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ARTIFACT REMOVAL FROM EEG RECORDINGS – AN OVERVIEW

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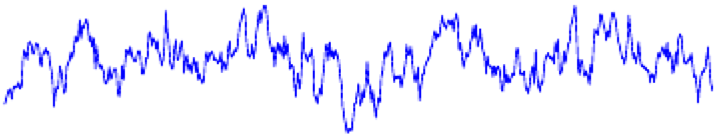
Abstract: Electrical impulses generated by nerve firings in the brain diffuse through the head and can be measured by electrodes placed on the scalp, is known as electroencephalogram (EEG) and was first measured in humans by Hans Berger in 1929. The EEG gives a coarse view of neural activity and has been used to non-invasively study cognitive processes and the physiology of the brain. The analysis of EEG data and the extraction of information from this data is a difficult problem. This problem is exacerbated by the introduction of extraneous biologically generated and externally generated signals into the EEG. EEG data is used for development of brain-computer interfaces (BCIs). A brain-computer interface has been defined as a "communication system that does not depend on the brain's normal output pathways of peripheral nerves and muscles" [1]. A BCI system allows users, typically people with motor disabilities, to communicate, via a computer, through their EEG signals. To increase the effectiveness of BCI systems it is necessary to find methods of increasing the signal-to-noise ratio (SNR) of the observed EEG signals. In the context of EEG driven BCIs, the signal is endogenous brain activity measured as voltage changes at the scalp while noise is any voltage change generated by other sources. These noise, or artifact, sources include: line noise from the power grid, eye blinks, eye movements, heart beat, breathing, and other muscle activity. Some artifacts, such as eye blinks, produce voltage changes of much higher amplitude than the endogenous brain activity. In this situation the data must be discarded unless the artifact can be removed from the data. The present paper gives overview of different techniques for artifact removal.

1.INTRODUCTION

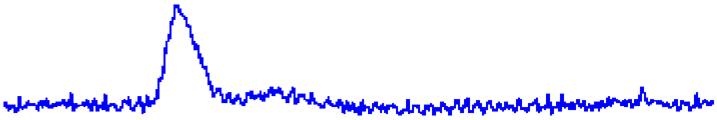
The electroencephalogram (EEG) was first measured in humans by Hans Berger in 1929. Electrical impulses generated by nerve firings in the brain diffuse through the head and can be measured by electrodes placed on the scalp, & is known as electroencephalogram (EEG). The artifacts, such as eye blinks etc, in EEG recordings obscures the underlying processes and makes analysis difficult. Large amounts of data
must often be discarded because of contamination by artifacts. To overcome this difficulty, signal separation techniques are used to separate artifacts from the EEG data of interest. The noise, or artifact, sources include: line noise from the power grid, eye blinks, eye movements, heart beat, breathing, and other muscle activity. Some artifacts, such as eye links, produce voltage changes of much higher amplitude than the endogenous brain activity. In this situation the data must be discarded unless the artifact can be removed from the data. The maximum signal fraction (MSF) transformation is an alternative to the two most common techniques: principal component analysis (PCA) and independent component analysis (ICA). A signal separation method based on canonical correlation analysis (CCA) is also used. The method of delays is used as a technique for dealing with non-instantaneous mixing of brain and artifact source signals.

2. ARTIFACTS

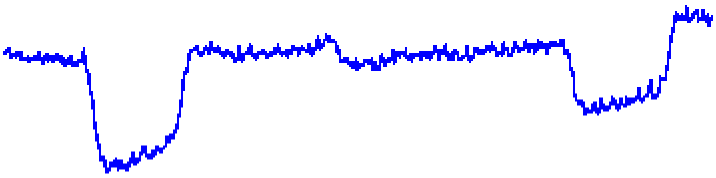
EEG data may be contaminated at many points during the recording and transmission process. Most of the artifacts are biologically generated by sources external to the brain. Improving technology can decrease externally generated artifacts, such as line noise, but biological artifact signals must be removed after the recoding process. Figure 1 shows waveforms of some common EEG artifacts.



(a)



(b)



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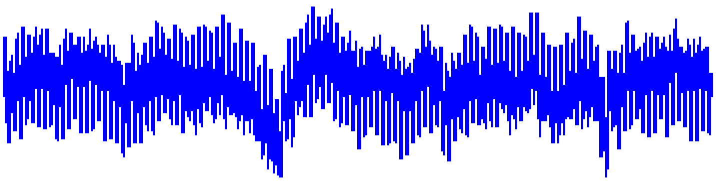

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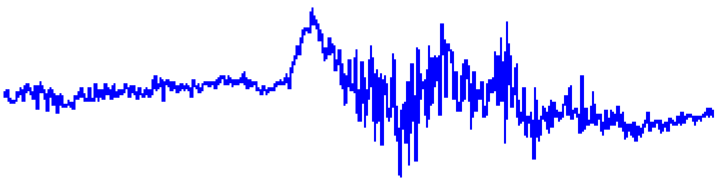
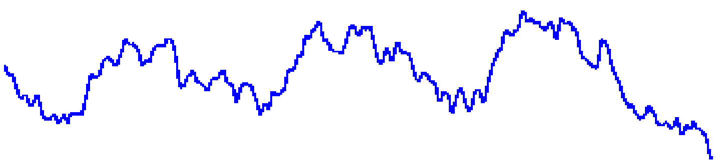


(e)



(f)

Figure 1 (a) Clean EEG, (b) Eye blink, (c) Eye movement, (d) 50 Hz, (e) Muscle activity, (f) Puse.

i)Eye Blink artifact: It is very common in EEG data, produces a high amplitude signal that can be many times greater than EEG signals of interest. Because of its high amplitude an eye blink can corrupt data on all electrodes, even those at the back of the head. Eye artifacts are often measured more directly in the electrooculargram (EOG), pairs of electrodes placed above and around the eyes. Unfortunately, these measurements are contaminated with EEG signals of interest and so simple subtraction is not a removal option even if an exact model of EOG diffusion across the scalp is available [2]

ii) Eye Movement: These artifacts are caused by the reorientation of the retinocorneal dipole [3]. The effect of this artifact is stronger than that of the eye blink artifact. Eye blinks and movements often occur at close intervals.

ii)Line Noise: Strong signals from A/C power supplies can corrupt EEG data during transfer from the scalp electrodes to the recording device. Notch filters are often used to filter this artifact containing lower frequency line noise and harmonics. Notch filtering at these frequencies can remove useful information. Line noise can corrupt the data from some or all of the electrodes depending on the source of the problem.

iv) Muscle Activity: These artifacts are caused by activity in different muscle groups including neck and facial muscles. These signals have a wide frequency range and can be distributed across different sets of electrodes depending on the location of the source muscles.

v)Pulse. When an electrode is placed on or near a blood vessel, it causes pulse, or heart beat, artifact. The expansion and contraction of the vessel introduce voltage changes into the recordings. The artifact signal has a frequency around 1.2Hz, but can vary with the state of the object. This artifact can appear as a sharp spike or smooth wave [4].

3. A SURVEY ON ARTIFACT REMOVAL TECHNIQUES

Artifacts in EEG are commonly handled by discarding the affected segments of EEG. The simplest approach is to discard a fixed length segment, perhaps one second, from the time an artifact is detected. Discarding segments of EEG data with artifacts can greatly decrease the amount of data available for analysis. EEG data collected from children is especially problematic in this respect [10]. The first attempts at removing artifacts focused on eye blinks. Regression using the EOG channel was attempted in the time and frequency domain [12, 11, 20, 24, 25]. These methods all rely on a clean measure of the artifact signal to be subtracted out. Since the EOG is contaminated with EEG signals, the regression of ocular artifacts has the undesired effect of removing EEG signals from the observations. A good reviw can be found in [8, 9].

Kenemans et al. [14] gave a general lagged regression model. Jung et al. [2] used this regression model for a baseline artifact removal method. Multivariate statistical analysis techniques, such as principal component analysis, have been used to separate and remove noise signals from the brain activity of interest [5, 16, 2, 13, 17, 7, 20]. Comparisons of artifact removal using different transformations can be found in [26, 22]. Comparison of four methods for artifact removal by artificially mixing an artifact signal from one subject with a set of EEG signals from another subject is given in[22]. The artificial mixing matrices were chosen to approximate mixing in the scalp. Two independent component analysis methods studied in [6], were significantly better than principal component analysis and simple EOG subtraction. Performance was measured using the mean squared error between the true artifact signal and the extracted artifact signal. Significance was measured using an F-statistic and Tukey's studentized range test [22]. However artificially mixing a signal from one subject with those of another subject can not approximates the actual circumstances of artifact contamination of EEG.

The common spatial patterns (CSP) technique, which requires the use of two data sets was used by Koles [15] to remove abnormal Components, It uses data from 80 patients. No quantitative evaluation was done on the removal but it was visually observed that the artifacts were extracted into a small number of components that would allow their removal. In online filltering systems, artifact recognition is important for achieving their automatic removal. One approach to recognition of noise components is based on measuring structure in the signal. The fractal dimension and a metric based on auto-regressive (AR) coefficients have been used for this purpose [7, 21].

Eye blinks and heart beats were found to have consistent fractal dimensions on the data studied [21]. Jung [2] suggests that the spectral structure might be distinct for certain artifact components (e.g., line noise) and that this would allow for automatic removal of these artifacts. Kalman filters and extended Kalman filters have also been used for artifact detection with success depending heavily on the artifact type [19, 18]. This approach was most successful at recognizing one second windows containing muscle and movement artifacts. The common signal separation approaches to artifact removal are: principal components analysis, maximum signal fraction analysis, canonical correlation analysis, and independent component analysis.

4. EEG DATA COLLECTION

EEG is most commonly recorded according to the international 10-20 electrode placement system shown in Figure 2 [29]. The 10-20 system was developed to standardize the collection of EEG and facilitate the comparison of studies performed at different laboratories. When only a few channels of EEG are collected the electrodes are placed at a subset of the sites.. The EOG channel generally consists of two electrodes referenced to each other. The recorded signal is obtained by subtracting a signal measured below the eye from one measured above the eye.

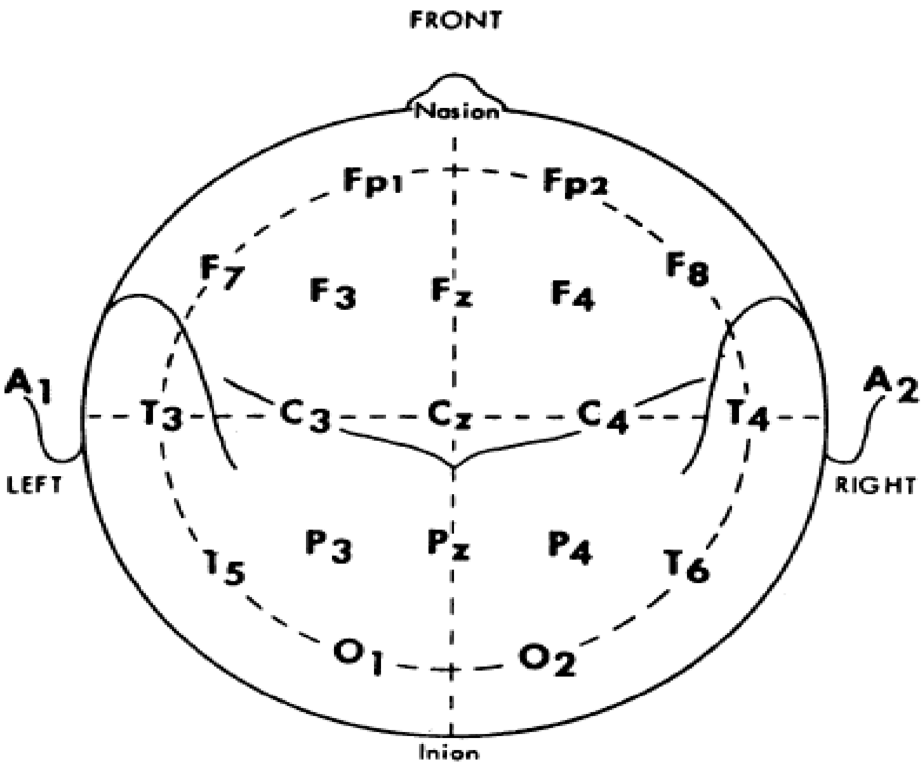


Figure 2: The International 10-20 electrode placement system

5. COMPARING ARTIFACT REMOVAL METHODS

Analysis of artifact removal is inherently difficult, because no truth is known by which methods can be compared. One validation criterion, originally proposed in [20], is that the EOG and the EEG should be uncorrelated. Croft and Berry [9] note that though this might serve as a guide, the true correlation between EEG and EOG is unknown, and so this cannot be a true validation measure. Nevertheless, considering these correlations can yield interesting information about the data.

The principal component analysis technique, or equivalently, the singular value decomposition (SVD), is limited in its signal separation capabilities by the simultaneous constraints of temporal and spatial orthogonality. For an artifact signal to be separated by the SVD, it must have high variance or it will be mixed with other components. For some large amplitude eye blinks this assumption may be met, but the SVD will generally not be successful at removing other lower amplitude artifact signals. The maximum signal fraction (MSF) transform enforces temporal decorrelation of the extracted components but only constrains the spatial patterns to forming an invertible matrix. The optimization criteria used to derive this technique allows the sorting of the transformed signals in order of decreasing signal-to-noise ratio. The ordering can be used to help automatically denoise signals since low signal-to-noise ratio components can be filtered out. Eye blink artifacts tend to have high signal-to-noise ratios and are generally the first or second component. The canonical correlation analysis (CCA) approach to signal separation requires that the signals to be separated have different 1-lag autocorrelation structures.

6. CONCLUSIONS AND FUTURE DIRECTIONS

The paper summarizes the overview of Artifacts and their removal in EEG Signals. Various techniques has been discussed for artifact removal. Authors are presently engaged in designing intelligent techniques for artifact removal and other Brain Computer interface related techniques such as classification of motor imagery etc. A survey on artifact removal techniques has been presented in this paper.

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