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Critical Heart Condition Analysis through Diagnostic Agent of e-Healthcare System using Spectral Domain Transform

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Abstract

Background/Objectives: As multi-agent system requirement is high in e-health care, this module for analysis and diagnosis of cardiac patients has been designed using transformation method in this work. **Methods/Statistical Analysis:** The baseline drift of the ECG has been eliminated and the beat rate is evaluated from the peaks of the signals using Fast Fourier Transform. It helps for analysis of the patients' cardiac condition. Further for an adaptive window size, wavelet transform is utilized for both time and frequency component of a signal. This makes it as a potential technique for baseline drift removal and detection more accurate than FFT. **Findings:** FT analysis provides only the frequency component of any signal. The analysis will be more versatile and informative if both time and frequency information are investigated. For an adaptive window size, wavelet analysis can take care of both time and frequency component of a signal adequately. This makes it as a potential technique for this work. Subsequently an attempt is made to estimate the base line drift removal of the signal to obtain the main signal using wavelet decomposition. Next to it discrete wavelet transform have been applied to enrich the result. **Application/Improvements:** This can be well utilized in e-healthcare systems for the benefits of both patients and hospitals irrespective of distance. Also this module can be improved for other diseases.

Keywords: Baseline Drift, Fourier Transform, Heartbeat Rate, Multi-Agent System, R-peak, Wavelet Transform

1. Introduction

Different signals of human body give information regarding his/her activities. These signals can be correlated with the healthy subject and also with the pathological parameters. Some of these signals are time-varying in nature. ECG is one of these signals and provides information about the state of heart functionality. This can also provide the information regarding heart related diseases, since it is the electrical characteristics of the heart muscles. The muscle function can be transmitted through the cellular structure and can be noted at the time of requirement. These signals can be helpful to the signal processing researchers for design and development of the modern equipments for diagnosis and monitoring[1-6]. Further research will grow for smart equipments and intelligent methods of diagnosis. Many techniques have been used to identify QRS region and R-peak detection[7-17].

Detection of R-peak from ECG signal using Hilbert Transform has been reported in. Also thresholding method has been applied for R-peak detection in. Wavelet packet is an alternative for such task as suggested in. Soft computing approaches like artificial neural network, fuzzy system and hybrid networks have been employed to improve the accuracy of the QRS detectors and ECG beat recognition[18-19]. For the same the abnormalities in ECG have been detected in. Similar work in this direction demands for an effective diagnosis and monitoring system based on ECG signals.

Extraction of suitable and reliable features describing the disease of a person is a prerequisite for any diagnosis and health monitoring system. Fourier transform has been

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an effective feature representing frequency component of the signal of interest. However, considerable information on the patients' health condition can be obtained by exploring both time and frequency component of the signal. Short time Fourier transform or windowed transform has been an effective method that takes care of both these components of a signal[20-21]. It can be effectively used for health monitoring and disease diagnosis by researchers. While STFT provides a uniform resolution due to fixed window size required to describe the signal; however, to represent different frequency component with varying window needs an adaptive resolution. Wavelet analysis can be a potential candidate in this regard and has been opted in[22-28]. Initially noise of the signal is removed using filtering technique during pre-processing stage before wavelet and FT analysis. Finally, different order of the Daubechies wavelet such as db2, db4, and db6 wavelet decomposition of the signal is carried out as a mode of comparison. Finally the results of both FT and wavelet analysis are compared to diagnose a potential ill human being. In this piece of work an approach has been proposed using wavelet transform for multiple tasks such as baseline drift elimination, R-peak detection and heartbeat evaluation. Instead of using too many methods wavelet transform is used reduce the task complexity and enhance the accuracy.

The paper is organized as follows. The introduction and state of art of the work is provided in section 1. Section 2 describes the methodology and its result is analyzed in section 3. Finally section 4 concludes the work and suggest for the application in e-health care use.

2. Methodology

ECG is the informative graph of the heart's electrical behavior, that helps the physicians for diagnosis of the disorder. The graph can provide different types of formation about the functionality of heart such as, rhythm, heart rate from which the physician can decide the future action of the human subject. Simultaneously, the graph helps the engineers and researchers for development and accuracy. As the electrical characteristics of EEG is around 10mV and 100Hz in standard form, the deviation will alert to the designers to check the equipment for better accuracy and detection of different segments as QRS, ST etc. Hence, the result can help the pathologist and physician for smart service. The analysis of the ECG signal not only help for diagnosis and detection, but also help to communicate different places for analysis and monitor the health condition of a patient. Since the analysis is helpful for many applications, it is proposed in this paper as a subsystem of the health care system. The spectral characteristics of the signal is more informative for which the attempt is taken with it. Similarly the single tool and transform can perform most of the operations like, noise removal, spectral representation with perfect time localization, and also can provide information about the bit rate of the heart in wavelet transform. The spectral characterization was tasted with popular Fourier Transform and next to it has been applied using wavelet transform. The basic waveform and its components are shown in Figure 1.

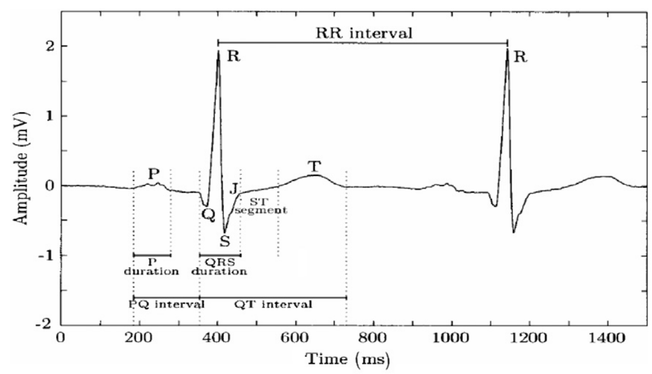

Figure 1. Components of ECG signal.

The method of detection of disease involves following steps as shown in the block diagram of Figure 2. Initially, the data has been acquired from the desired source. Pre-processing of the data has been done to remove any unwanted background and environment noise. Two methods of feature extraction as Fourier Transform and Wavelet Transform have been performed. Consequently, the R-peaks of the signal are detected based on these features. From the R-peaks, the baseline drifts are estimated to obtain the main signal from the original signal. The magnitude of the R-peak has been computed further. Finally, heartbeats are estimated based on the peaks of the signal as shown in the result. Both wavelet and FT analyses are made and results are compared.

Fourier Transform

The basic tool for spectral analysis is Fourier Transform. For discretized ECG signal Discrete Fourier Transform is used, that will produce the spectral content of the signal. It can be represented by.

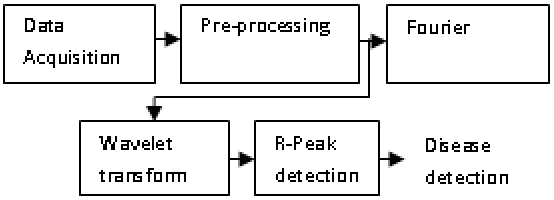

Figure 2. Proposed method.

$$G(k) = \sum_{n=0}^{N-1} g(n) e^{-\left(\frac{2\pi j}{N}\right)kn}, k = 0, \ldots, N-1 \quad (1)$$

The IDFT can be computed as

$$g(n) = \frac{1}{N} \sum_{k=0}^{N-1} G_k e^{\frac{2\pi j}{N}kn}, n = 0, \ldots, N-1 \quad (2)$$

By applying DFT initially, the low frequncies are removed in order to straighten the ECG which is uneven. Then the ECG signal is restored by applying inverse DFT (IDFT). Using windowing the maximum values are calculated by adjusting the window. The R-peaks are then detected and corresponding magnitudes are estimated. But the method has the problem in time scaling for which wavelet transfomr is used.

Wavelet Transform

Basically wavelet transform decomposes the signal in different scales. This will represent to the resolution of the signal. The corresponding frequency can be found according to time localization. Because of its scaling property, it holds a unique position for time-frequency analysis of the non-stationary signals. Since ECG is a category of non-stationary as well as noisy signal, wavelet transform is chosen for such analysis. In this case, noise is removed and simultaneously the specific peaks are located clearly.

In wavelet analysis any signal space of a multi-resolution approximation can be decomposed into lower frequency (lower-resolution) approximation and high frequency (higher-resolution) approximation as shown in Figure 3. This can be obtained by the division of the orthogonal basis, into corresponding two orthogonal basis as given by:

$$\left\{\theta_{i+1}\left(t-2^{i+1}k\right)_{k\in Z}\right\} \quad of\ U_{i+1} \quad (3)$$

$$\left\{\vartheta_{i+1}\left(t-2^{i+1}k\right)_{k\in Z}\right\} \quad of\ D_{i+1} \quad (4)$$

Where, U_i is the orthogonal basis, D_{i+1} is the detailed space and U_{i+1} is the approximation space.

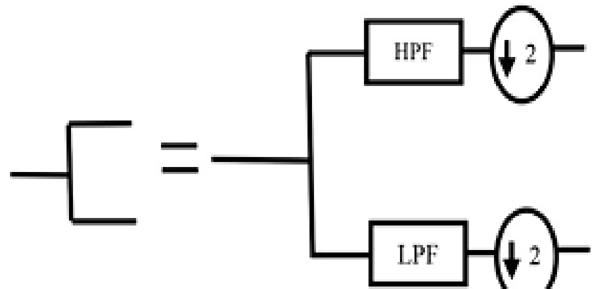

Figure 3. Wavelete decomposition into low and high frequncy components.

The noise is eliminated by discarding the detail coefficients D1, D2. Secondly, in our method, using filtering approach before wavelet and FT analysis we have removed most of the unwanted noise of the signal. The probability of error in R peak detection is minimized in spite of the presence of drastic irregularity in the baseline.

Haar wavelet is the simplest and first of wavelet family that resembles to a step function. Daubechies is the mostly discussed wavelet family in signal processing approach. It is generally represented as dbN where, *N* signifies order of the wavelet. An order of 2, 4 and 6 has been used for comparison of the unhealthy person from a normal person. In this case the 'R' peaks are detected successfully by selecting the optimum coefficients.

Different mother wavelets like Coiflet, Symlet and Daubechies have been tested for this problem. The best result with Daubechies have been reported. In case of high pass filtering Db 6 and for low pass filtering Db 2 have shown the best result and is shown in result section.

For 'R' peak detection the following processor has been proposed.

- Consider the filter ECG signal as the input and calculate the wavelet co-efficient.
- Initialize the window time the total time can be evaluated as total number of samples/sampling frequency.
- Find the maximum and minimum for each window from all possible QRS segment.
- Now locate the R peaks of QRS complexes from different segment.

3. Result and Discussion

Initally, FT analysis has been utilized to determine the persons health condition. It is shown in Figure 4 through

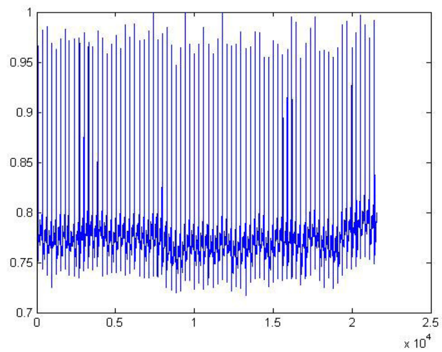

Figure 4. 100m, Original ECG signal.

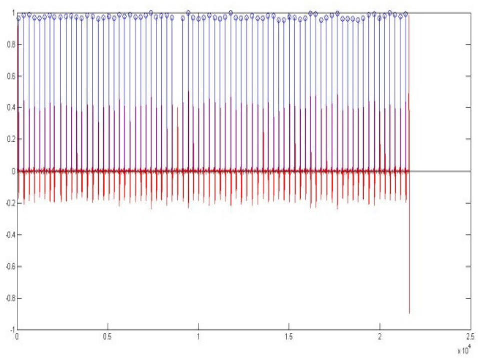

Figure 5. 100m, Original ECG signal including R-peak using Fourier transform.

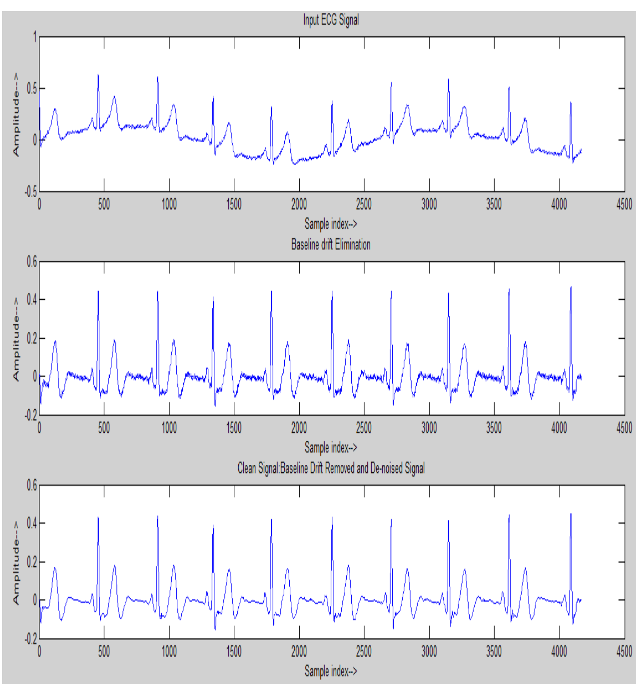

Figure 6. Baseline drift estimation using fourier transform on ECG signal.

Figure 6. The orignal 100m ECT signal is shown in Figure 4 and corresponding R-peaks in Figure 5. The FT analysis has been investigated in Figure 6. In the first segment of Figure 6, the original noisy signal has been shown. The baseline drift of the signal is estimated in second segment of the same Figure. The clean signal after denosing is shown in the last segment. The heartbeat rate of both normal and unhealthy persons has been investigated using wavelet analysis (Figure 7-Figure 11). The results of identifying an unhealthy person by analyzing his/her heartbeat, is shown in Figure 1 through Figure 11.

Each Figure consists of four components. The baseline drift of the heart beat rate is shown in second segment of the figures. The main signal after elimination of the baseline drift signal is given in third segment. The R-peaks are shown in fourth segments. Figure 1 provides the heartbeat of a person affected with the cardiac problem. As shown in Figure 7, the heartbeat rate is highest. Since, the normal heart beat rate of an average healthy person lies in between 72 to 120. Thus, a value of 132 as heartbeat indicates the degree of illness the person is affected with. Hence it requires immediate attention. The R-peaks are also of highest amplitude. Similar results could be observed from the wavelet features in Figure 8.

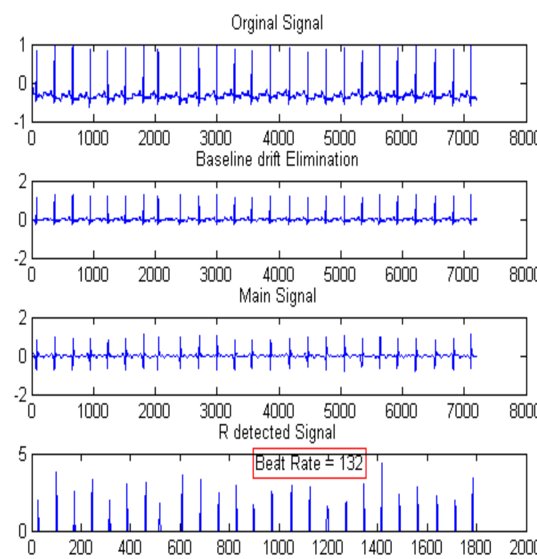

Figure 7. Identifiction of a terminal ill person from R-peak using db2 wavelet features.

In Figure 9, the value of heartbeat is shown as 90. It indicates the poor health condition of that person. The

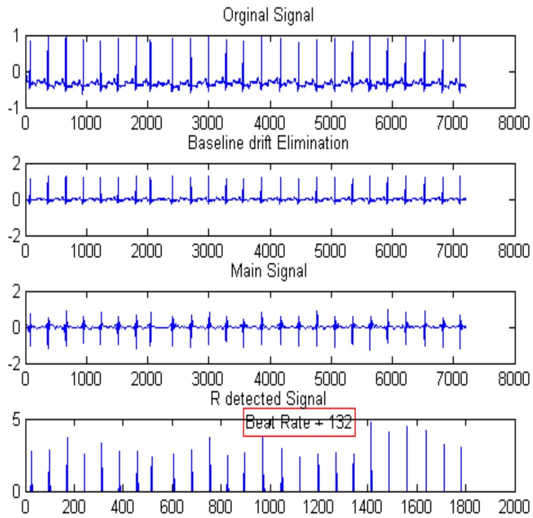

Figure 8. Identifiction of a terminal ill person from R-peak using Haar wavelet features.

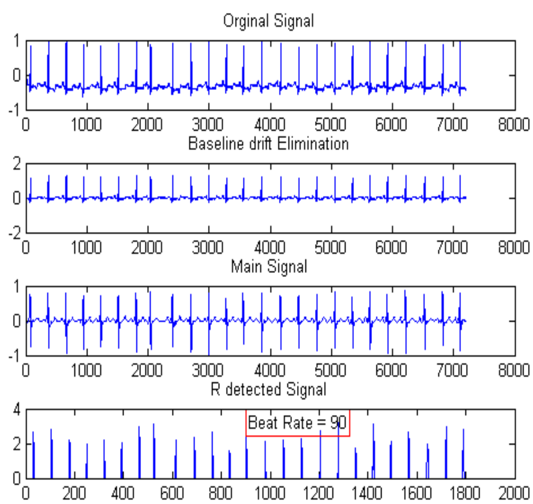

Figure 9. Identifiction of a sick person from R-peak using db6 wavelet features.

patients may not be seriosely ill but a higher beat rate indicates his/her level of sickness. The R-peaks are also large although less than that in Figure 7 and Figure 8.

Both db and Haar family of wavelet has been used to rate the normal person based on his/her heartbeat. The coefficients extracted and analysed in the Figure 4 and Figure 5. Analysis of these coefficients and indication of corresponding R-peaks point towards a normal human being. A beat rate of 74 in Figure 10 and 74 in Figure 11

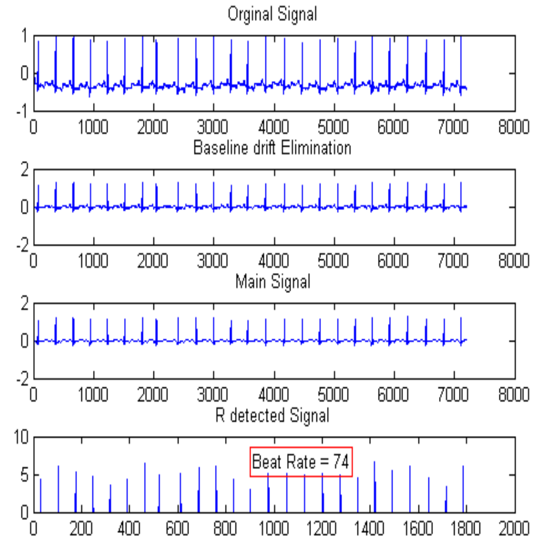

Figure 10. Identifiction of a normal person from R-peak using db4 wavelet features.

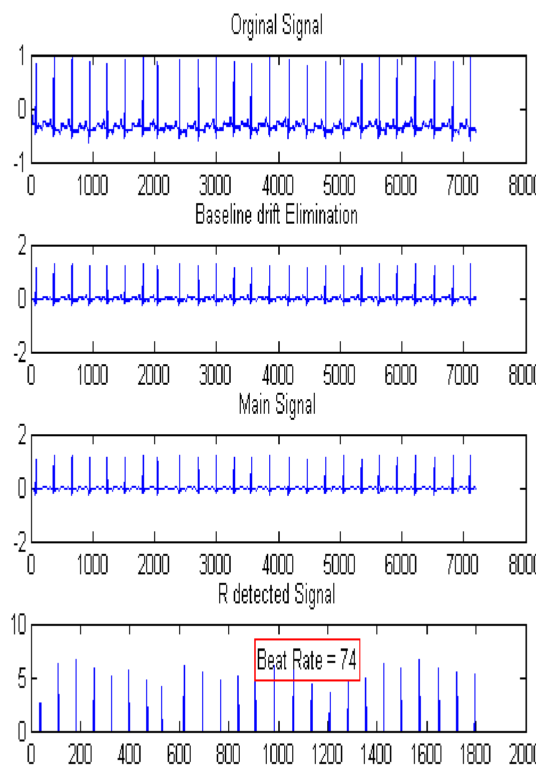

Figure 11. Identifiction of a normal person from R-peak using Haar wavelet features.

indicates that the person is perfectly healthy. The peaks are also minimum in both the Figures.

The representation and beat rate can be transmitted over the communication module, which is another agent of the system. Finally the principal agent (Doctor) can decide the future action.

4. Conclusion

In this paper the analysis for the diagnostic agent is done accurately for further suggestion. This may be implemented in the full system to be effective one. Proper diagnosis of cardiac related symptoms can prevent longtime health issues of human being. Though, researchers are endeavoring to achieve an efficient diagnosis system, still there is scope for further research. By analysis both time and frequency module of an ECG signal, we have moved a step closure in this direction. The method tried to focus one of the crucial R-peak components of the signal. Removal of noise before analysis of the signal and during feature extraction made the signal able to indicate accurate heartbeat measurement of an acute ill person in this work.

5. References

1. Su JC. Mobile multi-agent based, distributed information platform (MADIP) for wide-area e-health monitoring. Computers in Industry. 2008 Jan; 59(1):55-68.
2. Benhajji N, Roy D, Anciaux D. Patient-centered multi agent system for health care. IFAC-Papers On Line. 2015; 48(3):710-14.
3. Silverman GB, Hanrahan N, Bharathy G, Gordon K, Johnson DA. Systems approach to healthcare: Agent-based modeling, community mental health and population well-being. Artificial Intelligence in Medicine. 2015 Feb; 63(2):61-71.
4. Ferrer J, Salmon M, Temime L, Nosolink. An agent-based approach to link patient flows and staff organization with the circulation of nosocomial pathogens in an intensive care unit. Procedia Computer Science. 2013; 18:1485-94.
5. Vaidehi V, Vardhini V, Yogeshwaran H, Inbasagar G, Bhargavi R, Sweetlin Hemalatha SC. Agent Based Health Monitoring of Elderly People in Indoor Environments Using Wireless Sensor Networks. Procedia Computer Science. 2013; 18:64-71.
6. Armentia A, Gangoiti U, Priego R, Estevez E, Marcos MA. Multi-Agent Based Approach to Support Adaptability in Home Care Applications. IFAC-Papers On Line. 2015 Sep; 48(10):1-6.
7. Pan J, Tompkins WJ. A real time QRS detection algorithm. IEEE Transactions on Biomedical Engineering BME. 1985 Mar; 32(3):230-36.
8. Hamilton PS, Tompkins WJ. Quantitative investigation of QRS detection rules using the MIT-BIH arrhythmia database. IEEE Transactions on Biomedical Engineering BME. 1986 Dec; 33(12):1157-87.
9. Xue Y, Hen HU, Tompkins WJ. Neural Network based adaptive matched filtering for QRS detection. IEEE Transactions on Biomedical Engineering BME. 1992 Apr; 29(4):317-19.
10. Majumder S, Dhar S, Sinha A, Roy A. A hybrid wavelet and time plane based method for QT interval measurement for ECG signals. Proceedings of Ninth International Conference on Signal Processing. 2009 Aug; 2(4):280-86.
11. Pandey S, Ayub S. Wavelet Based R Peak Detection ECG Signals Using Matlab. Journal of Basic and Applied Engineering Research. 2014 Oct; 1(2):101-3.
12. Kohli SS, Makwana N, Mishra N, Sagar B. Hilbert Transform Based Adaptive ECG R-Peak Detection Technique. International Journal of Electrical and Computer Engineering (IJECE). 2012 Oct; 2(5):639-43.
13. Nouira I, Abdallah AB, Bedoui MH, Dogui M. A Robust R Peak Detection Algorithm Using Wavelet Transform for Heart Rate Variability Studies. International Journal on Electrical Engineering and Informatics. 2013 Sep; 5(3):270-84.
14. Bensegueni S, Bennia A. R-PEAK detection using wavelet transforms technique. Universitatea Politehnica din Bucuresti Series C. 2015; 77(3):135-48.
15. Birle A, Malviya S, Mittal D. A Novel Technique of R-Peak Detection for ECG Signal Analysis: Variable Threshold Method. International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE). 2015 May; 4(5):1167-69.
16. Singh O, Sunkaria RK. A Robust R-peak Detection Algorithm using Wavelet Packets. International Journal of Computer Applications. 2011 Dec; 36(5):37-43.
17. Rabbani Hossein, Parsa Mahjoob M, Farahabadi E, Farahabad A. R Peak Detection in Electrocardiogram Signal Based on an Optimal Combination of Wavelet Transform, Hilbert Transform, and Adaptive Thresholding. Journal Medical Signals Sensors. 2011 May-Aug; 1(2):91-98.
18. Ojha D, Subashini M. Analysis of Electrocardiograph (ECG) Signal for the Detection of Abnormalities Using MATLAB. World Academy of Science, Engineering and Technology. International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering. 2014; 8(2):120-23.

19. Osowski S, Hoai LT. ECG beat recognition using fuzzy hybrid neural network. IEEE Transactions on Biomedical Engineering. 2001 Nov; 48(11):1265-71.
20. Mohanty MN, Kumar A, Routray A, Kabisatpathy P. Evolutionary Algorithm based optimization for PQ Disturbances Classification using SVM. International Journal of Control and Automation Systems. 2010 Dec; 8(6):1306-12.
21. Mohanty MN, Routray A, Pradhan AK, Kabisatpathy P. Power Quality Disturbances Classification using Support Vector Machines with optimized time-frequency kernels. International Journal of Power Electronics. 2012; 4(2):181-96.
22. Grap A. An Introduction to Wavelets. IEEE Computational Science & Engineering. 1995; 2(2):50-61.
23. Muhidin A Mohamed, Mohamed A Deriche. ECG feature extraction using Daubechies wavelets. International Journal of Computer Applications. 2014 Jun; 96(12):36-41.
24. Ecgpedia. Date Accessed: 25/04/2016: Available from: http://en.ecgpedia.org/index.php?title=Main_Page.
25. MIT-BIH databas. Date Accessed: 8/10/2015: Available from: https://www.physionet.org/physiobank/database/mitdb/.
26. Radhimeenakshi S, Nasira GM. Remote Heart Risk Monitoring System based on Efficient Neural Network and Evolutionary Algorithm. Indian Journal of Science and Technology. 2015 Jul; 8(14):1-6.
27. Bensujin B, Vijila CKS, Hemanth J, Hubert C. Frequency Dependent Adaptive Chemotaxis in Bacterial Foraging Optimization for ST Segment Elevation Myocardial Infarction Prediction. Indian Journal of Science and Technology. 2016 Jan; 9(1):1-9.
28. Kavitha R, Kannan E, Kotteswaran S. Implementation of Cloud based Electronic Health Record (EHR) for Indian Healthcare Needs. Indian Journal of Science and Technology. 2016 Jan; 9(3):1-5.