of the system is going to increase [14].The minimization is done using an estimation of the power spectral density of the signal and its artifacts. Hence it does not need a reference signal. The main disadvantage is that it needs to be calibrated before usage. It gives better SNR compared to kalman filter because it is able to filter out the more noise compared to the Kalman filter because higher the SNR means better artifact removal filtering shown in table 1.

B. Wavelet based techniques

a) Wavelet transform: Limitations of STFT are overcome by introducing wavelet transform. It decomposes a time varying signal into sets of basis function called wavelet [15]. These basis functions known as wavelets are obtained by performing dilations and shifting of the mother wavelet as shown by equation 1. Different wavelets like db4, haar, sym3, coif3 etc. are used for different parameter according to requirement [16]. Wavelet transform can be applied to any single channel EEG data to remove ocular artifact without information from any

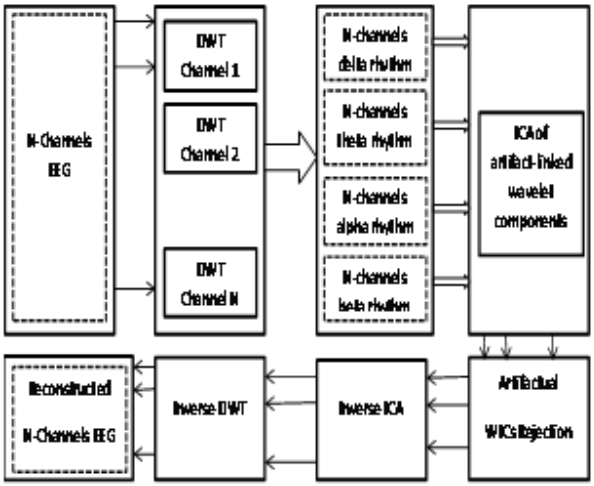

Fig 4: Block diagram of Wavelet ICA for EEG artifact rejection

other EEG or EOG channels. The advantage of this method is that it allows a more precise local description and separation of signal characteristics.

$〚 Ψ〛_{(a,b)}(t)=Ψ((t-b)/a)$ (1)

Where a is the scaling parameter and b is the shifting parameter.

C. Blind source separation Techniques

a) ICA (Independent component analysis):ICA is selected based on the removal of the different artifacts which are overlapped with the different rhythms.Independent component analysis is generally used for feature extraction and source separation [17]. It decomposes the mixed signals into independent one. This gives better separation based on two main assumptions: one of assumption is that the source signals are not dependent on others and second assume that each source signal is having non-Gaussian distribution. This technique is based on high order statistical mostly used to separate the independent component from the measured signals [18]. ICA operates in time domain but sometimes the valuable information can be lost. This is the main limitation of the ICA. Its performances depend on size of samples and the algorithms might not be able to separate the artifactual component from the rest of the signal. ICA has been mainly used in feature extraction, and blind source separation with prominence on physiological signals. It is mainly used in removing ocular artifacts.

b) PCA (Principal component analysis): This method involves mathematical procedure which converts a number of correlated variables into a smaller no of uncorrelated variables called principal components [19]. This method is very sensitive to the relative scaling of the original variable. PCA may be useful for the certain types of artifacts in the various contaminations. The main problem is that it is unable to separate some artifactuals components from brain signals especially when they have similar amplitude [20]. The maindisadvantage of this method is that it is not able to remove the ocular artifacts completely

C) Hybrid Based Techniques

a) WICA: It is based on the joint use of DWT & ICA. However this method is not automatic but the useris required toselect the wavelet components to be processed by ICA. If there are a large no of sources than ICA is not sufficient so it is merge with wavelet transform. Signal reconstruction without artifact components was performed to obtain artifact-free signals.

The first block in figure 4 separate the original dataset into four major ranges of brain activities. After that the data is load into an n-dimensional space where ICA is performed. The basis of n space is the no of level of decomposition that will depend on the wavelet family. Firstly the raw data has to be fall on the n dimensional space then it is linked with the wavelet component selected for ICA. Then inverse ICA has been performed by multiplying the unmixing matrix so that wavelet components are reconstructed without the artifact. Then wavelet reconstruction is performed in order to reconstruct the clean EEG recordings [21].

b) AWICA: AWICA (automatic wavelet independent component analysis) is effective for real time assessment and it takes less time and performance is improved [22]. Automatic artifact rejection is needed for effective real time inspection because manual rejection is time consuming.It is fully automated method. This method merge the advantage of adaptive wavelet decomposition and independent component analysis. It is optimized for EEG signals. The first level is decomposed DWT which divides the original dataset in four major band then each rhythms is represented by wavelet component then it is passed through ICA in order to concentrate the arti-factual events in few independent components. It preserves the cerebral activity and having good suppression performance. The main advantage is that it improves the quality of separation and artifact removal.

IV. DISCUSSION

The objective of the different methods for the artifact removal is to study that which method is best and how these methods are to be implemented. Table 1 lists some of the work reported by the researchers. Kalman filter, Adaptive filter and wiener filter are compared based on the SNR. It shows that Wiener filter technique gives the best SNR because it is able to filter out the noise component completely. Blind source techniques give the details about the component based method like ICA, PCA. ICA is based on the second order statistics thod which used to separate the independent component. PCA attempts to find uncorrelated source whereas ICA attempts to find independent source. Hybrid based techniques like

WICA and AWICA is able to remove the artifacts automatically. The main advantage of AWICA over WICA is that it improves the quality of the separation and artifact removal.

TABLE 1

Filtering techniques	Algorithm used	DATA	SNR
Adaptive filter	LMS(Least mean square) algorithms	EEG	5.1 dB
Wiener filter	Linear time in variant methods	EEG	5.3 dB
Kalman filter	LQE(Linear quadratic estimation)	EEG	9.7 dB

V. CONCLUSION

EEG artifacts can easily be removed by using several techniques. This paper gives detailed information regarding the different artifact removal techniques. Each method has its own advantage and disadvantage. Recent advancements and algorithms used at each stage are reviewed giving a clear bird view to someone new to this field.

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