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Detection of Abnormalities in Fetal by non invasive Fetal Heart Rate Monitoring System

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Abstract: *Fetal Heart rate is very important to obtain the information about the fetal condition during pregnancy. This is obtained by detecting the peaks of the FECG signal in R-R interval FECG is obtained here by extracting from the composite abdominal ECG. Extraction using advanced and powerful tools has been the ultimate interest in the biomedical field. Here the FECG is obtained from abdominal ECG by treating Maternal ECG as noise. Least Mean Square adaptive filter is used for this purpose. Noise like Power line interference and DC drift are removed by using notch filter and Chebyshev Filter respectively. Finally the peaks are counted for detecting abnormalities. Implementation is done using MATLAB GUI.*
Keywords: *abdominal ECG; MECG; FECG; LMS; MATLAB GUI.*

I. Introduction

During pregnancy and labor, Fetal heart rate (FHR) indirectly indicates the Fetal well- being. Proper information obtained results in good treatment[1]. If the heart rate is abnormal then it means that there is insufficient oxygen supply or any other problems[2]. The simple test which is used for this is Electrocardiogram (ECG) and is non invasive[3]. The electrical activity of heart is reflected in this ECG Signal which is obtained by employing a set of electrodes on patient[4]. Fetal ECG (FECG) that is extracted from the abdominal ECG (AECG) signal gives the FHR by counting the peaks. AECG contains FECG as well as Maternal ECG (MECG). Hence MECG is treated as noise and eliminated. ECG signal contains noises like power line interference, electromyography, baseline wander etc. [5]. FECG extraction is done based on Least Mean Square adaptive Filtering technique. Two ECG signals that is MECG and AECG are preprocessed to remove the power line interference of 50 Hz and then the extraction is done. To detect the heart rate post processing is done which removes DC drift and counts the peak to detect the FHR for abnormalities.

II. FECG Tracing

2.1 ECG Tracing

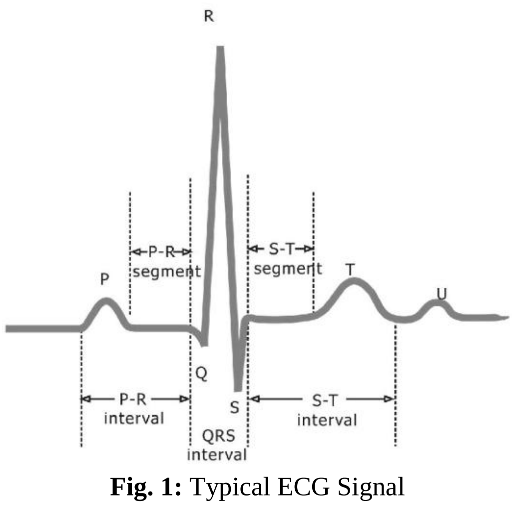

Fig. 1: Typical ECG Signal

Typical ECG signal shown in figure 1 contains P, QRS, T and U waves. P-wave is very small and curved. Next comes the QRS complex, which is the combination of sharp Q, R and S Points. T-wave followed by QRS complex is also curved having its amplitude more than that of P-wave. The important wave that is used to detect the heart rate is the QRS complex [6].

In ECG system contains 12-lead that includes three limb leads I, II or MLII, III, three augmented leads aVR, aVL, aVF , six precordial leads like V1, V2, V3, V4, V5, V6. These are the commonly used ECG system in clinic or health care centers[7].

2.2 ECG Signal measurement

During pregnancy, the signal measurement is done at chest and abdomen for a pregnant woman. The MECG is obtained at the chest and FECG is contained in the AECG signal with the MECG. Hence there is a need to eliminate MECG. Then FHR is obtained by counting the peaks of RR interval in FECG signal [8]. The amplitude in MECG is lesser than that of FECG however beats per minute (bpm) of fetal is more than that of maternal [9]. Since there are fluctuations in extracted FECG, R peaks of couldn't be determined in previous works. This paper overcomes the difficulties [10].

III. Methodology

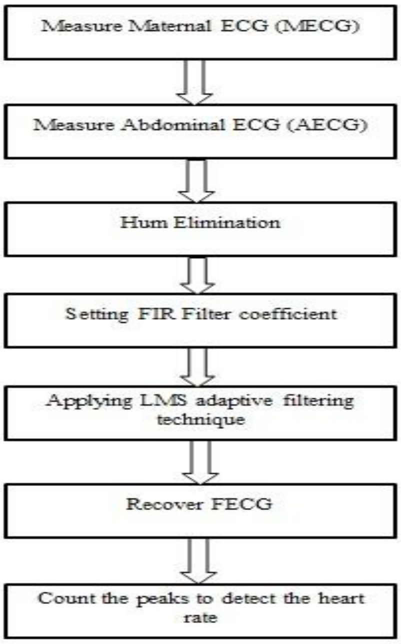

Fig. 2: Flow diagram representation

Fig. 2 shows the flow diagram of the proposed system. The two signals obtained, MECG and AECG are preprocessed to remove power line interference of 50 Hz. The filtered signal is then passed to LMS Filter where MECG is treated as noise and is eliminated. Step size of 0.001 and 15 coefficients are used here. Here the signals are separated and the error signal obtained is FECG. After the extraction post processing is done where the DC drift is removed to detect the heart rate. Chebyshev Filter of fourth order is used here. Peaks are counted to obtain the heart beat having 0.5 threshold. According to the heart rate the abnormalities are detected so that proper steps can be taken.

3.1 Preprocessing Stage

ECG signal contains noise like Baseline wander noise, EMG signals, power line interference of 50 Hz etc. The cables that get ECG signals are usually affected by power line interference which is of 50 Hz. This noise is also called as Hum noise. It is sufficient if its harmonics are eliminated. Hence in preprocessing stage this is eliminated by using band reject filter having band reject frequencies at 50, 100 and 150 Hz. Fig. 3 shows the functional block diagram. Design of FIR filter is done and simulated in MATLAB GUI.

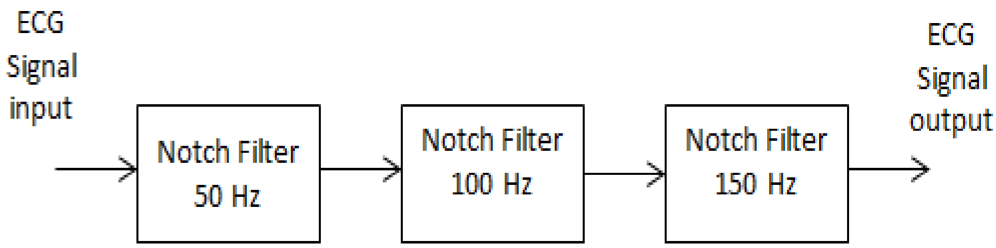

Fig. 3: 50 Hz Hum Eliminator

3.2 FECG Extraction

Adaptive filters are the filters that adapt to the environment. They are advantageous because they have the ability to set the coefficients as per the needs. Fig.4 depicts the block diagram of adaptive filter. In this x(n) and y(n) are the input signal and corresponding output signal, d(n) is desired signal given to the adaptive filter, e(n) is the error signal that denotes the difference between d(n) and y(n).

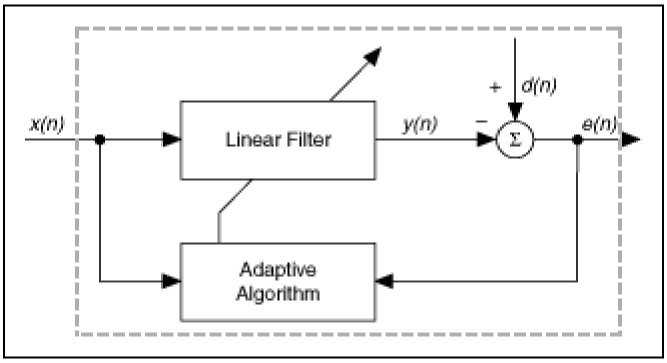

Fig. 4 Adaptive Filter

The extraction of FECG from the composite signal is done using LMS adaptive filtering technique. The preprocessed signals are passed to LMS Filter where MECG is treated as input signal and AECG as the desired signal. Step size of 0.001 and 15 coefficients are used here. Here the signals are separated and the error signal obtained is FECG. MECG is treated as noise and is eliminated from the AECG signal.

3.3 Post processing

After the extraction of FECG from the composite AECG signal, heart rate needs to be detected. To detect FHR, DC drift which may occur at 40 Hz or more need to be removed. This can be done using IIR Filter. Chebyshev type 2 fourth order filter is used for this purpose. Bandpass filter having passband from 1.3 Hz to 3.5 Hz is used here. Bilinear transformation is done here. Further usage of this signal is not recommended as the original signal occupies frequency range 0.01 to 250 Hz. Hence it is not used for general applications.

3.4 Peak detection

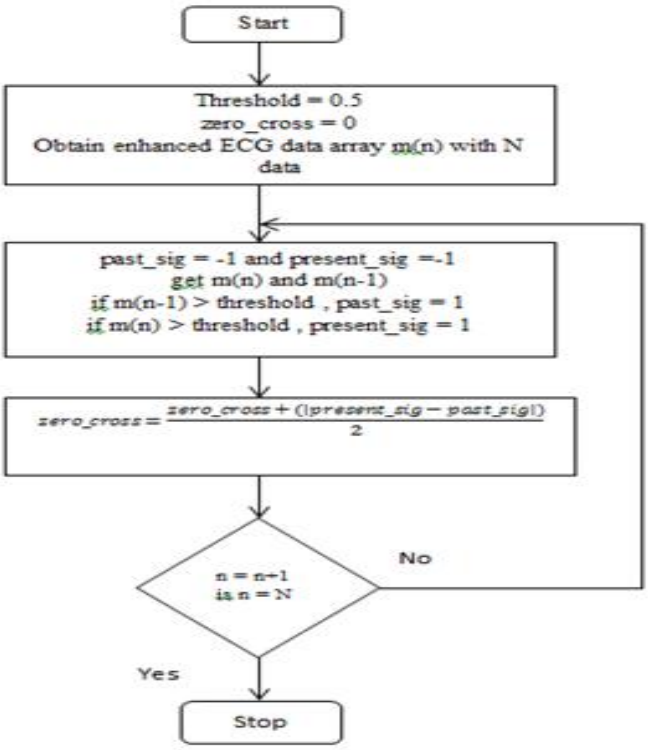

Fig. 5: Zero cross algorithm

Fig. 5 shows a simple zero cross algorithm which is used to count the peaks. 0.5 Threshold is taken for reference and and concurrently the samples are monitored. If the outcomes are contrary, it approach that there's a zero go and it is given via

$$zero\_cross = \frac{zero\_cross + (|present\_sig - past\_sig|)}{2} \quad (1)$$

Here in Eq. 1, present and past input signals, m(n) and m(n-1) are indicated by present_sig and past_sig respectively.

If present _sig m (n) ≥ threshold, present_sig = 1 else present_sig = -1

If past _sig m (n-1) ≥ threshold, past _sig = 1 else past _sig = -1

Half of the zero _cross is the number of peaks present in it. Heart rate in Bpm is given by

$$HR = \frac{60}{\frac{No.of\ enhanced\ ECG\ data}{f_s}} x \frac{Zero\_cross}{2} \quad (2)$$

3.5 FECG Classification

Below Table shows the classification of FECG. There are three categories as shown below.

Table.1: FECG classification

Rate		Bpm
Normal		110 - 160
Indeterminate	Bradycardia	100 – 109
	Tachycardia	161 - 180
Abnormal		<100 and >180

IV. Block Diagram

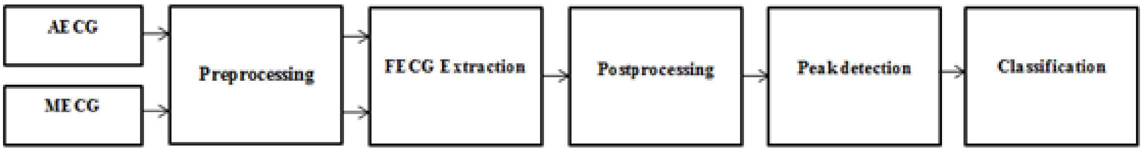

Fig.6: Block diagram of the prosed system

MECG and AECG signals are obtained from the chest and abdomen of the patient. These signals are preprocessed to remove the power line interference at preprocessing stage. Further the noise free signals are send to FECG extraction stage where the MECG is treated as noise and AECG is treated as the desired signal. This requires approved specifications and coefficients. Thus adaptive filter overcomes these problems by updating its coefficients. Here 15 coefficients with step size of 0.001 is taken. MECG signal obtained from the chest is treated as the input signal to the LMS Adaptive filter and the AECG which contains the mixture of MECG as well as FECG is taken as desired signal d (n).The output of LMS Adaptive filter is subtracted from the desired signal d(n) and FECG is obtained as the error signal e(n). Fig.7 depicts the FECG extraction block.

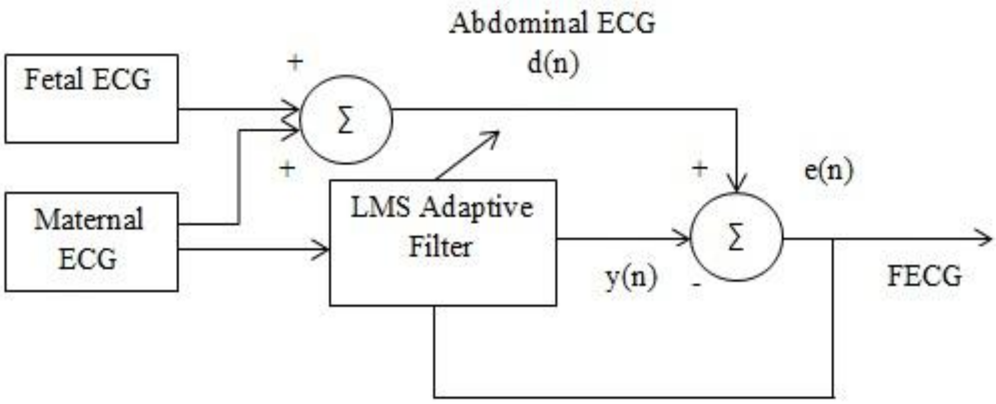

Fig.7: FECG extraction block

The obtained FECG signal is then passed to Postprocessing block where the DC drift is removed to count the peaks. By counting the peaks the FHR is obtained and then the classification is done accordingly . Thus abnormalities are detected.

V. Results

Designing and simulations of filter are done in MATLAB GUI. Databases are obtained from MIT-BIH databases. The data recorded were stored in '.mat' file and were used for the project. Different data were taken and checked for zero cross and abnormalities. Fig.8 and Fig.9 shows the simulation result of preprocessing stage of MECG and AECG signal respectively. Fig. 10 shows the MATLAB GUI model of the preprocessing stage where 50 Hz power line interference is removed.

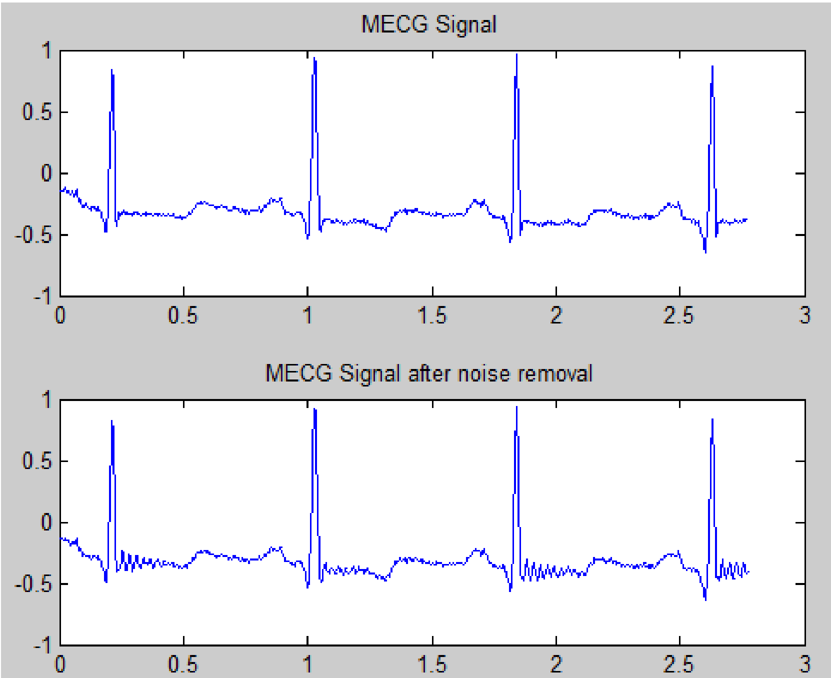

Fig.8 MECG Signal before and after preprocessing stage

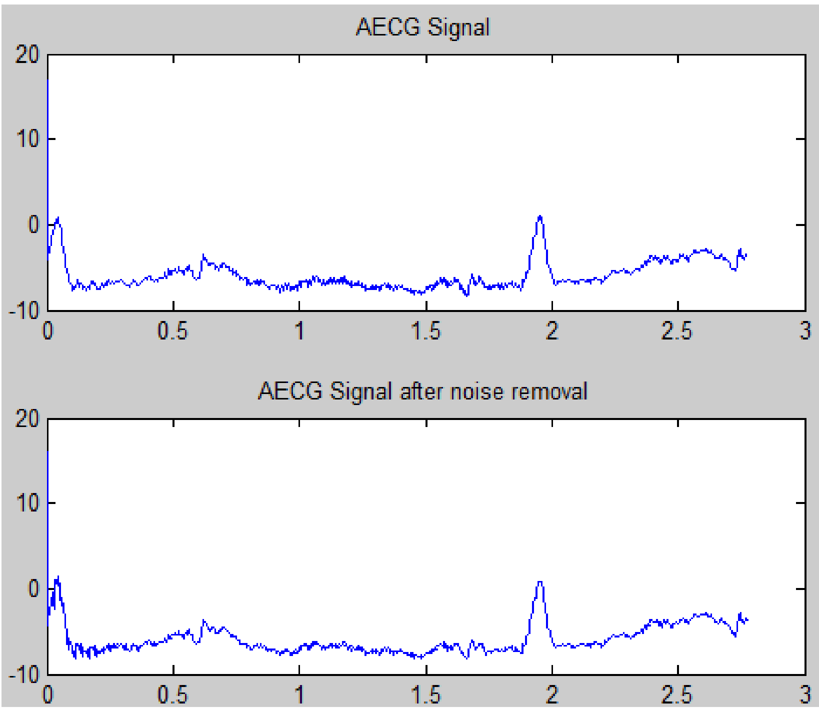

Fig.9 AECG Signal before and after preprocessing stage

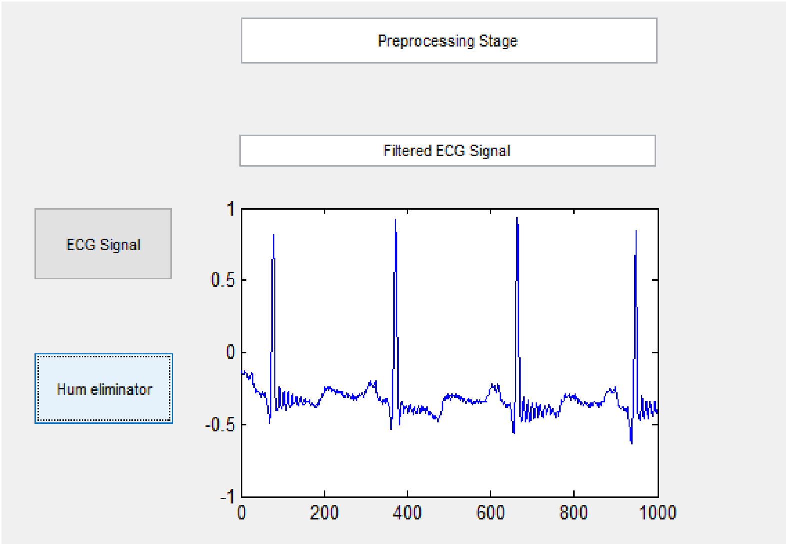

Fig.10: MATLAB GUI simulation result of preprocessing stage

Fig.11 shows the MATLAB Simulation of the proposed system and Fig.12 shows the MATLAB GUI model of the same. Table 2 shows the zero cross, FHR and categories.

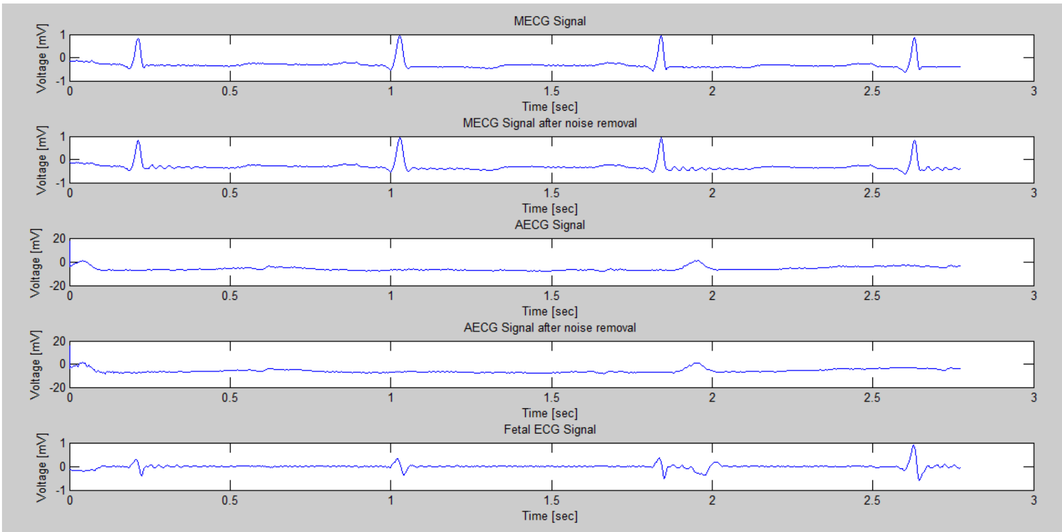

Fig.11: MATLAB Simulation of the proposed system

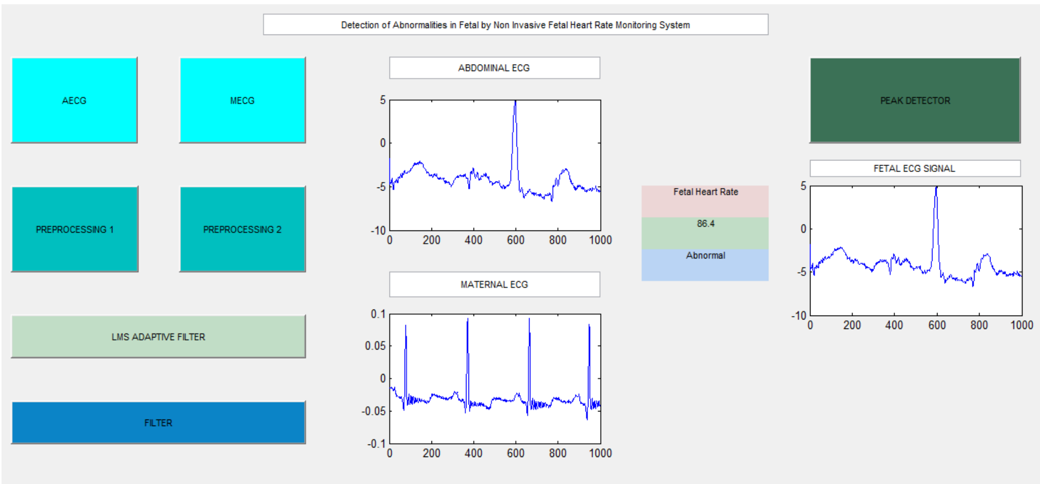

Fig.12: MATLAB GUI model of the proposed system.

Table.2: Experimental outcomes

Zero cross	FHR (Bpm)	Category
8	86	Abnormal
15	162	Indeterminate, Tachycardia
12	129	Normal
10	108	Indeterminate, Bradycardia
11	119	Normal
13	140	Normal
14	151	Normal
16	173	Indeterminate, Tachycardia
15	162	Indeterminate, Tachycardia
18	194	Abnormal

VI. Conclusion

A FHR monitoring system to detect abnormalities is successfully designed. Extraction of FECG is done using Adaptive filtering technique and is successful. From this extracted signal, the FHR is obtained and the abnormalities are detected. The proposed system is designed and simulated successfully in MATLAB GUI. As a future work implementation can be done in real time using hardwares. Different extraction techniques can be used.

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