Extraction of Fetal ECG from Maternal ECG using Least Mean Square Algorithm

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---Abstract---

Fetal Electrocardiogram recording and monitoring plays an important role in medical field. As the cardiac defect will be very slight, the baby appears to be healthy and normal, but after birth it might lead to severe heart defect. Hencemonitoring of fetal ECG in early stage is very important to avoid such risk of loss in fetal well being. The fetal ECG helps in determining the fetal life, development and maturity. But,it is not so easy to record fetal ECG, due to the co-existence of maternal and fetal signals acquired from the mother, as well as the fetal signal level is of low amplitude signal.This paper presents a novel method of extracting fetal ECG(FECG) from maternal ECG(MECG) using Adaptive filtering technique.

Keywords-**Adaptive filtering technique, ECG,LMS algorithm**

I. Introduction

Fetal heart rate monitoring helps us to know about the growth of fetus and also about any abnormalities present. Hence it is very necessary to record fetal ECG. But the extraction of FECG is very difficult as it is corrupted by different types of noise such as maternal ECG, noise due to electrode movements and also noise due to the motion of mother during diagnosis. Because of these unwanted signals, the interpretation of fetal ECG has become difficult.

Congenital heart defects originate when the heart is forming i.e. in the early stages of pregnancy. It can affect any part or the function of heart. Structural defects in heart cannot be diagnosed effectively using fetal electrocardiography, except during labor. FECG is confined to issues such as general ischemia due to specific fetal positioning. This limitation is because the FECG is contaminated by fetal brain activity, muscle activity from both mother and fetus. No signal processing technique can accurately provide an undistorted FECG signal from electrodes placed on the maternal abdomen because of the low signal to noise ratio of FECG recorded from the maternal body surface.

Adaptive filters are time variable filters whose characteristics can be varied with time. This incorporate adaptation mechanism by which filter coefficients can be adjusted. These types of filters are used to process the signal whose statistics are not known. Primary and at least one reference input is required for adaptive filter. The method consists of removal of maternal ECG using several or one maternal reference channel which includes morphologically similar maternal ECG. This method is quite practically inconvenient because, the morphology of maternal ECG contaminants highly depends on the electrode locations. Therefore, adaptive filter with only one reference is of great use.

LMS is a type of adaptive filter that mock as wanted filter by finding the filter co-efficient that correlate to produce LMS of error signal (differentiated between desired and actual signal).
The difficulties involved in extracting FECG are;

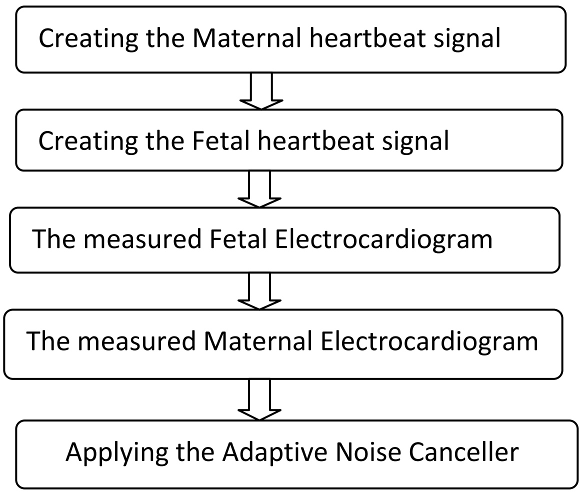
- Low conductivity layers surrounding the fetus and weak cardiac potentials from fetus results in low amplitude FECG.The characteristics of FECG such as heart rate, waveform and dynamic behavior are important in determining the fetal life, fetal development, fetal maturity and existence of fetal distress or congenital heart disease.
- Motion artifacts, contractions of uterus, movements due to maternal respiration and also interference of maternal ECG.

II. Literature survey

Yalan Ye et.al proposed a algorithm that adopted two non-linearities and a flexible non-linear model switching technique to separate mixture of pure sub-guassian source signals and super-guassian source signals [1].Kavuri Swathi Sri et.al described to evaluate different criterias for generating reference signals which is close to describe signal to exhibit the rhythm in EEG signal [2]. Jiazhi zang et.al developed a cost function to remove noise effects in the signal. Algorithm which takes into account the effect of noise is obtained when the cost function is made maximum. Algorithm efficiency is demonstrated by the analysis of artificial generated and also original ECG corrupted by noise [3]. Giulia Da Poian et.al proposed a new method for the separation of maternal and fetal heart beats based on the sparse decomposition in an over complete dictionary of Gaussian like functions. The method allowed to identify beats belonging to the fetal signal and to distinguish them from the mother ones[4].D.Sugumar et.al proposed a paper mainly focused on separation of maternal and fetal ECG signal and performance measure of various BSS and JBSS algorithm in term of SIR and execution time. They concluded JBSS CUM4 algorithm was the best algorithm in terms of performance for separating MECG and FECG.[5]. Yaping Ma et.al proposed a method for extracting fetal ECG using a hybrid non linear adaptive noise canceller with single or multi-reference channels. The new hybrid ANC including both exponential terms and cross terms is more capable of approximating the nonlinearity between the MECG at the chest and a transformed version of it at the abdomen[6].

III. Methodology

In adaptive noise cancelling, a measured signal d(n) contains two signals: - an unknown signal of interest v(n) - an interference signal u(n) The goal is to remove the interference signal from the measured signal by using a reference signal x(n) that is highly correlated with the interference signal. The example considered here is an application of adaptive filters to fetal electrocardiography, in which a maternal heartbeat sign signal is adaptively removed from a fetal heartbeat sensor signal.



1. Creating the Maternal Heartbeat Signal
The electrocardiogram for both the mother and fetus is simulated assuming a 4000 Hz sampling rate. The heart rate for this signal is approximately 89 beats per minute, and the peak voltage of the signal is 3.5 millivolts, as shown in fig.2a.

2. Creating the Fetal Heartbeat Signal
The heart of a fetus beats noticeably faster than that of its mother, with rates ranging from 120 to 160 beats per minute. The amplitude of the fetal electrocardiogram is also much weaker than that of the maternal electrocardiogram. The ECG signal corresponding to a heart rate of 139 beats per minute and a peak voltage of 0.25 millivolts is generated, as shown in fig.2b.

3. The Measured Fetal Electrocardiogram
The measured fetal electrocardiogram signal from the abdomen of the mother is usually dominated by the maternal heartbeat signal that propagates from the chest cavity to the abdomen. We shall describe this propagation path as a linear FIR filter with 10 randomized coefficients. In addition, we first add a small amount of uncorrelated Gaussian noise to simulate any broadband noise sources within the measurement.

4. The Measured Maternal Electrocardiogram
The maternal electrocardiogram signal is obtained from the chest of the mother. The goal of the adaptive noise canceller in this task is to adaptively remove the maternal heartbeat signal from the fetal electrocardiogram signal. The canceller needs a reference signal generated from a maternal electrocardiogram to perform this task. Just like the fetal electrocardiogram signal, the maternal electrocardiogram signal will contain some additive broadband noise.

5. Applying the Adaptive NoiseCanceller
The adaptive noise canceller can use most any adaptive procedure to perform its task. For simplicity, we shall use the least-mean-square (LMS) adaptive filter with 15 coefficients and a step size of 0.00007. With these settings, the adaptive noise canceller converges reasonably well after a few seconds of adaptation--certainly areasonable period to wait given this particular diagnostic application, as shown in fig.2e.

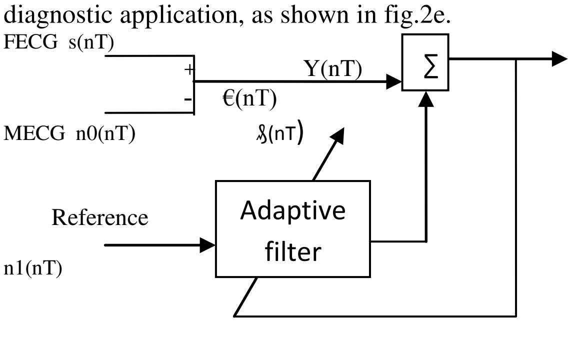


Fig.1: Adaptive noise canceller

The input to the filter is taken from the mother's abdomen which is consisting of MECG and FECG i.e.n0(nT)+s(nT). Mother's chest ECG is taken as secondary reference inputn1(nT) to the filter, which produces output that is the close estimate of result. The output of the adaptive filter $\hat{s}(nT)$ is subtracted from the input, to produce the system output *Y(nT)*.

$$Y(nT)=s(nT)+n_0(nT)-\hat{s}(nT)$$

Squaring the output and making the (nT) implicit to simplify each term

$$Y^2=s^2+(n_0-\hat{s})^2+2s(n_0-\hat{s})$$

Taking expectations on both sides,

$$E[Y^2]=E[s^2]+E[(n_0-\hat{s})^2]$$

When the system output is minimized,

$$\min E[Y^2]= E[s^2]+\min E[(n_0-\hat{s})^2]$$

the mean square error (MSE) of ($n0-\hat{s}$) is minimized, and the filter has adaptively synthesized the noise ($\hat{s}\approx n0$), but $E[s^2]$ is unaffected by adjustments to the filter.

IV. Results

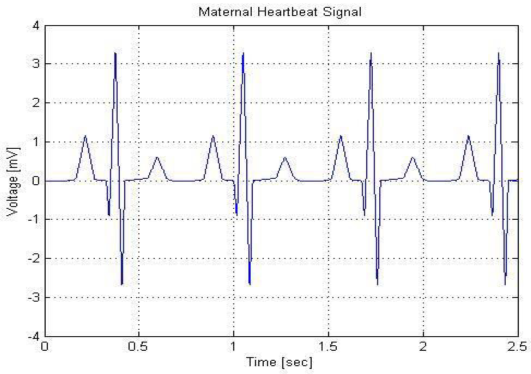


Fig.2a: Generated Maternal heartbeat signal

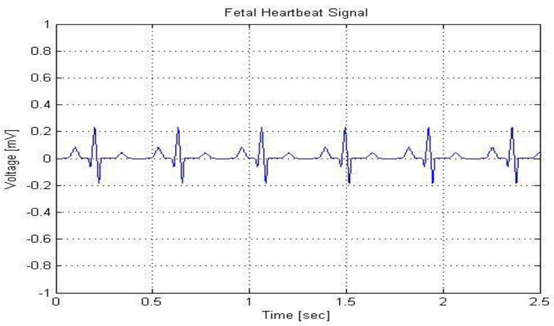


Fig.2b: Generated Fetal heartbeat signal

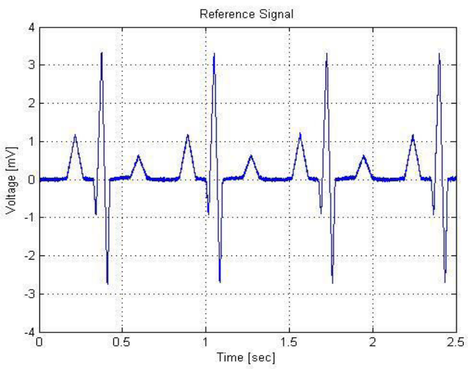


Fig.2c: Reference ECG signal

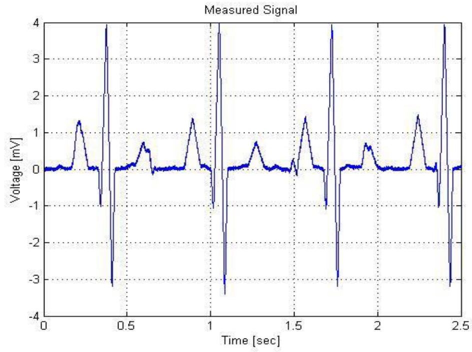


Fig.2d: measured signal (maternal and fetal ECGs)

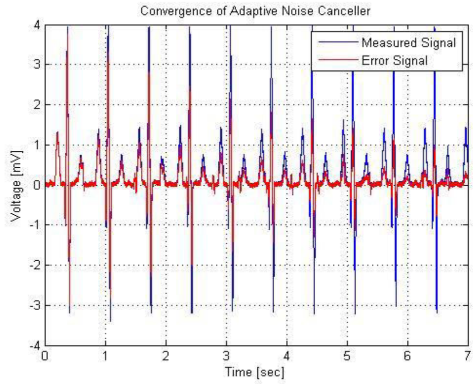


Fig.2e: Convergence of Adaptive noise canceller

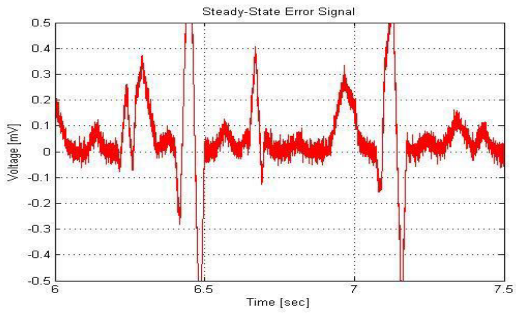


Fig.2f: Steady-state error signal (Fetal ECG signal)

The Maternal ECG generated, as in the fig.2a and the Fetal ECG as in fig.2b. is combined to make it as the mixture of maternal and fetal ECGs as shown in the fig.2d. The reference signal is taken as mother's chest ECG as shown in fig.2c. When this mixture signal is passed through the Adaptive filter, the mixed signal is compared with the reference signal and the maternal ECG is cancelled, as it is of high amplitude and matches with reference signal as shown in fig.2e.

With the weights added to the filter the FECG signal is not destroyed. Hence the fetal ECG is separated from the MECG. The extracted FECG signal appears to be steady state error signal as shown in fig.2f.

V. Conclusion and future scope

Least mean square algorithm gives better extraction of fetal ECG signal from Maternal ECG signal.

Adaptive filtering technique provides easy extraction of fetal ECG from MECG by adjusting the parameters automatically.

By calculating the R-R intervals from the obtained FECG, fetal heart rate can be calculated. But, the traces of peaks of MECG will be present which causes the difficulties.

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