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Regressive and Blind Source Separation Techniques for Ocular Artifact Removal

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Several ocular artifact removal techniques for electroencephalographic data are evaluated in this paper. EEG recordings are taken from an emotion recognition experiment, which contains several instances of ocular artifacts like eye blinks and eye movements. The data is preprocessed through a Butterworth band-pass filter and a 60Hz notch filter to remove most electrical and high frequency noise. Once preprocessed, the data will be used to evaluate three different types of ocular artifact removal techniques: EOG based linear regression, Principal Component Analysis, and Independent Component Analysis. A new metric called Strength of Eye Blink (SEB) is created to automatically determine the removal of different components used in the Blind Source Separation techniques. Each technique is tested using two different metrics: Kurtosis, and a new metric called Zero-Mean Normalized Sum Squared Error. The new metric shows that Independent Component Analysis reduced eye artifacts, the best out of all methods while keeping uncontaminated EEG signals unchanged (Average SSE of 0.1126).

Keywords : Electroencephalography, Electrooculography, Eye Artifact Removal, Independent Component Analysis, Strength of Eye Blink

1. INTRODUCTION

ElectroEncephaloGraphic (EEG) research is a wide area of research that encompasses several signal processing techniques to describe psychological phenomena occurring deep inside the brain. As neurons in the brain fire, these electric potentials radiate towards the scalp, where electrodes can detect these potentials in an EEG recording. Based on the firing locations of the neurons and the timing of the firing with respect to a stimulus, spatio-temporal analysis of EEG signals can be done to analyze different regions of interest in the brain and determine. Since EEG recordings detect the diminutive activations in the brain, there also other sources of electrical potentials that corrupt the EEG signals detected from the brain.

Therefore, noise/artifact removal is an important area of study for EEG research. These different sources of noise and artifacts must be removed to ensure a clean EEG signal for extracting the most salient features of the EEG signal. A comparison between the recorded EEG and the ElectroCardioGram (ECG) by Dirlich et al., [1], show that cardiac field artifacts are high amplitude potentials which affect EEG performance. Dewan et al., [2] were able to remove these ECG-type artifacts by developing a noise model based on energy functions to subtract the noise from the recorded EEG. Muscle activations, such as jaw clenching and facial movements, are also potential sources of artifacts in the EEG. Narasimhan and Dutt [3] found that muscle artifacts hidden in EEG potentials can be removed by least mean squared adaptive predictive filtering. De Clercq et al., [4] found that using a blind source separation technique called Canonical Correlation Analysis proved to be better for muscular artifact removal than low pass filters and Independent Component Analysis. Ferdjallah and Barr [5] developed different types of adaptive FIR and IIR notch filters to remove power line noise in EEG signals. The noise/artifact removal research is most prevalent in the removal of

Table 3
Sum Squared Error for Each Eye Artifact Removal Technique on Different EEG Channels

Type	Linear	PCA	ICA
Chan 26	1.4446	1.8032	0.5175
Chan 126	0.5984	0.8326	0.0427
Chan 18	0.6726	0.7363	0.1541
Chan 15 (Fz)	1.2159	0.3673	0.1850
Chan 101 (Pz)	0.0159	0.0070	0.0060
Chan 137 (Oz)	0.8937	0.9815	0.0446
Chan 95 (T5)	1.5447	0.3671	0.0476
Chan 178 (T6)	1.2779	1.3803	0.0419
Chan 59 (C3)	0.7380	0.6239	0.0372
Chan 183 (C4)	1.2401	1.8705	0.0491
Average	0.9642	0.8970	0.1126

removing other types of artifacts. We also observed that Independent Component Analysis gave the best eye artifact removal by removing the artifacts from the EEG while maintaining the integrity of the EEG signal based on our new metric called Zero-Mean Normalized Sum Squared Error (Average SSE of 0.1126). This artifact removal technique is able to localize specific components that are generated by the eyes, in which our automated component selection criteria, called Strength of Eye Blink (SEB), defines a threshold by which these components are removed. Principal Component Analysis does remove eye artifacts using the automated component selection criteria but tends to remove other EEG components as well due to the components maximizing variance. The EOG based linear model also offers great artifact removal, but due to the EOG channels having some EEG components, the linear model affects the clean EEG portions. For future work, we will experiment with other types of artifact removal algorithms and develop new algorithms to improve the speed and accuracy of these techniques.

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