Removal of Ocular Artifacts From electro-Encephalogram by Adaptive Filtering and Independent Component Analysis

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Abstract- EEG is brain signal processing technique that allows gaining the understanding of the complex inner mechanisms of the brain and abnormal brain waves have shown to be associated with particular brain disorders. The analysis of brain waves plays an important role in diagnosis of different brain disorders. MATLAB provides an interactive graphic user interface (GUI) allowing users to flexibly and interactively process their high-density EEG dataset and other brain signal data different techniques such as independent component analysis (ICA) and/or time/frequency analysis (TFA), as well as standard averaging methods[4][5]. We will be showing different brain signals by comparing, analysing and simulating datasets which is already loaded in the MATLAB software to process the EEG signals. Unfortunately, EEG data is commonly contaminated by ocular artifacts which makes the analysis of neuronal data very difficult[2]. The focus of this research is the development of a novel technique that can automatically detect and remove eyeblink artifacts in order to facilitate analysis of EEG recordings. For this project we used EEGLAB matlab toolbox. By using this toolbox we have done the the simulation of our project.

Keywords- electro-encephalogram (EEG), electro-oculogram (EOG), EEGLB toolbox, magnetoencephalography (MEG).

I. INTRODUCTION

The Eye forms an electric dipole, where the cornea is positive and the retina is negative. When the eye moves (saccade, blink or other movements), the electric field around the eye changes, producing an electrical signal known as the electro-oculogram (EOG)[3][7]. As this signal propagates over the scalp, it appears in the recorded electro-encephalogram (EEG) as noise or artifacts that present serious problems in EEG interpretation and analysis. To correct or remove ocular artifacts from EEG, many regression-based techniques have been proposed, including simple time-domain regression, multiple-leg time-domain regression and regression in the frequency domain.

Figure 1. EEG electrodes placement and EOG(electro-oculogram) electrodes placement[3][7]
In all these regression-based approaches, calibration trials are first conducted to determine the transfer coefficients between the EOG channels and each of the EEG channels. These coefficients are then used later in the ‘correction phase’ to estimate the EOG component in the EEG recording for removal by subtraction. More recently, independent component analysis (ICA) has been proposed to separate the EOG signals from the EEG signals. This method requires off-line analysis and processing of data collected from a sufficiently large number of channels, and its success largely depends on correct identification of the noise components[10]. When the applications require real-time removal of ocular artifacts, or when the calibration trials cannot be conducted owing to various constraints, the methods described above become unsuitable. For example, researchers in our laboratory are developing methods for accessing a pilot’s functional state during flight, so that adaptive aid can be provided in the case of mental overload. In one of the approaches currently under investigation, spectral EEG information recorded at several sites over the scalp (e.g. Fz, F7, Fz, etc.) is used by a neural network to perform real-time classification of the pilot’s functional state. As the pilot’s activity is accompanied by a significant amount of eye movement, either voluntarily or involuntarily, EOG contamination is a serious problem in EEG-based analysis. In this paper, we describe a noise cancellation method based on adaptive filtering to remove ocular artifacts from EEG[1][7]. This method is particularly suitable to our applications because it does not require calibration trials, and the EOG artifacts can be removed on-line. Previous studies have shown that there are at least two kinds of EOG artifact to be removed: those produced by the vertical eye movement (the corresponding EOG is called VEOG) and those produced by the horizontal eye movement (HEOG). Consequently, a noise canceller with two reference inputs is used in this application[3].

II. SYSTEM AND ARCHITECTURE

In this section we provide details description about hardware and software of our system. In our system we use different device for sensing, wireless transmission of signal and controlling.

2.1 Principle of removing EOG artifacts by adaptive filtering:

In conventional adaptive noise cancellation systems, the primary input signal is a combined signal \( x(n) + i(n) \) where \( x(n) \) represents the “clean” (unavailable) signal and \( i(n) \) is the interference. We assume the availability of a reference signal \( r(n) \) assumed to be correlated with \( i(n) \). The goal is to obtain an output signal \( e(n) \) that is the residual after subtracting from \( x(n) + i(n) \) the best least squares estimation of \( i(n) \), \( \hat{i}(n) \). The proposed artifact removal method comprises two steps.[1]

![Figure 2. General scheme of automatic EOG noise cancellation using adaptive filtering and ICA. Processing of signal from sensor “m” is shown, this scheme has to be run M times in parallel to process all EEG data by Automatic Removal Of Ocular Artifacts From Eeg Data Using Adaptive Filtering And Independent Component Analysis Carlos Guerrero-Mosquera, Angel Navia Vazquez University Carlos III of Madrid, Signal Processing and Communications Department Avda. Universidad, 30 28911 Leganes. Spain[1]](image)

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First, ICA projections are obtained for EEG data (W matrix in $S'=WX$) and for reference data (V matrix in $T'=VR$), where $R = [r(1), r(2), ..., r(N)]$ and $r(n) = [r1(n), r2(n), r3(n), r4(n)]T$, $rjn$ being signals obtained from electrodes localized close to eyes as Fp1, Fp2, F7 and F8, which register vertical and horizontal eye movements. The second step is the use of every ICA projection data in an adaptive filter scheme, to be run $M$ times (possibly in parallel). The adaptive filter with weights $h_m(n)$ aims at estimating the interfering component $\hat{t}_m(n)$ present in the $m$-th ICA channel in a Least Squares sense, from the reference signal $t'(n)$.

The filter operates in ICA domain, and the residual signal is:

$$e'(n) = s'(n) - \hat{t}_m(n)$$  \hspace{1cm} (1)

Where

$$\hat{t}_m(n) = h_m^T(n) t'(n)$$  \hspace{1cm} (2)

The equation (2) represents a transversal filter with four tap weights. We need to estimate the clean EEG ICA components $x'm(n)$ adjusting the coefficients of the filter by solving:

$$\min_{h_m(n)} \left\{ \sum_{i=1}^{N} \lambda^{-i} \left( s'(n) - h_m^T(n) t'(n) \right)^2 \right\}$$  \hspace{1cm} (3)

We expect that $x'm(n)$ and $t'(n)$ are incorrelated, and hence the filter only estimates the interference $\hat{t}_m(n)$. The solution of Eq.(3) is given by the well known Recursive Least Square (RLS) algorithm. The use of the forgetting factor $\lambda$, where $0 < \lambda \leq 1$, allows to use the algorithm in non-stationary situations. Finally, in this section we present the pseudo code of EEG adaptive filtering using RLS and ICA[1][4][10].

2.2 Procedures:

1) First we have to collect different datasets of of EEG signals of different patients.
2) Load the datasets by using MATLAB software and its EEGLAB toolbox[2].
3) Do Process on this datasets
4) Extract and select the specific features for different EEG datasets[2].
5) detect a eyeblink artifacts in order to facilitate analysis of EEG recording
6) If eyeblink artifacts not present in EEG signals then display the clean signal on computer screen.
7) If eyeblink artifacts present in EEG signals then it gives to filtering block.
8) After filtering display this signals waveform on computer’s screen[2].
9) finally store this clean EEG signals datasets on specified location of computer storage.

2.3 Flowchart:

```
START

Collect the EEG datasets and store it in your computer’s specified location

Load a datasets in MATLAB software

Collect the EEG datasets and store it in your computer’s specified location

Load a datasets in MATLAB software

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2.4 EEGLAB:

As of version 7.1.2.10b, EEGLAB now exist as a compiled binary. Although the compiling function (compile_eeglab.m) should allow to compile EEGLAB on any platform, we only make available the Windows OS (32-bit) binary since this is the most popular platform. We have also successfully compiled EEGLAB under Linux 32 and 64 bits. This EEGLAB toolbox available on this [http://sccn.ucsd.edu](http://sccn.ucsd.edu) website.

### III. CONCLUSIONS

An automatic artifact cancellation using EEG data is presented. This method efficiently rejects artifacts produced by eyes movements and it relies on independent component analysis (ICA) and Recursive Least Squares (RLS) adaptive filtering[5]. Further analysis in distortion or correlation between corrected EEG and original EEG is necessary for fully demonstrating the effectiveness of our method. Such analysis and the extension of the method to pure on-line scenarios is proposed as further work. ICA appears to be a generally applicable and effective...
method for removing artifacts and independent noise, providing considerable performance improvements. It is commonly supposed that the introduction of a new block in a preprocessing system is not suitable, but the proposed approach gives us a new alternative method for eliminating noise without calibration. Furthermore, it is easy to implement, very stable and presents a fast convergence. As we discussed before, the ICA potential is the availability of removing real noise components without modifying others in standard EEG[4][5][10]. Adaptive filtering based on ICA would be very helpful in long recordings and on-line analysis, and although the approach developed in this paper is oriented to the elimination of EOG signals, it would be possible to apply it in artifacts more difficult to suppress such as muscle or electrodes artifacts.

REFERENCES
