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Detection of Fetal Stress from Maternal Abdominal Electrocardiogram Signal

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Abstract— In recent research, recognition of fetal stress is significant in fetal monitoring during pregnancy. In order to evaluate the health of the fetus, a non-invasive fetal monitoring method should be used for measuring the Fetal Heart Rate (FHR).Many methods are available for assessing the FHR. Among these methods, Cardiotocography (CTG) and Fetal Electrocardiogram (FECG) are common methods for monitoring FHR. The most important parameter for determining the fetal health is the FHR. Lot of algorithms are available extracting FECG signals from mothers abdomen. An algorithm is proposed to extract FECG from signals measured from the maternal abdomen. Wavelet transform technique is the most popular and efficient method for determining ECG characteristics. Independent Component Analysis (ICA) and Principle component Analysis (PCA) techniques are used in wavelet transform. This proposed work consists of three algorithms for finding out the fetal heart rate and stress. The proposed algorithm consists of three steps: 1) Abdominal ECG signal (AECG) is acquired from maternal abdomen i.e. Maternal ECG (MECG). 2) FECG signal is extracted by subtracting MECG signal from AECG signal by PCA method. 3) Then fetal R peaks are calculated in extracted FECG signal to detect fetal heart rate. Finally fetal stress is monitored from the measured FHR. The main contribution of our work is the fetal stress analysis from the fetal heart rate.

Keywords— Fetal Heart Rate, Cardiotocography, Fetal Electrocardiogram, PCA, ICA, ECG.

I. INTRODUCTION

Recently, some of the medical records illustrate that most of the fetus is getting affected due to the tension factor level of the maternal. At present, in many medical applications an Electrocardiogram (ECG) signal is one of the most excellent ways to perceive the Heart Rate Variability (HRV). Cardiac problems are analyzed through ECG signals. A cardiac task plays a significant role in a human body through which the health situation can be observed. Abnormal or pathological condition in the fetus is caused by the stress and disquiet of the maternal. The consequence of this type of pressure is excreted in the pregnancy period of the maternal. Accuracy in the fetal rate helps to know the actual fetus condition. There is more number of techniques used for the FHR extraction, but they do have their own disadvantages in terms of their computational complexity. Hypoxia is a serious outcome of preterm delivery in the neonate. The main reason for this is that the lungs of the human fetus are among the last organs to increase during pregnancy. To support the lungs to give out oxygenated blood all through the body, infants at risk of hypoxia are often placed inside an incubator capable of providing permanent positive airway pressure (also known as a humid crib).Intrauterine hypoxia occurs when the fetus is destitute of an enough deliver of oxygen. Intrauterine growth restriction (IUGR) may cause or be the effect of hypoxia. This results in an increased mortality rate, including an enlarged hazard of sudden infant death syndrome (SIDS). Oxygen deprivation in the fetus and neonate have been concerned as either a primary or as a causative threat factor in abundant neurological and neuropsychiatric disorders such as epilepsy, Attention Deficit Hyperactivity Disorder ADHD, eating chaos and cerebral palsy [1]. The paper is organized as follows: Section I deal with the introduction, Section II presents the related works. Section III explains the proposed methodology, Section IV deals with performance evaluation of the proposed methodology and Section V involves conclusion and future work.

II. RELATED WORK

Lot of researchers have explored the above issues comprehensively. In the paper [2], the author Reza S et al discusses about the nonlinear Bayesian filtering frame- work for filtering of single channel noisy electro-cardiogram recordings. An improved version of this model is used in some Bayesian filters, including the Extended Kalman Filter and Unscented Kalman Filter, especially for eliminating the noises presented in the fetal ECG. In [3] the author N P. Joshi et al, the system uses the combination of morphological and dynamic features of ECG signal. Morphological features extracted using Wavelet transform and independent component analysis (ICA). Reza Sameni et al. [4] propose the application of the generalized Eigen value decomposition for the multichannel ECG recordings. The proposed method uses slightly modified version of a earlier compute of periodicity and a phase-wrapping of the RR-interval, for extracting the periodic linear mixtures of a recorded dataset. The author shows that the method is an improved method of those conventional source separation techniques, specifically customized for ECG signals. J.L.C Olivares [5] proposed a successful system for recovering the fetal Electrocardiogram using Multidimensional Independent Component Analysis (MICA). MICA helps in separating the maternal and fetal ECG signal accurately which will be more useful in obtaining the condition of the fetus. But, it needs more observation as sources. C. Saritha et al. [6] deals with the study of ECG signals using wavelet transform analysis. In the first step an attempt was made to generate ECG waveforms by developing a suitable MATLAB simulator and in the second step, using wavelet transform, the ECG signal was denoised by removing the corresponding wavelet coefficients at higher scales. Then QRS complexes were detected and each complex was used to find the peaks of the individual waves like P and T and also their deviation. Yatindra Kumar et al. [7] discusses that Electrocardiogram signal most comely known recognized and used biomedical signal, the ECG signal is very reactive in nature, and even if undersized noise mixed with original signal then the various quality of the signal changes. Data spoiled with noise must either filtered or discarded, filtering is a very important issue for design consideration of real time heart monitoring systems. Also the author analyzed the performance of different filtering methods for power line interface reduction. The results also showed that the Signal to noise ratio is lesser.

From the literature survey, it is clear that the most of the proposed methods for fetal heart rate detection are based on Multidimensional Independent Component analysis and adaptive filter, but however using Principle Component Analysis accuracy can be achieved in this method of about 98% .A suitable method is proposed using Principle Component Analysis for the extraction of fetal ECG from Maternal ECG signal. An artificial neural network is trained to classify the Hypoxia. This method has a simple approach compared to other methods and produces an exact output and has a efficiency of more than 98%.

Motivated by the issues observed from the related works, the main contributions of our proposed work are:

- Preprocessing of the MECG signals using various filters
- Feature extraction and selection using PCA and Continuous wavelet Transform (CWT).
- Probabilistic Neural Network classification for the classification of pathological conditions such as hypoxia.

The research contribution of the proposed work involves the FECG extraction with two methods and texture feature extraction for classification process.

III. METHODOLOGY

The fetal Electrocardiogram (FECG) is used for the computation of the fetal cardiac rate and in the calculation of the fetal acidosis. Acquiring of accurate information from the fetus during fetal monitoring is a challenge in the medical field and a major problem in modern obstetrics to gauge its state. Principle component analysis (PCA) is a superior signal processing technique that is used for separating out the FECG from the MECG and the interferences. From the extracted heart rate the fetus condition is obtained whether normal or abnormal. Every action of human body manipulate the heart rate signals, thus revision of those signals are significant.

In our proposed work, three modules are involved. Module-I involves the extraction of MECG from the abdomen and preprocessing of the acquired signals. Preprocessing involves filtering methods to remove various noises present in the signals. Module II involves the Principle component analysis which is used for untying FECG from the Maternal Electrocardiogram (MECG).From the existing works, there is need of performance in separation techniques. So usage of PCA in separation of signal, results in high Signal Noise Ratio (SNR) as well as better separation quality. The PCA separates the FECG from the MECG and from the other unwanted background interferences, since the FECG contains minimal amount of noise that can be eliminated using post-processing. Module III involves the feature extraction of the signal and QRS detection for the heart beat calculation and probabilistic neural network for normal and hypoxia condition. Figure 1 shows the flow diagram of the proposed methodology.

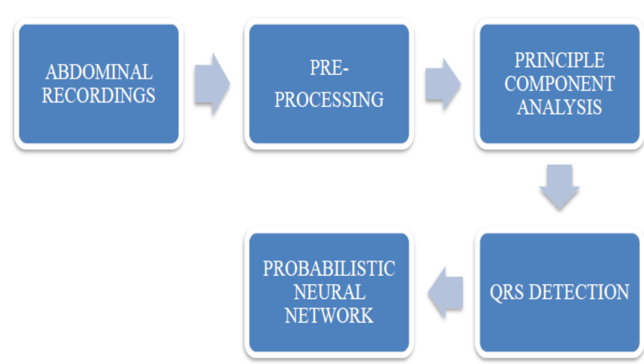


Fig.1. Flow diagram of the Proposed Methodology

A) Preprocessing of ECG Signals

Mother abdominal signals are taken from the MIT Database. Since real time signals are hard to acquire, database signals are taken. While acquisition of FECG, it gets contaminated due to diverse types of artifacts and interferences such as Power line interference, Electrode contact noise, Motion artifacts. The FECG signals are affected by the power line interference and the baseline wandering. Artifacts are the noise induced to FECG signals that result from movements of electrodes. Removal of baseline wander is therefore required in the analysis of the ECG signal to minimize the changes in beat morphology. This baseline drift can be eliminated without changing or disturbing the characteristics of the waveform. Filters are used to alter or eliminate superfluous components from signals. The Butterworth digital filter, Savitzky –Golay (sgolay) filter and Median filters are used for noise removal as they are characterized by a magnitude response that is maximally smooth in the pass-band and monotonic on the whole. Processes involved in the preprocessing stage are:

1) Removal of Noise from signal: Additive White Gaussian Noise is added with the signal and the Root Mean Square (RMS) value of the signal and noise is measured and the value of the Signal to Noise Ratio (SNR) of the ECG signal is determined. A suitable filter is used to remove noise and the value of the SNR of the signal after filtering is determined.

2) The SNR's are compared to determine the efficiency of the filter bank used and the peak SNR value of the filtered signal is determined.

a) Savitzky-Golay Filter:

A Savitzky–Golay filter is a digital filter used for smoothing the data, which is applied to a set of digital data points which in turn increases the signal-to-noise ratio without greatly deforming the signal. This is achieved, in a process known as convolution, by appropriate consecutive sub-sets of neighbouring data points with a low-degree polynomial by the method of linear least squares.

b) Median Filter:

The median filter is a nonlinear digital filtering technique, often used to remove noise. The main idea of the median filter is to scamper through the signal entry by entry, replacing each entry with the median of neighboring entries.

c) Butterworth Filter

The Butterworth filter is a type of signal processing filter designed to have as smooth a frequency response as probable in the pass band. It is also referred to as a maximally flat magnitude filter. After the preprocessing stage, i.e. after the removal of noises, PCA method is applied for the extraction o FECG signal.

B) Feature Extraction

Feature Extraction involves two processes such as: 1) FECG signal Extraction from MECG signal 2) Continuous Wavelet Transform for Heart beat Detection

a) PCA:

PCA is a way of training second-order enslavement in the data by turning the axis to communicate to the directions of utmost covariance. However, it does not tackle the high -order dependencies in the data. An correspondent formulation of PCA is to find a set of orthogonal components for the data. More formally, PCA is a linear alteration that prefer a novel coordinate system for the data such that the greatest variance by any protuberance of the data lies on the first axis (then called the first principal component), the second greatest variance on the second axis, and so on. PCA can be used for dipping dimensionality in a data while holding those characteristics of the data that donate most to its variance by abolishing the later principal components (by a more or less heuristic decision). PCA extracts the FECG signal from MECG signal.

b) CWT:

Continuous Wavelet Transform (CWT) is very efficient in formative the damping ratio of oscillating signals (e.g. identification of damping in dynamical systems). CWT is also very challenging to the noise in the signal. Like the Fourier transform, the continuous wavelet transform (CWT) uses inner products to calculate the similarity between a signal and an analyzing function. In the CWT, the analyzing function is a wavelet, ψ. The CWT evaluates the signal to shifted and compressed or stretched versions of a wavelet. By comparing the signal to the wavelet at various scales and positions, a function of two variables is obtained. The two-dimensional representation of a one-dimensional signal is outmoded. The CWT involves the FECG signal averaging, Maternal QRS suppression and extraction of fetal QRS.

C) Heart Beat Calculation

From the output obtained from the wavelet transform applied for the QRS-detection the next step is carried on to remove the edge effects and to calculate the number of heart beats for the FECG signal. A suitable type of wavelet known as "Coif1" is used to extract the peaks for the entire time distribution of the ECG signal spectrum and the number of heart beats which are denoted by the number of peaks in the ECG signal are calculated.

D) Probabilistic Neural Network

A probabilistic neural network (PNN) is a feed forward neural network, which was extended from the Bayesian network and a geometric algorithm called Kernel Fisher discriminate analysis. When an input is present, the first layer computes the distance from the input vector to the training input vectors. This produces a vector where its elements specify how slam the input is to the training input. The second layers sums the contribution for each class of inputs and construct its net output as a vector of probabilities. Finally, a complete transfer function on the output of the second layer picks the maximum of these probabilities, and produces a 1 (positive identification) for that class and a 0 (negative identification) for non-targeted classes.

IV. Results and Discussion

The performance parameters are most important criteria to validate the output simulation results. The PSNR and MSE are considered as evaluation parameters. The MSE is defined in the equation 1,

$$MSE = \frac{1}{m \times n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2 \qquad (1)$$

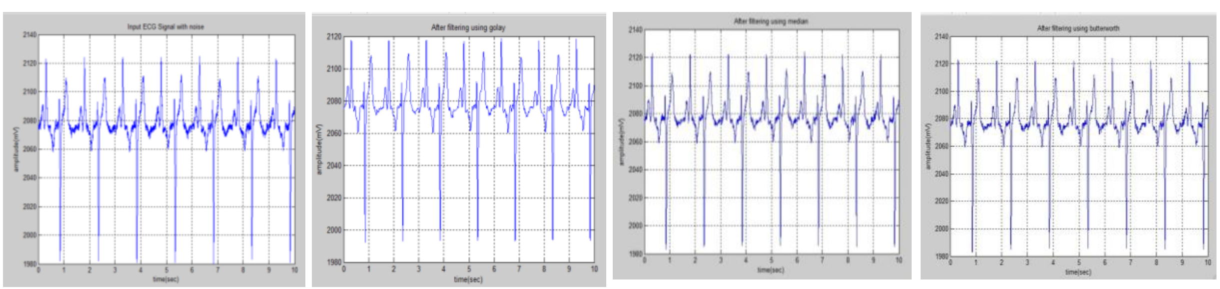
Where, m × n – size of noise-free monochrome image I, K- Its noisy approximation. The PSNR (in dB) is defined in the equation 2,

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right) \qquad (2)$$

where, MAX_I is the maximum possible pixel value of the image. Denoising is performed using three filters i.e. Golay Filter, Median filter and Butterworth filter. Results are shown through comparison among them. The various signals from MIT physiobank after preprocessing and their PSNR are shown in the Table1. From the results, it is clearly seen that Golay filter gives better performance in terms of MSE and PSNR. The PSNR values ranges in the value of 42 db to 50 db. When comparing with the other filters such as median and Butterworth filter, Golay filter performance better suits for the preprocessing of the signals. The denoised signal after preprocessing is shown in the following figures.

Table1. Comparison of performance of various filters of the Mother Abdominal ECG signals

Input Signal/MIT Physiobank	**Filters**	**MSE**	**PSNR (db)**
101 MECG	Golay	**0.7120**	**49.6060**
	Median	1.8460	45.4685
	Butterworth	1.2865	34.1136
102 MECG	Golay	1.1657	39.3869
	Median	**0.9221**	**42.2586**
	Butterworth	0.9635	35.1245
103 MECG	Golay	**0.3734**	**49.4088**
	Median	1.8748	45.4013
	Butterworth	1.4088	34.3288
104 MECG	Golay	**0.8956**	**44.5283**
	Median	1.6985	39.2354
	Butterworth	1.2358	36.2586
105 MCEG	Golay	**0.9658**	**47.2359**
	Median	1.3654	42.1582
	Butterworth	1.8145	39.2536



(a) (b) (c) (d)

Fig. 2. (a) 101MECG input signal (b) Golay Filtered Signal (c) Median Filtered Signal (d) Butterworth filtered signal

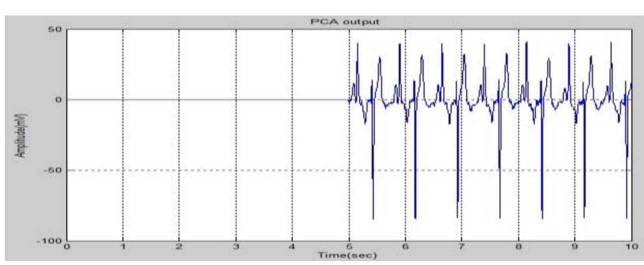


Fig.3. PCA Waveform for 101MECG signal

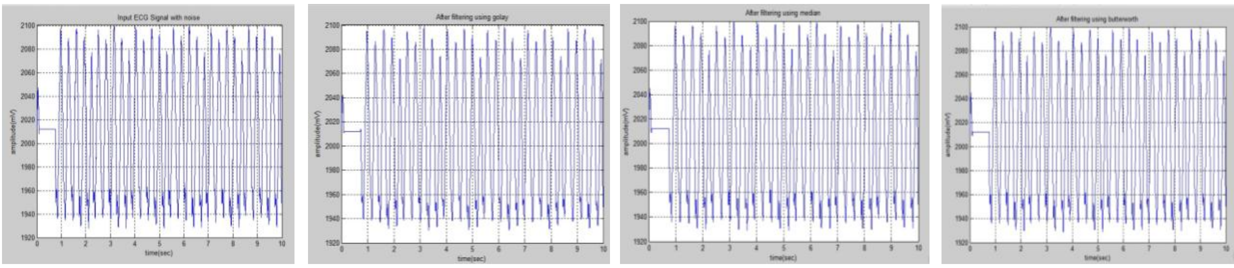


Fig.4. Input Signal from Physionet database, Golay Filter Output, median Filter output and Butterworth Filter output

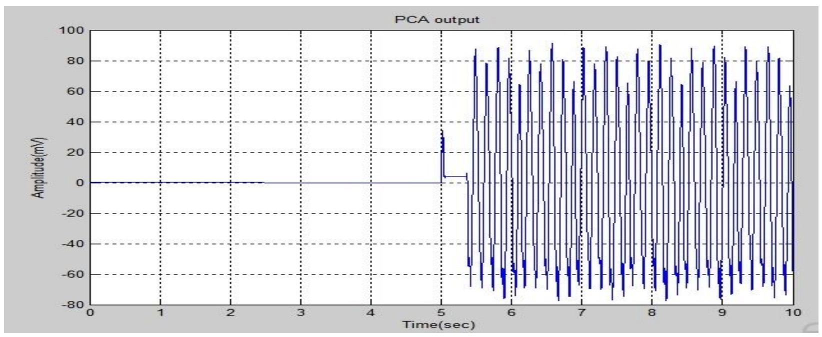


Fig.5. PCA output waveform for signal from Physionet database

The input signal 101MECG and its denoised output using Golay filter, median filter and butter worth filter is shown in the Fig.2(a) Fig.2(b), Fig.2(c) and Fig.2(d) respectively. After denoising, the proposed method involves the PCA which includes i) Mean and the subtracted value ii) Covariance iii) Eigen Vectors and iv) The new data set which derives the FECG signal. The waveform shown in Fig. 3 is obtained after PCA which shows the extracted FECG signal. After PCA, The feature extraction involves the QRS detection and peak identification of the fetal ECG signal. After the feature extraction, the final step is to classify the hypoxia. For more validation of the algorithm another input signal from the Physionet database is loaded into the program and outputs of the Golay Filter, median filter and Butterworth filter is shown in the Fig.4. Fig.5 shows PCA output waveform for signal from Physionet database.

Table 2. Classification accuracy of the proposed work with probabilistic neural network and the result comparison with ICA

Method	Accuracy
Proposed PCA+ PNN	98%
ICA + Neural Network	98%

From the extracted features the output is classified using neural network classifier as a normal or abnormal case. Advantages of neural networks include their high tolerance to noisy data as their ability to classify patterns on which they have not been trained. The obtained results are compared with the previous work such as ICA. The results are tabulated in terms of accuracy.

V. CONCLUSION AND FUTURE SCOPE

It is a great research to dig about the papers related to the extraction of FECG signal and analyze the Heart rate of the fetus. The literature survey shows lot of methods used for FECG extraction without noises. Also heart rate analysis plays a major role to analyze the fetus pathological condition. This work comprises an implementation of the extraction of fetal heart rate from the abdominal Electrocardiogram (ECG) of mother. The golay filter, median filter, butter worth filter and the Principal Component Analysis (PCA) clearly derives the fetal heart to know the condition of the fetus and to classify the fetal hypoxia effect. . It is better to come up with a better solution with the physician for easy analysis of Fetus condition. In this work, the extraction of fetal heart rate is done by using MATLAB simulation. In future the proposed work can be implemented using hardware processors. It can be more suitable for real time applications for the analysis of fetal hypoxia.

REFERENCES

[1] J.Shamira and R.Tamilselvi, "Extraction of Fetal Heart Rate and Respiratory Rate from Abdominal Electrocardiogram", Pak. J. Biotechnol. Volume 13 (special issue on Innovations in information Embedded and communication Systems) pp. 400-404, 2016.

[2] Reza Sameni, Mohammad B. Shamsollahi, Christian Jutten and Gari D.Clifford, "A Nonlinear Bayesian Filtering Framework for

ECG Denoising", IEEE Transactions On Biomedical Engineering, Volume 54, Issue 12,2007.

[3] N P. Joshi, Shweta A.Tambe1, P.S. Topannavar, "Morphological &Dynamic Feature Based Heartbeat Classification", International Journal of Engineering Research and General Science, Volume 2, Issue 3, 2014.

[4] RezaSameni, Christian Juttenand, Mohammad B.Shamsollahi, "Multichannel Electrocardiogram Decomposition Using Periodic Component Analysis", IEEE Transactions on Biomedical Engineering. Volume 55, Issue 8, 2008.

[5] Camargo-Olivares J. L, R. Martin-Clemente, Hornillo-Mellado S, M. M.Elena, and I. Roman, "The Maternal Abdominal ECG as Input to MICA in the Fetal ECG Extraction Problem", IEEE Signal Processing Letters, Volume 18,Issue 3,2011.

[6] C. Saritha,V. Sukanya,Y. Narasimha Murthy, " ECG SignalAnalysis Using Wavelet Transforms", Bulg. J. Phys. Volume 35 pp. 68–77,2008.

[7] Yatindra Kumar et al, "Performance Analysis of different Filters for Power Line Interface Reduction in ECG Signal" International Journal of Computer Applications ,Volume 3,Issue.7,pp.1-6, 2010.