EXTRACTION OF FETAL HEART RATE AND RESPIRATORY RATE FROM ABDOMINAL ELECTROCARDIOGRAM

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ABSTRACT
The major problem in modern obstetrics with respect to fetal monitoring is the difficulties to extract information from the fetus to know its actual health condition. The Fetal Electrocardiogram (FECG) is used for the calculation of the fetal cardiac frequency and in the observation of the fetal acidosis. Multidimensional Independent Component Analysis (MICA) is one of the improved advanced signal processing technique which is to be used for separating the FECG from the Mother ECG(MECG) and the interferences. MICA is an extension of Independent Component Analysis(ICA). After the extraction of FECG Pan-Tompkins method is used to extract Fetal Heart Rate(FHR) in order to determine fetal condition. Also in addition the Fetal Respiratory Rate (FRR) is also extracted to know the fetus condition. FHR and FRR plays a major role in determining the fetal health condition exactly.

Key Words: FECG; MECG; FHR; FRR

I. INTRODUCTION
A normal pregnancy takes nine months. Every three-month period of pregnancy is called a trimester. During this trimester, the fetus will be developed. There are some related prenatal tests to monitor both the mother's and fetal health condition during this trimester. With modern technology observations, health professionals and detect birth defects, identify problems that may affect childbirth and correct some kinds of fetal problems before the baby is born.[1]

During pregnancy period, it is an important factor that the health condition of fetus must be monitored continuously to know its condition of the health. By monitoring continuously the clinical specialists can increase their level of attendance and in emergency situations they can take a better decision quickly. For this one of the best techniques is heart signal monitoring which gives us important information about fetal health condition. Electrical potentials produced by heart are graphically recorded as ECG. The electrical potentials are generated by simultaneous repolarization and depolarization of cells due to Na+ and K+ ions momentum in the blood. The range of ECG signal is typically 2mv and requires 0.1 to 120 Hz recording bandwidth. ECG is acquired by placing electrodes at standard locations on the skin which comes under non-invasive technique. Heart rate and ECG reflects the health of human heart. The duration and amplitude of the ECG wave gives the useful information about the health of the heart. An ideal FECG is shown in Figure 1

For heart signal monitoring of fetus one of the best technique is FECG signal recording, which is used for monitoring fetus condition in pregnancy period continuously. Most diseases of fetus are discovered in FECG. Fetal Electrocardiogram can be obtained in two ways: direct method and the other is in-direct method. In the direct method, electrode must passed through abdomen of mother and enter the womb to touch the fetus’s head. This may cause some problems to both mother and fetus. Hence nowadays indirect method is used for recording FECG, i.e. FECG is extracted from a signal recorded on the mother’s abdomen.

Abdomen signal includes Mother ECG, Fetal ECG and noise signal. Noise signal includes muscular noise, electrode noise, base lines noises and recording system noise. In-direct method also has some difficulties such as permanent appearance of Mother’s ECG signal which dominates FECG as it is 5-20 times bigger in amplitude which is considered as noise in Fetal ECG extraction. There are so many signal processing techniques which include adaptive filtering, ICA, SVD, wavelet based techniques etc., for extracting FECG from AECG [2]. Recently, some of the medical records show that most of the fetus are getting affected due to the stress factor level of the mother. The cause of stress and anxiety of maternal will lead a fetus to the abnormal condition. There are many types of stress that occur to the maternal during the time of pregnancy. The effect of this type of stress is excreted in the pregnancy period of the mother. Therefore, the extracted FHR must be taken accurately to know the actual fetus condition. The performance of real and simulated multichannel ECG signals with different degrees of morphological, heartbeat deviations and in different sampling rates and SNR can be studied. The fundamental period contains information that is used for the indication of the
physical condition of the fetus such as hypoxia and acidemia[1]. Sometimes all these methods are unable to produce useful information.

II. FETAL HEART RATE EXTRACTION APPROACHES

Various papers have been analyzed for the review of Fetal Heart Rate extraction from the maternal ECG signal. In the paper titled “A Method for Subsample Fetal Heart Rate Estimation Under Noisy Conditions”, Ismet Sahin et al., [1] consider a new method for the estimation of fundamental period in fetal ECG wave forms. The fundamental period contains information that is indicates the physiological condition of the fetus such as academia and hypoxia.

In the paper titled “Amendment of Cardiac Rate with Respiratory Rate and Body Temperature in Habitual Proviso”, Tamilselvi et al., [2] described that every human activity is purely based on human biological conditions and parameters which are body temperature, heart rate, blood flow and respiratory rate. Biological parameters fascinate wide interest as diagnosing many diseases of patients in today’s medical implants and developments. The aim of the proposed work is to recognise the relationship between biological parameters that is relation between heart rate and respiratory rate.

In the paper titled “A Successive Cancellation Algorithm for Fetal Heart-Rate Estimation Using an Intrauterine ECG Signal”, Kuei-Chiang Lai et al., [3] presents a two-stage successive cancellation (SC) algorithm that is used for sequentially separating the fetal and maternal ECG from an Intrauterine Electrocardiogram (IuECG) signal that contains both fetal and maternal QRS complexes.

In the paper titled “Fetal Heart Rate Extraction from Composite Maternal ECG Using Complex Continuous Wavelet Transform”, Karvounis et al., [4] describes about the Fetal Heart Rate extraction from the abdominal ECG is of huge important because it carries the information about the actual fetus condition during pregnancy. In this work a novel automated method is considered for the detection of the QRS complexes of the fetus using multi-channel maternal ECG recordings.

The paper titled “The Maternal Abdominal ECG as Input to MICA in the Fetal ECG Extraction Problem”, Camargo-Olivares et al., [5] proposed a successful system for recovering the foetal Electro-cardiogram using MICA. MICA helps in seperating 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.

The paper titled “Fast Technique for Non-invasive Fetal ECG Extraction”, Ruben Martin-Clemente et al., [6] describes a fast and very simple algorithm for the extraction of Fetal Heart Rate from FECG. The author discusses on Independent Component Analysis, its computationally demanding calculations for simple procedure. And the resulting method consists of two steps: 1) a dimensionality reduction step and 2) a computationally light post-processing stage which were used to enhance the FECG signal.

In the paper titled “Extraction of Fetal Heart Rate and its variability from mother's ECG signal”, Kaldon Lweesy et al., [7] describes a new method for extracting the Fetal Heart Rate (fHR) and the Fetal Heart Rate Variability (fHRV) signal non-invasively using abdominal MECG recordings.

In the paper titled “Multichannel Electrocardio- gram Decomposition Using Periodic Component Analysis”, Reza Sameni et al., [8] proposes the application of the generalized Eigen value decom-position for the multichannel Electrocardiogram (ECG) recordings. The proposed method uses slightly modified version of a existing measure 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, speci-fically customized for ECG signals.

A paper titled “A Nonlinear Bayesian Filtering Framework for ECG Denoising”, Reza Sameni et al., [9] discusses about the nonlinear Bayesian filtering frame-work for filtering of single channel noisy electrocardiogram recordings, speci-ally for eliminating the noises presented in the fetal ECG.

The paper titled “An Automated Methodology for Fetal Heart Rate Extraction From the Abdominal Electrocardiogram”, Evag-gelos C. Karvounis et al., [10] introduces an automated methodo-logy for the extraction of FHR from cutaneous potential abdominal electro-cardio-gram (abd ECG) recordings. The abdominal ECG signal normally consists of both Maternal as well as Fetal signal. A three-stage methodology is proposed. Having the initial recording as input, which has small number of abdECG leads in the first stage, QRS onset and offset are detected using time-frequency (t–f) analysis and medical knowledge. Then, the mother QRS complexes are eliminated. In the second stage, the positions of the candidate fetal R-peaks are located using matching theory techniques. In the third stage, the fetal R-peaks, which overlap with the maternal QRS complexes are found using two approaches: a Heuristic Algorithm technique and other is the histogram-based technique. The R-peaks detected are used for the calculation of the FHR.

In the paper titled “An Improved Adaptive Power Line Interference Canceller for Electrocardiography”, Suzanna et al., [11] tells that the power line interference may severely corrupt a biomedical recording. In order to avoid such problems some kind of filters must be undertaken. Here, Notch filters and adaptive cancellers have been suggested to suppress this interference.

In the paper titled “Fetal Electrocardiogram
Extra- tion by Sequential Source Separation in the Wavelet Domain’, Maria G. Jafari et al., [12] a point out the the problem of FECG extraction using BSS in the wavelet domain. A new approach is proposed, which is an advantageous method when the mixing environment is noisy and time-varying to improve the convergence rate of the natural gradient algorithm.

In the paper titled “Probabilistic Estimation of Respiratory Rate using Gaussian Processes”, Marco A.F. Pimentel et al., [13] describes that the presence of respiratory information within the ECG signal is a well-noted phenomenon. It will be more advanta- geous in finding out the medical condition of the Fetus during its pregnancy period.

III. PROPOSED SYSTEM

Based on the literature survey, a method is proposed to extract heart rate of the fetus and Respiratory Rate. The FECG is used for the extraction of the fetal cardiac frequency and in the observation of the fetal acidosis. MICA is one of the improved advanced signal processing technique that is used for separating out the FECG from the MECG and the interferences. MICA is an extension of Independent Component Analysis. Also in addition the respiratory rate is also extracted to know whether the fetus condition is normal or abnormal.

In our proposed work, MICA is used for separating FECG from the MECG and the interferences. In addition to the Fetal Heart Rate, Respiratory Rate is also extracted from the abdominal ECG signals. Every activity of human body influences the heart rate and respiratory signals, thus study of those signals are substantial. MICA is used for avoiding problems based on accuracy and prediction. From the existing works, there is lack of performance in separation techniques. So, utilizing MICA in separation of signal results in high SNR as well as better separation quality. The MICA separates the FECG from the MECG and from the other unwanted interferences, since the FECG contains less amount of noise that can be eliminated using post processing [7]. The Figure 3 shows the block diagram of the proposed methodology.

B. PAN-TOMPKNIPS ALGORITHM

The QRS detection provides the necessary data for almost all ECG analysis algorithms. Pan-Tompkins proposed a real-time algorithm for QRS detection which is based on analysis of the amplitude, slope and width of the QRS complexes of typical cardiac signal as shown in the block diagram. The algorithm includes a series of filters and operators that perform integration, squaring, adaptive thresholding operations, derivative and search procedures. Figure 5 shows the block diagram of Pan-Tompkins algorithm.
IV. RESULTS

The output of MICA algorithm which separates the fetal ECG signal and the maternal ECG signal is shown in the waveform. After the extraction of Fetal ECG signal the Fetal Heart Rate is extracted by pan-tompkins algorithm. The Fetal Heart Rate extracted is as follows: THE BEAT INTERVAL IS 229 BEATS PER MINUTE

![Separated maternal and fetal signals.](image)

**Fig 5.** Separated maternal and fetal signals.

![Respiratory Rate.](image)

**Fig 6.** Respiratory Rate.

V. CONCLUSION AND FUTURE WORK

The results show discussions about the implementation of the extraction of Fetal Heart Rate from the existing MICA method and respiratory rate from the abdominal ECG. The pan-tompkins algorithm and the Kalman filter clearly derives the Fetal Heart Rate and Fetal Respiratory Rate to know the condition of the fetus. The result provides the conclusion that the abnormality of the fetus can be derived from the mothers ECG and hypoxia condition related to respiratory rate. The derived works says the relation of respiratory rate to the heart rate (R peaks)

In this work, the extraction of Fetal Heart Rate and respiratory rate is done by using MATLAB simulation. In future the proposed work can be implemented using hardware processors which will be more suitable for real time applications for the analysis of Fetal Hypoxia.

The respiratory rate is extracted from the R peak detection by filtering the signal using Kalman filter, the respiratory signal is as follows and the respiratory rate is 17 breaths/min

REFERENCES


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