Enhancement of Twins Fetal ECG Signal Extraction Based on Hybrid Blind Extraction Techniques

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Abstract

ECG machines are noninvasive system used to measure the heartbeat signal. It's very important to monitor the fetus ECG signals during pregnancy to check the heat activity and to detect any problem early before born, therefore the monitoring of ECG signals have clinical significance and importance. For multi-fetal pregnancy case the classical filtering algorithms are not sufficient to separate the ECG signals between mother and fetal. In this paper the mixture consists of mixing from three ECG signals, the first signal is the mother ECG (M-ECG) signal, second signal the Fetal-1 ECG (F1-ECG), and third signal is the Fetal-2 ECG (F2-ECG), these signals are extracted based on modified blind source extraction (BSE) techniques. The proposed work based on hybridization between two BSE techniques to ensure that the extracted signals separated well. The results demonstrate that the proposed work very efficiently to extract the useful ECG signals.

Key words: ECG, Blind source extraction, blind source separation, Twins Fetal ECG

الخلاصة :

جهاز تخطيط القلب هو جهاز غير جراحي يستخدم لقياس الاشارات الناتجه من القلب من الضروري مراقبة قلب الاجنه التوائم خلال عملية الحمل لتشخيص كفائة القلب والكشف المبكر عن اي مشكله قبل الولاده، في حالات الحمل المتعدد تقنيه استخدام الفلاتر غير كافيه في فصل اشارات قلب الاجنه عن اشرات قلب الام ، في هذا البحث مزيج اشاره القلب المتكون من ثلاث اشارات ناتجه من الجنين الاول والجنين الثاني وقلب الام استخلصت عن طريق تقنيه الفصل العمياء المعدله. حيث ان هذه التقنية تعتمد على خوارزميتن دمجت سويه للحصول على افصل عمليه فصل بين الاشارات . بينت النتائج ان العمل المقترح هو جيد وكفؤء في استخلاص اشارات القلب .

الكلمات المفتاحية : جهاز تخطيط القلب ، استخلاص الاشارات العمياء ،فصل الاشارات العمياء ، تخطيط القلب للتوائم

1. Introduction

The heartbeat of the fetus are very fast from mother's heartbeat about 120-160 beat/minute, but the amplitude of the ECG-fetus is very weak compared with mother-ECG signal (Álvarez and Alberto, 2015). The technique for getting the fetus ECG signals are noninvasive techniques (Gao *et.al.*, 2003). The electrical signals generated from fetus heart are very small and weak. The position of the electrodes are very important to detect useful information from the mixture (Saranya and Priyadharsini 2010), therefore the electrodes or sensors are sited on the abdomen as near as possible to the heart of the fetus. The ECG signals are collected by putting the electrodes about the place of the fetal and wanting the electrodes have the high signal to noise ratio(Saranya and Priyadharsini, 2010). The position of electrodes represent one of the problem can be solved by expert but the noise and interface with ECG signal still effect on the diagnosis. Many methods like doppler ultrasound used to detect fetus ECG signal during 10^{th}-12^{th} week (Graupe and Zhong ,2005), but this technique cant remove the noise or interference from the mixture. Many practical difficulties related with the ECG signal detection and extraction of fetus from mother ECG, which placed on the abdominal. Almost these due to low electrical signal which generated from fetus signal and contaminated by numerous signals of interference (Camps-Valls , 2004). Also the artifact signals represent one of the limitations in ECG signal analysis and can be solved by blind source extraction

technique. The undesired signals should be removed from wanted ECG signal to get good diagnosis. Fuzzy and neural system is used to extract the fetus ECG from mother ECG signal (Saranya and Priyadharsini , 2010). Many algorithms and techniques for Fetus ECG detection and extraction presented with variable grades of achievement. Such as filters (Callaerts *et.al.,* 1990), correlation (Camps-Valls *et.al.,* 2004), Blind source extraction (BSE) (Jan. 2007), and many other techniques. Blind source separation or extraction is representing one of the most important and successful techniques used to extract the fetus ECG signals. However the ICA technique is not sufficient for acceptable fetus ECG signal extraction because the nonlinear association between the mother ECG and the fetus ECG signals due to mixing system inside the abdominal (Saranya and Priyadharsini, 2010; Abdullah *et.al.,* 2014).

2. Theoretical background

Different ways and algorithms to perform blind source extraction technique (BSE) such as dependent and independent component (DCA and ICA), Singular Value Decomposition (SVD), Common Spatial Pattern, and many another technique used to extract the useful information from mixture (Jan. 2007). EFICA and MCOMB techniques are used in this paper to get good separation process between the ECG signals without effect on the hidden information in the mixture. First of all, in any ICA technique if the sources have more Nongaussinity properties then the source represent more independency. In the model or formula the kurtosis mathematical operation is used to extent the Nongaussinity of the sources (Chaozhu *et.al.*, 2013; Choung, 2013).

2.1 Kurtosis

It is a mathematical expression the 4^{th} moment, generally, the 1^{st} moment is the Mean value, the 2^{nd} moment called the variance value, and the 3^{rd} moment is identified as Skewness(Hippel, 2005). Kurtosis is used to investigate the random value that covers in a list of values. The most nongaussian value gives the independent sources as possible (Hyvarinen,1999).

2.2 Cross correlation (X-Correlation)

X-correlation is used to identify the separated sources. Firstly, before any X-correlation process, the discrete Fourier transform (DFT) is used to transfer the source to time domain in order to make things easier in signal processing analyzing (Choung, 2013).

2.3 Independent Component Analysis (ICA)

The ICA is used to analyze the sources into its components from their mixture. Generally the mixture can be classified into linear and nonlinear (Abdullah *et.al.,* 2014). ICA is a multichannel process technique, where the detected signal is analyzed to list of ICs. The ICA technique is started for a cocktail party problem, this technique is suitable, and very useful for many applications in signal processing field. Figure 1 describes the main steps of ICA (Abdullah *et.al.,* 2014; Abdullah *et.al.,* 2014).

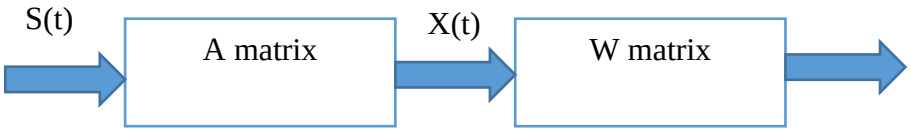

Figure 1: Independent component Analysis Technique

3. Fetal ECG signal

The Fetus ECG electrical signals are associated to the mother ECG signal with similar waveform but weak amplitude and fast rate, it has P-wave, QRS-wave, and T-wave as demonstrated in figure 2. These electric signals are generated by the reduction of the muscle of heart which named myocardium (Peddaneni ,2004; Hasan *et.al.,* 2009).

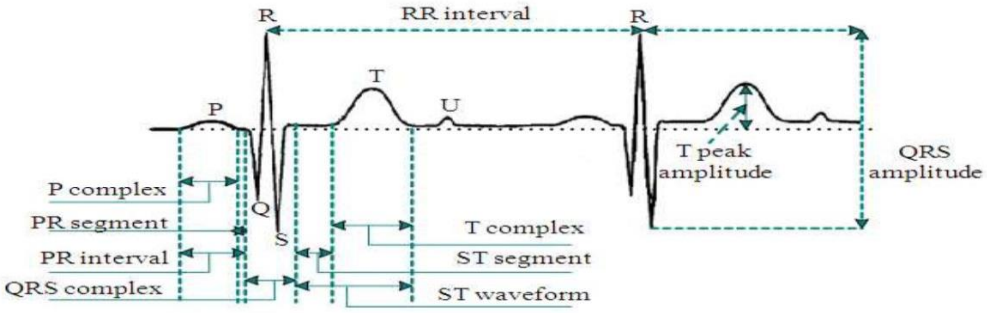

Figure 2: Fetal ECG signal

4. Proposed work

First of all, in order to explain the proposed algorithm, the conventional technique is illustrated in figure 3 to understand the behavior of previous techniques. For single fetal there is no more enhancement and difference between conventional and the proposed work. But in multi-fetal pregnancy, there are many advantages for blind source extraction technique compared with classical systems as demonstrated in the results(Graupe and Zhong ,2005).

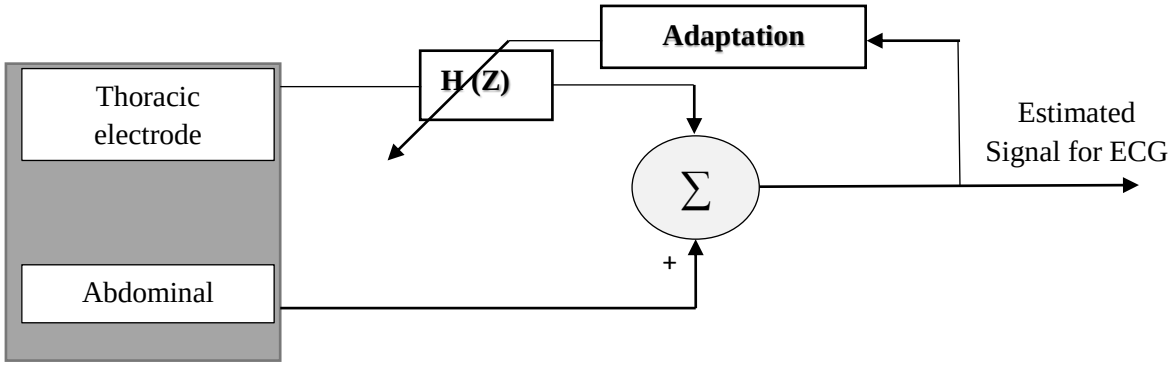

Figure 3: Conventional method for M-ECG cancellation

In this paper twins ECG signals (F1-ECG and F2-ECG) are measured from three sensors or electrodes placed on the chest and abdominal as shown in figure 4, first electrode called thoracic sensor and other two sensors called abdominal sensors (Fanaswala,2005).

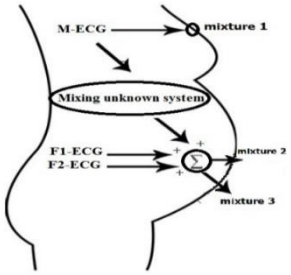

Figure 4. Biological model of ECG signals

In the conventional technique the thoracic sensor record only the mother ECG signal (M-ECG), but really it records mixture from three signals (M-ECG, F1-ECG, and F2-ECG), therefore this is one of the weak points in the conventional system. The abdominal sensors record mixtures from three sources (mother and fetus). The filtering technique can extract mother ECG signal from the fetus ECG signals, but cannot isolate F1-ECG from F2-ECG, therefore the blind source extraction technique is used here to solve this problem. Figure 5 shows the block diagram of the proposed algorithm, firstly, the signals are measured and acquisition and then initialize in order to prepare the signals for separation by EFICA technique to produce initial separation for the next step, the step 2 is MCOMB technique used to enhance the separation process and get optimum solution.

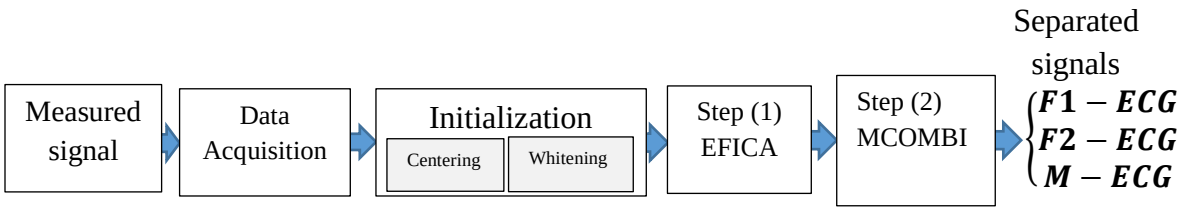

Figure 5: Block diagram of the proposed algorithm

5. Simulation Results

To check the performance of the proposed algorithm, MATLAB simulation is presented to simulate the ECG signals for mother (M-ECG) and twins (F1-ECG and F2-ECG), the M-ECG signal is sampled by 4000 Hz with 72 beats/minute and amplitude about 3.5 mv. The fetus heart beats are faster than mother heartbeat as mentioned earlier in the introduction part. The rage of the rate about 139 beat/minute, weaker amplitude 0.25 mv. Figure 6 shows the simulated and generated ECG signals based on **ECG( )** function.

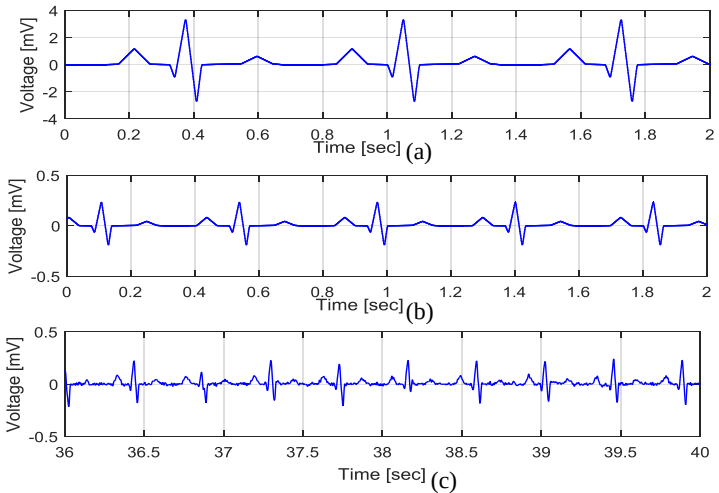

Figure 6: input ECG signals: (a) mother ECG (b) Fetal-1 ECG (c) Fetal-2 ECG

Figure 7 demonstrates the mixture signals from three original sources mixed randomly, these mixtures represent the measured signals (raw data) from three electrodes

placed on the chest and abdominal. The first step is to initialize the mixture of Pre-processing technique represented by centering and whitening.

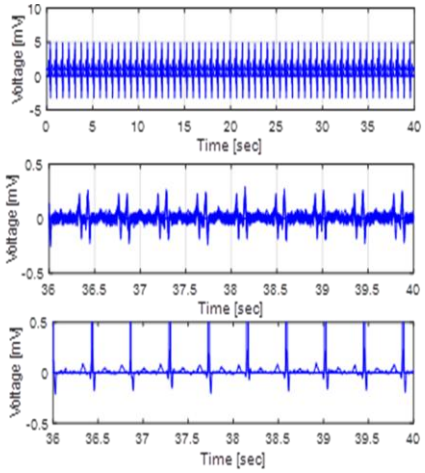

Figure7: Mixture signals between mother ECG, Fetal-1 ECG, and Fetal-2 ECG

The first step after initialization process, the mixtures are separated by JADE technique but the results are not sufficient, therefore the MCOMB technique is used to enhance the separation process and get optimum separation as shown in figure 8.

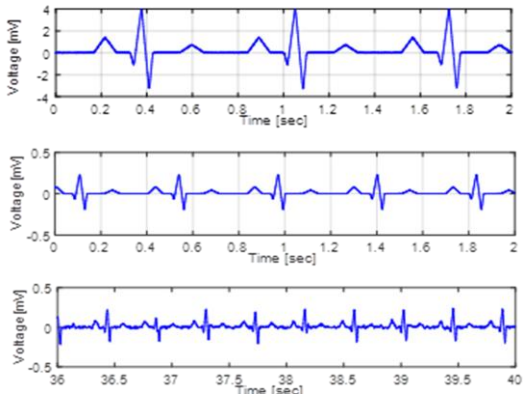

Figure 8: Extracted ECG signals: (a) Extracted mother M-ECG (b) Extracted Fetal-1 ECG (c) Extracted Fetal-2 ECG

The simulation results are well, whatever the Interference signal ratio (ISR) measure is less as shown in Table 1. The results from this table is clearly better than JADE and MCOMBI techniques, the best average value of ISR for the proposed work is (-57.57 dB) and the minimum value is obtained by JADE about (-26.33 dB) as shown in the table 1.

Table 1: Comparison of ISR values

Methods	Interference signal ratio (ISR) for recovering signals			ISR Mean
	S_1	S_2	S_3	
JADE	-22.13	-29.93	-50.90	**-34.32**
MCOMBI	-29.17	-56.28	-45.73	-43.72
Proposed	-46.91	-66.13	-59.67	**-57.57**

6. Conclusion

In this work, the hybrid blind source extraction based on two BSE techniques is investigated to extract the fetus ECG signals (F1-ECG and F2-ECG) from mother ECG signal (M-ECG) and clean the signals from interference signals in order to not effect on the fetal health diagnosis. The performance of the proposed algorithm is checked and shown that the improvement enhancement in source separation. Generally, the proposed algorithm does not only suggest a novel algorithm, but furthermore offers a good judgment among the existing original BSE techniques in the works for twin ECG signal processing technique.

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