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Reduction of artifacts in 12-channel ECG signals using FastICA algorithm

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ECG signals are required to be reduced for accurate and easier diagnosis in clinical resting ECG, ambulatory ECG, exercise ECG and long-term ECG monitoring. In this paper, Fast ICA algorithm has been used for reducing artifacts and noise from 12-channel ECG recordings. A Graphical User Interface is also made for the same purpose.

Keywords*:* Artifacts reduction, Blind source separation, ECG, Fast ICA algorithm, Independent component analysis

Introduction

A number of attempts[1-3] have been made to reduce artifacts and noise from ECG signals and various types of analog and digital filters, both linear and non-linear, have been implemented to reduce interferences from ECG signals. Several adaptive filtering techniques have also been implemented[4-5]. Other methods include averaging[6] and neural networks[7]. However, many of these methods are only partially successful and tend to suppress ECG components along with noise.

Artifacts, which are generated independently as compared to ECG signals, can be separated effectively using Independent Component Analysis (ICA). It is superficially related to Principal Component Analysis (PCA) and Factor Analysis (FA). ICA can be used for reduction of artifacts and noise in many biomedical signals like EEG[8-9], EMG[10] etc. In fetal[11], ECG is effectively extracted from multi-lead cutaneous potential recordings of a pregnant woman and the concept of application of ICA for ECG noise reduction has been introduced successfully[12-13].

This paper discusses fast ICA algorithm to carry out ICA of 12-channel ECG recordings and hence reduces artifacts and noise present in the recordings. Graphical User Interface (GUI) has also been developed for bio-signal artifacts reduction, which enables user to operate the application intuitively. All the implementations are done in Matlab on a Windows platform.

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Independent Component Analysis (ICA)

ICA is a statistical technique for finding underlying components from multidimensional data[14]. The most well known application of ICA is blind source separation (BSS).

Fast ICA Algorithm

Fast ICA algorithm[15] is an efficient and popular algorithm for ICA, which is based on a Newton-iteration based fixed-point optimization scheme for maximizing non-gaussianity of $y_i = \mathbf{w}_i^T \tilde{\mathbf{x}}$. This algorithm estimates just one of the ICs. To estimate n ICs, this algorithm has to be run n times. To ensure that a different IC is estimated each time, one must de-correlate the outputs ($\mathbf{w}_i^T \tilde{\mathbf{x}}$) after every iteration. Based on the type of de-correlation method used, algorithm can be operated in the following two modes:

Deflation Mode

In this mode, ICs are estimated one by one. Gram-Schmidt-like de-correlation is used to de-correlate the data.

$$\mathbf{w}_i = \mathbf{w}_i - \sum_{j=1}^{i-1} \mathbf{w}_i^T \mathbf{w}_j \mathbf{w}_j \quad \ldots (1)$$

$$\mathbf{w}_i = \mathbf{w}_i / \|\mathbf{w}_i\| \quad \ldots (2)$$

In this, previously estimated ICs are privileged in step 1. This means that only currently estimated weight vector is affected and the order of estimation matters. Thus, estimation error might accumulate into the last components in this mode.

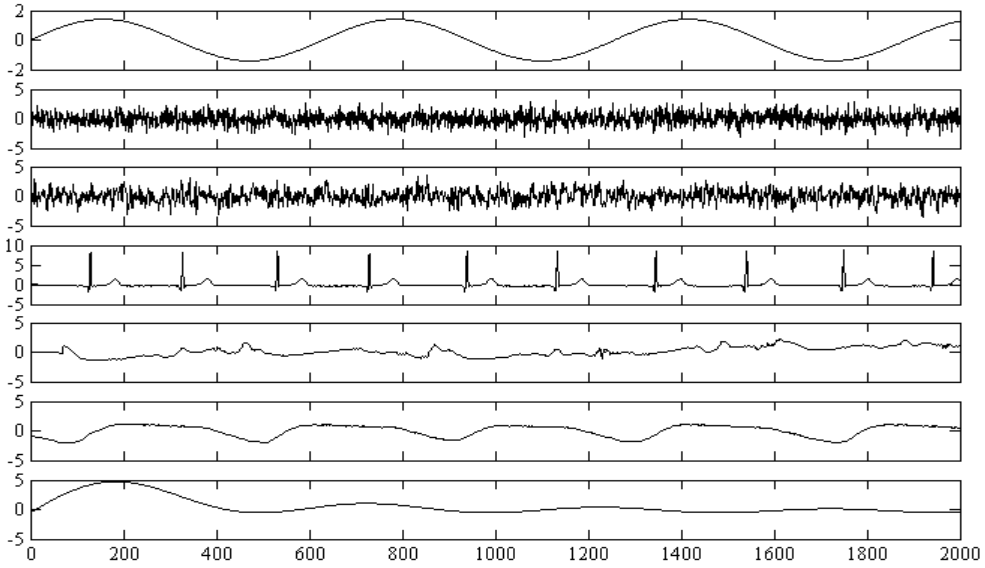

Fig. 1— Source signals

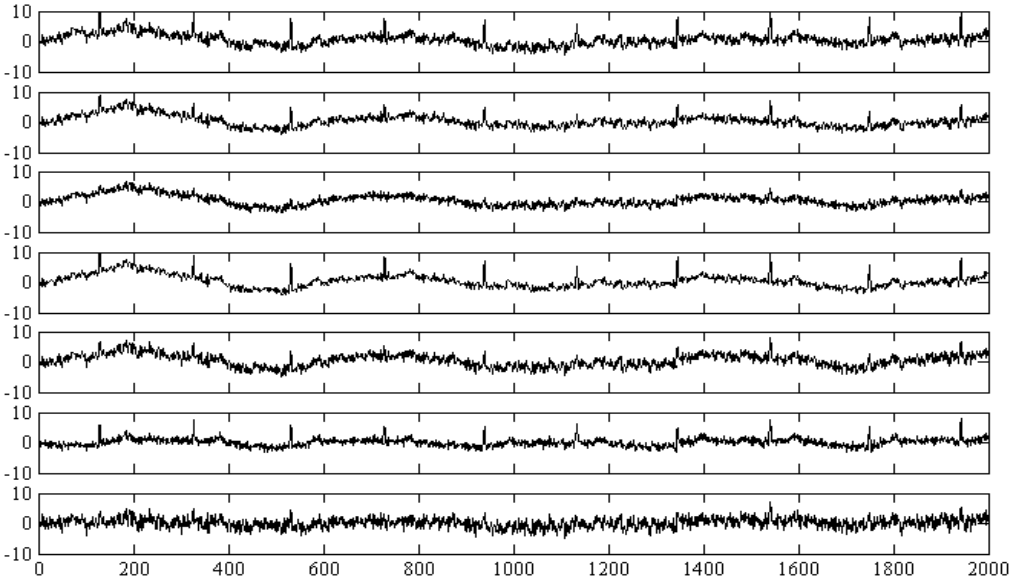

Fig. 2 — Mixed signals

Symmetric Mode

In certain applications, it may be desired that no vectors be privileged over others. This can be achieved in this mode by estimating first all ICs and then performing orthogonalization.

$$\mathbf{W} = (\mathbf{W}\mathbf{W}^T)^{-1/2}\,\mathbf{W} \qquad ...(3)$$

Demonstration of ICA

Source signals consisting of 7 typical artificially generated biological signals[16] (Fig. 1) were mixed to generate mixed signals (Fig. 2). It is almost impossible to guess the shape of original signals by just looking at the mixtures. Estimated source signals using ICA (Fig. 3) show that neither the order nor the sign of sources has been preserved. Also, energy of ICs has changed. However, these problems don't matter much in most of the applications.

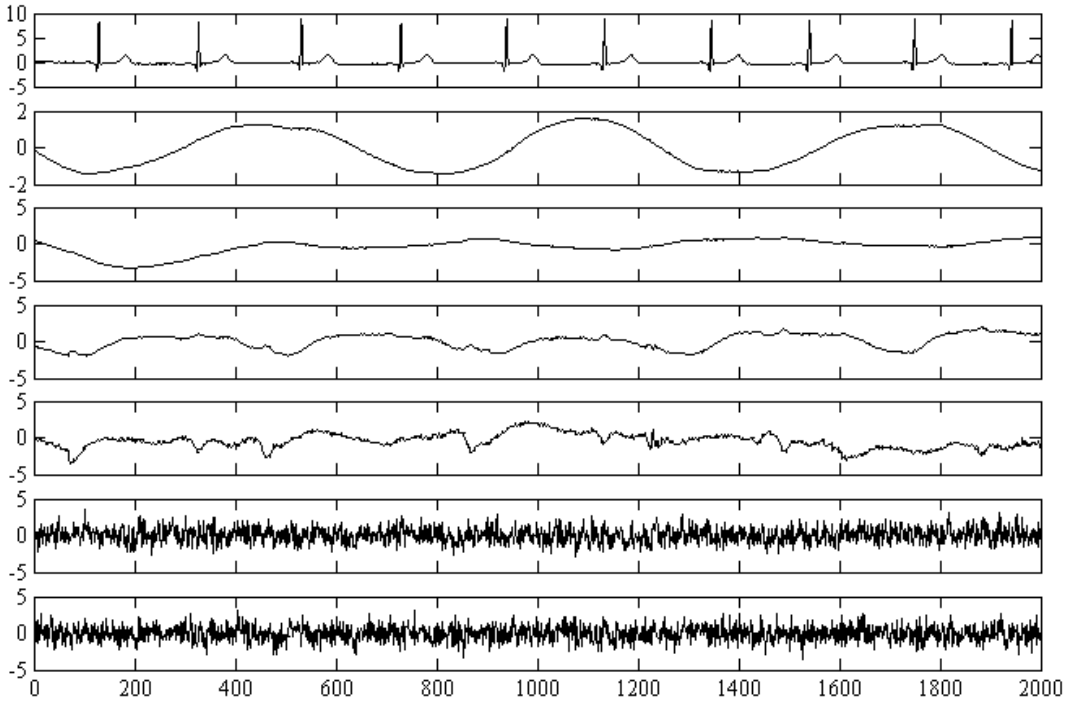

Fig. 3 — Estimated signals

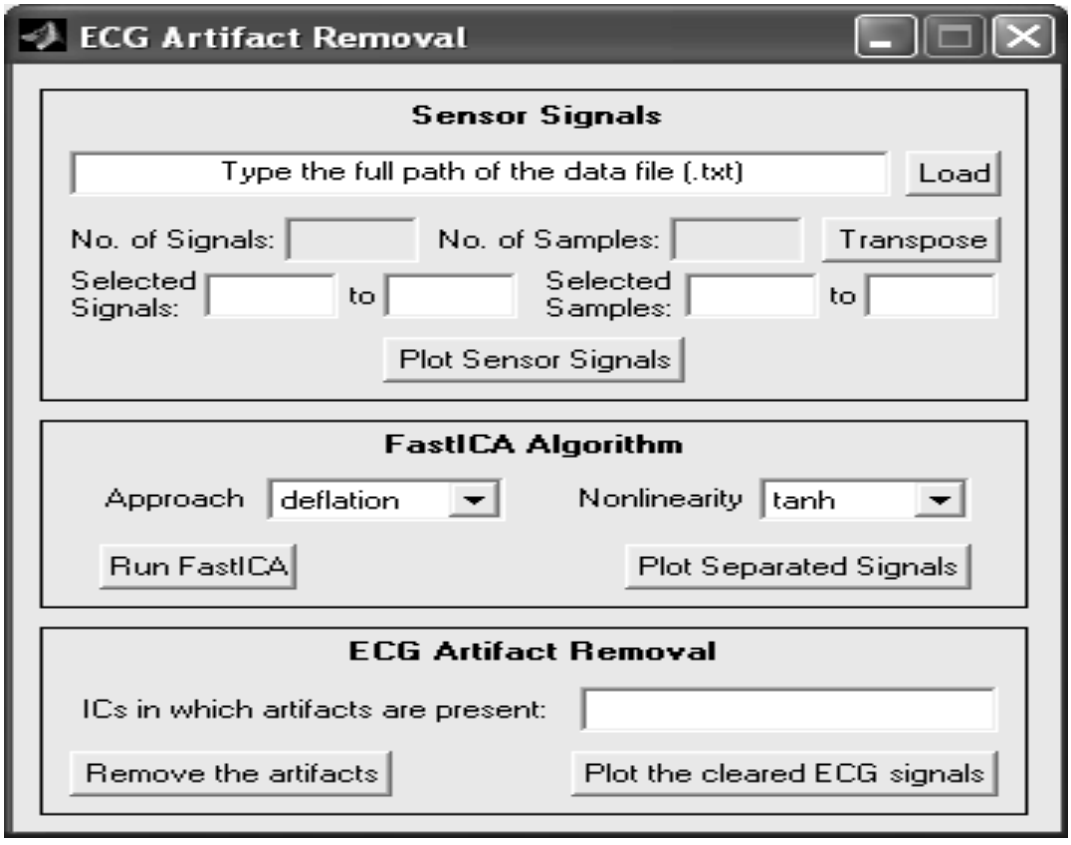

Fig. 4 — GUI – ECG artifact removal