ICA-based spatial filters to reduce cardioballistic noises in EEG signals acquired inside the MRI magnet

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Synopsis

Cardioballistic noises in the EEG data measured inside the magnet are very troublesome in combinatory studies of EEG and fMRI. We used the ICA method to reduce cardioballistic noises in the EEG data measured inside a 3.0 Tesla MRI magnet. With the spatial filter that was constructed through ICA during the preparatory period, we have successfully reduced cardioballistic noises in the EEG data measured later on in a real time processing mode. It has been found that the proposed technique is more robust to temporal variations in the cardioballistic waveform than the conventional averaging method.

Introduction

EEG measurements have been greatly used in fMRI studies for many purposes such as patient monitoring during the scan or epileptic spike triggered EPI scans. In using EEG data in fMRI studies, cardioballistic noises are very troublesome since the noises are often much bigger than the EEG signal. Cardioballistic noises are due to the heart and vessel motions in the main magnetic field. Several techniques to suppress the cardioballistic noise were introduced with experimental results [1]. In suppressing the cardioballistic noise in EEG data, real time processing is very desired since fMRI scans interacting to the concurrent EEG are essential in the combinatory study. In this work we propose a spatial filtering method based on the independent component analysis (ICA) method to suppress the cardioballistic noise in the EEG data acquired inside a 3.0 Tesla MRI magnet.

Methods

A 29-channel MRI-compatible EEG system has been used in the experiment with a 3.0T MRI system. A human subject wearing an electrode cap was positioned at the center of the magnet to record EEG data. In the preparatory period, EEG data were recorded for 10 seconds. We used FastICA algorithm to separate independent components from the recorded EEG data [2]. With the mixing matrix derived from the ICA, we constructed a spatial filter F as follows,

$$S_{EEG} = AS$$

$$A=[a_1^e,\ldots,a_I^e,a_1^c,\ldots,a_J^c],\ A'=[a_1^e,\ldots,a_I^e,0,\ldots,0] \qquad [1]$$

$$F = A'A^{-1}$$

where $\boldsymbol{S_{EEG}}$ is the measured EEG signal set, $\boldsymbol{A}$ the mixing matrix, $\boldsymbol{S}$ the independent component matrix, a_i^e and a_i^c the column vectors representing the weighting factors of the EEG signal and cardioballistic noise components, respectively. Nullifying the weighting factors of the cardioballistic components a_i^c in A, we made the matrix A' and the spatial filter matrix F. The matrix size of F is N×N where N is the number of EEG channels. After constructing the spatial filter matrix F, we applied F to the EEG data acquired later on.

Results

Fig. 1(a) shows a typical cardioballistic noise waveform obtained with averaging 10 cardioballistic pulses. In Fig. 1(b), we have shown the 8 most significant independent-components of the EEG signal recorded inside the magnet. The cardioballistic noise components appear in the first 4 independent components. Fig. 2(a) shows a typical EEG waveform recorded inside the magnet. As can be seen from the figure, the cardioballistic component dominates over the EEG components. Fig. 2(b) and (c) show the EEG waveforms filtered with the averaging method and the proposed ICA-based spatial filtering method. As can be noticed from the figures, the averaging method leaves more remnant cardioballistic signals than the proposed method does. Since only temporal information of the cardioballistic noise is used in the averaging method, big remnant noises may appear when the cardioballistic noise waveform deviates from the averaged waveform. The ICA-based spatial filtering method is more robust to the temporal variations in the cardioballistic noise waveform since it is based on the spatial correlation of the noises.

Conclusions

The spatial filter designed with the ICA method works well in reducing cardioballistic noises in the EEG data acquired in the MRI magnet. Since the spatial filter size is only N×N, it can be used to monitor EEG signals during fMRI scans in a real time processing mode.

References

[1] J. Sijbers, et al., Magn Reson Imag. 18, pp881-886, 2000.

[2] A. Hyvärinen, et al., Neural computation. 9, pp1483-1492, 1997.

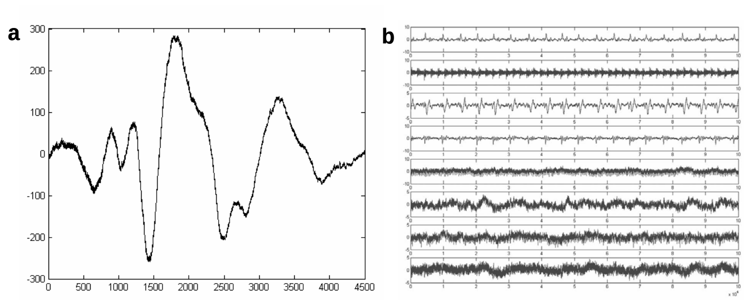

Fig.1 (a) A typical cardioballistic noise waveform.
(b) The 8 most significant independent components of the EEG signal.

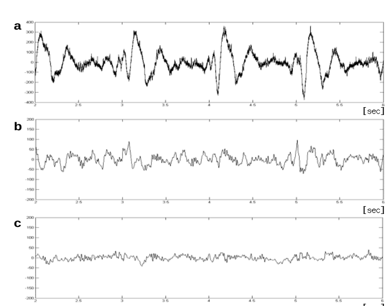

Fig. 2 (a) An EEG signal measured inside the MR magnet.
(b) The EEG waveform filtered by the averaging method.
(c) The EEG waveform filtered by the ICA method.