An auto detection system for Electrocardiogram of Foetal heart Issues

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Abstract

Knowledge of the foetal heart signal prevents Foetal problems in the earlier stage. Recently, there has been a growing interest study on extraction of FECG using noninvasive method rather than the old invasive method which was more risky for the mother's health. The problems of extraction of the Foetal signals are the problems that plagued researchers in the field of signal processing. The Objective of this paper is to develop a technique for auto extracting FECG signals based on adaptive filter and simple Genetic algorithm. Practical method for extraction using computer simulations is proposed. A program for carrying out the calculations was developed in MATLAB. The testing of the algorithms was done by using real data from SISTA/DAISY and Physionet. The proposed technique for extraction of FECG was useful and the results appear to agree with the mean values of FECG.

Keywords: *FECG, AECG), TECG, surface potentials, Genetic Algorithm (GA), processing communities, and cutoff frequency.*

1. Introduction

Foetal Electrocardiogram (FECG) [4] extraction is an interesting but a difficult problem in the field of biomedical signal processing. It's a technique for obtaining important information about the condition of the foetal during pregnancy by measuring the electrical signals generated by the foetal heart as measured from multi-channel electrodes placed on the mother's body surface.

Perhaps the question that comes to mind is, "what is the importance of studying the FECG?". This is because the heart is the most important organ in an animal's the body and if it stops for a few minutes, it may lose its life. Thus it is imperative to detect the importance of heart problems before it's too late. Heart disease is classified as the most dangerous to human life, of all diseases in the world [2]. The importance of understanding cardiac electrophysiology is basic to all clinicians whether in postnatal (pediatric or adult) or prenatal (foetal) medicine. The development one in the latter in terms of screening and monitoring purposes is not only an act of preventive medicine, but also to allow further progress in understanding the foetus as a patient [5].

The problem is how to diagnoses the foetal life in the mother's abdomen The most common symptom of foetal death in most of the cases is the decrease in foetal movement which is only diagnosed by examining the absence of cardiac activity in foetal's heart.

In clinics today, two techniques are generally being used to detect the foetal heart beat; these include Ultrasound and Foetal Electrocardiography (FECG). Ultrasound provides only the images but does not confirm whether the foetus is alive or dead, especially if the foetus falls asleep for long periods [3]. Furthermore, ultrasound techniques require a trained technician/physician that can frequently reposition the transducer. Therefore, it cannot be done in a home environment which could be beneficial for problematic pregnancies. Foetal Electrocardiography (FECG) can be an attractive candidate to measure heart conduction signals by means of ordinary electrodes placed on the mother's abdomen.

2. Recording of the foetal ECG

There are two methods used to of record Foetal ECG (FECG). The first one relies on placing an electrode in direct contact with the scalp of the foetal. This is named an invasive technique that can only be used during labor. The second one is non-invasive which involves attaching electrodes on the maternal abdomen. The signals recorded by invasive methods have better quality as compared with noninvasive methods; but the procedure is rather inconvenient and it's limited to recordings during labor [18]. For this reasons the procedure for obtaining the

FECG should be non-invasive. The foetal heart is small so the electrical current it generates is very low. In order to record the FECG, electrodes are placed on the maternal abdomen as close as possible to the foetal heart. The FECG may be acquired by placing a number of electrodes around the general area of the foetal and hoping that at least one of the electrodes will have the FECG with high enough SNR. Beside the problem of electrode placement, noise from electromyography activity affects the signal due to the foetal low voltage signal. Another interfering signal is the maternal ECG (MECG) which can be 5-1000 times higher in its intensity and ability to induce surface potentials [1]. The MECG affects all the electrodes placed on the chest (thoracic electrodes) and also affects the abdominal electrodes, while FECG affects only the abdominal electrodes.

2.1. Foetal signals

The Foetal Electrocardiogram (FECG) is a time-varying signal reflecting the ionic current flow which causes the cardiac fibers to contract and subsequently relax [14]. The surface FECG is obtained by recording the potential difference between two electrodes placed on the surface of the skin [12]. The standard FECG signal consists of six peak signals each defined with a different letter, the P, Q, R, S, T and U peaks. Where the P peak results from the depolarization of the atrial, the P-R interval is the time between the depolarization of the atria and the depolarization of the ventricles. The QRS-complex results from the depolarization of the ventricles, The T wave displays the depolarization of the ventricles and the U wave is usually not present or not important resulting from a rest potential. The origin of the U wave is not clear but it probably represents "after depolarization's" in the ventricles [11]. The FECG may be divided into the following sections.

P-wave: A small low-voltage deflection away from the Baseline caused by the depolarization of the atria prior to atrial contraction as the activation (depolarization) wave front propagates from the SA node through the atria.

PQ-interval: The time between the beginning of atria depolarization and the beginning of ventricular depolarization.

QRS-complex: The largest-amplitude portion of the FECG caused by currents generated when the ventricles depolarize prior to their contraction. Although atrial repolarization occurs before ventricular depolarization, the latter waveform (i.e., the QRS-complex) is of much greater amplitude and atrial repolarization is therefore not seen on the FECG.

QT-interval: The time between the onset of ventricular depolarization and the end of ventricular repolarization. Clinical studies have demonstrated that the QT-interval increases linearly as the RR-interval increases [14]. Prolonged QT-interval may be associated with delayed ventricular repolarization which may cause ventricular tachyarrhythmia's leading to sudden cardiac death.

ST-interval: The time between the end of S-wave and the beginning of T-wave. Significantly elevated or depressed amplitudes away from the baseline are often associated with cardiac illness.

T-wave: Ventricular repolarization, whereby the cardiac muscle is prepared for the next cycle of the ECG.

The signals shape in FECG are the same as at maternal ECG (MECG), but completely different in values. Table 1 shows the variation of the ECG signals value between the maternal and foetal. Figure (1) shows the standard P, Q, R, S, T and U complex signals, the entire non-invasive FECG signal should be processed to be like this shape and around the values shown in Table 1.

Also can compare the maternal normal heart beat rate, during pregnancy the heart rate goes around 80-90 beats per min when was the normal adult heart beat bout 72 rate and the mean foetal heart beat rate along gestational period varying from 120 to 160 beats per min. There is a variation in heart beat rate because more QRS signal in FECG than QRS signal in MECG. As mentioned above a human heart can be described as an electrical dipole, unfortunately till now no finding information on the exact voltage value coming from the heart and, may any human body has a unique voltage value.

Table 1: Amplitude-time relations in maternal and foetal electrocardiography signal calculated as mean values from 20 traces recorded between week 36 and 41 of gestation (620 averaged QRS complexes from maternal and 760 from foetal electrocardiogram were analyzed)[16].

	QRS amplitude (μv)	***QRS Width (ms)***
Mother	150	100
Foetal	30	50

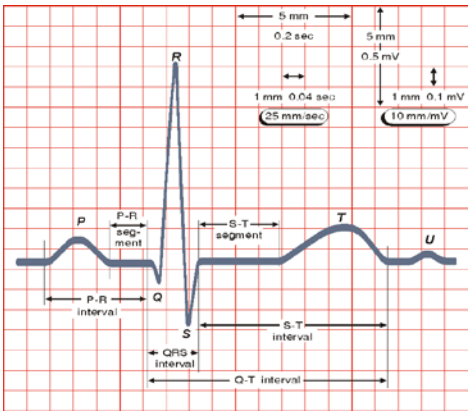

Fig. 1: Standard P, Q, R, S, T and U wave form of human heart; adopted from [1].

3. MATERIALS AND METHOD

3.1. Model Extraction

In this study the signal picked up by the Thoracic Electrodes (TECG) is represented by $X_T(t)$ and the one taken by Abdominal Electrodes (AECG) is represented by $X_A(t)$. These two signal models can be written as:

$$x_A(t) = M_a(t) + F_a(t) + N_a(t) + \eta_a(t) \quad (1)$$

$$x_T(t) = M_b(t) + N_b(t) + \eta_b(t) \quad (2)$$

Where:

$M_a(t)$ and $M_b(t)$ are Pure maternal ECG,

$F_a(t)$ is the pure foetal ECG

$\eta_a(t) = \eta_b$ are the low-rank or structured noise representing other biological sources that contaminate the ECG,

$N_a(t)$ and $N_b(t)$ are the full-rank observation noise that always exists in physiological measurements.

The foetal ECG is very weak compared to the maternal ECG signal and noise level, so it is shownonly in Eq.(1) and neglected in Eq.(2).

In these equations $\eta_a(t)$ and η_b can be eliminated by a high pass filter with a cutoff frequency of 2Hz. Therefore Eq. (1) and Eq. (2) can be simplified to:

$$x_A(t) = M_a(t) + F_a(t) + N_a(t) \quad (3)$$

$$x_T(t) = M_b(t) + N_b(t) \quad (4)$$

To extract a pure $F_a(t)$, Eq. (4) and Eq (3) can be used as follows:

Since $M_a(t) \neq M_b(t)$ and $N_a(t) \neq N_b(t)$, use a factor K to equalize (4) to have

$$Kx_T(t) = KM_b(t) + KN_b(t) \quad (5)$$

Then subtract Eq. (5) from Eq. (3) to get

$$[x_A(t) - Kx_T(t)] = [M_a(t) - KM_b(t)] + F_a(t) + [N_a(t) - KN_b(t)] \quad (6)$$

Thus, the pure FECG can be obtained from the following equation:

$$F_a(t) = [x_A(t) - Kx_T(t)] - [M_a(t) - KM_b(t)] - [N_a(t) - KN_b(t)] \quad (7)$$

After cancelling the maternal signal and noise we get:

$$F_a(t) = [x_A(t) - Kx_T(t)] \quad (8)$$

The output of this equation is used as input to simple Genetic Algorithms (GA) to remove any undesired signals.

3.2. Genetic Algorithm and Adaptive Filtering Model

Fig.2 shows the form of the technique used to extract the desired FECG signal. The figure contains the steps of simple Genetic Algorithms (GAs); The GA used here is adaptive heuristic search algorithm premised on the evolutionary ideas of natural selection and genetic.

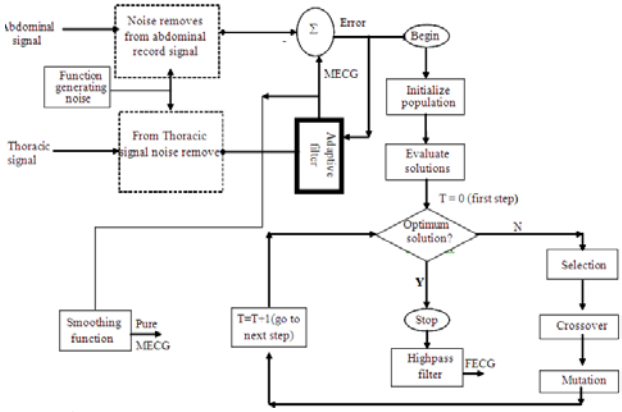

Fig 1: model for auto extraction FECG

3.3. Analysis of Maternal Abdominal Signals:

It is believed that the signals acquired from the wall of abdomen motherland (Non-invasive record) is in fact FECG signal and MECG signal with several overlapping noises .The analysis of these signals is shown in Fig.3 where the amplitude and frequency range of foetal ECG have been compared with other noises. The labels in this figure is as follows: (mECG) stand for the maternal electrocardiogram, (mEEG) for electroencephalogram, (mEHG) for electrohystrogram, (mEOG) for electrooculogram, (mEMG) for electromyogram, (mEHG) for electrohystrogram, and (fECG) stand for the foetal ECG

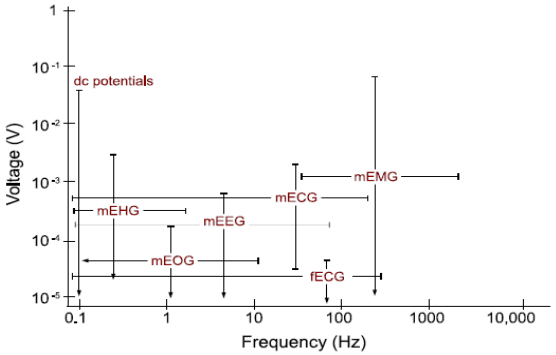

Fig.3: The amplitude and frequency range of biosignals that can interfere with foetal cardiac signals [19].

3.4. Adaptive filtering

An adaptive filter is a self-adjusting filter [8]. Its transfer function according to an optimization algorithm is driven by an error signal. The purpose of the adaptive filter in noise cancellation is to remove the noise from a signal adaptively to improve the signal to noise ratio. The usage of adaptive filters is one of the most popular proposed solutions to reduce the signal corruption caused by predictable and unpredictable noise[17]. Adaptive filters are required for some applications because some parameters of the desired processing operation are not known in advance. Adaptive filters have been successfully applied in diverse fields such as communications, radar, seismology, and biomedical engineering. Figure. (4) shows the diagram of a typical Adaptive Noise Cancellation (ANC) System used for removing noise from human ECG. This paper uses the same idea to extract the signal of foetal heart in a better modified way as contained in Figure.(2).

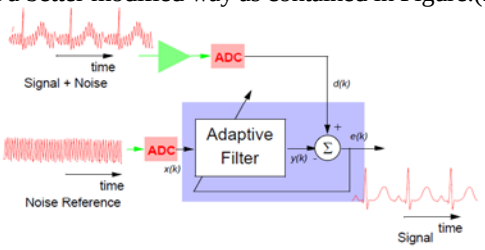

Fig .4: Adaptive Noise Cancellation (ANC)[21].

3.5. Genetic algorithm(GA)

GA is a powerful & broadly applicable stochastic research techniques that is practically being used to solve optimization problems on the basis of natural genetics. Genetic algorithms, are the most widely known type of evolutionary computation method today [7]. It is also applicable in problems where traditional estimation and optimization methods are not appropriate [13]. Genetic algorithms generally start with a population of randomly generated design vectors, test the fitness of those vectors, select the best ones, and recombine the parameter values (i.e., exchange some elements) of the best designs. Recently, the genetic algorithms technique was applied to biomedical engineering especially in foetal electrocardiogram signal [9]. The architecture Figer.(2) used for this paper is a combination of an adaptive filter and genetic algorithm (GA), where the GA is recruited whenever the first step adaptive filter is suspected of reaching local minima. The second step is an independent GA search without the adaptive filter. The process of exchanging elements among successful designs of GA also has a biological analog, which is referred to as “crossover and mutation.” In this paper the case is Scheduling problem, so the method used here is string crossover. During crossover step of the algorithm, segments are cut and spliced between strings. The general framework and basic step of GA can be viewed as the flowchart at the right side of Figer.(2).

3.6. Frequency Response &Cutoff Frequency

It is essential that the ambient noise should be kept as low as possible and this is carried out with the help of an active low pass filter having a cutoff frequency of 70 Hz, due to the fact that the foetal heart beats lies in the frequency range of 20 to 70 Hz [20].
The filter used to compute the frequency response is using discrete Fourier transforms (DFT) with transfer function. This can be written as:

$$H(z) = \frac{b(1) + b(2)z^{(-1)} + \cdots + b(M+1)z^{(-m)}}{a(1) + a(2)z^{(-1)} + \cdots + a(N+1)z^{(-n)}} \quad (9)$$

Where
B; is coefficient vector of numerator polynomial
a; is coefficient vector of denominator polynomial
After optimizing the foetus signal, a high pass filter with normalized digital cutoff frequency, $\Omega c = \omega c\, T/\pi$ equal to 0.1 H(z) and number of poles equal 3is designed,

3.7. FECG DATABASE

To test the algorithm, public databases widely used by the signal processing community known as SISTA/DAISY dataset [10] is used. It consists of a single dataset of cutaneous potential recording of a pregnant woman. A total of 8 channels (4 abdominal and 3 thoracic) are available, sampled at 500 Hz , lasting 10 seconds and The lengths of the data were 2500 point. The heart rate of the mother’s signal is approximately 84 beats per minute and the Foetus corresponding to a heart rate of 132 beats per minute.
The locations of leads on maternal body for an 8-channel maternal ECG acquisition system are shown in Figure.(5). Maternal thorax ECG (TECG) signals are sampled from thorax leads while maternal abdominal ECG (AECG) signals are obtained from abdominal leads.

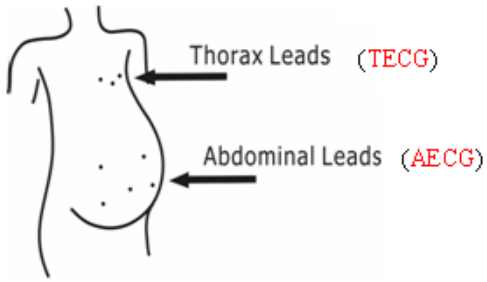

Fig.5: Positions electrodes lead on the body of mother.These methods can be practically applied from the 11th week of gestation, but the signal quality depends on recording period between 26 and 41st week of gestation.

3.8. Original signal distortion

Figer.(6) shows in section (a) real thoracic signal (TECG) of maternal which contain MECG + noise and shows in section (b) real sample of abdominal signal (AECG) which contains MECG + FECG + noise. Where M denotes maternal QRS amplitude region and F denotes foetal QRS amplitude region. These graphs show direct plot using SISTA/DAISY data without any filter effects.

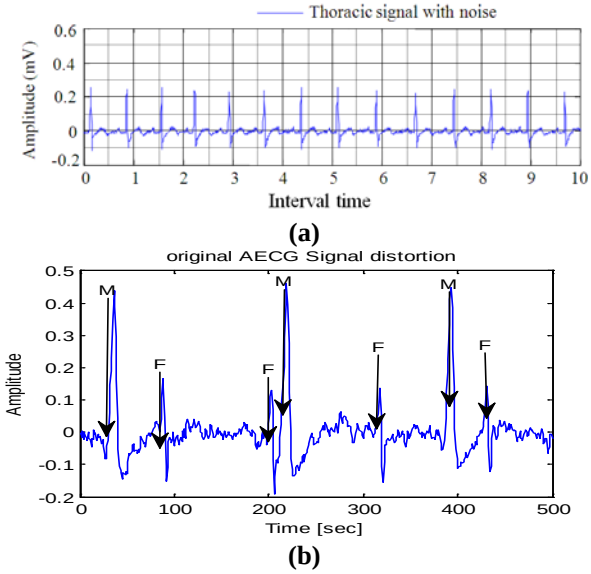

Fig. 6 original graph for (a) TECG, (b) AECG

RESULTS AND DISCUSSION

The proposed scheme shown in Fig.2 is modeled under MATLAB domain, thereafter, the proposed model is trained with the SISTA/DAISY dataset. A combined signal shown in the upper part of Figer.(9) is then applied to the model and successively being extracted as shown in the lower part of Figer.(9). Thus the maternal ECG signal interference was canceled from the foetal heart ECG signal. Figer.(7) and Fig.8 represent noise that was already contaminating with signal taken from thoracic and abdomen of the mother. Also the noise figures show the evidence of an effective noise removal tool system.

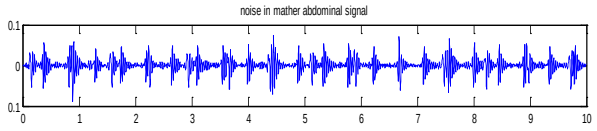

Fig. 7: Noise in abdominal signal

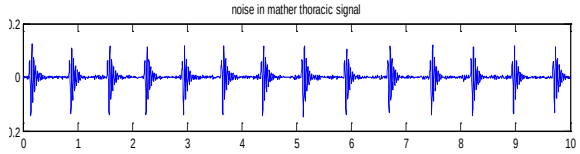

Fig .8: Noise in thoracic signal

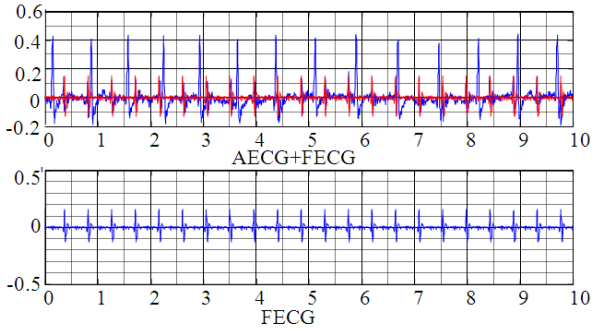

Fig. 9:A graph for MECG and FECG recombined after extracted, B graph for FECG

The results shown in Figer.(9) contain two graphs .the upper graph shows AECG and FECG. The amplitude of QRS of FECG is about 30 microvolt while that of MECG is about 150 microvolt. These values are almost in agreement to the values of QRS amplitude appeared in Table.1. The obtained results show the effectiveness of the proposed algorithm.

CONCLUSION

In this study we presented Hybrid adaptive filtering with simple genetic algorithm for removing undesired signals which are difficult to be removed by normal filters. The performance and validity of the proposed algorithm have been confirmed by computer simulations and experiments in real-world ECG data. The results obtained almost agree with the standard Foetal ECG signals.

ACKNOWLEDGEMENT

This work was supported in part by the national sciences foundation of china (NO.60971016). I wish to thank Chinese scholarship council (CSC) and Chongqing University for offering me scholarship to pursue my Ph.D study.

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