Constrained ICA-based Ballistocardiogram Artifacts Removal from EEG Signals Acquired in MRI

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Introduction

Simultaneous EEG-fMRI acquisitions hold promises toward imaging brain activities at superior spatiotemporal resolution. However, EEG signals acquired inside MRI contain significant Ballistocardiogram (BCG) and Electrooculogram (EOG) artifacts. The BCG artifacts are generated by the movements of EEG electrodes inside magnetic field due to the pulsatile blood flow tied to cardiac cycle and EOG artifacts by the movement of the eyes. There have been few attempts toward the removal of these artifacts using the template subtraction [1] and conventional Independent Component Analysis (ICA) [2], but they are associated with less representative templates and manual selection of artifact components. In this work, we propose a use of constrained ICA (cICA) [3] for the removal of artifacts. With our design approach for better references of the artifacts, 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 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 correct reference function generation schemes. In this study we have tested the following three different approaches for an optimal design of reference functions of the BCG and EOG artifacts.

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

<u>Square EEG-R (SEEG-R):</u> the BCG reference obtained using EEG-R, is converted to a square wave using a threshold, but retaining fundamental frequencies of the BCG artifact. The EOG signal is used a reference.

<u>PCA-R:</u> Perform Principal Component Analysis (PCA) on multi-channel EEG signals and take prominent principle components as reference functions for the artifacts. In this study, we have used two PCs as references for the artifacts.

Once cICA extracts ICs constrained by the designed references, artifact-free EEG signals are reconstructed after discarding the extracted artifacts ICs.

Results

Fig. 1 (top) shows an original EEG signal with the BCG artifact (blue) and a reference derived using SEEG-R (red). Fig. 1 (bottom) shows the EOG signal. In Fig. 2, cICA derived ICs are shown which were constrained by the references shown in Fig. 1. Using PCA-R, we have removed the artifacts from all EEG channels. Fig. 3 shows all EEG channels with the BCG artifacts regions indicated by the dotted bars. Fig. 4 shows the results after the removal of artifacts. Our examination of signal frequency components confirms that the reduced frequency components in the signals closely match those of the artifacts.

Conclusions

We believe that cICA along with the proposed reference function generation schemes can be an effective tool for the BCG and EOG artifacts removal from the EEG signals acquired inside MRI. This presented technique should be useful in simultaneous EEG-fMRI imaging of the brain activity.

References

[1] Allen et al, Neuroimage, 8, 229-239, 1998 ; [2] Srivastava et al, Neuroimage, 24, 50-60, 2005 ; [3] Lu and Rajapakse, IEEE Trans Neural Networks, 16, 203-212, 2005

Fig. 1. (Top) a reference function (red) derived from an EEG signal (blue). (Bottom) EOG signal.
Fig. 2. cICA derived ICs for the references shown in Fig. 1.
Fig. 3. EEG signals of all channels before artifacts removal
Fig. 4. EEG signals of all channels after artifacts removal using PCA-R cICA.

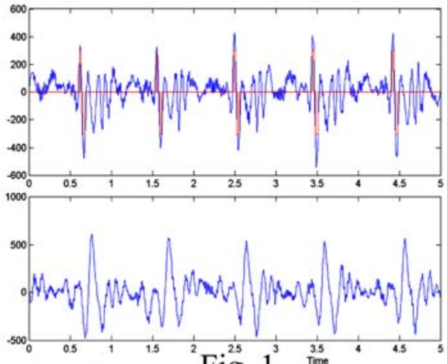

Fig. 1

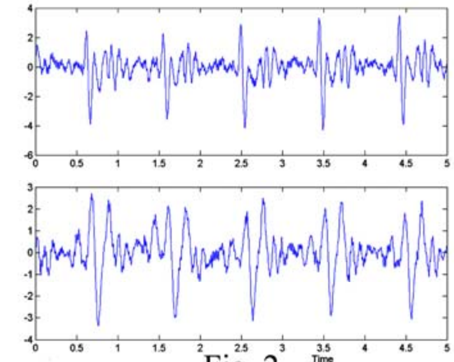

Fig. 2

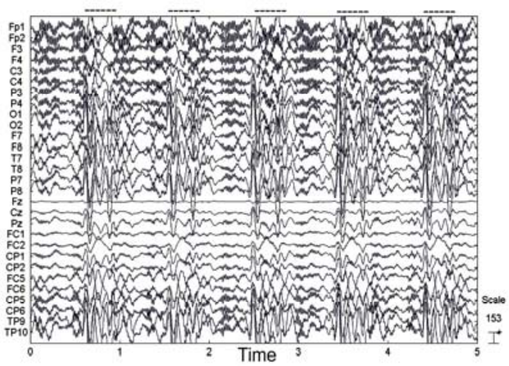

Fig. 3

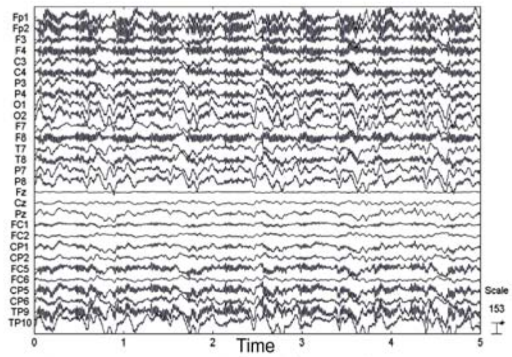

Fig. 4