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A Novel Approch for Fetal Ecg Using Adaptive Filter Algorithm

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ABSTRACT: *- Fetal Electrocardiogram (FECG) signals, non-invasively taken from the Abdominal Electrocardiogram (AECG) of a pregnant woman is an efficient diagnostic tool for evaluating the health status of foetus. Clinically significant information in the Fetal Electrocardiogram signal is often masked by Maternal Electrocardiogram (MECG) considered as the most predominant interference, power line interference, and maternal Electromyogram (EMG), baseline wander etc. Fetal Electrocardiogram signal features may not be readily comprehensible by the visual or auditory systems of a human. Therefore Fetal Electrocardiogram should be extracted from composite Abdominal Electrocardiogram for clinical diagnosis. There are many powerful and well advanced methods for this purpose. A methodological study has been carried out to show the effectiveness of various methods which helps in understanding of Fetal ECG signal and its analysis procedures by providing valuable information and we have proposed a method to find the size of fetal for every month. We have finded the edges of fetal using edge detection algorithm for forth month and compared with fifth month by using adaptive filter algorithm. This is done for every advanced month of fetal.*

Keywords: FECG; Adaptive Filter; Edge detection; Abdominal ECG; Maternal ECG; ElectroMyoGram.

I. INTRODUCTION

Fetal electrocardiogram (FECG) signal contains potentially precise information that could assist clinicians in making more appropriate and timely decisions during labor. The ultimate reason for the interest in FECG signal analysis is in clinical diagnosis and biomedical applications. The extraction and detection of the FECG signal from composite abdominal signals with powerful and advance methodologies are becoming very important requirements in fetal monitoring. The purpose of this review paper is to illustrate the various methodologies and developed algorithms on FECG signal detection and analysis to provide efficient and effective ways of understanding the FECG signal and its nature for fetal monitoring. A comparative study has been carried out to show the performance and accuracy of various methods of FECG signal analysis for fetal monitoring.

Fetal heart rate (FHR) monitoring is a routine for obtaining significant information about the fetal condition during pregnancy and labor. The characteristics of the fetal electrocardiogram (FECG), such as heart rate, waveform, and dynamic behavior, are convenient in determining the fetal life, fetal development, fetal maturity, and existence of fetal distress or congenital heart disease. The FHR may change as the fetus responds to conditions in the uterus. An abnormal FHR or pattern may mean that the fetus is not getting enough oxygen or there are other problems. Sometimes an abnormal pattern also may mean that an emergency or cesarean delivery is needed. During pregnancy, the motivation for monitoring the fetal 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.

1.1. Clinical Significance of Fetal Heart Rate

During the last decades, FHR monitoring has been extensively used for intrapartum and antepartum monitoring to assess fetal well-being. It is commonly used as a screening modulus of the fetus to detect in advance possible fetal problems that could result in irreversible neurological damage or even fetal death during labor. FHR has become a routine physiological measurement both during labor and during the antenatal period when certain pregnancy risk factors have been identified. The normal pattern of FHR is well established and easily recognized while other patterns (e.g., decelerations, loss of high-frequency variability, and pseudo-sinusoidal) can be indicative of fetal asphyxia. Although detection of fetal compromise is one benefit of fetal monitoring, there are also risks, including false-positive tests that may result in unnecessary surgical intervention. Therefore, it has been classified that there are two methods of FHR monitoring during labor and delivery.

Auscultation is a method of listening to the fetal heartbeat from mother's abdomen. Electronic fetal monitoring is a procedure in which instruments are used to record the heartbeat of the fetus and the contractions of the mother's uterus during labor. Sometimes, auscultation and electronic fetal monitoring are used together to determine the status of the fetus perfectly. Either method is a good way to measure how well the baby is doing during labor and delivery. The choice of which method is used depends on how a pregnant women's labor is going and her risk of problems.

1.1.1. Auscultation

Auscultation involves listening to one's baby's heartbeat. There are two ways of listening to the fetal heartbeat with auscultation:

1. A *Doppler* ultrasound device is a small device that is pressed against mother's abdomen. This device uses a form of ultrasound to convert sound waves into signals of fetal heartbeat.

2. A special device like a stethoscope called a fetoscope is placed in the ears of doctor or nurse. The open end is pressed on mother's abdomen. The fetoscope allows fetal heartbeat to be heard clearly. It is used less often than Doppler.

The heart rate of the fetus will be monitored before, during, and just after a contraction or nonstop during labor to tell how the fetus reacts to the contraction. Electronic monitoring can be the better option for fetal monitoring if abnormal patterns are found in auscultation method.

1.1.2. Electronic Fetal Monitoring

Electronic fetal monitoring uses special equipment to measure the response of the FHR to contractions of the uterus. It provides an ongoing record that can be read by the doctor or nurse. Electronic fetal monitoring can be external (outside), internal (inside), or both. The pregnant woman needs to stay in bed during both types of electronic monitoring, but she can move around and find a comfortable position.

Internal monitoring

Internal monitoring involves placement of a small plastic device about the size of a pencil eraser through the cervix. A spiral wire called the fetal scalp electrode is placed just beneath the skin of the fetal scalp. The fetal scalp electrode then transmits direct information about the fetal heart rate through a wire to the fetal monitor that prints out this information. Because the internal fetal monitor is attached directly to the baby, the FHR signal is sometimes much clearer and more consistent than with an external monitoring device. However, there may be a slight risk of infection with internal monitoring. The scalp electrode may also cause a mark or small cut on the baby's head, but this usually heals quickly [1].

External monitoring

By definition, external fetal monitoring is done through the skin and is not meant to be invasive. Sensitive electrodes are placed on mother's abdomen over conducting jelly that can sense both FHR and the strength and duration of uterine contractions. The nonstress test (NST) is another way of externally monitoring the baby. The NST can be done as early as the 27th week of pregnancy and it measures the FHR accelerations with normal movement [2]. The contraction-stress test is a final method of externally monitoring the baby. This test measures the ability of the placenta to provide enough oxygen to the fetus while under pressure during the contractions [2]. In fact, there are no known risks by using the fetoscope, Doppler, or external monitoring for FHR. Some FHR monitoring techniques are highlighted in terms of patient's benefits and maintenance.

1.2. FHR Monitoring Techniques

Fetal heart rate analysis has become a widely accepted means of monitoring fetal status [3]. The most familiar means of acquiring the FHR is Doppler ultrasound. In addition, the FHR monitoring is also done by considering fetal magneto cardiogram (FMCG) that uses superconducting quantum interference device magnetometers [4]. Apart from this, fetal phonocardiography (FPCG) allows the heart sounds to be detected for FHR monitoring [5]. The majority of FHR analysis technique is performed using a bedside monitor over a relatively short period, with the mother-to-be in a recumbent position. All of the above techniques that are mentioned have been successfully used for FHR monitoring, although the initial choice was which of the above techniques would be employed. Obviously, a fetal scalp electrode cannot be used antepartum period as there is a great risk to cause a mark or small cut on the fetal head; the instrumentation required for the acquisition of the FMCG is too cumbersome for ambulatory use; while fetal phonocardiography was felt to be too susceptible to movement artifacts effects. Therefore, the Doppler ultrasound and the abdominal FECG (as it is commonly referred to) are the most viable options for the monitoring of FHR.

Currently, Doppler ultrasound and FECG have proven to be reliable techniques for monitoring FHR. The FHR monitoring using the Doppler ultrasound is widely used and appropriate because an invasive test cannot be used daily [6]. The advantage of the Doppler ultrasound technique is that it can be virtually assured that a recording of FHR will be obtained. The disadvantages of such systems require intermittent repositioning of the transducer and they are only suitable for use with highly trained midwifes. The ultrasound transducer is problematic and uncomfortable while the procedure involves launching a 2-MHz signal towards the fetus [7]. The use of Doppler ultrasound (noninvasive manner) is not suitable for long periods of FHR monitoring [8]. This may involve skillful placement and continual repositioning of the transducer, which would be a severe problem for long-term ambulatory use. It may cause records of uncertain accelerations or decelerations and true abrupt changes can be misinterpreted as noise [9-11]. The major limitation of the Doppler ultrasound technique is its sensitivity to movement. The movement of the mother can result in Doppler-shifted reflected waves, which are stronger than the cardiac signal. This Doppler ultrasound technique is inappropriate for long-term monitoring of the FHR, as it requires the patients to be bed-rested [12]. Moreover, the detection of the heartbeat using Doppler ultrasound relies upon a secondary effect (the mechanical movement of the heart) and is therefore not as accurate for beat-to-beat analysis as detection of the QRS complex. Allied to this drawback is the fact that most Doppler systems rely upon some form of averaging to produce their FHR data.

In contrast, methods utilizing the abdominal electrocardiogram (AECG) have a greater prospect for long-term monitoring of FHR and fetal well-being using signal-processing techniques [13]. The AECG signal can also be used for antepartum noninvasive FHR determination through the detection of small fetal cardiac potentials at the surface of the maternal abdomen [14]. The AECG can be used to produce true R–R interval data, which is suitable for heart rate variability studies if required. Its advantage is that it is completely noninvasive and unobtrusive, has comparatively low power requirements, and can be used over extended (e.g., 24 h) periods. The method additionally allows the maternal heart rate (MHR) to be recorded since the MECG is also detected from the AECG. It is advantageous of using AECG to extract FECG with the additional information compared to using Doppler ultrasound [15]. Some new highly accurate techniques are reported for monitoring the

FHR [16,17]. The major disadvantage with this technique is that the acquisition of the FECG cannot be guaranteed and often has a very low signal-to-noise ratio (SNR) because of the interference caused by MECG, electromyogram (EMG), and motion artifact in determining the FHR from the AECG signal. To overcome the above problems, some multiple-lead algorithms use the thoracic MECG to cancel the abdominal MECG [18], though this is inconvenient for the patient during long-term monitoring. Hence, to make the AECG suitable for the detection of the FECG, the SNR must be enhanced. The decision was therefore made to base the investigation on the possibility of constructing an ambulatory FHR recorder around the acquisition of the abdominal FECG.

The FECG is an electrical signal that can be obtained noninvasively by applying a pair of electrodes to the abdomen of a pregnant woman [14]. Therefore, detection of FECG signals with powerful and advance methodologies is becoming a very important requirement in biomedical engineering for the interest in FECG signal analysis in clinical diagnosis and biomedical applications. The FECG contains potentially valuable information that could assist clinicians in making more appropriate and timely decisions during labor, but the FECG signal is vulnerable to noise and difficulty of processing it accurately without significant distortion has impeded its use [19-22]. A number of difficulties and complication are associated with recording the AECG. The signal-processing algorithm needs to remove the MECG complexes, reduce the effects of motion artifact, muscle noise, and power line interface, and then enhance the fetal QRS complexes before they can be consistently detected. Therefore, to get proper information of the FHR and fetal status, it is necessary to improve the SNR of the abdominal signal.

Although there are still limitations for monitoring the FHR perfectly, currently, there is a significant amount of effort being done to improve SNR of FECG signal. Traditional system reconstruction algorithms have various limitations and considerable computational complexity and many show high variance. Up-to-date advances in technologies of signal-processing and mathematical models have made it matter-of-fact to develop advanced FECG detection, extraction, and analysis techniques. Ranges of mathematical techniques and artificial intelligence (AI) have acknowledged comprehensive attraction. Mathematical models incorporate wavelet transform (WT), time–frequency approaches, Fourier transform, statistical signal analysis, and higher-order statistics. AI approaches towards signal recognition include artificial neural networks (ANN) [23], self-organizing map (SOM) neural network [24], finite impulse response (FIR) neural network [25], and fuzzy logic system [26]; a technique combining the adaptive noise canceller and adaptive signal enhancer [27] in a single recurrent neural network is being used for the processing of AECG signal. Singular value decomposition [13] and IIR adaptive filtering combined with genetic algorithms [28] are also used for FHR monitoring. The computerized analysis of FHR monitoring based on the combination of wavelet analysis and artificial neural network is a very promising technique in objective intrapartum diagnosis of fetal hypoxia. In the field of FECG and FHR extraction, various research efforts have been carried out, including subtraction of an averaged pattern, matched filtering, adaptive filtering, orthogonal basis functions, fractals, temporal structure, frequency tracking, polynomial networks, wavelets, and real-time signal processing.

Methods of extracting FECG from the AECG have been recently introduced for the monitoring of FHR. These methods can be classified with respect to the principle ideas of signal processing as follows: threshold technique, spectral analysis, linear combinations, or weighted sums. The extraction of FECG from the complex signal (mother and fetus) can be reframed in a more efficient manner using blind source separation (BSS) methods such as principal component analysis [29] and independent component analysis (ICA) [16,29]. Wavelet transform is well fitting to nonstationary signals like ECG. The combination of wavelet analysis and BSS methods also shows potential attitude for the separation of the maternal and fetal signals from ECGs. Blind-adaptive-filtering [30] tactic overcomes the theoretical limitations in applying conventional BSS methods based on ICA for FECG signal extraction problem. So far, research and extensive works have been made in the area, developing better algorithms, upgrading existing methodologies, and improving detection techniques to reduce noise and acquire accurate FECG signals to obtain reliable information about the fetal state thus assuring fetal well-being during pregnancy period.

The aim of this paper is to explore by highlighting the different approach and methodologies for monitoring the FHR. Therefore, this paper firstly gives a brief clarification about FECG signal and a short historical background of FECG signal analysis as well. This is followed by highlighting the up-to-date detection, extraction processing, and classification methods of FECG signal along with a comparison study. Lastly, some hardware implementations of FECG signal analysis to monitor FHR have been discussed.

Heart defects are being the most common birth defects and the leading cause of sudden prenatal death. The cardiac defect may be very slight so that the baby appears healthy and normal for many years after birth, but suddenly becomes so severe due to that its life is in immediate danger. Congenital heart defects originate when the heart is forming and they can affect any of the parts or functions of the heart. Cardiac anomalies may occur due to an inherited disorder, genetic syndrome, or environmental factors such as infections or misuse of drug during pregnancy. Every year one out of 125 babies is born with some kind of congenital heart defects. FECG carries vital information about the cardiac function of foetus. The characteristics of the foetal

Electrocardiogram (FECG), such as heart rate, waveform, and dynamic behavior, are important in determining the foetal life, fetal development, fetal maturity, and existence of fetal distress or congenital heart disease. Fetal electrocardiography has proved an effective tool for imaging specific structural defects only at the time of labor not during pregnancy because FECG is contaminated by fetal brain activity, myographic (muscle) signals (from both the mother and fetus), movement artifacts and multiple layers of different dielectric biological media through which the electrical signals must pass. Fetal monitoring is based entirely on the fetal heart rate and does not incorporate characteristics of the fetal ECG (fECG) waveform that are the cornerstone of cardiac evaluation. The main reason for this is there is no available technology to reliably measure fECG. Most of the heart defects have some manifestation in their morphology, which is believed to contain much more information as compared with other conventional methods. Most of the clinically useful information in the FECG signal is found in the amplitude and duration of its waveforms. Fetal cardiac waveform helps physicians to diagnose fetal heart arrhythmia such as Bradycardia, Tachycardia, Asphyxia and Hypoxia. It has long been recognized that persistent of fetal tachyarrhythmia and brad arrhythmia may also lead to the evolution of heart failure and may be associated with neurological injury.

II. METHODS

There are many methods for extracting FECG from AECG such as Adaptive Neuro Fuzzy Inference System, Support Vector Machine, Independent component Analysis etc.

Adaptive filtering

An adaptive filter is a filter that self-adjusts its transfer function according to an optimization algorithm driven by an error signal. Here v(n) is signal of interest. m(n) is major mater interference overlapped with the signal of interest. Adaptive noise canceller requires a secondary input also known as reference input r(n) that should be uncorrelated with signal of interest and closely correlated with the interference. Adaptive filter learns and adapts the characteristics of reference signal and modifies it exactly similar to the influencing interference y(n). Assume that v(n), m(n), r(n), y(n) are stationary and have zero means. Adaptive filtering, wavelet Transform, soft computing tools like Adaptive neural network,

Genetic Algorithm,
$e(n)=x(n)-y(n)=v(n)+m(n)-y(n)$

$y(n)=\sim m(n)$ is the estimate of the primary noise obtained at the output of the adaptive filter.

Taking the square and expectation (statistical average)
$E[e2\ (n)]=E[v2\ (n)]+E[\{m(n)-y(n)\}2]+2E[v(n)\{m(n)-y(n)\}])$

Since m(n) and y(n) are uncorrelated with v(n)

$E[v(n)\{m(n)-y(n)\}]=E[v(n)]E[m(n)-y(n)]=0$

$E [e2(n)]=E[v2 (n)]+E[\{m(n)-y(n)\}2]$

$\text{Min } E[e2 (n)]=E[v2 (n)]+\min E[\{m(n)-y(n)\} 2]$

When $E[e2 (n)]$ is minimized, $\min E[\{m(n)-y(n)\}2]$ is also

Minimized. When $E [\{e (n)-v(n)\}2]=0$

Output SNR is improved.

Minimizing the total output power minimizes the output noise power and maximizes the output SNR. Different types of adaptive filters have been used for fetal and maternal signal separation. These methods use one or more reference maternal signals for training an adaptive or matched filter, or directly training the filter without reference signal for extracting the fetal QRS waves. Ad hoc filters such as least square error fittings and partition-based weighted sum filters have also been used for FECG extraction. The kalman filter, a general class of adaptive filter used in uses only an arbitrary MECG as reference for MECG cancellation and FECG extraction. In and, a set of state-space equations was used to model the temporal dynamics of ECG signals, for designing a Bayesian filter for ECG denoising. This Bayesian filter framework was used in to extract fECG from single channel mixture of mECG and fECG. However, as mentioned in, the filter fails to discriminate between the maternal and fetal components when the mECG and fECG waves fully overlap in time. The reason is that when mECG is being estimated, fECG and other components are supposed to be Gaussian noises. However, this assumption is not true, especially when mECG and fECG waves fully overlap in time it is difficult for the filter to follow desired ECG.

An improved method proposed in [84] uses multistage adaptive filtering for FECG extraction in which MECG cancellation has been done by considering thoracic ECG as reference signal also denoising methods were used to improve the quality of extracted signal. A linear adaptive filter was used to extract the FECG by considering abdominal ECG as primary inputs whereas thoracic ECG taken from maternal chest as reference inputs. Though this method provides a solution it fails to extract when maternal and fetal signals are overlapped each other. So it is not best for clinical practice.

A. Scanning the 12-lead ECG paper, convert it into grayscale levels and select the desired signal.

B. Separation of the desired signal from its background (lines of squares grid).

C. The signal and the background lines must be of finite thickness (one pixel must represent width lines).

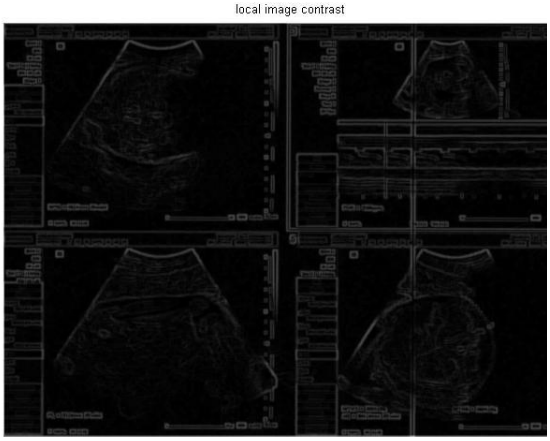
D. Compute the size of the small and large square from the background (scaling).

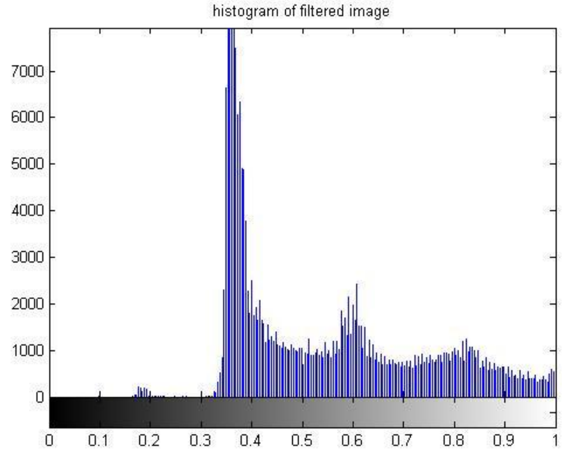
E. Signal period identification and find feature extraction

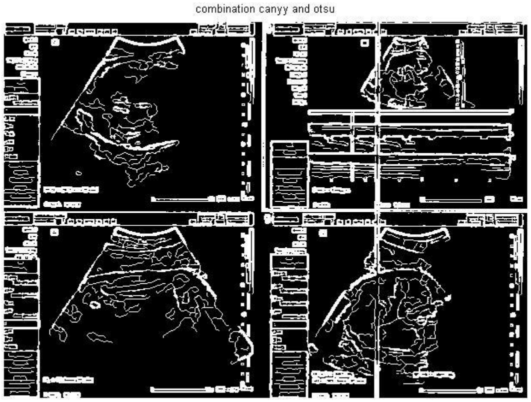
III. ICA FOR TWIN FECG EXTRACTION

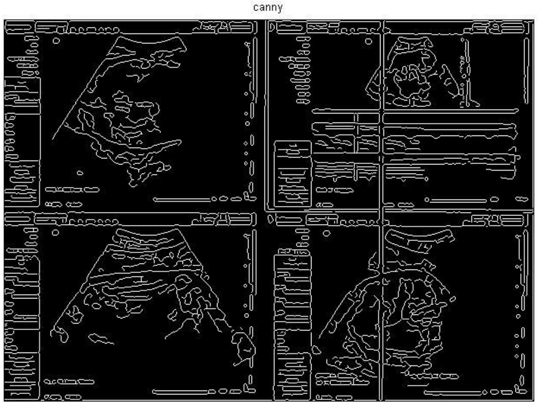
The algorithm proposed the fetal QRS complexes and converts the QRS onset series into a binary signal that is then recursively scanned to separate the contributions from the two foetuses. In ICA based method was proposed for the separation of fetal ECG signal from magneto cardio-graphic signals in twin pregnancy. ICA used higher order statistics to decompose the input signal that is AECG, into statistical independent components. Fast ICA method was employed to extract twin fetal EMG from 55-channel recording.

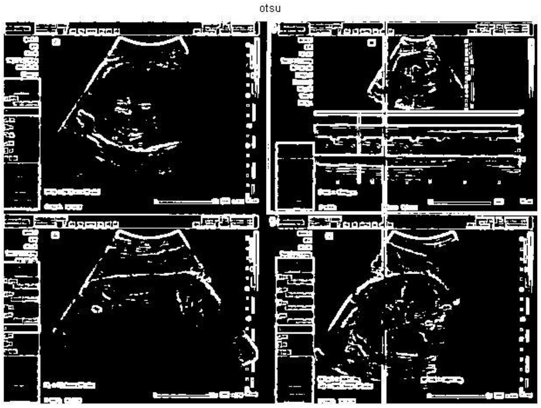
IV. RESULTS

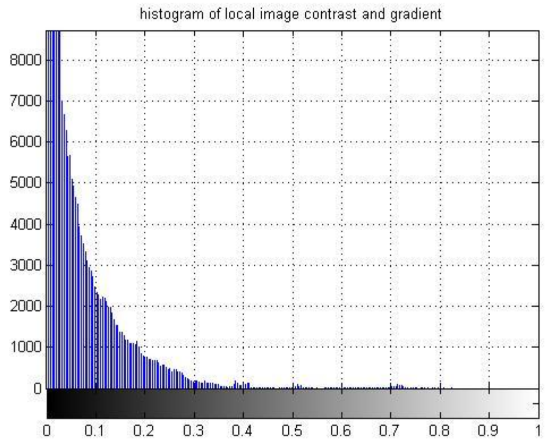








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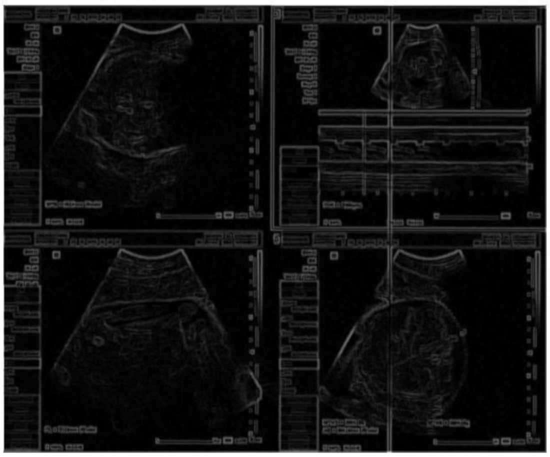
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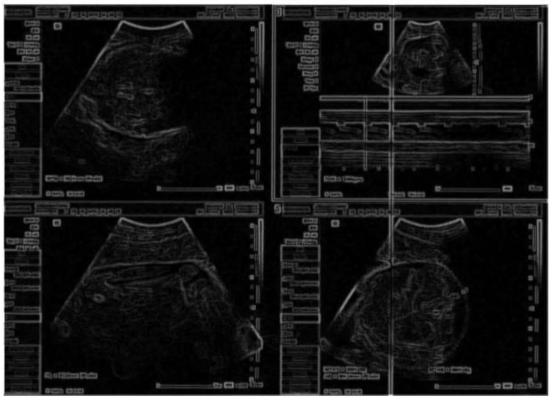
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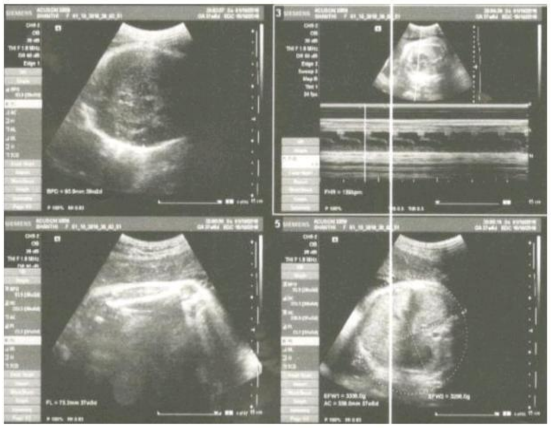
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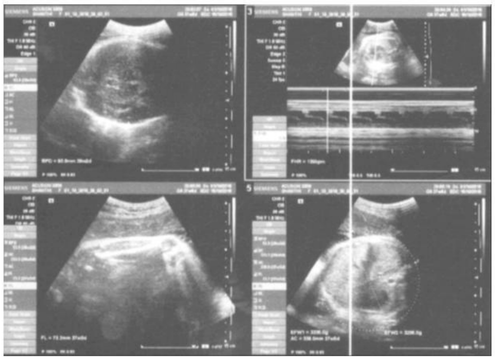
FILTERED IMAGE

V. CONCLUSION

The Fetal Electrocardiogram (FECG) was first demonstrated 114 years ago, initial progress of analysis in this area was limited. As improved amplifiers and filters became available, the detection of the waveform became easier, but observation of waveform morphology was complex due to the existing background noise after filtering the corrupted signal. The signal-to-noise ratio of the original FECG was increased considerably by efficient signal processing and computer techniques though the signals obtained non-invasively. In this survey paper various techniques for FECG signal extraction from the composite AECG signal were discussed, that gives up the various types of FECG signal analysis and extraction techniques so that accurate efficient methods can be applied during any clinical diagnosis, biomedical research. The FECG helps in finding the size of feotuses for every month by edge detection method and comparing that will give us the result of growth of fetal and shape of fetal.

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 incidents of unnecessary medical intervention. As a result, long-term FHR monitoring is important during the pregnancy and labor. Therefore, the aim of this paper was to provide concise information about FECG and reveal the different methodologies to analyze the signal for efficient FHR monitoring. Techniques for FECG signal detection and extraction from the composite AECG signal were discussed along with their advantages and drawbacks. Finding of a difficulty or problem in one method leads to other improved methods.

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A. Scanning the 12-lead ECG paper, convert it into grayscale levels and select the desired signal.
B. Separation of the desired signal from its background (lines of squares grid).
C. The signal and the background lines must be of finite thickness (one pixel must represent width lines).
D. Compute the size of the small and large square from the background (scaling).
E. Signal period identification and find feature extraction