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R-R INTERVAL & HEART RATE CALCULATION IN MATLAB

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Abstract
During pregnancy, the motivation for monitoring the fetal heart rate is to recognize pathologic conditions, typically asphyxia, with sufficient warning to enable intervention by the clinician. Therefore, FHR carries a significant importance of clinical perspectives. Digital Signal Processing based techniques have played a significant role in obtaining and processing the fetal ECG signal. The objective of this project is to extract the fetal heart rate from abdominal electrocardiogram (ECG). In this work an algorithm to extract the fetal heart rate from the abdominal electrocardiogram (ECG) is presented. In this work Invasive (Abdominal and direct fetal ECG database) Database is used. The signal were digitized at 1KHz. Firstly (Maternal's + Fetal's) QRS peaks are detected by Pan and Tompkins algorithm. Then a threshold value for maternal's R peak is selected. Then maternal peaks are removed by taking average of Q to S values. Next a bandpass filter is applied in order to filter out the fetal ECG signal. After this, fetal's QRS peaks are detected using Pan and Tompkins algorithm. The QRS detection of the fetal ECG signal has been done in order to get the fetal R peaks values to calculate the fetal R-R interval and heart rate.
Keywords -- ECG, MECG, FECG, FHR, QRS complex.

INTRODUCTION

A medical topic which attracted the interest of engineers is the electrocardiography. It is a useful noninvasive medical diagnostic test (an estimated 200 million ECGs taken each year). Its technological challenge is to improve performance by increasing number of recorded signals, raising the signal to noise ratio, and accomplishing these goals. The electrocardiogram (ECG) signal is the most important parameters monitored from heart patients. The purpose of ECG is to help the doctors to diagnose human or animals heart activity and to detect abnormality functions of the heart. The function of the heart is to contract rhythmically and pump blood to the lungs for oxygenation and then pump this oxygenated blood into the general circulation. This perfect rhythm is continuously maintained and signaled by a spread of electrical signals generated by the heart pacemaker, the Sinoatrial (SA) node. Detecting such electrical activity of the heart can help us to identify many heart disease. By measuring and tracing the potential difference between two points on the outer surface of the body is the simplest ECG chart. Just as an electrocardiogram is useful in diagnosing cardiac diseases in children and adults, the analysis of the fetal electrocardiogram (FECG) could be a reliable information for diagnosing cardiac diseases, especially fetal arrhythmias, fetal development, fetal maturity, and existence of fetal distress or congenital heart disease. The Fetal electrocardiogram (FECG) is the electrical activity of the fetal heart over a period of time. As the fetus responds to conditions in the uterus the FHR may be change. An abnormal FHR mean that the fetus is not getting enough oxygen or there are other problems. Sometimes an abnormal pattern also mean that an emergency delivery is needed. The fetal electrocardiogram is extracted from two ECG signal recorded at the thoracic and abdominal areas of the mother skin. The thoracic ECG is assumed to be completely neutral and the abdominal ECG is composite as it is contains both the mother's and FECG signals. There are two methods of recording Fetal ECG invasive and non-invasive method. The first is placing an electrode in direct contact with the scalp of the fetal. This is named an invasive technique. This method can only be used during labor. In the second method non-invasive electrodes are attached on the maternal abdomen. The signals recorded by invasive methods have better quality as compared with noninvasive methods but the procedure is in convenient and is limited to recordings during labour.

2.RESEARCH METHODOLOGY

2.1 DATABASE USED

The database of ECG recordings has been taken from physionet(www.physionet.org). In this project Invasive database is used.This database contain five-minute multichannel fetal ECG recordings, with cardiologist-verified annotations of all fetal heart beats, from five women in labor, from the Medical University of Silesia, Poland. Each record includes four signals from the maternal abdomen and a simultaneously recorded reference direct fetal ECG

from the fetal scalp. All signals are sampled at 1 KHz with 16-bit resolution. In the Invasive data Abdominal and direct fetal ECG signals obtained from 5 different women in labor, between 38 and 41 weeks of gestation and the duration of each signal is 10 seconds.

2.2 PROPOSED ALGOROTHM

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. Several techniques are reported to improve the accuracy of QRS complex detection from ECG signal because the exact detection of QRS complex is difficult, as the ECG signal is added with different types of noise like electrode motion, power-line interferences, baseline wander, muscles noise etc. A real-time QRS detection algorithm developed by Pan and Tompkins (1985) was further described by Hamilton and Tompkins (1986). Pan-Tompkins algorithm based on analysis of slope, amplitude and width of QRS complexes of typical cardiac signal. The algorithm includes a series of filters and methods that perform lowpass, highpass, derivative, squaring, integration, adaptive thresholding. The Pan- Tompkins algorithm gives results 99.3% detection of QRS complex(1).

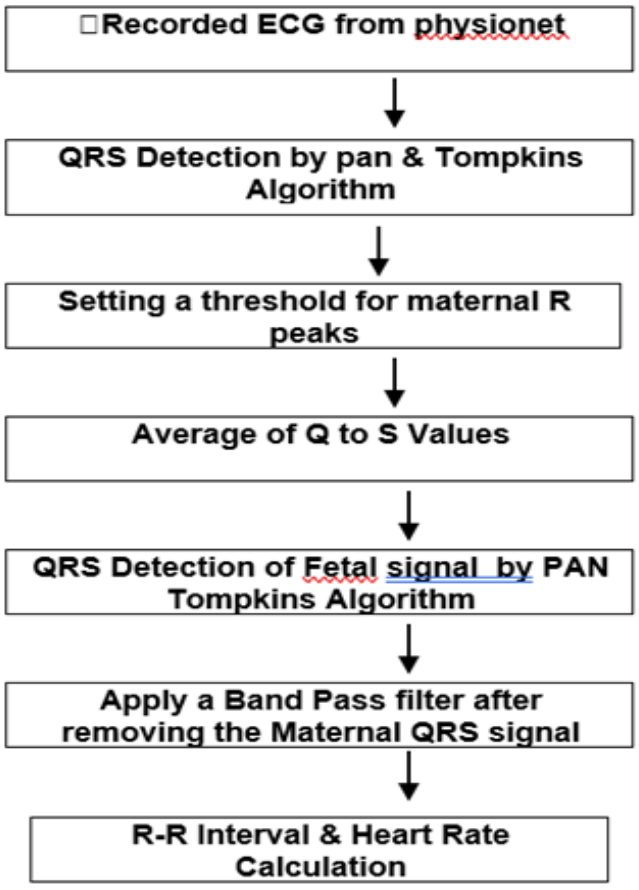
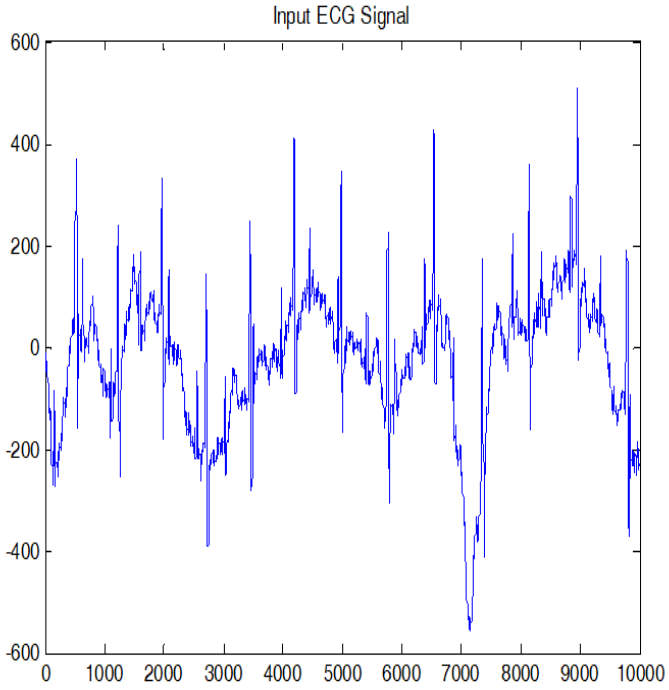


Fig. 1 Block diagram of proposed Algorithm

2.3 PROCESSING ON ORIGINALABDOMINAL INPUT SIGNAL

2.3.1Plotting of original abdominal 3 (r04) signal in MATLAB



2.3.2 QRS Detection technique using Pan-Tompkins Algorithm

2.3.2.1 Band-Pass integer filter

The band- pass filter for the QRS detection algorithm reduces noise in the ECG signal by matching the spectrum of the average QRS complex. It attenuates noise due to muscle noise, 60-Hz interference, baseline wander, and T-wave interference. The pass-band used is in the range of 5-11 Hz(7). The filter implemented in this algorithm is a recursive integer filter in which poles are located to cancel the zeros on the unit circle of the z plane. The filter implemented in this algorithm is composed of cascaded high pass and low pass Butterworth IIR filters. Band pass filter is designed from a special class of digital filters that require only integer coefficients. This permits the microprocessor to do the signal processing using only integer arithmetic, there by permitting real-time processing speeds that would be difficult to achieve with floating-point processing. Since it was not possible to directly design the desired band pass filter with this special approach, the design actually consists of cascaded low-pass and high-pass filter sections.

2.3.2.1.1 Low pass filter

The recursive low pass filter used in the Pan-Tompkins algorithm has integer coefficients for reducing computation-

al complexity, with the transfer function defined as.
H(z)= (1)
The output y(n) is related to the input x(n) as.
(2)
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 Low pass filter effectively suppresses power-line interference from the signal. The gain is 36. In order to avoid saturation, the output is divided by 32, the closest integer value to the gain of 36 that can be implemented with binary shift arithmetic.

2.3.2.1.2 High pass filter

The high pass filter used in the algorithm is implemented as an all pass filter minus a low pass filter. The low pass component has the transfer function

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

(3)

the input-output relationship is

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

(4)

The transfer function $H_{hp}(z)$ of the high pass filter is specified as.

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

(5)

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

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

(6)

The high pass filter has a low cutoff frequency is 5*Hz* and introduces a delay of 16 samples or 80ms. The gain is 32.

2.3.2.2 Derivative operator

The next processing step is differentiation, a standard technique for finding the high slopes that normally distinguish the QRS complexes from other ECG waves.
The derivative operation used by Pan and Tompkins is specified as:

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

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. The derivative has a filter delay of 2 samples. The fraction 1/8 is an approximation of the actual gain of 0.1.

2.3.2.3 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.(1)

2.3.2.4 Moving window integration

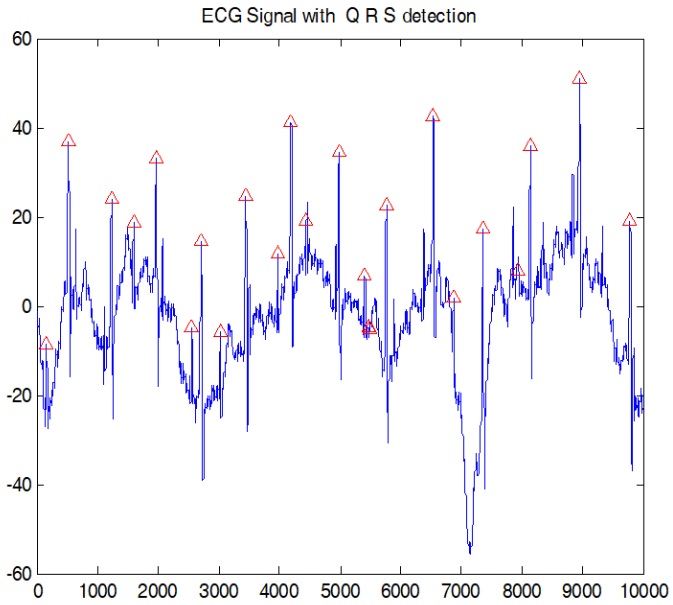
The slope of the R wave alone is not a guaranteed way to detect a QRS event. Many abnormal QRS complexes that have large amplitudes and long durations (not very steep slopes) might not be detected using information about slope of the R wave only. Thus, we need to extract more information from the signal to detect a QRS event. Moving window integration extracts features in addition to the slope of the R wave.
Moving window integration performs smoothing of the output of the preceding operations through a moving-window integration filter as.

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

The width of the window should be approximately the same as the widest possible QRS complex. Where N is the number of samples in the width of the moving window. The value
of this parameter should be chosen carefully. If the N is to be made 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. For a sampling frequency of 1000 Hz the window chosen for this algorithm was 158 samples wide.

2.3.2.5 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 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.

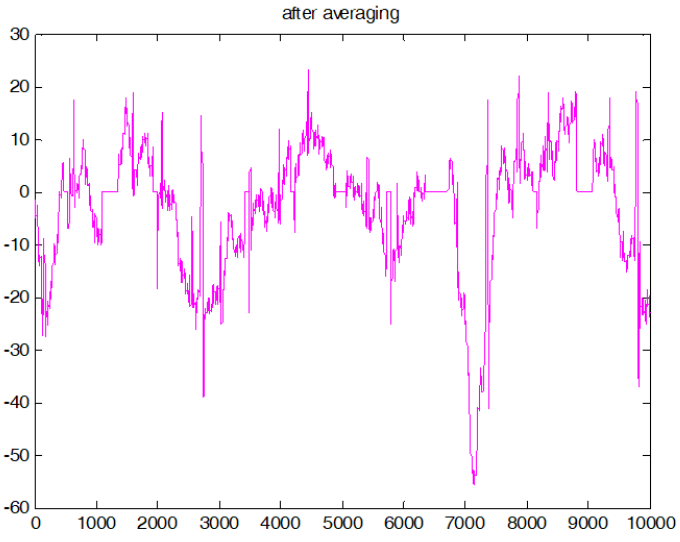


2.3.3Setting a threshold value for maternal's R peak

In this step, a threshold value for maternal's R peak is selected to remove the maternal's R peaks from the overall signal. A 20 microvolts value is selected as a threshold value.

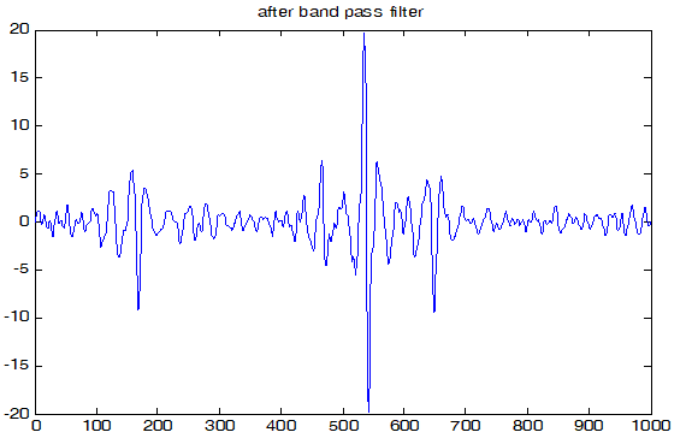
2.3.4 Averaging of Q to S value of only maternal ECG signal.

In this step, Q to S values of the maternal ECG signal are averaged to remove the total influence of maternal ECG signal in order to get only fetal ECG signal.(2)



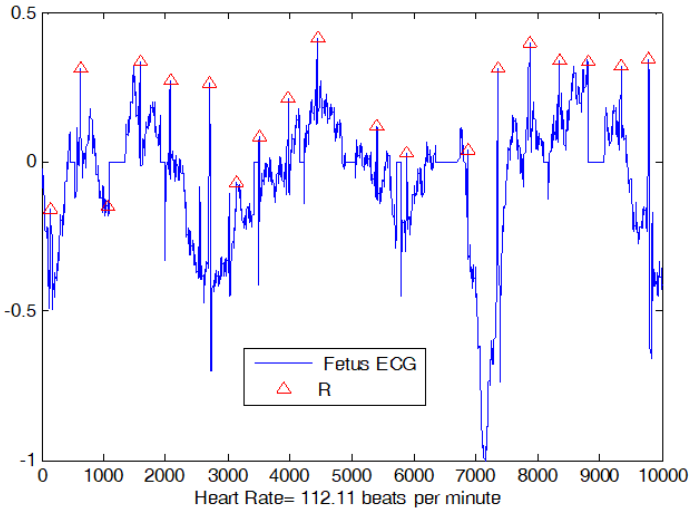
2.3.5 Design a Band pass filter

In this step, a Band pass filter is designed in order to filter out the fetal ECG signal. The specifications of the Band pass filter are 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. The Sampling frequency is 1000 Hz (79). The filter is designed in MATLAB using FDATOOL. Kaiser window is used.



2.3.6 QRS detection of fetal ECG signal

Here Pan and Tompkins QRS detection algorithm is applied again 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.



2.3.7 Fetal R-R Interval And Heart Rate

The RR interval is the time between QRS complexes. After detection of R-peaks in fetal ECG signal first of all the distance between each R peak (R-R interval) is calculated. Then the mean of a distance is computed. Then this mean distance is multiplied by time.

beat = Mean distance * Timescale

Heart rate = 1/ beat * 60

2.3.8 Evaluations

The proposed algorithm have been implemented in Matlab codes. The performance of the algorithm is then evaluated in terms of their sensitivity and positive predictivity. The sensitivity is the fraction of real events that are correctly detected and it is defind by

$$Se=\frac{TP}{TP+FN}(9)$$

The Positive Predictivity is the fraction of detections that are real events and it is defind by

$$P+=\frac{TP}{TP+FP}$$

Where FN (False Negatives) denotes the number of missed detection,

FP (False Positives) represents the number of extra detections

TP (True Positives) is the number of correctly detected QRS complexes.

5.5 Performance Evaluation

5.5.1Performance for Fetal R Peak Detection of Abdominal 1

Records	SE(%)	P+(%)	Heart Rate (b/m)
R01	60	71	103.9
R04	70	80	120.9
R07	75	85	130.87
R08	65	75	139
R10	72	83	119

5.5.2 Performance for Fetal R Peak Detection of Abdominal 2

Records	SE(%)	P+(%)	Heart Rate (b/m)
R01	65	75	154.8
R04	60	72	105
R07	65	73	160.76
R08	70	77	150.9
R10	50	62	121

5.5.3Performance for Fetal R Peak Detection of Abdominal 3

RECORDS	SE(%)	P+(%)	HEART RATE(b/m)
R01	49	59	103.3
R04	73	85	112
R07	68	72	160
R08	53	69	105
R10	58	36	197.8

5.5.4Performance for Fetal R Peak Detection of Abdominal 4

RECORDS	SE(%)	P+(%)	Heart Rate(b/m)
R01	60	70	101.9
R04	86	82	130
R07	70	86	135.3
R08	65	72	140.5
R10	75	85	128.5

6.1CONCLUSION AND FUTURE SCOPE

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 the incidents of unnecessary medical intervention. So long-term FHR monitoring is important during the pregnancy and labor. The results clearly confirmed that the PAN & TOMPKINS based method is more successful in detecting the Fetal ECG. The principal advantage of the method its low output noise, and its low signal distortion. The heart rate of fetal can be used in order to be analysed by a set of medical rules which can be defined in collaboration with medical experts. The proposed algorithm is applicable for extraction of the desired components in any composite signal. The aim of this project is to provide concise information about FECG and reveal a method to analyze the signal for efficient FHR monitoring. It was concluded that invasive method for calculate heart rate gives good results. Data fusion and information integration is almost a completely unexplored area of fetal monitoring. For better predictive performance and more accurate decision support, it is likely that a combination of cardiac activity recording modalities, such as phono cardiogram, MCG and ultrasound together with the invasive and/or non-invasive ECG will provide improved performance. The proposed FECG detection method can be further improved, in terms of noise handling. The noise present in long duration MECG recordings is unavoidable so proper filtering must be utilized.

REFERENCES

1.Pan, J., Tompkins, W.J.(1985), "A Real Time QRS Detection Algorithm", IEEE Transactions on Biomedical Engineering, Vol. BME-32, No. 3, March1985, pp. 230-236.

2.Priya Rajput, Bhupendra singh, Pragati Karan (2012), " Fetal Heart Monitor", International journal of scientific & engineering research, volume 3, Issue10.

3.Dotsinsky I, Stoyanov T: Ventricular beat detection in single channel electrocardiograms. BioMed EngOnLine 2004, 3: 3.

4.Moreas JCTB, Seixas MO, Vilani FN and Costa EV: A QRS complex detection algorithm using electrocardio-

gram leads. Comp in Card 2002, 29: 205–208.
5.Friesen GM, Jannett TC, Jadallah MA, Yates SL, Quint SR, Nagle HT: A comparison of the noise sensitivity of nine QRS detection algorithms. IEEE Trans on Biomed Eng 1990, 37: 85–98. 10.1109/10.43620.
6.Afonso VX, Tompkins WJ, Nguyen TQ, Luo S: ECG beat detection using filter bank.
7.L. Patomaki, J. Forsti, V-M. Nokso-Koivisto, Y. Jokinen and E. Lansimies, "On line recording and analysis of the ECG in ambulatory patients", Computer. Cordia, pp. 173-175, 1981.
8.O. Pahlm and L. Sornmo, "Software QRS detection in ambulatory monitoring–A review", Med. Biol. Eng. Computer, vol. 22, pp. 289-297, 1984.
9.N. V. Thakor, J. G. Webster and W. J. Tompkins, "Design implementation and evaluation of a microcomputer-based portable arrhythmia monitor", Med. Biol. Eng. Computer, vol. 22, pp. 151-159, 1984.
10.H. G. Goovaerts, H. H. Ros, T. J. vanden Akker and H. Schneider, "A digital QRS detector based on the principle of contour limiting", IEEE Trans. Biomed. Eng., vol. BME-23, pp. 154, 1976.