A Hybrid Framework for ERP Preprocessing in EEG Experiments

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***Abstract*—Methods to derive information on neural processes from Electroencephalographic (EEG) signals become increasingly complex, especially with the introduction of deep learning algorithms. However, considering the low Signal-to-Noise Ratio (SNR) of raw EEG signals, the input data should be properly preprocessed. Common preprocessing algorithms using single method struggle to reduce several types of artifacts/noises without affecting the useful parts of the signal. We therefore propose a hybrid preprocessing framework to combine strengths of multiple state-of-the-art approaches. The latter method provides output signals of better quality than a common Independent Component Analysis (ICA) based pipeline on simulated data.**

***Clinical Relevance*— Our pipeline provides a standard to clean a wide range of Event-Related Potential (ERP) signals as required to improve the accuracy of further inference on neural processes.**

I. Introduction

The algorithms implemented in the main EEG toolboxes to process ERP signals mainly rely on channels/trials rejection and ICA. However, these methods are far from optimal as useful parts of the signal are lost, some artifact types (e.g., muscle artifact) are poorly reduced and high expertise of the operator is required. We therefore propose a new hybrid framework for ERP preprocessing compatible with the FieldTrip toolbox [1]. This pipeline reduces the usual EEG artifacts while minimizing useful signal lost and reducing the requirements on user expertise. The proposed version of the pipeline is optimized for source reconstruction purpose. Nevertheless, the main parameters can be modified through the freely accessible code[1] for other purpose.

II. Methods

The proposed preprocessing pipeline is composed of 8 steps following good practice recommendations from OHBM COBIDAS MEEG committee [2]: 1) bad channels removal by visual inspection; 2) ocular artifact rejection through a multi-channel Wiener filter [3] applied on blinking artifacts and eye movements; 3) detrending, demeaning and low pass filtering (4th order Butterworth, 200Hz); 4) data epoching around the stimuli appearance (from 500ms before to 1000ms after stimulus onset) and downsampling to 512 Hz; 5) power line noise reduction using the "Zapline" algorithm [4]; 6) muscle artifact removal using a combination of Ensemble Empirical Mode Decomposition (EEMD) and Canonical Component Analysis (CCA) as proposed by Chen *et al.* [5]. The autocorrelation between the different decomposed signals is used as rejection criterion; 7) baseline correction with a window spanning from 500ms to 200ms before stimulus onset; 8) signal re-referencing to common average.

[1] https://github.com/numediart/PreprocEEG

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III. Results

The framework has been validated using the simulated data proposed by La Fisca *et al.* [6]. Table 1 compares the performance of the proposed framework with a common pipeline consisting of manual trial/channel rejection, line noise filtering (stop band) and ICA for a set of 20 simulated sessions lasting 15min each. This comparison is only displayed for a SNR of 2 for conciseness. The normalized root-mean-square error (NRMSE) estimates the reconstruction accuracy, while the Pearson correlation coefficient (PCC) evaluates the covariance between the ground-truth simulated data and the preprocessed signals.

TABLE I. Preprocessing Perfomance Evaluation

Method	**NRMSE (mean ± std)**	**PCC *(mean ± std)***
Common Process (ICA based)	0.17 ± 0.02	**0.16±0.05**
Proposed Framework	**0.11 ± 0.02**	0.12±0.04
Control	0.27 ± 0.06	0.02 ± 0.02

The proposed framework outputs a signal closer to the ground-truth data than the common ICA-based process.

IV. Discussion & Conclusion

This work improves the quality of the available information in EEG signals, and so increase the accuracy of further inference on neural processes.

References

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