Master Thesis Proposal

Removal of Ocular Artifacts from EEG Recordings Using Eye Tracker Data

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Introduction

Eye movements and blinks are the main sources of artifacts in electroencephalogram (EEG). Eyes act like dipoles and when they move cause significant distortion in electrical potentials around the scalp. A method is needed to reduce or eliminate these artifacts without damaging that part of the signal which is related to brain activity. However, in many of the studies in which EEG is used, researchers cannot expect the subjects to stop moving their eyes. Many undeliberate eye movements and blinks are totally inevitable. Furthermore in many cases, eye movements themselves are part of the research. Therefore, removing ocular artifacts from EEG signals has a great significance in the research on brain activity.

Related Work

Many methods were used previously to achieve this goal, e.g. [1] suggested the regression analysis in frequency domain and used the frequency-dependent transfer function differences from Electrooculogram (EOG) to EEG. The disadvantage of this method is that it is conditional and is not useful in real-time applications. In [2], [3], it is suggested to use regression in time domain. But simple regression in time domain for artifact-removal leads to overcompensation of the blink artifacts and causes new artifacts in EEG records [4]. In [5] Independent component analysis algorithm (ICA) is used to separate the artifacts from EEG. In this method a linear representation of non-Gaussian data is found in such a way that the components be independent from each other. The limitation of this method is that if there is no clear information about the nature of the independent components, this method can lead to wrong results [6]. In [7] it is proposed to use an adaptive filter through wavelet transform. In this procedure Stationary Wavelet Transform is applied to the contaminated EEG and the reference EOG. In this process an adaptive filter with LMS algorithm is used. Another method is suggested by [8]. In this method Kalman filter is used along with RED eye tracker (made by SensoMotoric Instruments). Kalman filter can be used to estimate changes in a system in which there is some prior knowledge about noise and the system itself. Kalman filter minimizes the mean squared error of the parameters in a given system. In [9] it is suggested to use an adaptive filter and a high-speed eye tracker as a reference. In this study different types of eye-movements are tested which are categorized based on the speed and the direction of the movements.

Removing Ocular Artifacts Using High-Speed Eye Tracker

Removing ocular artifacts from EEG is always problematic since it is possible that some small but useful information related to brain-activity be removed from EEG signals. Both brain activity and eye movements change the electrical potentials on the scalp. Therefore, the recorded EEG signal is a combination of ocular and brain-related components. In this thesis the data from eye tracker will be used to remove these artifacts. Using eye tracker data in artifact-removal from EEG signals has many advantages. An eye tracker system cannot be corrupted by any electrophysiological signals, and is only related to pure eye movements [10]. Eye-tracker detects the eyes of the subject and shows the gaze position. Therefore, it can clearly record horizontal or vertical eye movements. The idea is to remove the ocular artifacts using the gaze information taken from the high-speed eye tracker. Using eye tracker data as a reference, which is free from electrophysiological influences, is an effective way in artifact removal.

Using Adaptive Filters

Conventional filtering is not suitable to remove ocular artifacts from EEG because EEG signal and ocular artifacts have overlapping spectra [11]. Adaptive filters self adjust their transfer function according to optimization algorithm driven by error signal. Different configurations exist including noise cancellation, linear prediction and system identification [12]. Eye tracker data will be used as a reference for the adaptive filter along with the frontal EEG electrodes around the eyes. In the first step an interface is needed to record EEG and eye tracker data and synchronize them. In the next steps a kernel adaptive filter and an efficient procedure is needed to get to a maximum removal of the ocular artifacts from EEG signals. Kernel adaptive filters are linear filters in reproducing kernel Hilbert spaces. They learn from the network topology and adapt the free parameters from data simultaneously. The learning part is a combination of error-correction and memory-based learning [13]. A kernel adaptive filter can be a good substitute for the other types of the adaptive filters and has a great advantage because of simultaneous memory-based learning and adaptation.

Plan

1. Literature review about the previous research on artifact removal.
2. Investigating the limitations of EEG and eye tracker systems and how to overcome the problems regarding the recording and synchronization procedure.
3. Designing a program in Python to save and synchronize the data from EEG and eye tracker.
4. Literature review about kernel adaptive filter and its limitations and advantages.
5. Designing a paradigm for the experiment.
6. Implementing the filtering algorithms using pySPACE.
7. Implementing some previous methods to compare the results.
8. Recording data from different subjects.
9. Analyzing the results and enhancing the methods.
10. Comparing the results with the other methods
11. Writing up the master thesis.
12. Final presentation.

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