IJCTA, 10(9), 2017, pp. 795-801 ISSN: 0974-5572

Feature extraction and Techniques to Minimize Noises in ECG Signal: A Survey

Mohan H.M.* and P.V. Rao**

ABSTRACT

The Electrocardiogram (ECG) is a technique of recording bioelectric currents generated by the heart which will help clinicians to evaluate the abnormal conditions of a patient's heart. While recording, ECG is contaminated with noises and artifacts which constantly degrade its quality, and makes exact interpretation of the signal more difficult. The clinically useful information of the ECG signal is found in the time intervals between its consecutive waves and amplitudes defined by its features. The raw ECG signal has to be processed In order to extract valuable information from the noisy ECG signals. Numerous research and techniques were developed for analyzing the ECG signal based on like Wavelet transforms, Genetic Algorithm, Fuzzy Logic Methods, Artificial Neural Networks, Empirical Mode Decomposition, Support Vector Machines and Signal Analysis techniques. This proposed paper discusses various techniques for extracting features and denoising from an ECG signal. The author proposes the innovative method for preprocessing extracting the main characteristics and of ECG signal through the Undecimated Wavelet Transform.

Keywords: **ECG, Denoise, Wavelet transforms, Artificial Neural Network**,

1. INTRODUCTION

The Electrocardiogram (ECG) signal is a graphical representation of cardiac activity. A cardiac cycle in an ECG signal fundamentally consists of the P-QRS-T waves as shown in fig [1]. The cardiac rhythm is controlled by the pacemaker cells known as sinoatrial (SA) node The ECG indicates the magnitude and direction of the electrical activity generated by depolarization and repolarization of the atria and ventricles. It provides vital information about the functional conditions of the circulatory system and the heart. Due to the vast clinical significance of the ECG signal and its associated heart rate variability analysis in the diagnosis of the ischemia changes like the severe arrhythmias, myocardial infarction and conduction defects, the signal denoising process has become an important task in the engineering and medical communities. Table 1 shows the different parametric measures used for analyzing ECG signal.

Electrocardiography due to Pathological alterations can be mainly divided into three areas: (a) Cardiac rhythm disturbances (arrhythmia) (b) Chronic alteration of the mechanical structure of the heart (for instance biventricular cardiac hypertrophy) (c) Dysfunction of myocardial blood perfusion (cardiac ischemia)

The recorded signal could be degraded by various kinds of noise signal, namely artifacts include motion artifacts, electrode contact noise, power line interference, Electromyography (EMG) noise, baseline drift, and some instrumental noise generated by the electronic ECG monitoring device, all of which can corrupt the ECG which can lead to a wrong diagnosis. A standard filtering requirement has been defined by American Heart Association (AHA) for clinical ECG equipment [1]. Numerous methods have been applied to denoise the ECG signal, such as adaptive filters, Wiener filtering, band pass filter, the ensemble averaging technique,

* Assistant professor T. John Institute of Technology Bangalore, India, *Email: mohanhm@tjohngroup.com*

** Professor, Dept of ECE Vignana Bharathi Institute of Technology, Ghatkesar, Hyderabad, India, *Email: pachararao@rediffmail.com*

extended Kalman filters, wavelet denoising, Artificial Neural Networks, Empirical Mode Decomposition, and Fuzzy logic methods. Some of these methods have demonstrated an excellent performance in terms of Signal to Noise Ratio (SNR), but they can be sensitive to varying parameters.ECG denoising techniques and algorithms must: (a) Improve signal-to-noise ratio (SNR) for obtaining readily observable recordings accurately and subsequently yield straightforward approaches for accurate automatic detection of characteristic points in the ECG signal and detection of its specific waves and complexes (b)The most crucial step is to retain the original shape of the signal and especially the sharp Q, R and S peaks, without any distortion of P and T waves and the smooth transition of the ST-T segment

A literature review is presented on various Extraction, Noise removal techniques for ECG by using Filters, wavelet transforms, non-linear dynamics, Fuzzy Logic and Artificial Neural Network (ANN).

1.1. Review of ECG signal extraction and denoising using Wavelet Techniques

Gradl S, et al. has evaluated the accuracy of the R-peak localization by using special state-of-the-art algorithms. To beat slackness of QRS detectors the author suggests a method to estimate the R-peak temporal inaccuracy. The results showed an average slackness of 9ms for normal beats and 13ms for abnormal beats. The slackness reduction algorithm proposed, showed impressive results which reduced it to 7ms for abnormal and 4ms for normal beats beats to improve the accuracy of R-peak detection. [2] Afghani R.G, et al. proposed a novel feature selection method for exact classification of cardiac arrhythmias. To fit the probability density function of cardiac beats Gaussian mixture modeling and Enhanced expectation maximization solution is used. The Parameters of Gaussian mixture modeling along with shape parameters such as kurtosis, 5th moment and skewness, are also included in vector. The accuracy of 96.15% is achieved in subject oriented scheme and 99.70% in class-oriented scheme. [3] Afef elloumi, et al. proposed a new technique based on Pitch Synchronous Wavelet Transform [PSWT] to filter out the EMG noisy components from ECG. A modeling concept, by means of basis elements is being used which captures period-to period fluctuations of the signal. The performance of the Pitch Synchronous Wavelet Transform technique is evaluated and results shows the accuracy of the proposed technique for all corrupted synthetic ECG signals. [4]

Majdi Bsoul, et al. adopted a technique of using 2nd generation wavelets specifically lifting scheme in electrocardiogram detrending, characteristic point detection and denoising, by using only one decomposition phase. A different technique of enhanced level–based detail coefficients thresholding method is implemented. The method successfully achieved 99.50% predictivity performance for QRS complex detection. By comparing the Daubechies D4 UWT and undecimated lifting scheme of wavelet transform ULWT implementation the results clearly indicates that the ULWT reduces the computation cost [5] V.Naga Prudhvi Raj, et al exploited the denoising technique by Undecimated Wavelet Transform UWT to decompose the processed ECG signal and perform the shrinkage operation to eliminate the noise. Along with traditional hard and soft, an additional Stein and semi-soft thresholding operators are used in the shrinkage step in order to verify the correctness of different wavelet families. The denoised signal using Undecimated Discrete Wavelet Transform yielded a better balance between smoothness and accuracy than the Discrete Wavelet Transform technique DWT. [6]

Muhammad Sheikh Sadi, et al. explains a novel approach for data preprocessing and feature extraction. Experimental results indicate that the presented method yield 96.79% accuracy and five features recognition with reduced computational complexity. [7] Muhidin A. Mohamed, focused on Daubechies Wavelet Transform [DB4] method for an ECG feature based on the scaling function. This algorithm based on feature extraction by R peaks detection in the location of primary peaks. It is extracted by creating windows proportional within their normal intervals. The results of this algorithm significantly identify and extract all the primary features with a deviation error of less than 10% [8] Wissam Jenkal, et. al. adopted an noval method of ECG signal denoising using adaptive dual threshold filter [ADTF]. and the discrete wavelet transform [DWT] These results of this algorithm based on three steps of denoising, namely, the DWT decomposition, the ADTF step and the highest peaks correction step proves to be efficient. [9] Lukas Smital , et al focused on the concept of the wavelet Wiener filtering to reduce of Electromyography in cardiac beat signals. In the Wiener filter technique, the dyadic stationary wavelet transform [SWT] is being used. Adaptive setting parameters of filtering are adopted to improve the filtering performance. The average Signal to Noise Ratio for the entire test database obtained was about 10.6 dB. The proposed algorithm proves efficient and provides better results than the traditional wavelet Wiener filter. [10]

1.2. Review of ECG signal denoising using Adaptive filtering Techniques

Yichao Zhou, et al. Proposed a baseline wandering (BW) correction algorithm for ECG signal denoising. The proposed algorithm models a superposition of few inner filter structures. The authors have compared these two metrics between the DWT-based algorithm and proposed, EMD-based algorithm. The results indicate that the presented algorithm gave the best results to remove noise and other artifacts like baseline wandering [11] Uzzal Biswas, et al. presented a methodology for best adaptive filtering technique such as, normalized-least-mean-square (NLMS) and least-mean-square (LMS) are applied to remove the noises in ECG signal. Different performance parameters such as, spectrogram, power spectral density (PSD), frequency spectrum and convergence are compared via the Simulation results. The results clarify that adaptive NLMS filter is an exceptional method for denoising the ECG signal. [12] Nasreen Sultana et al. Compared performance of two adaptive filters namely Discrete Wavelet Transform and Savitzky -Golay [SG] Filter for noisy heart beat signals. The Results obtained are quiet encouraging. The Mean Square Error (MSE) reduced to 5.07, 3.72, and 1.101 with Savitzky-Golay (SG) Filter, DWT, and SG Smoothing Filter respectively. The results highlight that Savitzky-Golay filter with smoothing is Impressive for denoising ECG signals. [13] Kazi Reyadul Hasan, et al made a study with various wavelet families identification and performance estimation for denoising ECG signal. The results are compared with notch filter and adaptive NLMS in both frequency and time domain. The simulation result analysis represent that wavelet transform is an outstanding technique for denoising ECG signal. [14] Akanksha Mittal, et al. has worked on reducing 50Hz power line noise in ECG signal by using a digital FIR filter. The design and implementation with different windowing methods is carried using Hamming, Chebyshev and Kaiser. The result obtained for all FIR filters are compared. The Chebyshev Window filtering technique proved to give the best results. [15]

1.3. Review of ECG Signal classification using Computational Intelligence Techniques

Rosaria Silipo et al. has proposed a method of an Artificial Neural Network technique for ECG signal classification and compared with its alternative integrating The trade-off between the time consuming training of ANN’s and their performances is explored.. The reduction of the input space dimensions, on a more considerable description of the input features, and on improving new event processing has been also recognized and documented. [16] G. Krishna Prasad et al. has worked on a discrete wavelet transform coefficients, which contain the set of information regarding the arrhythmia, which is selected from the wavelet decomposition. These coefficients along with the information about RR interval are fed to the back-propagation neural network which classifies the arrhythmias. The proposed method distinguishes the 12 unusual arrhythmias and normal sinus rhythm. The results Indicates that the accuracy of classification of the presented approach is 96.77%. There was an observation that the effect of base-line wander on the accuracy of detection was less than the other disturbances.[17]

2. METHODOLOGY

The detail methodology for ECG preprocessing and feature extraction is shown in Fig. 2 in the form of block diagram.ECG signal processing can be divided mainly into two stages preprocessing and ECG feature extraction.

2.1. Preprocessing

The process of Preprocessing includes removal of artifacts like Electromyography (EMG) noise, contact noise, Baseline wandering, Patient–electrode motion artifacts, Power line interference from the ECG signal. The baseline wandering is removed by using high pass digital filter.

It can also be suppressed by using wavelet transform. Wideband Noise is a complex stochastic process can be removed using wavelet denoising techniques.

2.2. Feature Extraction

In this step, various waves and complexes are detected in ECG signals. The morphological features namely RR interval, R peak amplitude, QRS duration, and PR intervals of every ECG beats are extracted. The ECG feature extraction is carried out using Undecimated Wavelet transform.

Table 1
Different performance metrics for ECG signal analyzing

Segment/wave	*Duration(msec)*	*Amplitude(mv)*
P wave	80-100	0.1-0.25
PR segment	120-200	—
QRS complex	80-120	1-1.12
QT	200-400	—
ST	80-120	—
T wave	120-160	0.1-0.5
U wave	20-40	—

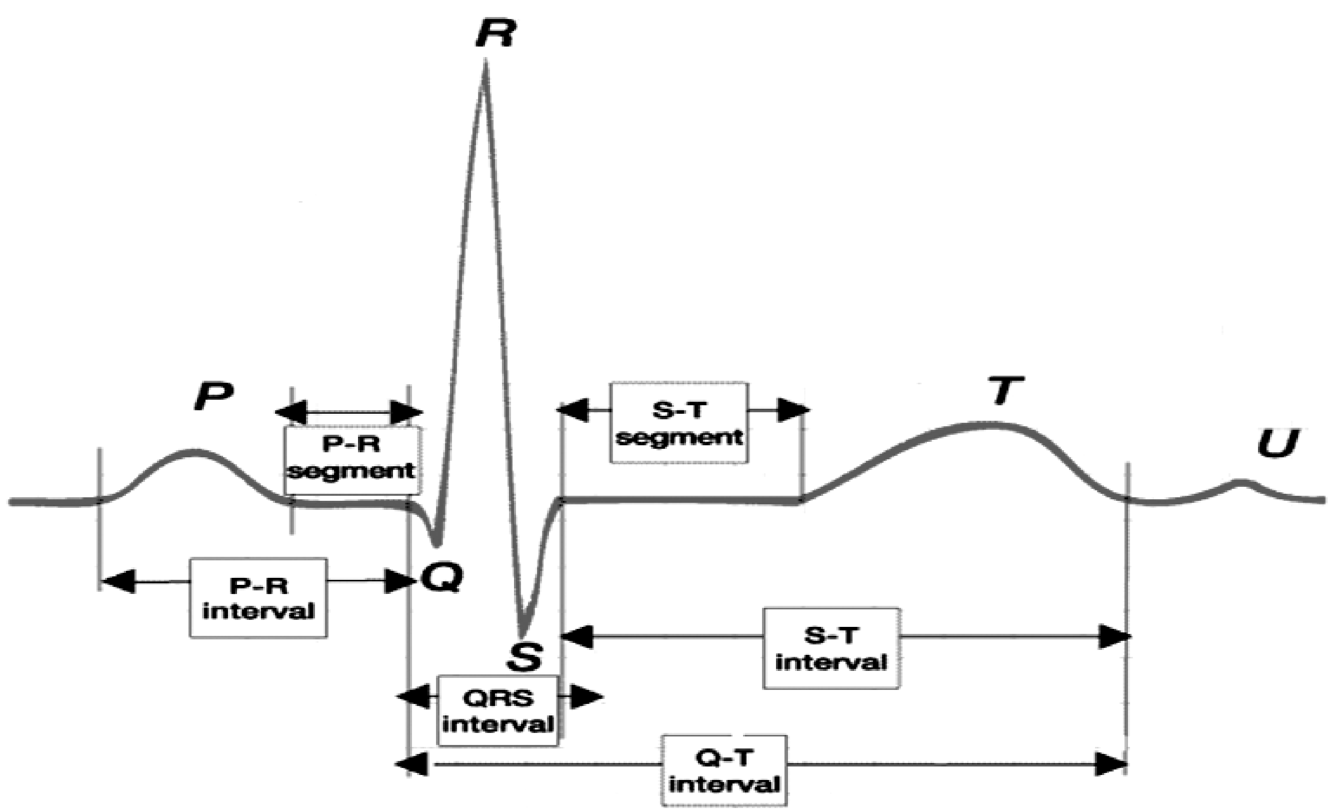

Figure 1: Typical ECG Signal

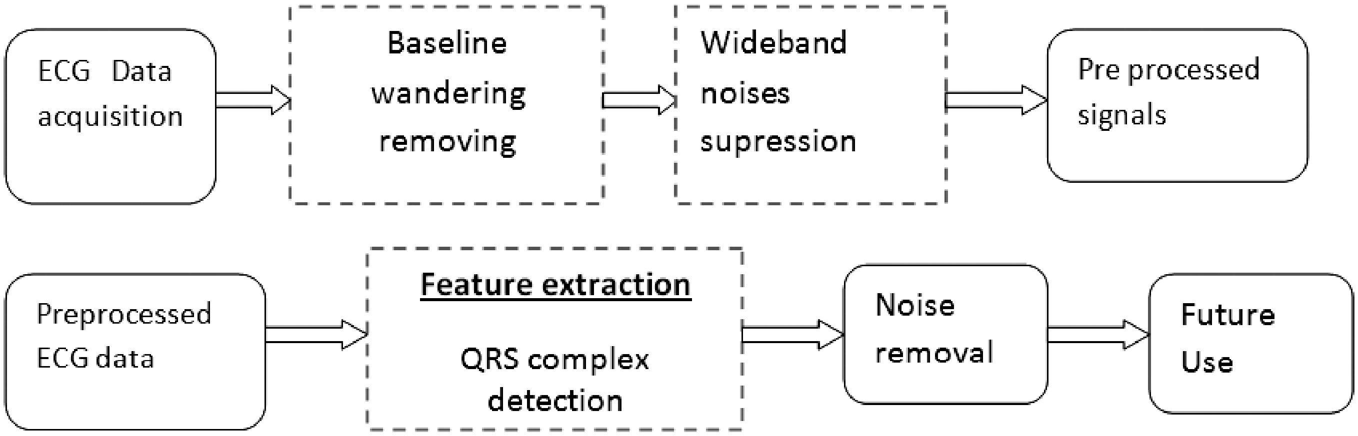

Figure 2: ECG Preprocessing and Signal extraction system

2.3. Denoising

The denoising can further be divided into steps based on wavelet shrinkage technique as shown in figure 3

i. Signal Decomposition using the Discrete wavelet Transform. (DWT): Many different can be selected like Daubechies , Symlets Haar, Coiflets, , Biorthogonal, Reverse Biorthogonal families depending on the suitability for ECG signal denoising.

ii. Thresholding.

iii. ECG signal Reconstruction using the inverse DWT (IDWT).

Undecimated wavelet transform is used to denoise the ECG preprocessed signal. The choice of Undecimated Wavelet Transform is made as it has some unique features like Better Denoising Capability, Best Peak Detection Capability, and better Translation-Invariant Property compared with the DWT

2.4. Quantitative analysis

Quantitative analysis of ECG signal will be performed by considering the following three parameters in this proposed work and the equations as follows.

Signal to Noise Ratio(SNR) is given by eqn 1,

$$SNR = 10\log\left[\frac{\sum_{i-1}^{N} x(i)^2}{\sum_{i-1}^{N}\left(x(i)-y(i)\right)^2}\right] \quad (1)$$

Mean square error(MSE) is given by eqn 2,

$$MSE = \frac{1}{N}\left[\sum_{i=1}^{N}\left(x(i)-y(i)\right)^2\right] \quad (2)$$

The root mean square error(RMSE)

$$RMSE = \sqrt{\frac{1}{N}\sum_{I=1}^{i=N}\left(x(i)-y(i)\right)^2} \quad (3)$$

Where, $x(i)$ is the original ECG signal, $y(i)$ is the denoised ECG signal and N is the length the signal.

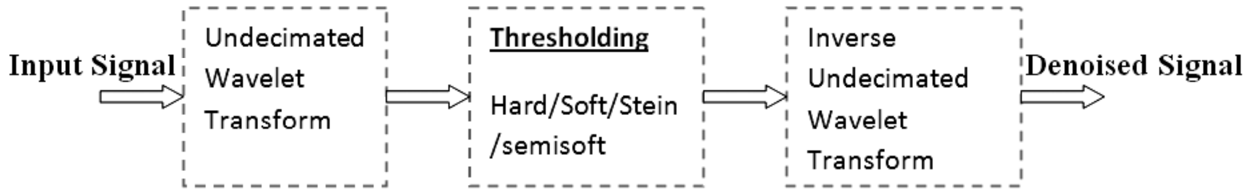

Figure 3: ECG Signal Denoising System

3. CONCLUSION

Here from the literature survey the author proposes an innovative technique and algorithmic approaches for extraction of signal parametric measures, denoising and classifying for the final ECG signal for detecting Arrhythmias. ECG Feature Extraction plays a significant role in diagnosing most of the cardiac diseases. The feature extraction technique or algorithm developed for ECG signal must be highly accurate and fast computing to extract features. Further it helps us to overcome limitation of heart beat rate interpretation of ECG signal for which the author proposes an algorithmic approach for accurate and fast feature extraction and Signal Denoising

REFERENCES

[1] Kligfield P, Gettes L, Bailey J, et al. Recommendations for Standardization and Interpretation of Electrocardiogram, Jam coll Cardiol; Vol 49, pp. 276-281, 2007

[2] Gradl S, Leutheuser H, Elgendi M, Lang N, Eskofier B M, “Temporal correction of detected R-peaks in ECG signals: A crucial step to improve QRS detection algorithms” ,Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS,Vol. 2015, pp. 522-525, 2015.

[3] Rashid Ghorbani Afkhami, Ghanbar Azarnia, Mohammad Ali Tinati “Cardiac arrhythmia classification using statistical and mixture modeling features of ECG signals” Elesvier- Pattern Recognition Letters Vol. 70, pp. 45–51, 2016

[4] Afef elloumi’, Zied oichlri’ and Noweddine ellouze “Denoising ECG contaminated with EMG components based on pitch synchronous wavelet analysis” IEEE International Conference on Industrial Technology, Vol. 3, 2004.

[5] Majdi Bsoul and Lakshman “ Using Second Generation Wavelets for ECG Characteristics Points Detection” IEEE 1st Middle East Conference on Biomedical Engineering , pp. 375-378, 2011

[6] V.Naga Prudhvi Raj Dr T Venkateswarlu “ECG Signal Denoising Using Undecimated Wavelet Transform” Electronics Computer Technology (ICECT), 3rd International Conference on Electronics Computer Technology, Vol 3, pp. 94-98, 2011.

[7] Muhammad Sheikh Sadi, Subroto Debnath, Fahim Feroje Al Jami, G.M. Mahmudur Rahman “A New Approach to Extract Features from ECG Signals” IEEE 2nd International Conference on Electrical Information and Communication Technologies, pp. 189-194, 2015.

[8] Muhidin A. Mohamed Mohamed A. Deriche” An Approach for ECG Feature Extraction using Daubechies 4 (DB4) Wavelet” International Journal of Computer Applications, Volume 96, pp, 36-41, June 2014.

[9] Wissam Jenkal , Rachid Latif , Ahmed Toumanari , Azzedine Dliou , Oussama El B’charri , Fadel M.R. Maoulainine “An efficient algorithm of ECG signal denoising using the adaptive dual threshold filter and the discrete wavelet transform” Elsevier- Biocybernetics and biomedical engineering Vol. 36, pp. 499-508, 2016.

[10] Lukas Smital , Martin Výtek, Jirý Kozumplýk, and Ivo Provazn “ Adaptive Wavelet Wiener Filtering of ECG Signals “IEEE transactions on Bio medical engineering, vol. 60, pp. 437-445, 2013.

[11] Yichao Zhou, Xiyuan Hu, Zhenmin Tang, Andrew C. Ahn “Denoising and Baseline Correction of ECG Signals using Sparse Representation” IEEE Workshop on Signal Processing Systems, pp. 1-6, 2015.

[12] Uzzal Biswas, Anup Das, Saurov Debnath, and Isabela Oishee “ECG Signal Denoising by Using Least-Mean-Square and Normalised-Least-Mean-Square Algorithm Based Adaptive Filter” 3rd International conference on informatics, electronics & vision, 2014.

[13] Nasreen Sultana and Yedukondalu Kamatham “Mitigation of Noise and Interference in ECG Signals with Savitzky-Golay Least Squares Polynomials and Discrete Wavelet Transform” IEEE International conference on electrical computer and communication technologies (ICECCT), 2015.

[14] Kazi Reyadul Hasan, Uzzal Biswas, Biswajit Sana and Md. Maniruzzaman “Denoising ECG Signal Using Different Wavelet Families and Comparison with Other Techniques” 2nd Int’l Conf. on Electrical Engineering and Information & Communication Technology (ICEEICT) , pp. 1-6, 2015.

[15] Akanksha Mittal, Amit Rege "Design of Digital FIR Filter Implemented with Window Techniques for Reduction of Power line Interference from ECG Signal" IEEE International Conference on Computer, Communication and Control (IC4-2015). pp.1-4, 2015.

[16] Rosaria Silipo and Carlo Marchesi "Artificial Neural Networks for Automatic ECG Analysis" IEEE transactions on signal processing, vol. 46, no. 5, May 1998.

[17] G.Krishna Prasad J. S. Sahambi , "Classification of ECG Arrhythmias using Multi-Resolution Analysis and Neural Networks" Vol 1, pp. 227-231, 2003.

[18] Bernard W, John R.G, John M.M, John K, Charles S, Williams, Robert H.H, James R.Z, Eugene D, and Robert C.G, "Adaptive Noise Cancelling: Principles and Applications", Proceedings of the IEEE, Vol 63, pp: 1692-1716, December 1975.

[19] Huang G, Huang G B, Song S, You K, "Trends in extreme learning machines": A review, Neural Networks, Vol.61, pp. 32–48, 2015.

[20] I. Daubechies, "Ten Lectures on Wavelets", SIAM Publishers, 1992

[21] Stephane Mallat, "A Wavelet Tour of signal Processing", Elsevier, 2006.

[22] Rangaraj M. Rangayyan, "Biomedical Signal Analysis A Case study Approach", IEEE press, 2005