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Analysis of Fetal Stress Developed from Mother Stress and Classification of ECG Signals

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Abstract. Recent works have shown that the fetal electrocardiogram (ECG) allows detecting cardiac pathologies or stressing conditions of the fetus by the continuous registration of the fetal heart activity. In this paper we propose a simple method to detect the presence of stress on the fetus developed due to the mother's stress. This is carried out by the analysis of mother's abdominal electrocardiogram. Our method allows to extract the fetal ECG in a noninvasive way. ECG signals are classified using Back propagation (BPN) network.

1. Introduction

The electrocardiogram (ECG) is used in cardio logical diagnosis, like tachycardia, arrhythmia and other disorders in the heart activation. Generally, this diagnosis is only based on the close study of the ECG waveform.ECG is generated by the bio electromagnetic fields that the heart produces during its activity; in particular the ECG records the overlapping of the bioelectric activities generated by the depolarization and repolarization processes that occur in the atrial and ventricular muscles. A complete ECG can be obtained by the placement of ten electrodes on the body [1].The electrocardiography can also be used to evaluate the fetal heart muscle activity; in particular the authors show that a close study of the fetal electrocardiogram (FECG) allows to detect cardiac pathologies or stress conditions of the fetus [2]. The routine for obtaining the significant information about fetal condition during pregnancy is fetal heart rate (FHR) monitoring. The characteristics of the FECG, such as heart rate and waveform are convenient in determining the fetal life, fetal development, fetal maturity, and existence of fetal distress or congenital heart disease. This can also be performed by detecting the ECG signal generated by the heart of the fetus, which is complicated. In this paper, we propose a simple methodology to determine the heart rate of the fetus using FECG which is extracted from the mother's abdominal ECG(AECG). After the extraction of FECG, the heart rate is calculated. From this, the condition for hypoxia (reduction in oxygen flow from heart to brain) is examined. The next phase involves the classification of various ECG signals using Back propagation network (BPN). The features used for this classification are heart rate, R-R interval, QRS amplitude and QRS duration of AECG.

2. Abdominal ECG

The ECG signal can be obtained by placing the electrodes on the body. The ECG signal recorded in the thorax region consists of heart pulses of the mother. The ECG signal can also be obtained from the abdominal part of the mother, which includes the fetal ECG. This resultant ECG can be termed as abdominal

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ECG (AECG). A sample AECG signal obtained from the database, which is recorded during the sixth week of pregnancy is shown in Fig.2.1.

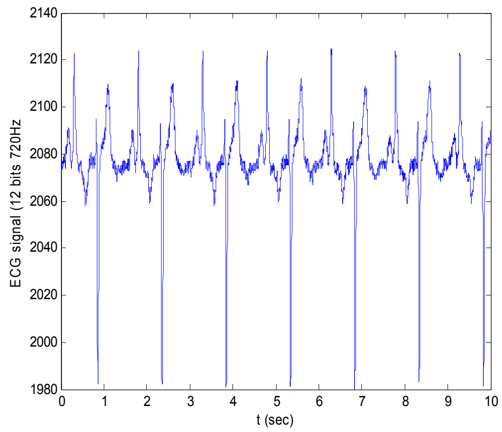

Fig.2.1 Real ECG loaded from MIT Database.

The processing was performed by MATLAB. The electrodes placed on the mother abdomen are the key to success. Fig.2.2 is showing AECG as the combination of MECG and FECG. This fact can be used to extract the FECG from the obtained AECG.

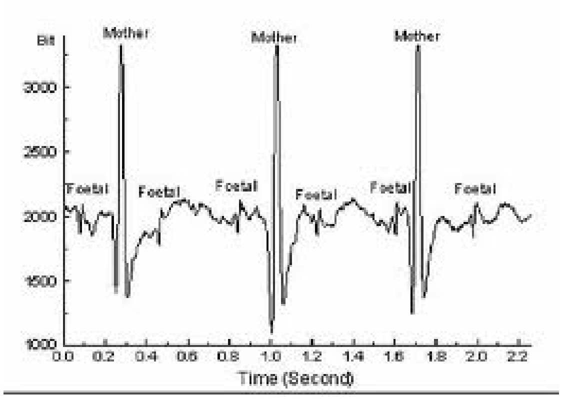

Fig.2.2 AECG showing both mother and fetal signals

3. Fetal ECG

Biomedical signal means a collective electrical signal acquired from any organ that represents a physical variable of interest where the signal is considered in general a function of time and is describable in terms of its amplitude, frequency and phase. FECG is a biomedical signal that gives electrical representation of FHR to obtain the vital information about the condition of the fetus during pregnancy from the recordings on the mother's body surface [3]. The FECG is very much related to the adult ECG, containing the same basic waveforms including the P-wave, the QRS complex, and the T-wave. The PQRST wave is composed of three parts; firstly, The P-wave occurs at the beginning of atrial contraction. Secondly, the QRS-complex is associated with the contraction of the ventricles. Due to the magnitude of the R-wave, it is extremely reliable. Finally, the T-wave, which corresponds to the repolarisation phase follows in each heart contraction.

4. FECG Extraction

Processing the AECG to detect the MECG and extract FECG for measuring the FHR and MHR is the most crucial part. Many different techniques have been developed for FECG extraction and enhancement from the AECG signal. For FECG extraction, the AECG signal has to be devoid of noise. Hence the pre-processing of the AECG has to be carried out before the FECG extraction.

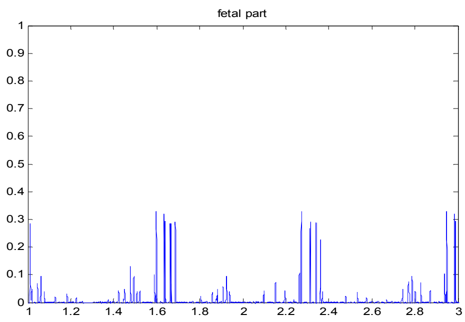

Fig.4.1 Fetal part extracted from AECG

This pre-processing stage involves removal of DC components, followed by normalization. The normalized signal is filtered to make it smoother. Then the FECG signal can be extracted from the AECG by means of Thresholding. The resultant FECG signal is shown in Fig.4.1.

5. FHR Monitoring

From the extracted FECG, the peaks are detected for the calculation of heart rate. The heart rate calculation requires the determination of number of pulses in the FECG signal. The pulses are calculated for the duration of 12 seconds. To find it for one minute it has to be multiplied by 5 as given in the following equation.

$$\text{Heart rate} = (\text{NO of pulses}/2)*5$$

Fig.5.1 shows the number of peaks as a function of time. The length of the plot gives the number of pulses, from which the heart rate can be determined[4]. We can conclude the presence of hypoxia in fetus, if this heart rate is found to be greater than 180 beats per minute. From this information, the remedial measures can be taken to avoid fetal abnormalities and death.

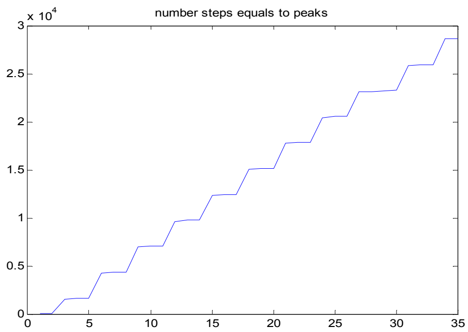

Fig.5.1.plot showing the peaks

6. Back Propagation

The back propagation is a systematic method for training multilayer artificial neural network. The typical back propagation network shown in Fig.6.1 has an input layer, an output layer and at least one hidden layer. Each layer is fully connected to the succeeding layer. The back-propagation network has been used because it requires a desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown[5]. A graphical representation of back-propagation network is shown. With back propagation, the input data is repeatedly presented to the neural network [6]. With each presentation, the output of the neural network is compared to the desired output and an error is computed. This error is then fed back (back propagated) to the neural network and used to adjust the weights such that the error decreases with each iteration and the neural model gets closer and closer to producing the desired output. This process is known as "training". The network is initialized with the following settings:

net.trainParam.show = 20

net.trainParam.epochs = 40000

net.trainParam.goal = 0.0001

In the network, for every 20 iteration, the error is displayed once. The maximum epoch for training is 40000 and the goal is to reach error at 0.0001.

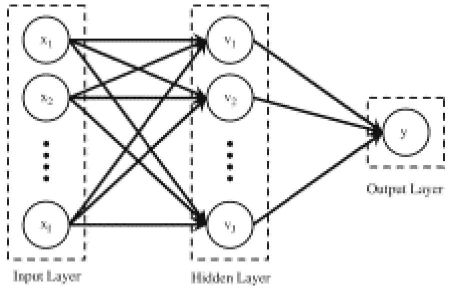

Fig.6.1.BPN architecture

For each training session, the training stops when reaches either maximum epochs or goal error. The features that are given as inputs are QRS amplitude, heart rate, QRS duration and R-R interval. Initially, the weight of input layer, hidden layer and bias values are considered randomly. The weight and bias values are saved for each training session. When the simulations are not satisfactory, the network is trained one more time with the last saved weight and bias values. This improves the network and reduces the number of times of training. After the inputs are applied, the network is trained to produce the desired output, from which the signal classification can be done successfully.

7. Results

The recorded ECG signals are obtained from MIT database. The signals are recorded during the sixth week of pregnancy. The algorithm has been tested using several AECG signals. One of the tested signals has been shown:

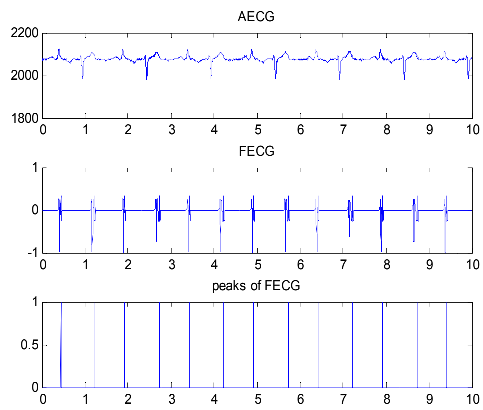

Fig.7.1.Results obtained in matlab

In this figure, the AECG signal contains the MECG and FECG. Our developed algorithm is able to extract FECG from the AECG completely. We have used the thresholding to extract the FECG from the AECG signal. Afterwards, the R-peak in FECG signals are also detected using the same procedure. From Fig.7.1 it can be said that the FECG signal is extracted efficiently (100%) from AECG signal. From these peaks, heart rate is calculated, which is useful in determining the stress condition (Hypoxia) of fetus. Various features such as QRS amplitude, heart rate, QRS duration and R-R interval of the recorded signals are applied to the BPN, based on which signals are classified as stressed or unstressed.

8. Conclusion

An efficient method of FECG extraction and R-peak detection from AECG signal has been successfully developed. The results obtained from the MATLAB simulation shows that the developed algorithm can separate FECG accurately from AECG and can detect R-peak in FECG for FHR monitoring. The presence of stress is detected from the calculated heart rate. Although the other research methods used by previous researchers accurately extract FECG from AECG, still all of them suffer from familiar limitations and not efficient enough for FHR monitoring. Using the proposed method, FECG extraction and R-peak detection are perfect enough even though, the FECG and MECG are overlapped in the AECG. In addition, the proposed method does not require constructing the full MECG signal template to extract FECG from AECG. This research is a non invasive approach therefore the problem for the invasive approach also had been solved. Also using Back Propagation Network, various signals are analyzed for stress in an easy way.

9. References

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