



AENSI Journals

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com



Fetal Heart Rate Detection and separation using genetic algorithm based Wavelet Signal analysis

¹M. Senthil Vadivu and ²Dr. S. Palani

¹Assistant Professor of Electronics and Communication Engineering, Sona College of Technology, Salem, Tamil Nadu, India.

²Director, Sudharsan Engineering College, Sathiyamangalam-622501, Pudukkottai (dt.), Tamil Nadu, India

ARTICLE INFO

Article history:

Received 13 November 2013

Received in revised form 20

December 2013

Accepted 23 December 2013

Available online 1 February 2014

Keywords:

Genetic Algorithm, Wavelet Analysis, Fetal Heart Rate, ECG.

ABSTRACT

We propose a new heart rate detection and separation framework for the fetal ECG extraction which uses genetic algorithm and wavelet signal analysis technique. The components of the ECG waves and their properties are used by the proposed system for wavelet analysis and we have defined various fitness functions for the separation of fetal ECG from the maternal ECG pattern. The maternal ECG is identified and separated as different components and the ECG signal is separated using wavelet analysis where the lower and upper signals are separated and the separated signals are identified using genetic algorithm approach. The fitness function used to separate the fetal electrocardiogram signal from mothers using the lower and upper values of the signals of different components.

© 2013 AENSI Publisher All rights reserved.

To Cite This Article: M. Senthil Vadivu and Dr. S. Palani., Fetal Heart Rate Detection and separation using genetic algorithm based Wavelet Signal analysis. *Aust. J. Basic & Appl. Sci.*, 7(14): 188-194, 2013

INTRODUCTION

The fetal psychological condition depends on the heart rate, which is most related to the mothers cardiogram signal. The Electro Cardiogram represents the electrical activity of the heart which is shown as the heart beat. The ECG records the electrical activity of the heart, where each heart beat is displayed as a series of electrical waves characterized by peaks and valleys. The ECG signal provides us two kinds of information, the duration of the electrical wave crossing the heart which in turn decides whether the electrical activity is normal or irregular and the amount of electrical activity passing through the heart muscle which enables to find whether the parts of the heart is proper (or) not.

Wavelet transform is a signal processing technique used in various applications - to decompose, filter, feature extraction etc.... Wavelet transform has a huge impact in biomedical systems for signal processing. For many signals, the low-frequency content is the most important part. It is what gives the signal its identity. The high-frequency content, on the other hand, imparts flavor or nuance. To gain a better appreciation of this process, it is performed with a one-stage discrete wavelet transform of a signal. The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components.

In wavelet analysis, a signal is split into an approximation and a detail. The approximation is then itself split into a second-level approximation and detail, and the process is repeated. The transformed signal provides information about the time and the frequency. Using this approximated information low frequency data could be identified, which is more important in cardiac disease prediction.

The fetal electrocardiogram (FECG) is used for the calculation of the fetal cardiac frequency and in the prediction of the fetal acidosis. An FECG provides information about the fetal well being and the physiological state of the fetus.

Genetic algorithm is a common methodology using which the range of values can be fit into a specific function and evaluated using an another function. Using genetic algorithm the electrocardiogram signal can be evaluated as whether the signal can be assigned to mother cardiogram or fetal cardiogram. The genetic algorithm can be applied for the separation of signals of Electrocardiogram as mother and fetal.

Corresponding Aurthor: M. Senthil Vadivu, Assistant Professor of Electronics and Communication Engineering, Sona College of Technology, Salem, Tamil Nadu, India.
E-mail: vadivu_mani@yahoo.co.in

Related Works:

There are many techniques that have been proposed for the separation of fetal electrocardiogram from maternal ECG. We discuss few of them here with statistical approach and propose a new methodology for the separation of fetal ECG signal.

In Fetal Electrocardiogram Extraction Using Adaptive Neuro-fuzzy Inference Systems and Undecimated Wavelet Transform (Sargolzaei, A., 2011), FECG is extracted from the maternal electrocardiogram using adaptive neuro-fuzzy inference systems and undecimated wavelet transform (UWT) is proposed. The performance of the proposed system is compared with the standard discrete wavelet transform (DWT). For numerical evaluation, the mean square error (MSE) between de-noised FECG signal and original FECG signal is used.

Fast technique for non invasive fetal ECG extraction (Pani, D., 2010), describes a fast and very simple algorithm for estimating the fetal electrocardiogram (FECG). It is based on independent component analysis, but we substitute its computationally demanding calculations for a much simpler procedure. The resulting method consists of two steps: as a dimensionality reduction step and a computationally light post processing stage used to enhance the FECG signal.

A Method for Subsample Fetal Heart Rate Estimation under Noisy Conditions (Morales, D.P., 2013), consider a new approach for estimating the fundamental period in fetal ECG waveforms. This method is based on the minimization of a cost function that measures the differences between the discrete Fourier transform (DFT) of the fetal ECG waveform and the DFTs of its circularly shifted forms. By using the linear phase shift property of the DFT, we show that the minimization of this cost function is equivalent to finding the cosine waveform that matches best to the ECG power spectrum. The optimal cosine waveform is then used to estimate the fundamental period. This method is based on the minimization of a cost function that measures the differences between the discrete Fourier transform (DFT) of the fetal ECG waveform and the DFTs of its circularly shifted forms. By using the linear phase shift property of the DFT, we show that the minimization of this cost function is equivalent to finding the cosine waveform that matches best to the ECG power spectrum.

A detail review and implementation issue of fetal ECG extraction and enhancement is presented in (Jafari, F. and M.A. Tinati, 2010). When methods like correlation and subtraction are obsolete, adaptive filtering and independent component analysis methods are mainly used for extraction and enhancement of FECG. The enhancement methods are used for classification and diagnosis purpose through parameter analysis. The method to be used depends on the number of electrodes used. If more number of electrodes is used, the accuracy is more but the complexity increases.

A method of extracting fetal ECG based on adaptive linear neural network is proposed in (Kovacs, F., 2011). It can be realized by training a small quantity of data. A lightweight algorithm, which extracts the fetal ECG with a pre-knowledge about its skewness is presented in (Sahin, I., 2011). By using the skewness, a cost function is defined by which Weight vector is updated and through this desired fetal ECG signal is extracted.

A technique based on the fetal ECG extraction algorithm OL-JADE (Jezewski, J., 2012), which tries to invert the whole blind extraction process only for the FECG, estimated sources in order to estimate the FECG power at the electrodes. Due to the recursive sample-by-sample nature of the whitening stage of OL-JADE, an approximated Least Squares solution has been introduced in the back projection scheme revealing adequate performance.

A successful system for recovering the FECG using multidimensional Independent component Analysis (MICA) is presented in (Camargo-Olivares, J.L. 2011). MICA requires as many observations as sources. To increase the number of observations, MICA is often applied to data sets that include measurements taken at the mother's thoracic region.

The previously discussed methods has the difficulty of separation of signals of fetal electrocardiogram from mothers ECG due to the unavailability of fitness function or an evolutionary method to check the signal whose it belongs to. We propose a new evolutionary approach which uses genetic algorithm for the evolution of the separated fetal electrocardiogram.

Proposed Method:

The proposed method has four stages: in the first stage the signal is transformed using wavelet transform to boost the signals, in the second stage we extract the features of the electrocardiogram signal, and in the third stage the boosted signals are applied with GA functions to evaluate the signal with the signals of the mother. Finally the fetal ECG is separated from mothers and combined to present the complete fetal ECG.

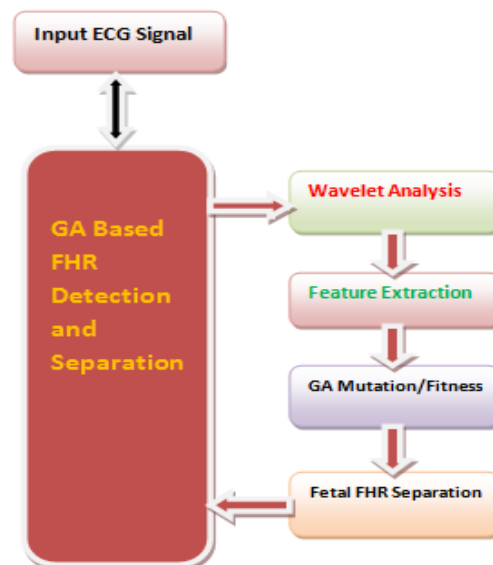


Fig. 1: Proposed System Architecture.

Wavelet Transform:

The wavelet analysis is applied on the wave form to decompose signals into several frequency bands. We select appropriate wavelet and the number of decomposition levels for the analysis of signals using DWT. The number of decomposition levels is chosen based on the dominant frequency components of the signal. The levels are chosen such that those parts of the signal that correlate well with the frequencies necessary for classification of the signal are retained in the wavelet coefficients. Since the ECGs have little useful information above frequency 30 Hz of 173.6 Hz, we have selected 5 different bands and frequency ranges and one approximation range.

Feature Extraction:

The electrocardiogram contains various time domain and space domain values; they are amplitudes and intervals of various sectors. We extract P-R interval, R-R interval, Q-T interval, S-T interval, P-wave interval, QRS interval and the amplitude values of P, R, S, Q, T, U waves. Each features extracted is stored in the data base for further manipulation.

Algorithm:

Step1: Read transformed ECG signal D_s .

Step2: Extract the following features.

Pr=P-R interval

Rr = R-R interval.

Qt = Q-T interval.

St = S-T interval

P= P wave interval.

Qrs = QRS interval.

PA- P wave Amplitude.

QA – Q wave Amplitude.

RA – R wave Amplitude.

TA - T wave Amplitude.

SA – Synus Amplitude

UA- U wave Amplitude.

Construct vector V_i and add to vector set V_s .

$V_s = \sum V_i(Pr, Rr, Qt, St, P, Qrs, PA, QA, RA, SA, TA, UA)$.

End.

Step3: stop.

GA Based FHR Detection:

The genetic algorithm based separation and fitness function separates the fetal heart electrocardiogram signals from mothers. The GA function has two set of six variables which represent the minimum and maximum values of the features of ECG signal. All the minimum and maximum values are initialized as follows: **minPA**,

maxPA, minQA, maxQA, minRA, maxRA, minSA, maxSA, minTA, maxTA, minUA, maxUA. The GA function selects each signal amplitude which has less amplitude value than the minimum threshold. The amplitude values which are not selected from the fitness function forms the fetal wave form. The GA was seeded with the initial population with approximate mid range of these 6 variables as 2.5, 2.0, 12.0, 1.0, 3.0 2.2. The algorithm will search for optimal location for the signal to be placed and on each iteration; the best candidate location is selected based on the overall fitness value.

Algorithm:

Step1: start

Step2: initialize midrange values m1, m2, m3, m4, m5, m6.

Step3: INITIALIZE population with random candidate solutions;

PA, QA, RA, SA, TA, UA.

EVALUATE each candidate;

Fitness f = Find fitness of the candidate.

repeat

SELECT parents;

RECOMBINE pairs of parents;

MUTATE the resulting children;

EVALUATE children;

until TERMINATION-CONDITION is satisfied

end

Step4: stop.

Algorithm GA Fitness:

Input: PA, QA, RA, SA, TA, UA, m1, m2, m3, m4, m5, m6

Output: Fitness value F, H1, H2.

Step1: start:

Step2: initialize H1, H2, F, support value for mother ECG, FECG.

Step3: $H1 = \$(PA, QA, RA, SA, TA, UA) < \hat{O}(m1, m2, m3, m4, m5, m6)$

Step4: $H2 = \$(PA, QA, RA, SA, TA, UA) > \hat{O}(m1, m2, m3, m4, m5, m6)$

Step5: if(H1 > H2)

Return 1. // specifies Fetal ECG

Else

Return 0.

Step6: stop.

FHR Separation:

Identified P-wave and QRS-wave are grouped to form the electrocardiogram wave of the fetal and separated from mother ECG. All identified wave forms of the fetal is joined to form the complete wave form to analyze the condition of the fetal for medical investigations.

Experimental Results:

To examine the efficacy of the proposed system in separating the preferred FECG signal from the MECG signals, experiments were conducted on the simulated signals. The ECG for both the mother and fetus has been simulated assuming sampling rate of 4 000 Hz.

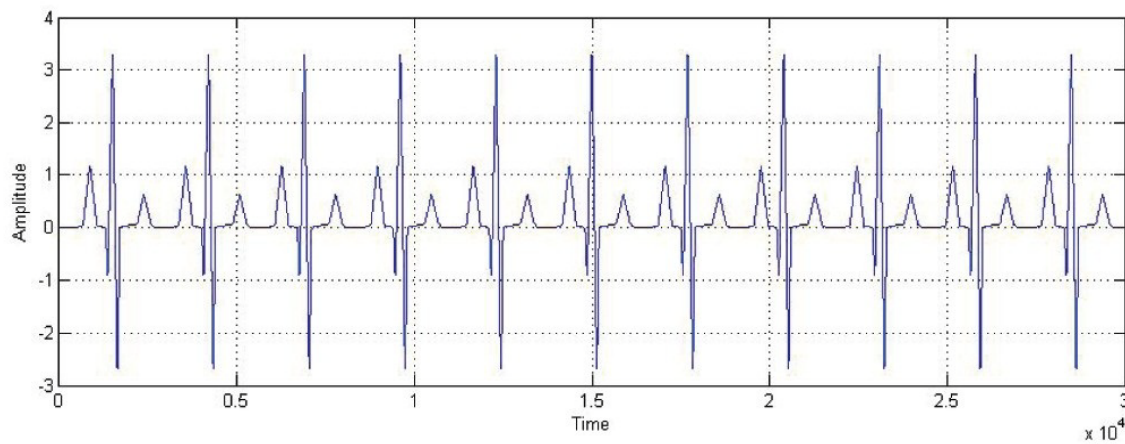


Fig. 2: Shows the MEKG as input ECG.

The figure 1 shows the electrocardiogram wave form of the mother.

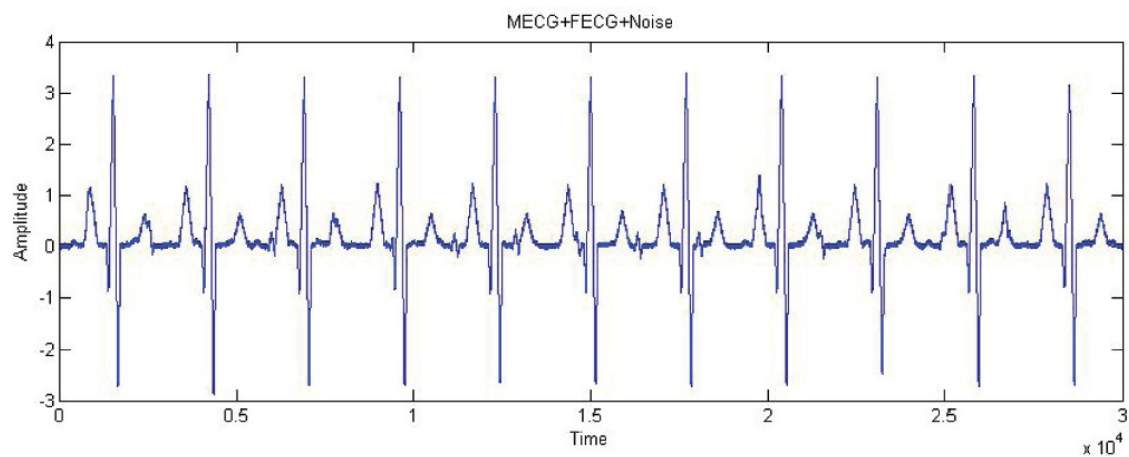


Fig. 3: Shows both mother+fetal+noise ECG.

Figure 3 shows the wave form which contains the electrocardiogram signal of both mother , fetal with noise signals.

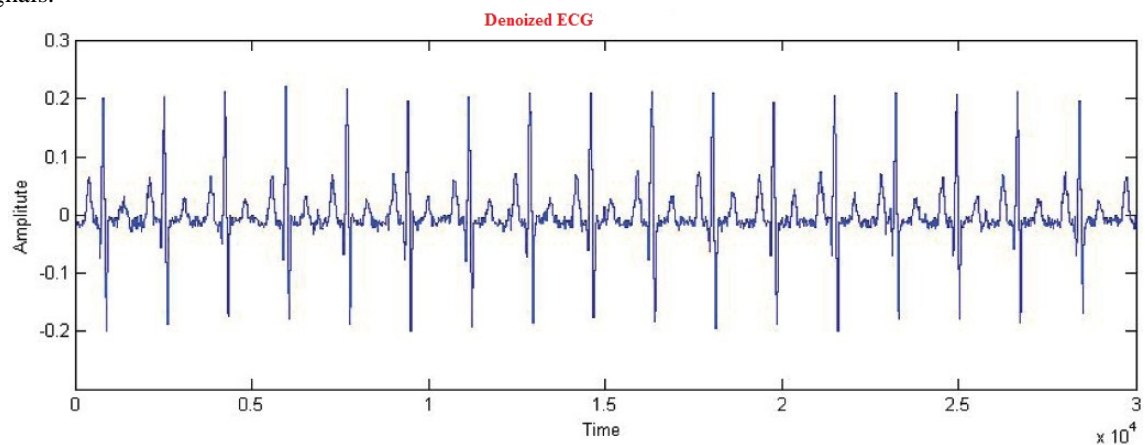


Fig. 4: Shows the Noise removed ECG.

The figure 4 shows the ECG wave form of both mother and fetal with noise been removed.

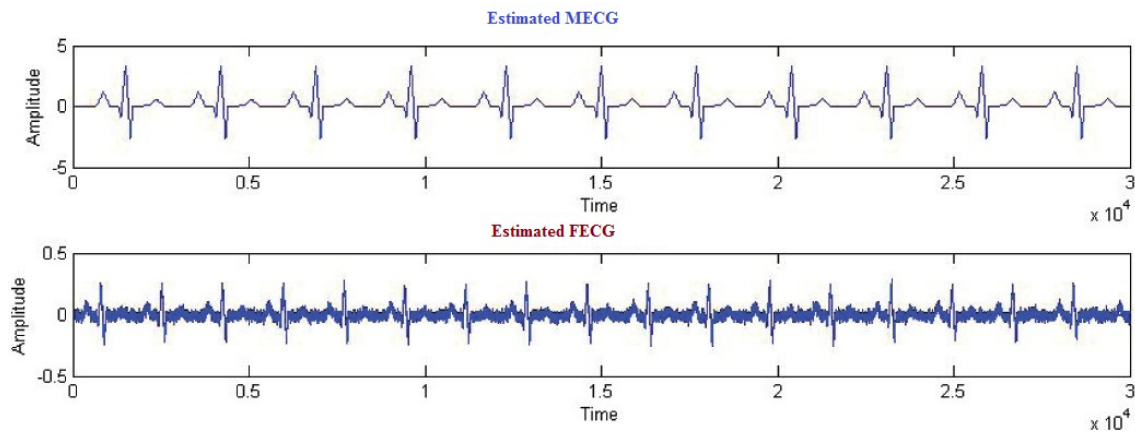


Fig. 5: Shows the separated FECG.

The figure shows the separated fetal electrocardiogram from the mothers ECG.

For numerical evaluation, the mean square error (MSE) between the de-noised FECG signal and the original FECG is used. The performance of the proposed system is compared with DWT.

Conclusion:

This paper presents a novel method for FHR detection by separating the fetal electrocardiogram from mothers ECG using wavelet transform and genetic algorithm. We have used wavelet transform to obtain the missing values of signals which are very low belongs to the fetal and boost using the wavelet transform. The genetic algorithm is used to identify the signal to which it belongs to by designing a fitness function which evaluates the amplitude of various signals of ECG wave. The proposed method has produced efficient results and the real time recording and separation of long time ECG with comparison to other methods also shows the efficiency of the proposed method.

REFERENCES

- Camargo-Olivares, J.L. and R. Martín-Clemente, 2011. The Maternal Abdominal ECG as Input to MICA in the Fetal ECG Extraction Problem, *IEEE Signal Processing letter*, Vol. 18, pp.161-4, Back to cited text no. 5.
- Chourasia, V.S., Anil Kumar Tiwari, 2009. Development of a signal simulation module for testing of phonocardiography based prenatal monitoring systems, in: *India Conference (INDICON), Annual IEEE*.
- Devoe, L.D., 2011. Electronic fetal monitoring: does it really lead to better outcomes. *Am. J. Obstet. Gynecol.*, 204(6): 455-456.
- Hasan, M.A., M.B.I. Reaz, M.I. Ibrahimy, M.S. Hussain, J. Uddin, 2009. Detection and processing techniques of FECG signal for fetal monitoring, *Biol. Proced. Online*, 27(11): 263-295.
- Jafari, F. and M.A. Tinati, 2010. A New Fetal ECG Extraction Method Using its Skewness Value Which lies in Specific Range", *IEEE Iranian Conference on Electrical Engineering*, pp: 30-34.
- Jezewski, J., 2012. Determination of fetal heart rate from abdominal signals: evaluation of beat-to-beat accuracy in relation to the direct fetal electrocardiogram, *Biomed.Eng. /Biomed.Techn.*, 57(5): 383-394.
- JIA, W., C. Yang and G. Zhong, 2010. Fetal ECG Extraction Based on Adaptive Linear Neural Network, *IEEE 3rd International Conference on Biomedical Engineering and Informatics*, 2: 899-902.
- Jothi, S.H., K.H. Prabha, 2012. Fetal Electrocardiogram Extraction Using Adaptive Neuro-fuzzy Inference Systems and Undecimated Wavelet Transform. *IETE J Res.*, 58: 469-75.
- Karvounis, E.C., M.G. Tsiouras, C. Papaloukas, D.G. Tsalikakis, K.K. Naka, D.I. Fotiadis, 2010. A non-invasive methodology for fetal monitoring during pregnancy, *Methods Inf. Med.*, 49(3): 238-253.
- Kovacs, F., C. Horváth, Á.T. Balogh, G. Hosszú, 2011. Fetal phonocardiography—past and future possibilities, *Comput. Methods Programs Biomed*, 104(1): 19-25.
- Martín Clemente Mellado, R., 2011. Fast technique for non invasive fetal ECG extraction, *IEEE Trans. Biomed. Eng.*, 58(2): 227-230.
- Morales, D.P., 2013. An application of reconfigurable technologies for non-invasive fetal heart rate extraction, *Med. Eng. Phys.*, 35(7): 1005-1014.
- Morales, D.P., *et al.*, 2011. Flexible ECG acquisition system based on analog and digital reconfigurable devices, *Sens. Actuators Phys.*, 165(2): 260-270.
- Pani, D., S. Argiolas and L. Raffo, 2010. Real-Time Back-Projection of Fetal ECG Sources in OL-JADE for the Optimization of Blind Electrodes Positioning, *IEEE Computing in Cardiology*, 37: 289-92.

Ravindrakumar, S. and K. Bommanna Raja, 2010. Fetal ECG Extraction and Enhancement in Prenatal Monitoring - Review and Implementation Issues, IEEE Trendz in Information Sciences & Computing, December issue, pp: 16-20.

Romano, M., 2009. Time–frequency analysis of CTG signals, Curr. Dev. Theor. Appl. Wavelets, 3(2): 169-192.

Ruffo, M., M. Cesarelli, M. Romano, P. Bifulco, A. Fratini, 2010. A simulating software of fetal phonocardiography signals, in: 10th IEEE International Conference on Information Technology and Applications in Biomedicine, 2–5, Corfu, Greece, paper no. 57.

Ruffo, M., M. Cesarelli, M. Romano, P. Bifulco, A. Fratini, 2010. An algorithm for FHR estimation from foetal phonocardiography signals, Biomed. Signal Process. Control, 5: 131-141.

S. De Ridder, 2011. Comparison between EEMD, wavelet and FIR denoising: Influence on event detection in impedance cardiograph, in: Annual International Conference of the IEEE, Boston, MA, Engineering in Medicine and Biology Society, EMBC, pp: 806-809.

Sahin, I., N. Yilmazer, M.A. Simaan, 2011. A method for subsample fetal heart rate estimation under noisy conditions, IEEE Trans. Biomed. Eng., 58(4): 875-883.

Sargolzaei, A., 2011. A new method for foetal electrocardiogram extraction using adaptive nero-fuzzy interference system trained with PSO al-gorithm, in: IEEE International Conference on Electro/Information Technology, EIT, pp: 1-5.