ABSTRACT

Fetal Electrocardiogram (FECG) signal contains precise information about the fetal condition such as heart rate, waveform and dynamic behavior which are convenient in determining the fetal life, fetal development, fetal maturity and existence of fetal distress or congenital heart disease which could assist doctors in making more appropriate and timely decisions during pregnancy and labor. Unfortunately, the desired fetal heart signals appear with undesirable disturbances. The FECG signal has to be separated from noisy environment in order to monitor both mother and child where risk factors are present during pregnancy.

FECG signal analysis could not be performed easily since the fetus is completely covered by the uterus. Therefore, various diagnostic methods such as fetal electrocardiography, fetal phonocardiography, ultrasonic diagnosis and Cardiotocography (CTG) have been developed to extract the FECG signal. Among these methods, ultrasonic and cardiocographic methods are more predominantly used.

Ultrasonic diagnosis performed by Doppler ultrasound techniques are reliable for monitoring the blood circulation in the fetus. The major disadvantage of this technique is its sensitivity to movement, limited image resolution and radiation dosage administered to the fetus brain. Currently, the
most used method to screen for the well being state of the fetus is the CTG, which provides only the fetal heart rate (FHR) and maternal uterine activity. But this technique cannot be used for long term monitoring and moreover, the fast changes in the FHR cannot be recorded which will lead to misinterpretation, inaccurate diagnostics and unnecessary obstetric interventions. To overcome the disadvantages of these techniques, digital signal processing techniques are preferred to extract FECG signal from maternal abdominal signals.

In the existing adaptive filtering method, Finite Impulse Response (FIR) systems are used to get FECG signal from the composite signal. But it does not guarantee global optimum in the non-convex error surfaces. On the other hand, Infinite Impulse Response (IIR) systems are preferred over FIR systems for modeling of systems. But, it is very difficult to provide stability of IIR filters during adaptation. In the gamma filtering method, significant properties of FIR and IIR are combined to solve the problems which occurred in adaptive filters but with low maternal to fetal signal-to-noise ratio. In the wavelet transform method, it is easy to separate noise in different frequency spectra but it is difficult when both the signals overlap in the same frequency spectrum.

The neural network method adjust easily to preserve the original signal by eliminating noises but has the problem of direct subtraction of MECG in original form without considering its distortion. The fuzzy logic method has the advantage of extracting FECG signal as close as possible the
proper selection of the number, the type and the fuzzy membership functions and rules is difficult for achieving the desired performance. The combined properties of neural network and fuzzy logic in Adaptive Neuro Fuzzy Inference System (ANFIS) has the advantage of removing the noises and the MECG signal present in the distorted form in the composite signal by adaptive noise cancellation property. It eliminates the non linear noise of any frequency thereby it reduces the error rate but not with optimal minimum value.

The proposed model uses the hybrid techniques of ANFIS with undecimated wavelet transform, splinelet transform, SURELET transform and equalizer to obtain the optimal minimum error rate which in turn results in better quality of the fetal ECG. In this study, signals obtained from thoracic area and abdominal area is given as inputs to the system. Fetal ECG signal is extracted by subtracting the estimated MECG signal from the measurable abdominal ECG signal.

The effectiveness of the proposed technique is evaluated by determining the minimum mean square error (MSE) and peak signal to noise ratio (PSNR). The performance results are compared to prove the efficiency of the proposed technique. The results indicate that the combination of equalizer and ANFIS gives the best result and the closest match to the simulated fetal ECG with high PSNR and low MSE among all the proposed methods which will help the doctors to diagnose the congenital heart problems easily at the earlier stages.