Constrained ICA –based Ballistocardiogram and Electro-oculogram Artifacts Removal from EEG Signals Acquired inside MRI

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Synopsis

Ballistocardiogram (BCG) artifacts and Electro-oculogram (EOG) artifacts are troublesome in the simultaneous acquisition of EEG and MRI. We propose a new method for removing both artifacts simultaneously from the EEG signals acquired inside MRI using constrained Independent component analysis (cICA). With the designed reference functions for the BCG and EOG artifacts, cICA identifies the independent components (ICs) corresponding to the reference functions. Then artifact-removed EEG signals are reconstructed after removing the identified ICs. The performance of the "cICA with reference" technique has been evaluated by examining the artifact ICs and power spectrum of EEG, EOG, and EKG signals. The results show that this new approach is effective and should be useful in the study of simultaneous EEG and fMRI studies.

Introduction

Simultaneous EEG and fMRI acquisitions hold promises toward imaging spatiotemporal activities of the brain in superior resolution of space and time. However, EEG signals acquired in the MR scanner contain significant artifacts: most prominent of which are Ballistocardiogram (BCG) artifacts and Electro-oculogram (EOG) artifacts. BCG artifacts are generated by movement of EEG electrodes inside the magnetic field due to pulsatile changes in blood flow tied to the cardiac cycle and EOG artifacts are generated by the movement of the eyes of the subject.

Although there have been few attempts toward these artifacts removal using the template subtraction [1] and conventional ICA [2], they are associated with less representative templates and manual selection of artifact components. In this work, we propose a use of constrained ICA (cICA) for the removal of artifacts. With our design approach for better references, our proposed approach can be an effective means of BCG and EOG artifact removal.

Methods

cICA is an approach to extract subset of independent sources from multidimensional observations when some priori information that can be incorporated to the learning algorithm as reference(s) is/are available [3]. The effectiveness of this technique depends on the correct reference function generation and different schemes can be used for this purpose. In our study we have used following three different approaches for optimal design of reference functions for the artifacts.

<u>Technique-I:</u> Reference for BCG is taken directly from an EEG channel that is most representing the BCG artifact, and take the EOG channel as reference for EOG artifact.

<u>Technique-II:</u> Reference for BCG is generated from an EEG channel that is most representing the BCG artifact and then using a threshold convert the EEG signal into a square wave retaining fundamental frequencies of BCG. For EOG, the EOG channel is directly used as reference.

<u>Technique-III:</u> Perform Principal Component Analysis (PCA) of multi-channel EEG signals and take the first two principle components as two reference signals (as we are only concerned with two prominent artifacts at the moment).

Once cICA extracts ICs with the designed references, artifact-free EEG signals are reconstructed after discarding the ICs responsible for the BCG and EOG artifacts.

Results

Fig. 1 (a) shows a reference function (blue) for the BCG artifact derived using Technique-II and its corresponding IC. In Fig. 1 (b), a typical EEG signal recorded inside MRI is shown in blue showing the dominant BCG and EOG artifacts. Using Technique-III two reference functions (i.e., two PCs) and their corresponding ICs found. After removing the two ICs, artifact-free EEG signals are reconstructed as shown in Fig. 1 (b) in red. It is evident that there is a significant reduction of the artifacts. Fig. 1 (c) shows the power spectrum of the EEG signal with the artifacts (in blue) and without them (in red). Our examination confirms that the reduced frequency components of the artifacts closely match those of the separately measured EKG and EOG signals.

Conclusions

Among three reference generation techniques, it seems that PCA-based selection works best, but further validation is underway. Nevertheless, we believe that cICA along with the proposed reference function generation schemes can be an effective tool for the BCG and EOG artifact removal for the EEG signals measured inside MRI. The proposed technique could facilitate the simultaneous EEG and fMRI studies.

References

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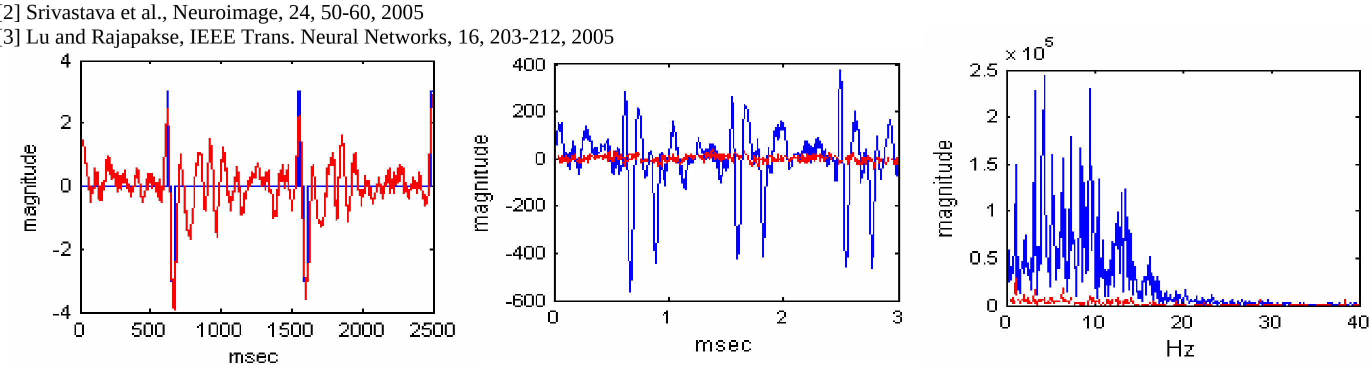

(a) (b) (c)

Fig. 1 (a) A reference signal derived from the BCG artifact (blue) and cICA found IC (red), (b) Original EEG signal containing the BCG and EOG artifacts (blue) and artifacts-removed EEG using Technique-III (red), and (c) Power spectrum of the original EEG signal (blue) and artifacts-removed (red).