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A Novel Approach to FEG Extraction based on Fast ICA

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Abstract - The extraction of Fetal Electrocardiogram (FECG) is vital to know the well being of the fetus and useful for doctors to decide the mode of delivery and period. The FECG contains activity of electrical depolarization and repolarization of fetal heart. In this paper, a simple algorithm, Independent Component Analysis (ICA), is used to extract FECG from Abdominal Electrocardiogram (AECG) of mother. The database used is non-invasive fetal electrocardiogram and direct fetal electrocardiogram, taken from physionet.org. ICA comes under the classification of Blind Source Separation (BSS) method. ICA is basically a filtering solution which gives the signal from an unknown source. In this problem, the signal from an unknown source is Fetal ECG. It is to be derived from the pure maternal ECG that is thorax signal and abdominal ECG

Key Words: Abdominal Electrocardiogram (AECG), Blind Source Separation (BSS), Database, Fetal Electrocardiogram (FECG), Independent Component Analysis (ICA).

1. INTRODUCTION

The noninvasive extraction of fetal electrocardiogram (FECG) from multichannel maternal abdomen recordings is an emerging technology used for fetal cardiac diagnosis. Independent Component Analysis (ICA) and its extensions are the well-known techniques for the extraction of FECG, which are proved to be more robust and accurate than most conventional methods [1]. This algorithm works as a filter for extracting the FECG from multichannel maternal recordings. Noise reduction and subsequent extraction has been attempted by various Independent Component Analysis (ICA) algorithms. ICA comes under the classification of BSS techniques that can be applied to biomedical signal processing by making an additional assumption of independence of original signals. Some of the previous approaches to ICA are FastICA, INFOMAX, Joint Approximate Diagonalization of Eigen Matrices (JADE), MeRMaid etc.

1.1 METHOD

ICA problem is to obtain the matrices [X] and [A] such that column vectors of the matrix $[X]^T$ are independent to each other. (i.e.) Kurtosis values computed for the column vectors are maximum. Kurtosis is the statistical parameter used to measure the Gaussian nature of the signal.

Kurtosis is inversely proportional to the Gaussianity of the signal. Note that the kurtosis values are maximum for independent signals compared to the mixed signals. (i.e.) Independent signals are more non-Gaussian compared with mixed signals. Mathematically kurtosis is computed using the formula as displayed below, where E[X] is the expectation of the vector X.

E [X^2]-3{E [X^2]}^2

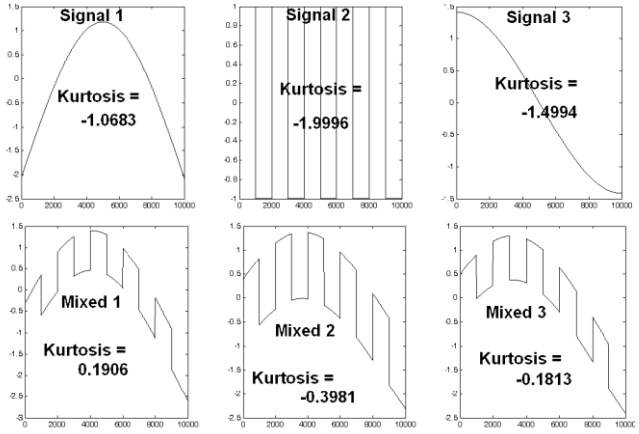


Fig. 1. Three independent signals and the corresponding mixed signals along with the kurtosis values are displayed above.

Algorithm

1) Given mixed signals y_1(t) and y_2(t) are converted into z_1(t) and z_2(t) such that the covariance matrix computed using the converted signals z_1(t) and z_2(t) is the identity matrix

2) Initialize the values for the matrix B such that $B^T B$=[I]

3) Update the elements of the matrix B using the Iteration formula:

$$b_{11}(t+1) = E[(b_{11}(t)z_{1i} + b_{21}(t)z_{2i})^3 z_{1i}] - 3 * b_{11}(t)$$

$b_{11}(t)$ is the value for b_{11} in t^{th} iteration

$b_{11}(t+1)$ is the value for b_{11} in $(t+1)^{th}$ iteration.

Similarly other elements of matrix B are computed.

4) Columns of the matrix B is made orthonormal to each other as mentioned below.

B = B * real (inv (B' *B)^(1/2));

5) Repeat step 3 and step 4 for 'N' Iteration.

6) Independent signals are obtained by multiplying B^T with the Z matrix

B. Algorithm Description

The mixed signal y(t) refers to the abdominal signal which is a mixture of fetal ECG, maternal ECG, muscle contraction noise, baseline wandering error, electrode leads noise etc. The mean variance of these signal is removed and the signal y(t) is converted to z(t). For this purpose, Hotellilng transformation can be used. Matrix B is actually the inverse of matrix A which is first initialized. Different noises are removed using particular filters during the preprocessing step. Later the ICA Algorithm is applied on the data to finally acquire the Fetal ECG. The results of this algorithm are discussed in the preceding paragraph under Experiments and Results.

Mathematical Analysis

The basis of most ICA approaches is a generative model; that is, a model that describes how the measured signals are produced. The model takes an assumption that the measured signals are the product of instantaneous linear combinations of the independent sources. Such a model can be mathematically represented as:

$$x_i(t) = a_{i1}s_1(t) + a_{i2}s_2(t) + \cdots + a_{iN}s_{1N}($$

for i=1,...,N

(1)

Where s = source signal,
x = mixed signal,
a = constant element.

Note that this is a series of equations for the N different signal variables, $x_i($. While considering the ICA model equation, we can ignore the time function. Indeed, most ICA approaches do not take the consideration of ordering of variable elements; hence, the fact that s and x are time function is irrelevant.
In matrix form, above equation can be represented as follows:

$$\begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} = A \begin{bmatrix} s_1 \\ \vdots \\ s_n \end{bmatrix}$$

From the algorithm section, the other elements of matrix B are computed using the following iteration equations:

$$b_{11}(t+1) = E[(b_{11}(t)z_{1i} + b_{21}(t)z_{2i})^3 z_{1i}] - 3 * b_{11}(t)$$

$$b_{21}(t+1) = E[(b_{11}(t)z_{1i} + b_{21}(t)z_{2i})^3 z_{2i}] - 3 * b_{21}(t)$$

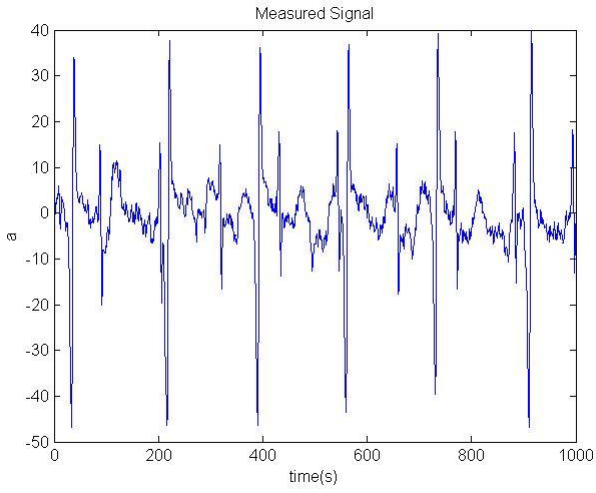
$$b_{12}(t+1) = E[(b_{12}(t)z_{1i} + b_{22}(t)z_{2i})^3 z_{1i}] - 3 * b_{21}(t)$$

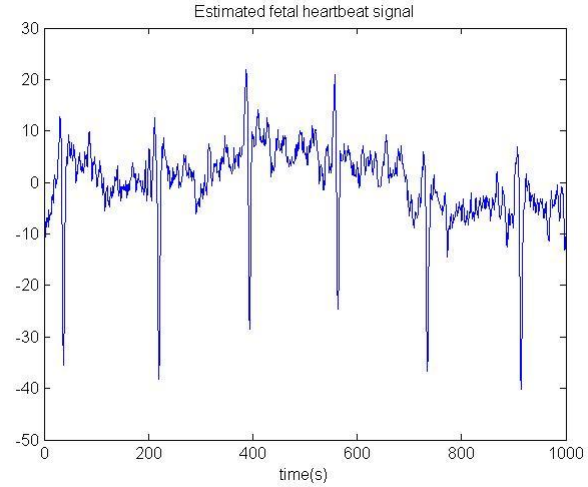
$$b_{22}(t+1) = E[(b_{12}(t)z_{1i} + b_{22}(t)z_{2i})^3 z_{2i}] - 3 * b_{22}(t)$$

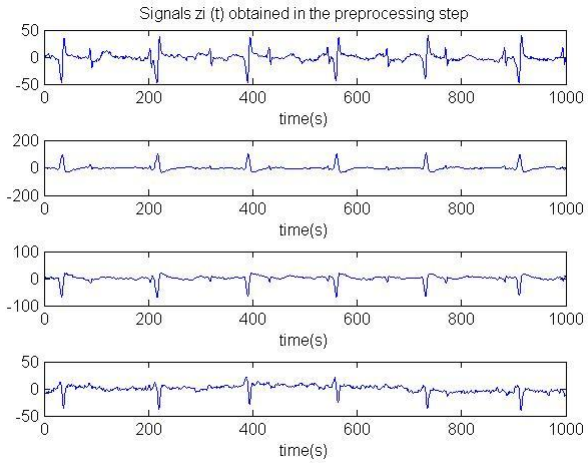
The columns of the matrix B are made orthonormal to each other. This can be explicitly performed in every iteration, after updating the values using the equations given above[1].

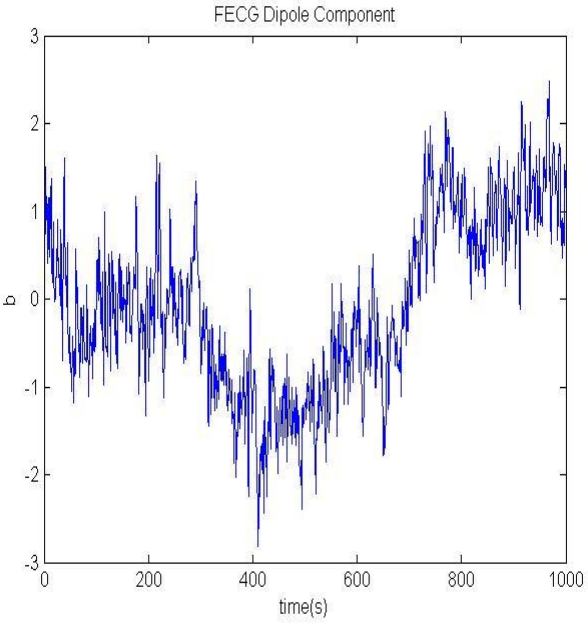
Experiments and Results

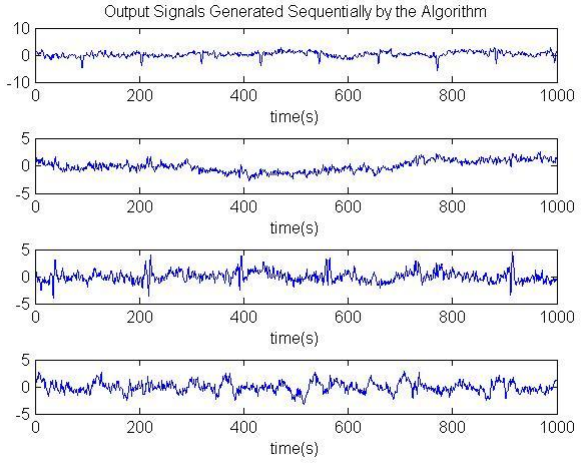
Types of Graphics

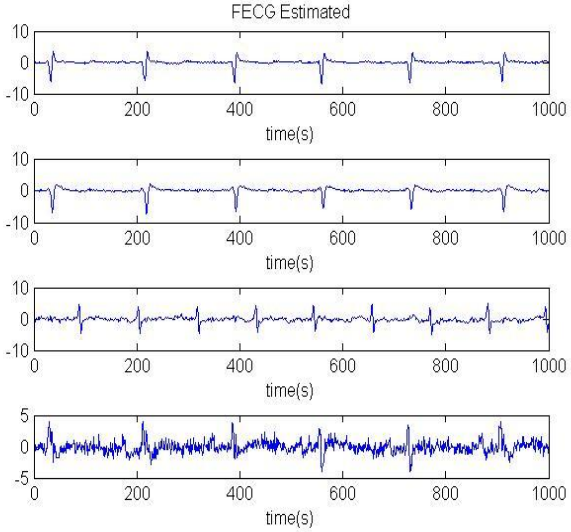












3. CONCLUSIONS

Efficient and fast results can be acquired using Independent Component Analysis. Various extensions of ICA are mentioned in this paper. In this paper, FECG is extracted from 8 lead electrode signals. This work is clinically important to estimate the different health related parameters regarding fetal[19]. The comparison results can also be found out by using peak detection and counting number of peaks of both Direct Fetal ECG and the Abdominal ECG to find the results in percentage.

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