Artifact removal in real-time for hdEEG-BCI systems

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Abstract— **We propose an automated online artifact removal (AR) method for brain–computer interfaces (BCIs) combined with high-density electroencephalography (hdEEG). We prove that our algorithm is capable of mitigating artifacts, while preserving true neural activity. Thanks to its low computational requirements, it can be effectively applied to hdEEG recordings.**

I. Introduction

Recent developments in hdEEG have recently permitted this technique to be used as a neuroimaging tool [1]. Using hdEEG, it is possible to extract neural activity of one or more brain regions instead of using sensor-space EEG signals [1]. For this reason, recent developments lead to innovative BCI applications requiring hdEEG recordings. However, EEG can be contaminated with artifacts. Here, we introduce an online hdEEG AR method (ICA-OLS) combining Independent Component Analysis (ICA) [2] and Ordinary Least Squared regression (OLS) [3].

II. Methods

Applying ICA on a calibration recording, we obtain a spatial filter. Then, during the actual experiment, EEG signals are read and stored in a buffer of acquisition. For each one, based on OLS, the real-time AR is implemented by dynamically adapting the spatial filter, obtaining an artifact-free signal. For the validation, we recorded resting state (4 minutes) and visual oddball task (3 minutes) hdEEG data in 8 male healthy participants, at 1kHz, using a 256-channel system from Electrical Geodesics. The pre-processing included bad-channel detection and interpolation, filtering (1-80 Hz), average re-referencing and AR by ICA. The attained artifact-cleaned dataset, used as a reference to evaluate the performance of ICA-OLS, was selected to generate a new dataset, adding artificial ocular artifacts. Hence, we used resting state hdEEG for the calibration and oddball hdEEG for pseudo-online AR with a 500 ms buffer. Using this simulated data, we compared ICA-OLS against Adaptive Filtering (AF) [4], Conventional Least Squared (CRLS) [4] and a H infinity algorithm (HINFTV) [5] in terms of accuracy and computation speed. We quantified accuracy by means of cosine similarity measure calculated between simulated and reconstructed data and computation speed, for each buffer of 500 ms, using Matlab 2016b running under MacOS (2.5 GHz Intel Core i7, 16GB RAM).

III. Results

The use of ICA-OLS permitted a more effective attenuation of ocular artifacts in comparison to alternative methods, both in terms of accuracy (Fig.1A) and computation speed (Fig.1B). Our algorithm yielded a CSM equal to 0.944, with a computation time of 2.25 ms.

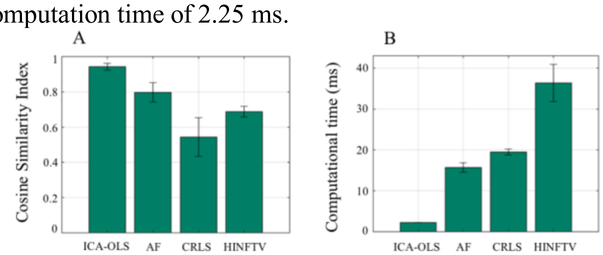

Figure 1. Bar plots showing A) cosine similarity measure across methods and B) computational time for each method for a data buffer of 500 ms.

IV. Conclusions

Based to the present findings, we argue that ICA-OLS may consent the development of novel BCI applications using hdEEG recordings, such as closed-loop neuromodulation and source-based neurofeedback.

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