International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 07 | July 2018 www.irjet.net p-ISSN: 2395-0072

Fetal ECG Extraction using Wavelet Transform

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Abstract - *Monitoring of fetal is the way to find the condition of unborn baby in the womb during pregnancy, labor and delivery period by continuous monitoring of fetal heart rate. Measurement of electrical activity of heart is called ECG i.e. Electrocardiography. This monitoring measures and records the electrical activity of the heart of the fetal and provide important details about fetal heart. Normal heart rate of the fetal shows the safe birth of the baby. The thorax (chest) ECG contains only maternal ECG (MECG) but abdominal ECG is a composite ECG signal containing both mother as well as fetal ECG. Since past, in this field lots of research work have been performed which uses threshold and filtering method along with neural network. This paper presents an algorithm which uses Wavelet Transform to extract fetal heart rate from an abdominal ECG signals which is measured at mother's abdomen. Wavelet Transform is very effective and most popular method for detecting the characteristics of non stationary signals. The proposed algorithm is implemented by in three steps: 1) The abdominal ECG signal (AECG) is recorded from mother's abdomen and decomposed to estimate maternal ECG signal using wavelet Transform. 2) ECG of fetal (FECG) is extracted by subtracting MECG from AECG signal. 3) Then from extracted FECG signal, R-peaks are identified to obtain fetal heart rate. This research is implemented on 15 recorded signals taken from Physionet using MATLAB which shows consistency of the proposed approach.*

***Key Words*: ECG(Electrocardiography), AECG(Abdominal Electrocardiogram),MECG(Mother Electrocardiography), FECG(Fetal Electrocardiography), FHR(Fetal Heart Rate), MHR(Maternal Heart Rate), Wavelet Transform, Mean RR interval, Non- Invasive technique.**

1. INTRODUCTION

Monitoring of fetal heart is the technique to find the health-status and possible heart diseases during pregnancy. Fetal heart rate (FRH) is the one of the most important tool which is used nowadays in clinical investigations to examine the heart status or health state of fetus during pregnancy and labor. FRH is the mostly used parameter during pregnancy. Monitoring of fetal heart rate helps to detect changes in normal heart rate and yields information about the condition of baby during pregnancy or labor. If any changes are detected, doctors can take some steps to treat the underlying problems. Fetal ECG (FECG) are generally much weaker than maternal ECG (MECG) but fetal heart rate (FHR) is higher than maternal heart rate (MHR) [1].

Eight out of one thousand born live infants have some form of heart defect, making it the single most common class of congenital abnormalities. Identification of the heart defects during early pregnancy reduces risks by timely treatment or planned delivery. Some defects are major while others are minor. They can effect baby's physical and mental development and appearances. During first trimester of pregnancy most of the heart defects are detected. Detection of heart rate of the fetal can be useful for other cases like: detection of gestational age, monitor the progress of labor, miscarriage rate detection and evaluation and monitoring of uterine contraction etc. To monitor the fetal during pregnancy techniques are classified into invasive and non-invasive methods. Invasive methods generally more risky to the fetal because this method involves needles and probes inserted into uterus. But it can be done from about 14 weeks to 20 weeks gestation. In the non-invasive Fetal ECG (FECG) monitoring, surface electrodes which is placed on abdominal surface of mothers provides valuable information about the cardiac electrical activity of fetus in the womb. By using traditional techniques, extraction of the FECG from the abdominal signal is very hard even not possible. Electrocardiogram (ECG) is the simplest and painless technique to find heart rate. It is non-invasive method to estimate fetal heart condition. ECG provides heart (cardiac) waveform. This cardiac waveform of fetal helps to the physicians to find out or diagnose the arrhythmia such as Bradycardia, Tachycardia, Congenital heart diseases, Asphyxia and Hypoxia. In non-invasive technique the electrodes are placed on the abdominal surface of the pregnant lady or mother, then AECG is recorded which is the combination of the mother and fetal ECG with some noises. It takes great amount of noises called as artifacts. In the ECG signal measuring process four main types of noise and interference occur such as 50 Hz power line interference, Base line drift, Maternal electromyogram (EMG) noise and random Electronic noise [2]. The original FECG signal is very complex and severely contaminated by external disturbances or noises. The object of our work is to remove the noises in signals which are occurred due to power line interference, movement of patient etc.

Numerous methods and different approaches have been proposed and used for fetal electrocardiogram (FECG) signal detection: Wavelet based ECG extraction methods [1][2][3][4][5], An Automated Methodology for Fetal Heart Rate Extraction from the Abdominal Electrocardiogram [8], least mean squares adaptive noise cancellation filtering [10],

Blind Source Separation (BSS) technique for extraction of FECG which is typical blind source separation problem [11][12]. We proposed here an algorithm using Wavelet Transform to extract fetal ECG from abdominal signals which is taken by mother's abdominal surface and calculate fetal heart rate. The amplitude of fetal ECG is always fluctuated. Some algorithms are not able to find out all r-peak. In this paper we create an algorithm with threshold dependency to find out all r-peaks of FECG. This proposed approach consists of two steps: decomposition of original signal into FECG and MECG with two level Wavelet Transform. Then r-peaks are found out from extracted FECG signals. This paper is organized as follows: Section II describes the approach which is used for extraction of fetal ECG (FECG). Section III describes the methodology with data acquisition and algorithm which is proposed in this paper and Section IV represent the result which is obtained by this research and showing fetal heart rate and also showing the advantages of this proposed approach.

2. PROPOSED APPROACH

There are several methods for ECG detection as mentioned above. For feature extraction by using DWT (Discrete Wavelet Transform) may leads to an optimal frequency resolution in all ranges of frequencies as it has a varying window size, broad and narrow at lower and higher frequencies. The DWT characterization will deliver the stable features of the variations of the ECG waveform [4].

Wavelet Transform is basically a convolution operation of the subjective signal and wavelet function. The Wavelet Transform decomposes a signal into two sub signals such as detail signal and approximation signal. The upper half of the frequency component contains in detail signal and lower half of the frequency component contains in approximation signals. Thus multi resolution analysis can be performed in discrete wavelet domain [1].

For large variety of applications the large number of known wavelet families and functions are available. Wavelet families are Bi-orthogonal, Coiflet, Harr, Symmlet and db (Daubechies) wavelet etc. Depends on the application wavelet function is used. We were seen the uses of these wavelet families in many research work. There is no way to choose a certain wavelet. Here we use MATLAB program to obtain the wavelet analysis. MATLAB contains a very rich wavelet toolbox. In this paper we use db (Daubechies) wavelet in the algorithm because it is similar in shape to the human heart beat waveform. The result of the daubechies is very good. In our research work we create an algorithm in MATLAB with the use of daubechies wavelet transform for decomposition the signal into approximate and detailed coefficients. Wavelet Transform works on the basis of convolution operation of the subjective signal and wavelet function. Here subjective signal is recorded signal which is taken from Physionet and wavelet function is daubechies.

3. METHODOLOGY

Five major steps involved in fetal heart rate are:

- Load raw AECG data from Physionet.
- Pre-processing (noise removed from signal)
- Apply wavelet transform
- Filtering the FECG signal
- Detection of R peaks and calculate FHR

Flow diagram of our methodology is shown in figure 1.

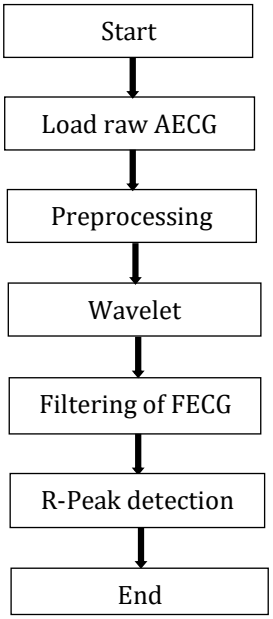

Fig -1: Flow chart of FECG analysis

3.1 Data Acquisition

The subjective signals which is abdominal electrocardiogram (AECG) signals used in this algorithm were taken from the Physionet [15]. In this work we use non-invasive fetal ECG database available in the website, which is up to 40 weeks of pregnancy and duration of each signal is 10 seconds long taken from a single subject. Frequency of these signals is 1000 Hz with 16 bits resolution. This records has two thoracic signals and 3 to 4 abdominal signals. Here we use only abdominal signals because it contains both mother and fetal ECG with noises. Electrodes are placed on mother's abdomen when abdominal signals are record. Thoracic signals contain only mothers' ECG. That is why we taken only abdominal signals.

50 Hz notch filter switched on to filter power line or other related disturbances.

3.2 Pre-processing

The raw signal which is taken from Physionet is very noisy. These noises are power line interface, baseline drift, mother EMG, motion artifacts, etc. Power line interface is 50 Hz or 60 Hz noise component. Here we use IIR-notch filter. 50 Hz IIR-notch filter switched on to filter PLI (power line interface) or other related disturbances. Then to get MECG and FECG here we apply Discrete Wavelet Transform. DWT is also remove baseline drift. After preprocessing we can apply wavelet transform for decomposition of the signal.

3.3 Proposed Algorithm

In the proposed algorithm, a Discrete Wavelet Transform with 10 level decomposition is used on the recorded signal. In this algorithm we use Daubechie wavelet because its shape is similar to the heart waveform. To estimate MECG signal, Decomposition of AECG is done by filtering and down sampling operations. To reduce the data rate or the size of the data down sampling is usually done. Level 1 coefficient are obtained at this stage. With the filter coefficients convolution of AECG signal is done. Here we use threshold which is more than 40%.

The energy of the FECG signal is lower while the energy of the MECG signal is higher. The abdominal signals are composite signals, it contains both MECG and FECG with some noises also because of some artifacts, EMG etc. The wavelet approximate coefficients of the decomposed signal may better estimate the maternal ECG (MECG) signal. After extracting MECG it is subtracted from the AECG signal. After the subtraction FECG signal is obtained. AECG and MECG are shown in fig. (2) and fig. (3) and extracted FECG is shown in fig. (4).

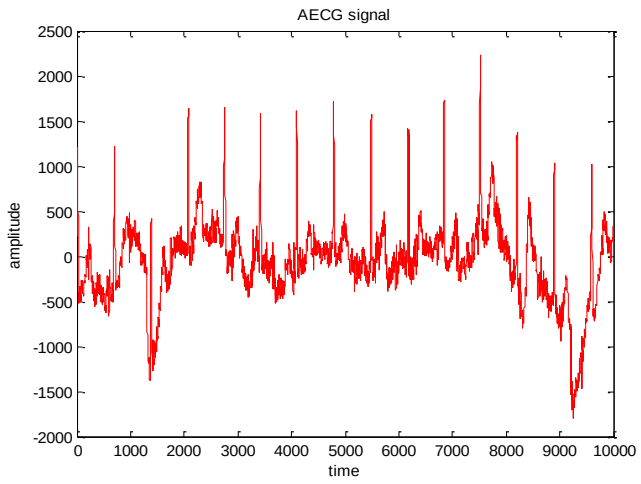

Fig -2: Abdominal ECG signal

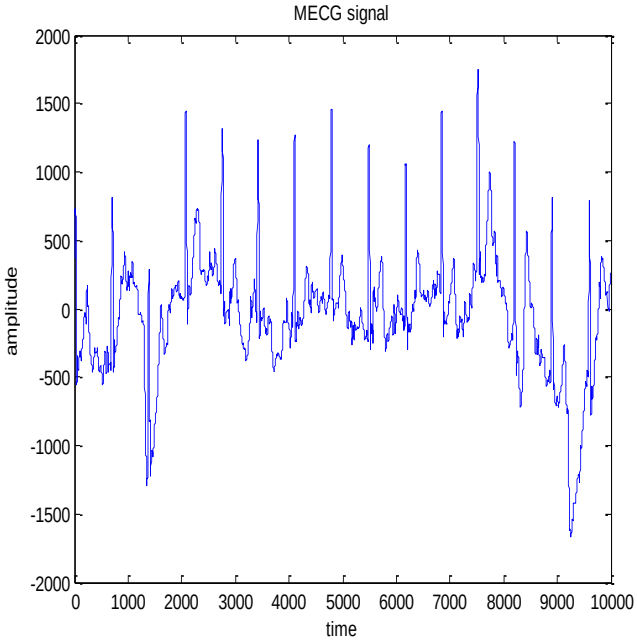

Fig -3: Maternal ECG signal

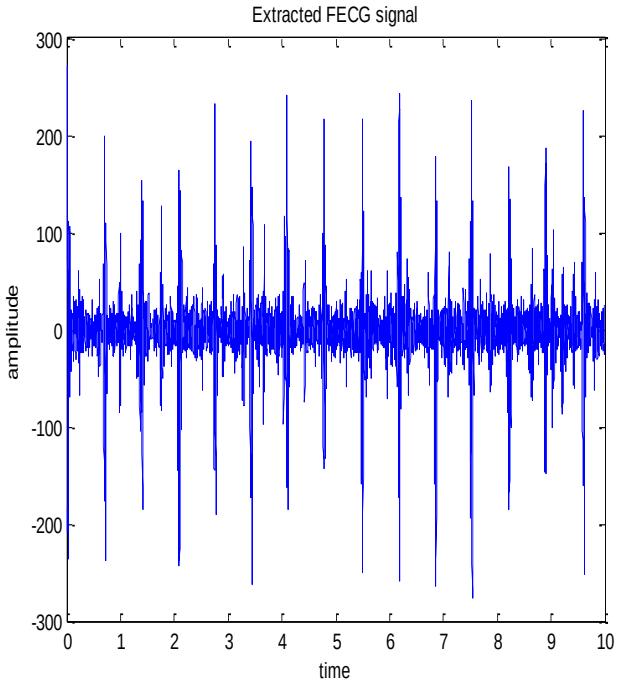

Fig -4: Extracted FECG signal

The extracted FECG signal is very noisy. For removing the noises we use sevitzky-golay smoothing fitter. Here we use order four sevitzky-golay smoothing fitter for decomposed signals. For denoising the FECG signals the frame size was chosen 301. For further improvement in FECG signal we use FIR hamming-band pass fitter with cutoff frequencies at 3 Hz and 35 Hz. Then filtered signal is obtained shown in fig. (5).

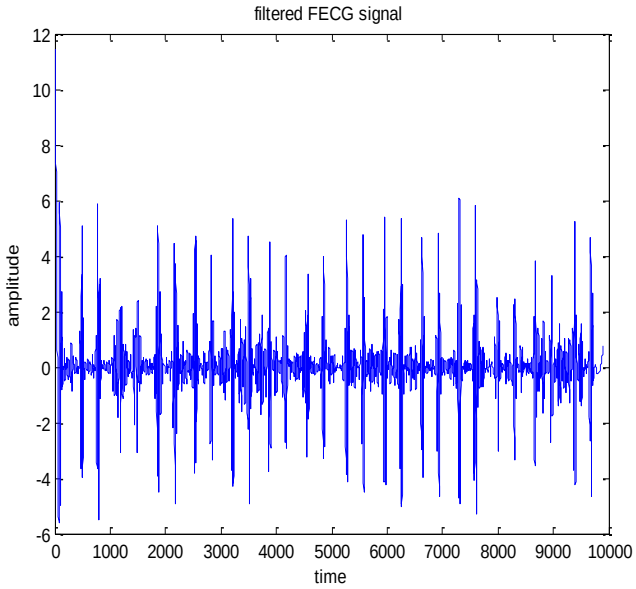

Fig -5: Filtered FECG signal

Fetal heart rate is obtained by calculating no. of R-peaks of extracted FECG signal that is 10 second long in duration. Detected R peaks are shown in fig. (6).Using RR interval including minimum &maximum heart rate, we first calculate R- peaks in the FECG signal. Based on the normal fetal heart rate, mean RR interval and sampling frequency, where the maximum heart rate is around 180 beats per minute and the minimum rate is around 90 beats per minute we can detect fetal peak. Here fetal peaks are detected which is shown by red stars in fig. (6).

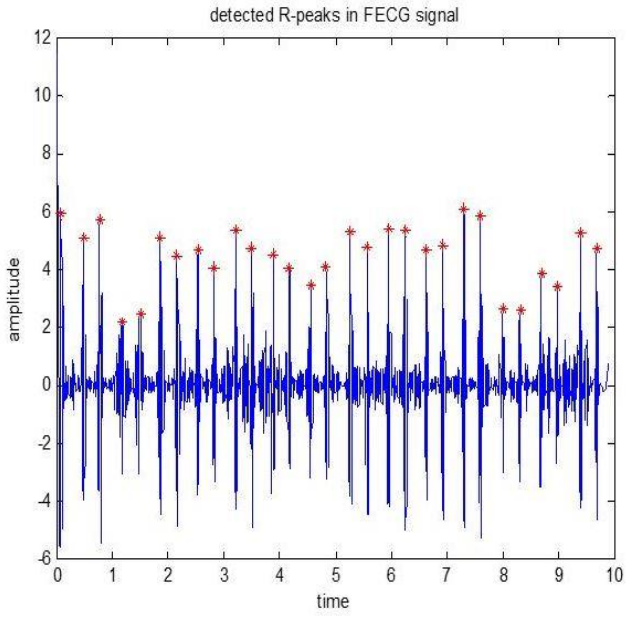

Fig -6: R-peaks detected in FECG signal

4. RESULT

This proposed algorithm is performed on 15 recorded signals which is taken from Physionet database. Table 1 shows the results obtained by proposed methodology applied on the signals. Fetal ECG is extracted at the end of the procedure. From Table 1, it can be easily observed that the Heart Rate of fetal varies from varies 172-189 and RR interval ranges from 0.3175 to 0.3488 sec, which is better than the existing algorithms for fetal heart rate detection.

Table -1: No. of R peaks, Mean RR Interval and Detected FHR

S. No.	No. of R peaks	Mean RR Interval	Fetal Heart Rate
1	29	0.3297	182
2	27	0.3409	176
3	30	0.3279	183
4	28	0.3209	187
5	27	0.3175	189
6	26	0.3371	178
7	29	0.3297	182
8	25	0.3191	188
9	28	0.3226	186
10	27	0.3315	181
11	26	0.3333	180
12	29	0.3352	179
13	24	0.3390	177
14	23	0.3488	172
15	30	0.3175	189

In above Table 1. Fetal Heart Rate shows heart rate of proposed method. Here we calculate standard deviation of heart rate then we compare standard deviation of our research work with standard deviation of other.

5. CONCLUSION

In this proposed method we calculate Standard Deviation of FHR is 5.1195 while other method gives standard deviation of FHR is 5.7553.Thus our proposed method achieved much better results and all R-peaks are detected successfully of resulted FECG signal which is presented in AECG signal. FHR (Fetal Heart Rate) calculated by this methodology has given good results comparison to the other methods. Table 1 shows detected R-peaks, mean RR interval and Heart Rate of

extracted FECG signals that is summarizes the performance of the detection scheme on fifteen recorded signals. With these results we can help the physicians to take some necessary steps.

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