ISSN 2229-5518

FETAL HEART MONITOR

Priya Rajput , Bhupendra Singh , Pragati Karan

Abstract--This research work proposes an improved algorithm or slash procedure for extracting the fetal heart rate from abdominal ECG recordings of a pregnant woman.
The basic goal of this project is to detect the fetal R-R intervals as well as fetal heart rate from abdominal non-invasive records.
The database of ECG recordings has been taken from physionet (www.physionet.org).This database contains a series of 55 multichannel abdominal non-invasive fetal electrocardiogram (FECG) recordings, taken from a single subject between 21 to 40 weeks of pregnancy. The records have variable durations, and were taken weekly.All data record is in .edf format(European Data Format).
The various noises can be removed from the abdominal signal by using various filtering methods. The maternal QRS segment is obtained and subtracted from the abdominal ECG signal. To evaluate the fetal's R peak, the fetal's QRS points have to obtain.
The application of the algorithm to all the abdominal channels will probably allow improving the obtained results.

Index Terms--ECG, MECG, FECG, FHR, QRS complex, FPGA.

1 INTRODUCTION

THE Electrocardiography (ECG) is a transthoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body. The recording produced by this noninvasive procedure is termed as electrocardiogram (also ECG or EKG). An electrocardiogram (ECG) is a test that records the electrical activity of the heart.

A typical ECG tracing of the cardiac cycle (heartbeat) consists of a P wave, a QRS complex, a T wave, and a U wave which is normally visible in 50 to 75% of ECGs. The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically the isoelectric line is measured as the portion of the tracing following the T wave and preceding the next P wave.

- *Priya Rajput has done masters degree program in Electronics and Communication Engineering from Amity University,Noida,India. E-mail: priya.rajput08@gmail.com*
- *Bhupendra Singh and Pragati Karan have done masters degree program in Electronics and Communication Engineering from Amity University,Noida,India. E-mail: bhupendra89saradhana@gmail.com, choudhary.pragati15@gmail.com*

This ECG is commonly measured at two locations:Chest and abdomen. The abdominal leads pick up a composite signal, consisting of the contributions from both the maternal electrocardiogram (MECG) and the fetal electrocardiogram (FECG) while the chest leads contains only MECG.

Like the standard ECG, which reflects cardiac and metabolic activity, the FECG yields information about the condition of child during pregnancy. Fetal ECG signals are generally much weaker than maternal ECG signals while the fetal heart rate is usually higher than the maternal heart rate [1],[6]. FECG signal is contaminated by various sources of interference. These sources include the maternal ECG, the maternal electromyogram EMG, 50 Hz power line interference, baseline wander and random electronic noise. The EMG noise can also be reduced but not necessarily eliminated with the use of low pass filtering techniques. Therefore, it is safe to eliminate the maternal ECG component in the composite signal, to get an estimate of the FECG signal.

A complete overview of various approaches can be found in [2]. Various research efforts have been proposed in the literature including algorithms based on filtering and threshold methods, the most well known one being the Pan and Tompkins algorithm for peak detection but it requires an initial pre-determined peak detection threshold [3].

This study introduces an approach for calculate the fetal heart rate is to calculate the distance between each R-R peaks and then calculate that particular distance of R-R interval which occurred maximum time throughout the fetal ECG waveform.

2 METHODOLOGY

2.1 Data Acquisition

The abdominal ECG (AECG) signals used were taken from
PhysioNet Non-invasive fetal ECG database. This database contains a series of 55 multichannel abdominal non-invasive fetal electrocardiogram (FECG) recordings, taken from a single subject between 21 to 40 weeks of pregnancy and the duration of each signal is 10 seconds. Signals were acquired using disposable Ag/AgCl electrodes, amplified with a g.BSamp (Guger Technologies) amplifier, and sampled with a 16 bit acquisition board at a sampling frequency of 1 kHz. In order to reduce skin impedance the areas of electrode placing were gentle abraded with Parker Redux Paste and positioning of electrode was varied in order to improve signal-to-noise ratio (SNR). The analog amplifier also includes a 50Hz notch filter switched ON. The gains and input ranges are included in the records in EDF format. The patient identification contains the gestational age. The format is week+day. Our proposed approach were implemented in WFDB Software and MATLAB.

The WFDB software is used to convert the .edf files into .dat files.The WFDB software package is written in highly portable C and can be used on all popular platforms, including GNU/Linux, Mac OSX, MS-Windows, and all versions of Unix.As it is a very efficient software for processing edf file as well as annotation file (.atr file).

MATLAB tool is used for various filteration and several plottings.

2.2 Proposed Algorithm

The block diagram in Fig. 1 shows the steps of the algorithm. An approach presented here to obtain all the peaks available in the AECG data. Firstly we detect the maternal QRS peaks by using Pan and Tompkins algorithm then removed the maternal peaks by taking average of Q to S values. After this again find out the fetal's QRS peaks by using same Pan and Tompkins algorithm then detect the fetal heart rate using frequency distribution of R-R interval.

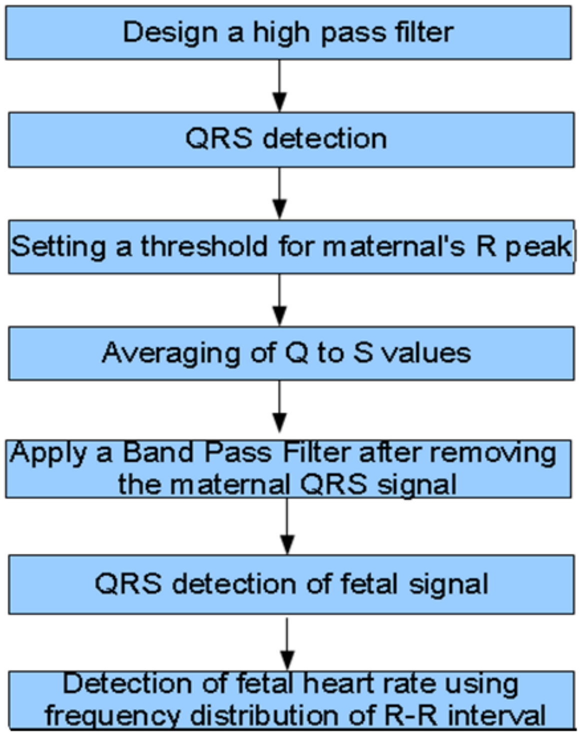


Fig 1: Block diagram of proposed algorithm

2.3 PROCESSING ON 40 WEEKS ABDOMINAL SIGNAL

2.3.1 Plotting of original 40 weeks abdominal signal in MATLAB

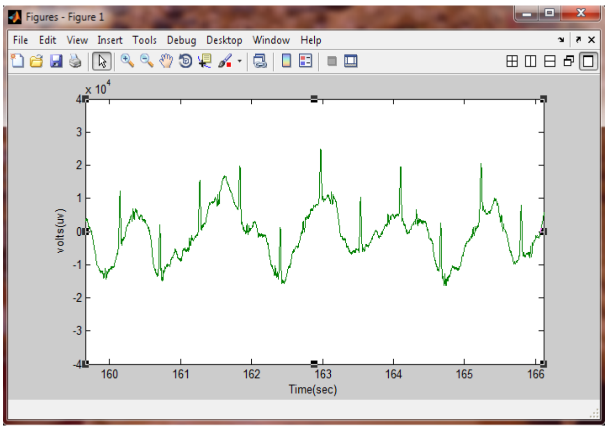


Fig 2: Plot of 40 weeks abdominal signal

2.3.2 High Pass Filter

Designed a FIR high pass filter of 1Hz cut-off frequency using FDA tool in MATLAB. By doing Highpass filtering, noise like base-line wander which

ISSN 2229-5518

occurs due to respiration and body movements has been removed from the abdominal signal.

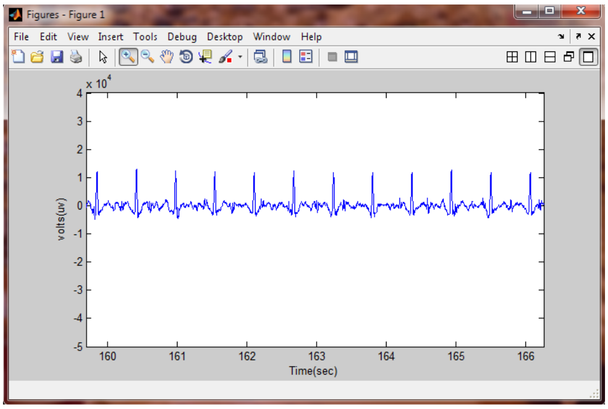
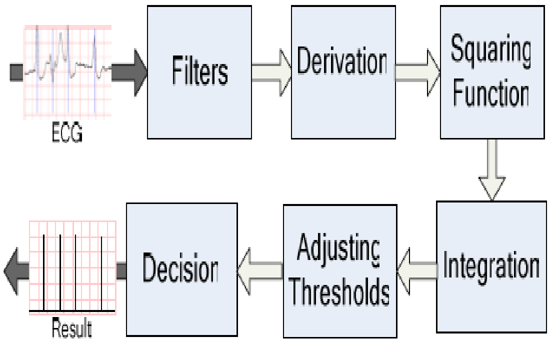


Fig 3: Plot of filtered abdominal signal

2.3.3 QRS Detection Algorithm

Here,we are using PAN and TOMPKINS algorithm of QRS detection[3]. Pan-Tompkins algorithm based on analysis of slope, amplitude and width of QRS complexes[4].The algorithm includes a series of filters and methods that perform lowpass, highpass, derivative, squaring, integration, adaptive thresholding.



2.3.3.1 Low pass filter

The recursive lowpass filter used in the Pan-Tompkins algorithm has integer coefficients for reducing computational complexity, with the transfer function defined as:

$$H(z) = \frac{1}{32} \cdot \frac{\left(1 - z^{-6}\right)^2}{\left(1 - z^{-1}\right)^2}$$

The output y(n) is related to the input x(n) as:

$$y(n) = 2y(n-1) - y(n-2) + \frac{1}{32}\left[x(n) - 2x(n-6) + x(n-12)\right]$$

The filter has a rather low cut-off frequency of fc=11Hz, and introduces a delay of 5 samples or 24ms. The filter provides an attenuation greater than 35dB at 60Hz.This Lowpass filter effectively suppresses power-line interference from the signal[6].

2.3.3.2 Highpass filter

The highpass filter used in the algorithm is implemented as an allpass filter minus a lowpass filter. The lowpass component has the transfer function

$$H_{lp}(z) = \frac{1 - z^{-32}}{1 - z^{-1}}$$

the input-output relationship is:

$$y(n) = y(n-1) + x(n) - x(n-32).$$

The transfer function Hhp(z) of the highpass filter is specified as:

$$H_{hp}(z) = z^{-16} - \frac{1}{32} H_{lp}(z).$$

The output p(n) of the highpass filter is given by the difference equation:

$$p(n) = x(n-16) - \frac{1}{32}\left[y(n-1) + x(n) - x(n-32)\right],$$

The highpass filter has a cutoff frequency of 5*Hz* and introduces a delay of 80*ms*.

2.3.3.3 Derivative operator

The derivative operation used by Pan and Tompkins is specified as:

$$y(n) = \frac{1}{8}\left[2x(n) + x(n-1) - x(n-3) - 2x(n-4)\right],$$

and approximates the ideal dt/d operator up to 30 Hz. The derivative procedure suppresses the low frequency components of the P and T waves, and provides a large gain to the high-frequency components arising from the high slopes of the QRS complex.

ISSN 2229-5518

2.3.3.4 Squaring function

The squaring operation makes the result positive and does non-linear amplification of the output of the derivative operation. It also emphasizes large differences resulting from QRS complexes; the small differences arising from P and T waves are suppressed. The high frequency components in the signal related to the QRS complex are further enhanced.

2.3.3.5 Moving window integration

The output of a derivative-based operation will exhibit multiple peaks within the duration of a single QRS complex. Moving window integration performs smoothing of the output of the preceding operations through a moving-window integration filter as:

$$y(n) = \frac{1}{N}\left[x(n-(N-1)) + x(n-(N-2)) + \ldots + x(n)\right]$$

The choice of the window width N is to be made with the following considerations: too large a value will result in the outputs due to the QRS and T waves being merged, whereas too small a value could yield several peaks for a single QRS. A window width of N=30 was found to be suitable for fs = 200Hz.

2.3.3.6 Adaptive thresholding

In the last step two thresholds are adjusted. The higher of the two thresholds identifies peaks of the signal. The lower threshold is used when no peak has been detected by the higher threshold in a certain time interval. In this case the algorithm has to search back in time for a lost peak. When a new peak is identified (as a local maximum – change of direction within a

Predefined time interval) then this peak is classified as a signal peak if it exceeds the high threshold (or the low threshold if we search back in time for a lost peak) or as a noise peak otherwise. Hence, the noisy signal has been removed from the signal.In order to detect a QRS complex the integration waveform and the filtered signals are investigated and different values for the above thresholds are used.

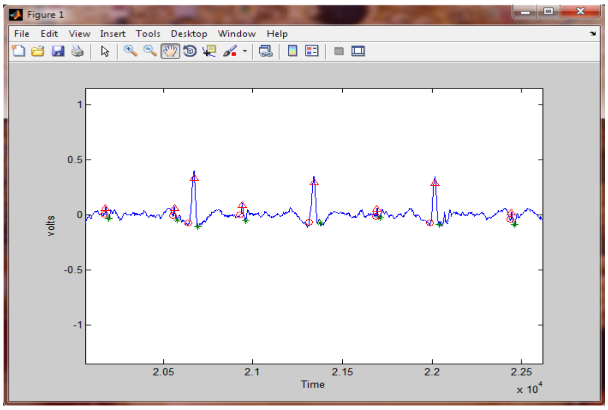


Fig 4: Plot after QRS Detection

Pan and Tompkins QRS detection algorithm detects all the QRS values of both fetal as well as maternal QRS points.

2.3.4 Setting a threshold value for maternal's R peak

In this step, a threshold value for maternal's R peak is selected to remove the maternal's R peaks from the overall signal. I am selecting 5000microvolts as threshold value.

2.3.5 Averaging of Q to S value of only maternal Ecg signal.

After removal of maternal's R peaks.In this step, I averaged the Q to S values of the maternal ECG signal to remove the total influence of maternal ECG signal in order to get only fetal ECG signal.

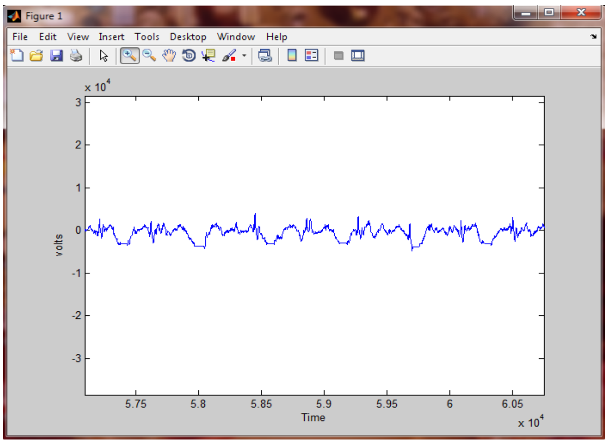


Fig 5: Plot after taking the average of maternal's Q to S values.

2.3.6 Design a Bandpass filter

In this step, a Bandpass filter is designed in order to filter out the fetal ECG signal.

ISSN 2229-5518

The specifications of the Bandpass filter are-

Sampling frequency is 1000Hz,First stop band frequency is 20 Hz,First pass band frequency is 30 Hz,Second pass band frequency is 120 Hz,Second stop band frequency is 130 Hz.

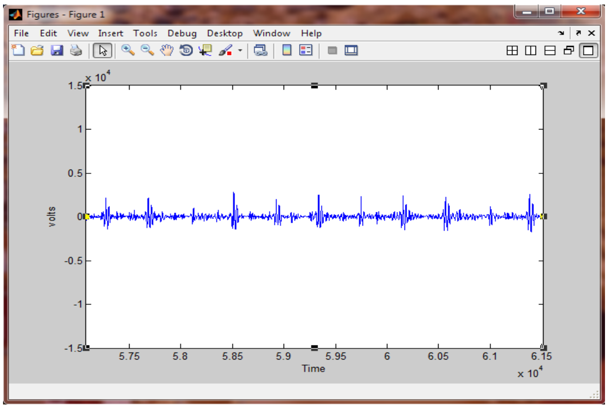


Fig 6: Plot after Band pass filtering

Here, we can clearly see the fetal ECG signal after performing Bandpass filtering.

2.3.7 QRS detection of fetal ECG signal

Here,applied the same Pan and Tompkins QRS detection algorithm for detecting the fetal QRS points. The QRS detection of the fetal ECG signal has been done in order to get the fetal's R peaks values to calculate the fetal's R-R interval.

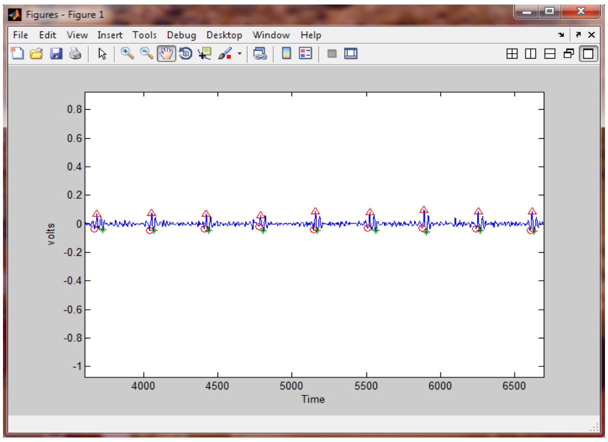


Fig 7: Plot after fetal's QRS detection

2.3.8 Detection of fetal heart rate using frequency distribution of R-R interval

After detection of R-peaks in fetal ECG signal. In this step, first off all we calculate the distance between each R peak(R-R interval).Then taken the frequency distribution of R-R intervals.

Then, we plotted the histogram graph of R-R interval with its frequency of occurrence, using Bin size of 10msec.After that, we observed, at what value of time the most average value of R-R interval has been occurred.

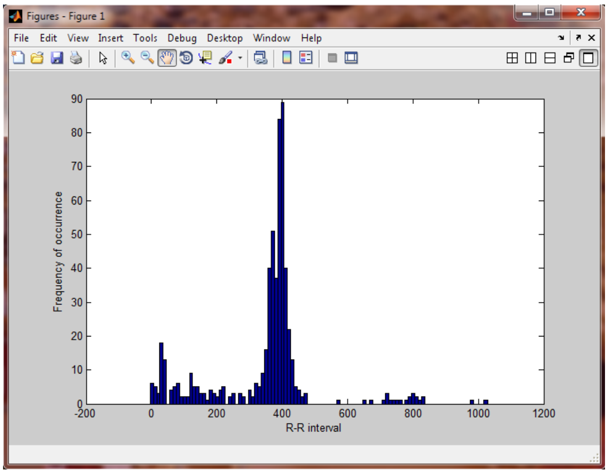


Fig 8: Histogram plot of R-R interval with its frequency of occurrence (40 weeks signal)

2.3.9 Results of 40 weeks of gestational period

The Sampling frequency of each signal is 1000 Hz.

i.e. 1000 samples are occurred in 1 sec.

Thus, from above histogram graph, we conclude that 400 samples are occurring in 0.4 second.

It means, there is 1 beat occurred in 0.4 second.

Thus, in 60 seconds there are 150 beats.

Hence, Fetal heart rate in 40 weeks of gestational period is 150 bpm which is lies in between the normal pulse rate of fetal i.e. 100-170 bpm.

2.3.10 Conclusions of 40 weeks of gestational period.

Here, I conclude that those peaks which are near to 0-200 samples are false peaks due to the false QRS detection of ECG signal because sometimes noises are also detected as QRS peak by QRS detection algorithm.

Also, it is physically impossible that the contraction of muscles of fetal's heart can happen in such a short period of time.

3COMPARATIVE STUDY

3.1Processing on 34 weeks of abdominal signal

By applying the same methodology as above ,we plotted the histogram graph of R-R interval with its frequency of occurrence, using Bin size of 10msec.After that, we observed, at what value of time the most average value of R-R interval has been occurred.

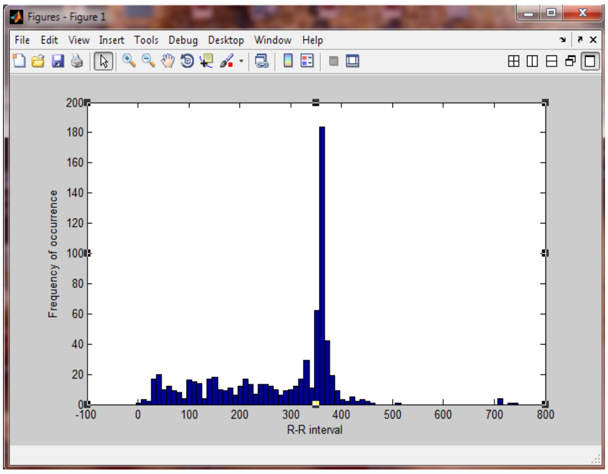


Fig 9: Histogram plot of R-R interval with its frequency of occurrence(34 weeks signal)

3.2 Results of 34 weeks of gestational period

The Sampling frequency of each signal is 1000 Hz.

i.e. 1000 samples are occurred in 1 sec.

Thus, from above histogram graph, we conclude that 360 samples are occurring in 0.36 second.

It means, there is 1 beat occurred in 0.36 second.

Thus, in 60 seconds there are 166 beats.

Hence, Fetal heart rate in 34 weeks of gestational period is 166 bpm which is lies in between the normal pulse rate of fetal i.e. 100-170 bpm.

3.3 Conclusions of 34 weeks of gestational period.

Here, I conclude that those peaks which are near to 0-200 samples are false peaks due to the false QRS detection of ECG signal because sometimes noises are also detected as QRS peak by QRS detection algorithm.

Also, it is physically impossible that the contraction of muscles of fetal's heart can happen in such a short period of time.

3.4 Processing on 29 weeks of abdominal signal

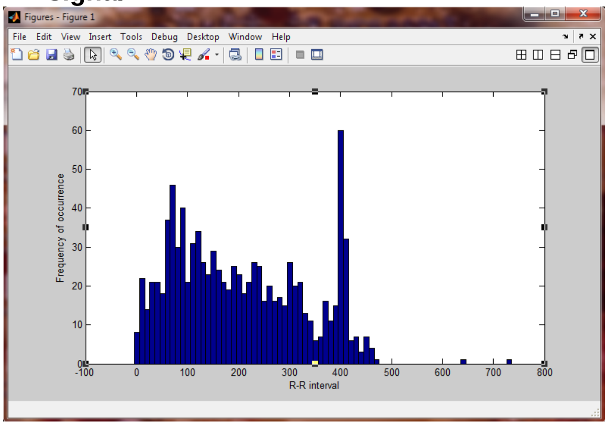


Fig 10: Histogram plot of R-R interval with its frequency of occurrence(29 weeks signal)

3.5 Results of 29 weeks of gestational period

The Sampling frequency of each signal is 1000 Hz.

i.e. 1000 samples are occurred in 1 sec.

Thus, from above histogram graph, we conclude that 402 samples are occurring in 0.402 second.

It means, there is 1 beat occurred in 0.402 second.

Thus, in 60 seconds there are 149 beats.

Hence, Fetal heart rate in 29 weeks of gestational period is 149 bpm which is lies in between the normal pulse rate of fetal i.e. 100-170 bpm.

3.6 Conclusions of 29 weeks of gestational period.

Here, I conclude that those peaks which are near to 0-200 samples are false peaks due to the false QRS detection of ECG signal because sometimes noises are also detected as QRS peak by QRS detection algorithm.

Also, it is physically impossible that the contraction of muscles of fetal's heart can happen in such a short period of time.

In 29 weeks of gestational period, I can also conclude that there is more noise presents in comparison to 40 weeks and 34 weeks of gestational period because in early stages of pregnancy, the baby's heart beats are week.

4 RESULTS

(1)-Fetal heart rate in 40 weeks of gestational period is 150 bpm.

(2)-Fetal heart rate in 34 weeks of gestational period is 166 bpm.

(3)-Fetal heart rate in 29 weeks of gestational period is 149 bpm.

5 CONCLUSION

Detailed analysis of the FECG during labor could provide valuable additional information about the health conditions of the fetus as well as to assist clinicians in reducing incidents of
unnecessary medical intervention. As a result, long-term FHR monitoring is important during the pregnancy and labor.
In this project, I tested my algorithm on 29 weeks of gestational period, 34 weeks of gestational period, and 40 weeks of gestational period.
After testing I conclude that in early stages of pregnancy, the baby's heart beats are weaker than the baby's heart beats of complete gestational period. As we can see in this project that the more noise is present in 29 weeks of gestational period in comparison to 34 weeks and 40 weeks of gestational period.

Therefore, the aim of this project was to provide concise information about FECG and reveal a method to analyze the signal for efficient FHR monitoring. Technique for Fetal ECG signal detection and extraction from the composite Abdominal ECG signal were discussed along with its advantages and drawbacks. This revised method can be applied during any medical diagnosis, biomedical research, hardware implementations, and end user applications.

6 REFERENCES

[1] E. M. Symond, D. Sahota, and A. Chang, '*Fetal Electrocardiography'*.Imperial College Press, London, 2001.

[2] B. U. K'ohler, C. Henning and R. Orgelmeister, "The principles of software QRS detection", IEEE Eng. Med. Bioi. Mag. vol. 21, pp. 42-57, Jan/Feb 2002.

[3]Pan J, Tompkins WJ. 'A real-time QRS detection algorithm'. IEEE Trans Biomed Eng 1985;32(3):230-6.

[4]Tompkins WJ., Biomedical Digital Signal Processing, *Prentice-Hall, Upper Saddle River*,NJ, 1995.

[5]Rangayyan R.M., *Biomedical Signal Analysis*, Wiley - Intersciene, John Wiley & SONS, INC.,2002.

[6]M. A. Hasan, M. B. I. Reaz, M. I. Ibrahimy, M. S. Hussain, and J. Uddin, 'Detection and Processing Techniques of FECG Signal for Fetal Monitoring', Shulin Li (ed.), Biological Procedures Online, Volume 11, Number 1© to the author(s) 2009.

[7] Peters M, Crowe J, Pieri JF *et al*. Monitoring the fetal heart non-invasively: a review of methods. J Perinat Med 2001; 29(5):408-16.

[8] Ibrahimy MI, Ahmed F, Mohd Ali MA, Zahedi E. Real-time signal processing for fetal heart rate monitoring. IEEE Trans Biomed Eng 2003; 50(2):258-62.

[9]SORNMO L., PAHLM O. and NYGARDS M. (1985): 'Adaptive QRS Detection: A Study of Performance', *IEEE Trans. Biomed. Eng.*, **32**, pp.392-401

[10]GRITZALI F. 'Towards a generalized scheme for QRS detection in ECG waveforms', *Signal Processing*, **15**,pp. 183-192, 1988

[11]Bergveld P., Arjan J. K., Peuscher J. H. J. (1986) Real-time fetal ECG Recording. IEEE Trans Biomed Eng BME-33:505– 509.

[12] Peters, C., Vullings, R., Bergmans, J., et al.(2006) Heart rate detection in low amplitude
non-invasive fetal ECG recordings. 28th Annual International Conference of the IEEE EMBS. New York. USA; 30 Aug–3 Sept 2006. p. 6092–6094