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Fetal ECG Signal Optimization on Signal Obtained From FECG Sensor for Remote Areas with Lower Signal Strength for Its Smooth Propagation to Medical Databases

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Abstract: ***Wearable ECG sensors are growing in their popularity day by day. These ECG sensors run on batteries, hence carry a limited battery life. The ECG sensors are also used to monitor the fetal health, which are called FECG sensors. These sensors are used with the pregnant women for the fetal ECG monitoring to avoid the critical health hazards. In this research, the signal optimized for its easy transfer to the central server over the cellular connections. In this research, we are trying to increase the battery life of the FECG sensor by optimizing the signal just after it is recorded which saves the battery life by smooth signal transmission and by lowering the load on buffer memory. Wearable sensors are used as FECG data collection and transmission units. But handling data transmission process on FECG sensors consumes a handful amount of energy. In this research, the FECG signal is optimized using genetic algorithm to reduce its size with no loss of quality and detail. This reduces the load on data transmission process. Hence, it improves the performance of the wearable FECG signals. The FECG signal optimization is done using Fitness function based Genetic Algorithm because Fitness function based genetic algorithms is an effective and robust optimization technique. Using this technique, the variety of FECG signal can be optimized using the quantization scheme of fitness function based ECG data compression based on a genetic algorithm. The compression performance and convergence speed of reconstruction quality maintenance is evaluated by using the collected FECG dataset for the research project.***

Keywords: Fetal ECG, FECG Sensor, ECG optimization, Genetic Algorithm, Particle Swarm Optimization

1. Introduction

The Electrocardiogram is a physiological signal which describes the electrical activity of a heart or it is a graphical report of direction and magnitude of the electrical activity that is created by the heart. Electrocardiogram is a representation of the electrical exertion of the heart muscle as it varies with time. Electrocardiogram wave clearly describe the essential traits like peak amplitudes (peaks of P, T or R waves) and wave intervals (PR,QT) for each discovered beat.

The main purpose of Electrocardiogram data compression technique is to conserve the utmost usable diagnostic information when compressed signal is accepted. Lossless compression is best because the ratio of compression is acceptable but it cannot usually give a satisfactory compression ratio. If we obtain significant signal compression, lossy compression is preferable than lossless compression.

The reason for accepting the Electrocardiogram as an important monitor is that it reflects well the condition of patient under anaesthesia by biological electric signals. This concept will be more clearly by three following points. First, the activity of cellular is because of the modification of normal resting membrane potential. In clinical practice it is not directly measured rather the changing pattern of electric potential are produced by the co-ordinated electrical activity of a group of active cells over the whole surface of the body is measured by electrodes. Second, the process of transfer the electrical current in the tissue is the result of migration of ions in contrast to electrons in metal conductors. When over the skin metal electrode is placed and any current passes from it than it must occur mainly in a result of electrons being exchanged for the ions. Such signal's amplitude is much lower because of electrical impedance of the tissue. Third, for Electrocardiogram signal the biological potentials are complex which is very characteristic. According to Fourier analysis, a precise original waveform is constructed when any waveform is algebraically combined by transferring from a number of sine waves of various type of frequencies. Electrocardiogram signal have frequency range from 0.05 to200Hz, but up to 100Hz are adequate for clinical diagnostic purpose.

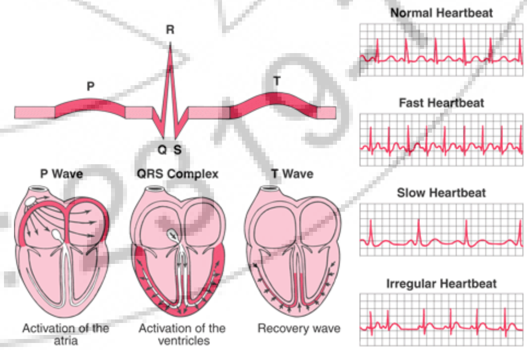

Figure 1: Process of Heart beat recoding by ECG Signal and ECG wave form

Anaesthesiologist gives the information from the different type of preoperative sources of Electrocardiogram that are very important for monitoring during intra operative period. They are holter monitoring, preoperative screening test and stress test.

There are so many health related problems to be found during human's lifespan can be make smaller if a change in the body or mind which indicates that a disease is present are noticed during pregnancy. The most important physiological indicators of health is the heart rate, the one of the very important task during pregnancy is to accurately determining a foetus's heart rate. One important low-cost non-invasive method for understand the heart rate is by recording and processing the Electrocardiogram .If sensors of Electrocardiogram are placed on the abdomen of mother than the result of these sensor are record the multiple differential signals between each pair of electrodes.

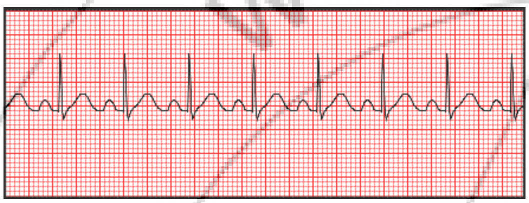

Figure 2: A snapshot of ordinary ECG signal collected by traditional ECG scanning device

Fetal electrocardiogram sensors sense the heart beat of fetus during pregnancy period. Fetal heart beat rate monitoring is best for maintain the health of fetus and mother. In remote areas and slums areas there are mostly 2G Fetal electrocardiogram are very much effective. On internet 2G network caries less transmission speed that's why this is most important thing about 2G network. Optimized and compressed signal are easily propagate over 2G with less ECG data loss in 2G network With the use of Particle Swam Optimization (PSO) and Genetic Algorithm (GA) these electrocardiogram signal are optimized. This optimized signal can also improve the quality of the electrocardiogram signal if we optimized the signal.

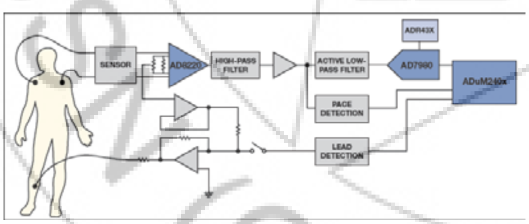

Figure 3: The process of obtaining ECG signal by sensors and delivering it to the central medical database

In the Fetal Cardiac cycle electrocardiogram of fetal is a process of measuring variations. Because of this process we get more help in the fetal surgery. Direct and Indirect are two type of system that we are used. In first system scalp electrodes are mostly used and in second system maternal abdominal wall sense the electrocardiogram. Mostly direct recording is performed at the time of labour the reason behind this is abdominal electrocardiogram faced more difficulties.

Figure 4: A close view of ECG waveform

In some of the cases the electrocardiogram is one of the oldest and most happening instrument-bound measurements in medical application. The progress of instrumentation technology has been followed by it. In this paper, by using any effective signal optimization method we compress and optimize the electrocardiogram signal of fetus , load on data transfer link will be reduced. Hence the performance of the wearable FECG signals will be improved. By using Fitness function based Genetic Algorithm signal optimization of fetus electrocardiogram will be done because this algorithm is an effective and robust optimization technique. The quantization scheme of fitness function optimized the variety of FECG signal based FECG data compression based on a Genetic Algorithm. A novel fetal ECG database will evaluate the compression performance and convergence speed of reconstruction quality maintenance.

2. Literature Review

Zhilin Zhan and associates have worked on the development of a new energy efficient compressed sensing wireless tele-monitoring. The new technique is used to monitor the heart beat rate of Non-Invasive Fetal ECG using Block Sparse Bayesian Learning. The authors have used BSBL framework for compression and reconstruction of non-sparse raw FECG recordings. Maryam Nasiri et. al. have proposed a new Fetal Electrocardiogram Signal extraction for adaptive Nero-Fuzzy Inference System. They have proposed an all new method for FECG signal extraction from two ECG signals recorded at thoracic and abdominal areas of mother. S. Sargolzaei, K. Faez, A. Sargolzaei have developed a new technique named Signal Processing Based Techniques for Fetal Electrocardiogram Extraction. In this paper, authors have described four important indirect methods which be used to extract the fetal Electrocardiogram (FECG) signal from an ECG recorded on the mother's abdomen. These methods include the following ones: singular value decomposition (SVD) method, independent component analysis (ICA) method, wavelet based methods and adaptive filtering method. Assaleh, K. have proposed the method of extraction of fetal electrocardiogram using adaptive neuro-fuzzy inference systems. The authors have investigated the use of adaptive neuro-fuzzy inference systems (ANFIS) for fetal electrocardiogram (FECG) extraction from two ECG signals in this paper. Camps, G., Martinez, M., & Soria, E. have developed a technique of Fetal Ecg extraction using an FIR neural network. Camps, G. et. al. have proposed Fetal ECG signal recovery using dynamic neural networks. Mehmet Korurek et. al. have proposed a classification method using PSO for ECG signal. Tsung-Ching Wu, King-Chu Hung, Je-Hung Liu, Tung-Kuan Liu has collectively developed a new technique based on wavelet-based ECG data compression optimization with genetic algorithm.

3. Problem Formulation

The wearable Fetal ECG sensors are the wireless sensors to monitor the heart beat rate of Fetus. Fetal ECG sensors have limited battery life. These sensor continuously monitor the Fetal heart and sends the data to the centralized medical databases, where the data is monitored continuously. The sensors usually works on cellular networks using SIM cards to keep themselves connected with the Medical Database. Whenever an abnormality is detected, the health team in the region same as the women, is update about the abnormality. This automatic alarming system can be very helpful for the pregnant women in the remote Indian regions/villages. A large number of the Fetal miscarriage cases can be fixed and a number of lives can be saved. The major problem lies with the remote no electricity or less electricity zones of the country. The body wearable sensors cannot be effectively charged in such areas. There is a strong need of an effective some method to increase the battery life of the wearable fetal ECG sensor. In this paper, the optimization of the FECG signal is proposed to increase the battery life of the FECG sensor.

4. Proposed Model

In this paper, FECG signal will be compressed and optimized using genetic algorithm for the FECG signal optimization. Genetic algorithm is used because of its effectiveness. Our study have proved that genetic algorithm and particle swarm optimization are the best signal optimization algorithms. The choice of genetic algorithm is made because it is more effective and consistent than particle swarm optimization. We have also implemented the particle swarm optimization algorithm for the FECG signal optimization, which is used for the comparison of the two. The optimization process reduces the load on data transfer link, Hence; improve the battery life of the wearable FECG sensor. Using this technique, the variety of FECG signal can be optimized using the quantization scheme of fitness function based FECG data compression based on a particle swarm optimization and genetic algorithm. The compression performance and convergence speed of reconstruction quality maintenance is evaluated by calculating the performance parameters like peak signal to noise ratio (PSNR), mean squared error (MSE), etc.

5. Experimental Design

The ECG data in this research project has been obtained from a body wearable ECG sensor called HOLTER. In this research, the signal undergoes the process of noise removal and decomposition prior to the optimization. The noise removal part of the experimental model consists of baseline drift removal, salt and pepper noise removal and signal burst removal. The signal quality has been measured using various performance parameters (statistical errors) like peak signal to noise ratio (PSNR) and mean square error (MSE).

$$PSNR = 10.\log_{10}\left(\frac{255 * 255}{MSE}\right) \quad ..$$

$$\mathrm{MSE} = \frac{1}{\mathrm{n}\sum_{\mathrm{i}=0}^{\mathrm{n}}(\mathrm{X}-\mathrm{X}')^2} \quad \mathrm{kl}$$

Where X is the Original ECG data and X' is the transformed ECG data and n is the number of samples.

The details of our implementation of GA are described as follow;

Algorithm 1: Genetic Algorithm

Input: Original ECG Signal
Output: Optimized ECG Signal
Step 0: parameter initialization (pop size, mutation rate and max pop generations)
Step 1: Initial population is created randomly
Step 2: chromosome fitness evaluation/computation
Step 3: If termination condition is not satisfied
  (i) do [Step 4-8]
Step 4: perform selection from P(t) to P(t+1)
Step 5: perform mutation and crossover
Step 6: recomputed the chromosomes fitness
Step 7: t=t+1
Step 8: go to Step 3

The described as following is the implementation PSO in our implementation;

Algorithm 2: Particle Swarm Optimization

Input: Original ECG Signal
Output: Optimized ECG Signal
Step 1: For every particle
Step 2: Initialize the particle formation
Step 3: End
Step 4: Do (overall)
Step 5: Do For every particle perform Step 6-8
Step 6: Calculate the fitness of all particles
Step 7: If fitness value better than personal best (pBest) in the current computational history
Step 8: set the pBest equals thegBest
Step 9: End
Step 10: Choose the best pbest as the gBest for overall solution
Step 11: Calculate velocity of the particles according to the equation (a)
Step 12: Shift the particle's positions according to equation (b)
Step 13: End

After each iteration Particle swarm optimizer updates velocity and positions of each sample in space with following equation (i) and (ii).

$$\mathrm{q[i]} = \mathrm{q[i]} + \mathrm{CL1} * \mathrm{rand}(\ ) * (\mathrm{pB[i]} - \mathrm{pR[i]}) + \mathrm{CL2} * \mathrm{rand}(\,) * (\mathrm{gB[i]} - \mathrm{pB[i]}) \qquad \mathbf{(1)}$$

$$\mathrm{pR[i]} = \mathrm{pR[i]} + \mathrm{q[i]} \qquad \mathbf{(2)}$$

Where q[i] denotes the particle velocity, pR[i] gives the current solution for that particle holds randomly. pB[i] and gB[i] are local and global best fitness values respectively for every particle . rand () is a random number between (0,1). CL1, CL2 are learning factors.

6. Result Analysis

In this research, a fetal heart beat signal optimization technique for the monitoring of the patients in the remote area using body wearable sensors for fetal heart rate monitoring (also known as Holter) connected through cellular network with the medical database. These environments are usually designed for the special medical environments where patients (pregnant women) are monitored on the regular basis to avoid the fetal health hazards. Under this research, the fetal ECG (FECG) signal propagation process is improved by making it energy efficient. The energy consumption can be minimized by optimizing the FECG signal to create compressed but equally detailed optimized FECG signal. The optimized FECG signal can be easily propagated over cellular network by consuming less energy and less buffer, which means minimizing the loss of the FECG data on the data collection end. Also, the energy consumption by Genetic Algorithm and Particle Swarm Optimization on the FECG sensor is recorded and compared. The signal optimized with the genetic algorithm consumes lower energy than particle swarm optimization.

The results have proved that Genetic Algorithm performed better than particle swarm optimization. GA has taken almost less than half energy than PSO for the FECG signal optimization. Each patient's ECG signal examined under this research project is of the length of 90 seconds and has recorded on the 356 samples per second.

Table 2: Energy Consumption by Genetic Algorithm and particle swarm optimization

Patient ID	*GA*	*PSO*
Pat 1	1011	1236
Pat 2	901	1293
Pat 3	966	1093
Pat 4	1134	1334
Pat 5	876	1033
Pat 6	987	1234
Pat 7	912	1184

The database contains 15 records from 25 subjects (aged between 22 and 38, mean age 30). Each subject is represented by one ECG record. Each record includes the continuously measured signals. Each signal is digitized at 356 samples per second, with 16 bit resolution over a range of ± 16.384 mV. On special request to the contributors of the database, recordings may be available at sampling rates up to 10 KHz.

The recorded/computer heart beat is computer by performing QRS-detection algorithm on the medical database server by using the optimized ECG signal as the input signal for QRS-detection algorithm.

Table 3: Heart Rate Computation after ECG Signal Optimization

Patient ID	*Heart Beat Rate (beats per minute)*
Pat 1	80
Pat 2	65
Pat 3	72
Pat 4	88
Pat 5	107
Pat 6	97
Pat 7	90

7. Conclusion and Future Work

The research project has undergone the development of the energy efficient FECG signal optimization using genetic algorithm. The project is implemented on the Windows 7 notebook equipped with Intel Core-i3 processor with 2 GB of RAM. The genetic algorithm has been compared with PSO in this paper. The optimized FECG signal is propagated through a cellular channel which also adds some voice to the FECG signal which is further de-noised at the receiver's end (Medical Database end). A novel energy computation algorithm has been implemented in the MATLAB to determine the energy consumed by the both of the optimization models. The results have proved that GA has performed better than PSO for the Fetal ECG signal optimization in the terms of energy consumption. ECG has consumed significantly less energy than particle swarm optimization. The results have shown that the results of heart beat rate computed on the optimized FECG signal have given the near perfect results as compared to the similar results obtained from the original FECG signal. In the future this algorithm can be implemented with other bio-inspired algorithm which is considered more effective than genetic algorithm. Other compression techniques can be also applied to the FECG signal to facilitate its smooth and fast transfer over the cellular network.

References

[1] Zhilin Zhang, Tzyy-Ping Jung, Scott Makeig, Bhaskar D. Rao, "Compressed Sensing for Energy-Efficient Wireless Tele-monitoring of Non-Invasive Fetal ECG via Block Sparse Bayesian Learning", ITBE, vol. 60, issue 2, pp. 300-309, IEEE 2013.
[2] Maryam Nasiri, Karim Faez , Ali Motie Nasrabadi, "A New Method for Extraction of Fetal Electrocardiogram Signal Based on Adaptive Nero-Fuzzy Inference System", ICSIPA, vol. 1, pp. 456-461, IEEE 2011.
[3] S. Sargolzaei, K. Faez, A. Sargolzaei, "Signal Processing Based Techniques for Fetal Electrocardiogram Extraction", Proc. IEEE International Conf. on Biomedical Engineering and Informatics, vol. 1, pp. 492-496, IEEE 2008.
[4] Assaleh, K., "Extraction of fetal electrocardiogram using adaptive neuro-fuzzy inference systems", Trans. on Biomed. Eng., vol. 54(1), pp. 59-67, IEEE 2007
[5] Camps, G., Martinez, M., & Soria, E., "Fetal Ecg extraction using an FIR neural network", Computers in Cardiology, pp. 249-252, IEEE 2004.

[6] Camps, G., Martinez, M., Soria, E., Magdalena, R., & CalpeGuerrero, J., "Foetal ECG recovery using dynamic neural networks", Art. Intel. Med., 31(3), pp. 197-209, IEEE 2004
[7] Mehmet Korurek, Berat Dogan, "ECG beat classification using particle swarm optimization and radial basis function neural network", Expert Systems with Applications, vol. 37, pp. 7563-7569, Science Direct, 2010.
[8] Tsung-Ching Wu, King-Chu Hung, Je-Hung Liu, Tung-Kuan Liu, " Wavelet-based ECG data compression optimization with genetic algorithm", vol. 6, pp. 746-753, J. Biomedical Science and Engineering, 2013