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Detecting Heart Rates of Expectant Mothers in their 3rd Trimester

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***Abstract*— The on-going research work involved in filtering abdominal electrocardiogram (aECG) and detecting maternal QRS complexes to calculate maternal heart rates will give this research a lead to further detect fetal heart rates. The monitoring of maternal and fetal heart rates help detect fetal hypoxia early in the evolution to acidosis. The maternal ECG is strongly distorted by artifacts like baseline wander and power line interference. This paper briefly recaps the implementation of some methods to remove these noise so as to calculate the maternal heart rate (R-R interval). Kaiser FIR High pass filter has been proved to be an efficient method for the removal of baseline wander from the aECG signal [7]. A Notch filter with a bandwidth of 2Hz was designed in Matlab using FDA tool to remove the 50 Hz power line interference[7]. In the proposed algorithm a RR interval is calculated, based on threshold detection of the R peaks which in turns calculates the maternal heart rates. The method is validated using 19 recorded signals taken from the Physionet non-invasive aECG database.**

***Keywords*— asphyxia, Abdominal Electrocardiogram (aECG), baseline wander, power-line interference, Physionet, threshold detection.**

I. INTRODUCTION

Monitoring of maternal and Fetal Heart Rates (FHR) is sensitive and can detect fetal asphyxia early in the evolution to acidosis. Electronic FHR monitoring was introduced in an attempt to reduce or eliminate the potentially disastrous consequences of fetal asphyxia. Previous studies of FHR signals obtained using Cardiotocography (CTG) have shown that fetal acidosis and fetal hypoxia are directly associated with reduced FHR [1-4], which is directly related to increasing risk of perinatal mortality. Currently, CTG is the main method by which fetal's wellbeing is monitored. However, fetal's beat-to-beat changes obtained using CTG are not accurate compared to those obtained from the electrocardiogram (ECG) signal [5].

Reports show in WHO Media Centre 2012, that Congenital anomalities (also referred as birth defects) affect approximately 1 in 33 infants and result in approximately 3.2 million birth defect related disabilities every year.

The Infant Mortality Rate (IMR) of 2012 in India is 11 deaths per 1000 live births. Reports also shows in chart I, that of the total infant deaths occurred due to birth asphyxia in the year 2012 at the Medical Hospitals , in the state of Goa, India, is 5 %.

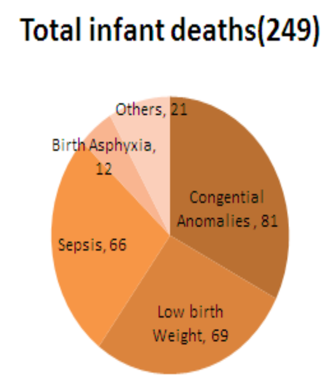

Chart I Cause Of Death In Infants At Medical Hospitals

Newspaper report, Heraldo (Insight) Friday , May 17 2013

Despite disadvantages, the goal of protecting the fetus during this potentially dangerous 3rd trimester end (37th week onwards) should and does supersede all other considerations. A thorough understanding of abnormal FHR patterns not only allows physicians to direct resuscitative efforts and prevent hypoxic damage but also prevents unnecessary interventions.

In this paper, efforts are made to denoise the maternal aECG before finding the maternal heart rates (R peak intervals) so as to use this as a reference signal during extraction of fetal ECG.

II. METHODOLOGY DENOISING AECG

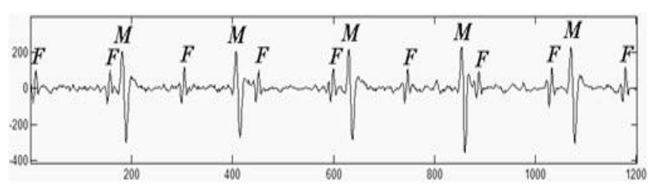

Figure 1: Composite Maternal Abdominal Signal; M- maternal QRS complex, F- fetal QRS complex

1. Data Acquisition:

The Non-invasive abdominal ECG (aECG) as shown in figure 1 is the recording of the cardiac activity of both the mother and the fetus when several leads are placed on the abdomen of the mother. The motivation for monitoring the fetal heart rate through pregnancy is to recognise pathologic conditions, typically asphyxia, with sufficient warning to enable intervention by the clinician before irreversible changes set in. The abdominal ECG signals are taken from the Physionet database [6]. Physionet offers free web access to large collection of recorded physiologic signals and related open-source software.The physionet ATM contains a collection of several ECG databases where each database comprises of patients records of ECGs of different types of diseases.Each patient's recording sampled at 1ms contains 11000 values. We took this database which contained a series of 55 multichannel abdominal non-invasive ECG recordings, taken from a single subject between 21 to 40 weeks of pregnancy and the duration of each signal is 10 seconds. The signals sampled at a rate of 1 kHz, with 16 bit resolution were imported into MATLAB.

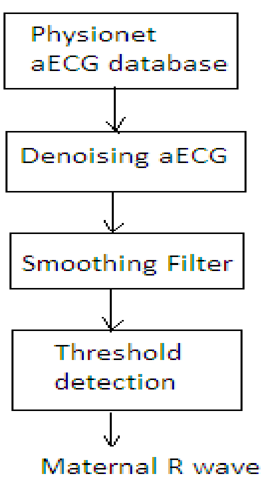

Figure 2: Proposed Methodology to obtain maternal R waves.

2. Denoising AECG:

2a. Base line wander removal

The Baseline wander due to respiration can cause problems to analysis, especially when examining the low frequency ST segment. The simple approach used to filter baseline wander was to use a highpass filter to cut off the lower-frequency baseline wander components up to 1 Hz. Performance of various FIR and IIR digital filters were compared using Matlab's FDA tool.

We used a high-pass FIR filter with a fixed cut-off frequency fc of 2 Hz at a sampling frequency of 1000 Hz [7]. The Signal to noise ratio formula [7] used here to compare the filters is given by:

SNR (db) = *10 * log* $_{10}$ *(FFT (filtered signal)*^{2} */(FFT (Input signal - Filtered signal)*^{2}*).*

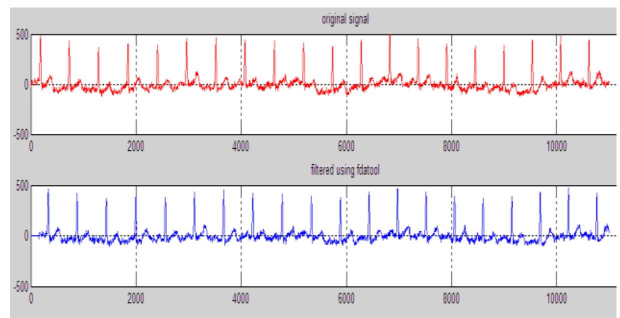

Figure 3 Kaiser FIR filter output

The IIR filters displayed poor SNR ratios compared to the FIR filters and Kaiser FIR high pass filter exhibited the highest SNR value [7]. Kaiser FIR filter showed the absence of the baseline wandering as shown in figure 3.

2b. Removal of Power Line interference

Power-line interference consists of a sine wave with a centre frequency around 50 Hz and harmonics at multiples of this frequency. Such noise can cause problems interpreting low amplitude waveforms and corrupt electro-physiologic recordings. The Fast Fourier Transform (FFT) of the denoised signal shows that the 50 Hz frequency component has been effectively removed using the Notch filter as shown in figure 4. The proposed methodology as shown in figure 2 uses the Kaiser FIR high pass filter, Notch filter followed by the Savitzky Golay smoothing filter which effectively denoises the abdominal Maternal ECG signal without destroying the fetal ECG information as shown in figure 5.

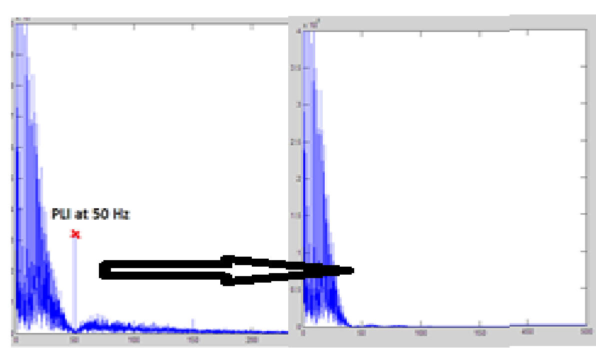

Figure 4 FFT of the denoised aECG signal with PLI absent at 50 Hz

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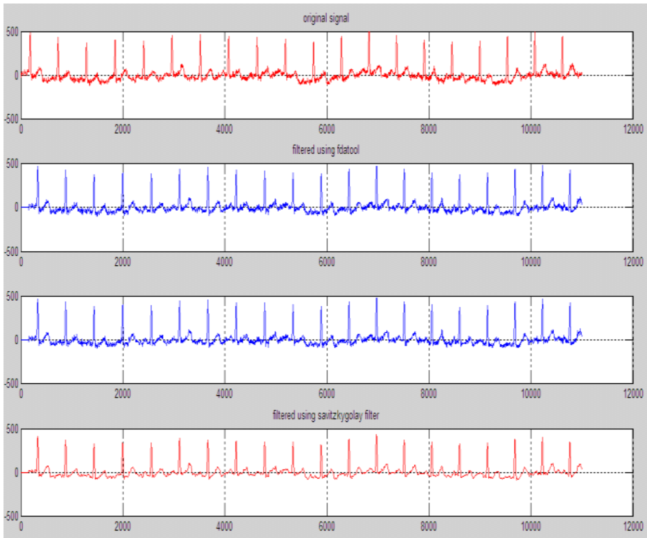

Figure 5: Proposed Technique [7] to filter aECG signals before detecting the maternal R peaks.

3. Algorithm To Detect Maternal Heart Rates.

Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval. In RR variability, R is a point corresponding to the peak of the QRS complex of the ECG wave; and RR is the interval between successive R peaks as shown in figure 6.

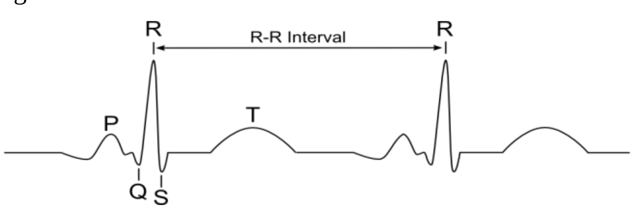

Figure 6: RR interval of a maternal ECG waveform

To obtain the RR interval, The aECG recorded data from the Physionet (record_1) was first filtered and imported into Matlab. The threshold R peak was set to 300 after observing the output signal from the smoothing Savitzky Golay filter as shown in figure 5. All the voltage points above the threshold value were summed up and the midpoint was calculated at each QRS. The sampling rate was 1100/sec (fs) since the record_1 contained 11000 samples for 10 seconds.

The implementation of this algorithm depends mainly on the normal heart rate (HR) and the sampling frequency. According to the RR interval and the sampling frequency, the heart rate interval can be calculated as follows:

$$HR = (1/ RR) * fs * 60 \qquad [8]$$

III. Results

The accuracy of the algorithm was tested by applying it to 19 recorded signals, each of them is about 10 seconds long. The algorithm was implemented through the use of MATLAB and its FDA tool. Figure 7 shows the twenty maternal R peaks of the record_1 for 11000 samples. There was not much variation between the maximum and minimum RR intervals for each of the records. All 19 aECG records from the Physionet database were checked for the RR intervals keeping the threshold level to 300. It was observed that the voltage level of the record_12 was very low, hence the threshold level was changed to 18. Some of the heart rates (maximum and minimum) of the AECG records were obtained, as shown in Table I using the heart rate formula [8].

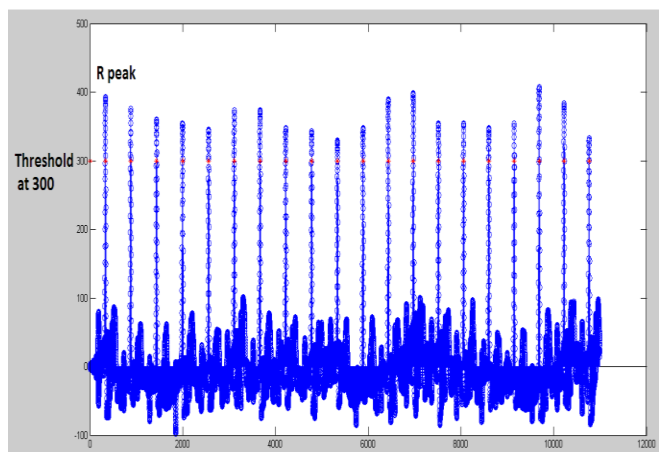

Figure 7: Twenty Maternal R peaks detected for record_1and a threshold set for 300

TABLE I
Hearts Rates of some aECG records

Record Number	RR_max	RR_min	Threshold for R peaks	Heart Rate bpm (min/max)
Record_1	622	570	300	106/115
Record_8	750	730	300	88/90
Record_12	*772*	*765*	*18*	*85/86*
Record_19	725	712	300	91/92

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IV. Conclusion And Discussion

The non-invasive abdominal ECG (aECG) taken from the Physionet database is the recording of the cardiac activity of both the mother and the fetus when several leads are placed on the abdomen of the mother. Abdominal ECG is distorted by the artifacts such as baseline wandering and power line interference. This paper provides an efficient way to find the maternal heart rates after filtering the AECG signals. The combined methodology of using the Kaiser FIR high pass filter, Notch filter followed by the Savitzky Golay filter effectively denoises the abdominal Maternal ECG signal without destroying the fetal ECG information. In the proposed algorithm a RR maximum and minimum interval are calculated based on threshold detection of the R peaks. The algorithm is successfully implemented using MATLAB which calculated the maximum and minimum heart rates of each of the 19 records keeping the threshold level to 300 except for record_12 which is set to 18. Further research can use this aECG as a reference signal to extract Fetal ECG.

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