



## ECG Denoising Using Wavelet Transform and Soft Thresholding

Savita Chandel, Kuldeep Singh

Department of Electronics and Communication Engineering, Baddi University of Emerging Science & Technology,  
Baddi, Himachal Pradesh, India

*Abstract-Biomedical signals like heart wave (ECG) tend to be non stationary which gives vast information about the heart's activity. To analyze this kind of signals wavelet transforms are a powerful tool. In this paper we make use of Discrete Wavelet Transform to filter and analyze noisy ECG signals which is called de-noising which is accomplished by thresholding wavelet coefficients in order to separate signal from noise. The result is computed for two different ECG data records of 7200 samples of same sampling frequency. The PSNR and MSE value is calculated by Db2 wavelet before denoising and after denoising.*

**Keywords-** Db (Daubechies), De-noising, Discrete Wavelet Transform (DWT), ECG (Electrocardiogram), MSE, Non-stationary, PSNR, Thresholding.

### I. INTRODUCTION

The human ECG signals are in the mv range and the frequency range is 0.05-100Hz and most of the useful information is contained in the range of 0.5-45Hz [5]. Electrocardiography is the starting point to diagnosis of many heart disorders. Electrocardiography is the recording of the electrical activity of heart, and it is monitored by placing sensors at limb. The arrhythmia of the heart is determined by the ECG waveform. A one cardiac cycle of heart waveform is shown below [5].

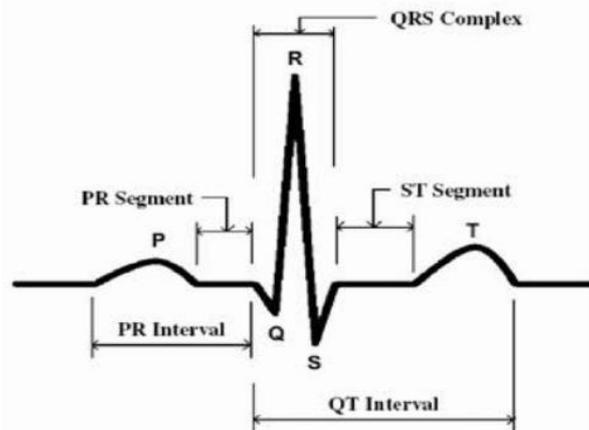


Fig. 1. ECG waveform for one cardiac cycle

A signal is often corrupted by noise during its acquisition or transmission [1][20]. The de-noising process is to remove the noise while retaining and not distorting the quality of the processed signal. The traditional way of signal de-noising is filtering. From few years a lot of research about non-linear method of signal de-noising has been developed. These methods are mainly based on thresholding the Discrete Wavelet transform (DWT) coefficients [19]. Simple de-noising algorithms that use DWT consist of three steps.

- DWT is adopted to decompose the noisy signal and get the wavelet coefficients.
- These wavelet coefficients are denoised with wavelet threshold.
- Inverse transform is applied to the modified coefficients and get denoised signal.

Mostly the noised ECG signals are evaluating by MATLAB software using different wavelet to measure their corresponding PSNR, MSE, SNR, PRD [1-28].

### II. NOISES IN ECG SIGNAL

In ECG signal there are present different types of noises from which some of noise signal present in ECG are given below. Most effective noise on ECG is baseline wander noise so in this paper we work with to remove the baseline wandering noise from ECG signal.

#### A. Baseline wandering-

Baseline wander is a low frequency component present in the ECG system. This is due to offset voltages in the electrodes, respiration, and body movement. The baseline wandering signal shown below fig 1.2 [27]



Fig. 2. Baseline noise

This can cause problems in the analysis of the ECG waveform. The offset also limits the maximum value of gain which can be obtained from the instrumentation amplifier. At higher gains, the signal can saturate. This noise can be removed by implementing a high-pass filter using hardware. The cut-off frequency should be such that the ECG is undisturbed while the baseline wander must be removed. A typical value of the cut-off frequency is 0.05Hz. Since this cut-off frequency is very low, this method requires bulky capacitors.

#### B. Electromyographic Noise-

Electromyographic noise is caused by the contraction of other muscles besides the heart. When other muscles in the vicinity of the electrodes contract, they generate depolarization and repolarization waves that can also be picked up by the ECG. The electrical activity of muscles during periods of contraction can generate surface potentials comparable to those from the heart and could completely drown out the desired signal. The frequency of this EMG noise is in between 100 -500 Hz. The muscle noise or tremors are often a lot more delicate than that shown in Fig. 3 [12].

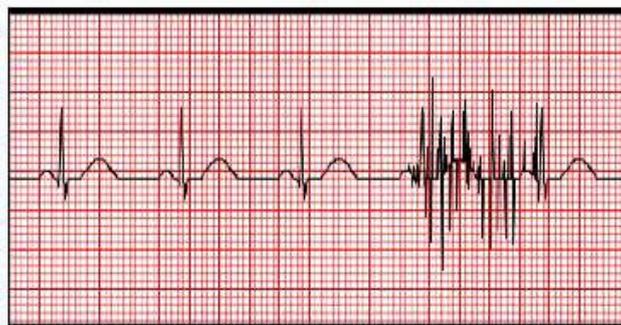


Fig. 3. Muscle tremor

#### C. Channel noise-

Poor channel conditions can also introduce noise to ECG when ECG is transmitted. Usually it is modeled using white Gaussian noise which contains all frequency components.

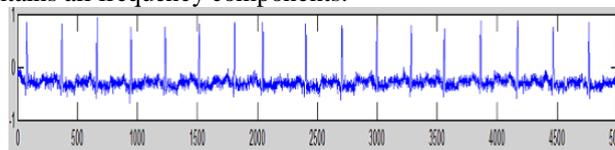


Fig. 3. Gaussian noise

### III. WAVELET TRANSFORM

A wavelet is a small wave like oscillation with amplitude that begins at zero, increases and then decreases back to zero.[29]. As a mathematical tool, wavelet can be used to extract information from many different kinds of data. The theory of wavelet transform based on signal processing and developed from the Fourier Transform basis. Wavelet transform of a function in a real space as a linear combination of wavelet basis function. It performs the linear operation of the signal and the basis function. WT have become an attractive an efficient tool in many applications especially in coding and compression of signals because of Multi-resolution and high energy compaction properties [11]. The WT is designed to address the problem of non-stationary signals. It involves representing a time function in terms of simple, fixed building blocks, termed wavelets. These building blocks are actually a family of functions which are derived from a single generating function called the mother wavelet by translation and dilation operations. Dilation, also known as scaling, compresses or stretches the mother wavelet and translation shifts it along the time axis [5, 7, 8, 11, 12].The WT can be categorized into continuous and discrete.

### A. Continuous wavelet transform

Continuous wavelet transform is described by [29]

$$CWT(a, b) = \int_{-\infty}^{\infty} x(t) \varphi^*_{a, b}(t) dt \quad (1)$$

Where  $x(t)$  represents the analyzed signal,  $a$  and  $b$  represent the scaling factor (dilatation/compression coefficient) and translation along the time axis (shifting coefficient), respectively, and the superscript asterisk denotes the complex conjugation is obtained by scaling the wavelet at time  $b$  and scale  $a$ .

### B. Discrete Wavelet Transform

DWT as a wavelet transform with a discrete time mother wavelet, integer dilation parameter and a discrete translation parameter. The DWT, which is based on sub-band coding, is found to yield a fast computation of wavelet transform. It is easy to implement and reduce the computational time. In the case of DWT, a time scale representation of the digital signal is obtained using digital filtering techniques. DWT is performed by repeated filtering of the input signal using two filters. These filters are a low pass filter (LPF) and a high pass filter (HPF) to decompose the signal into different scales. The output coefficient obtained by LPF is the approximation coefficients. The coefficient obtained from HPF is detailed coefficient. The process of decomposition shown in fig.5 [12].

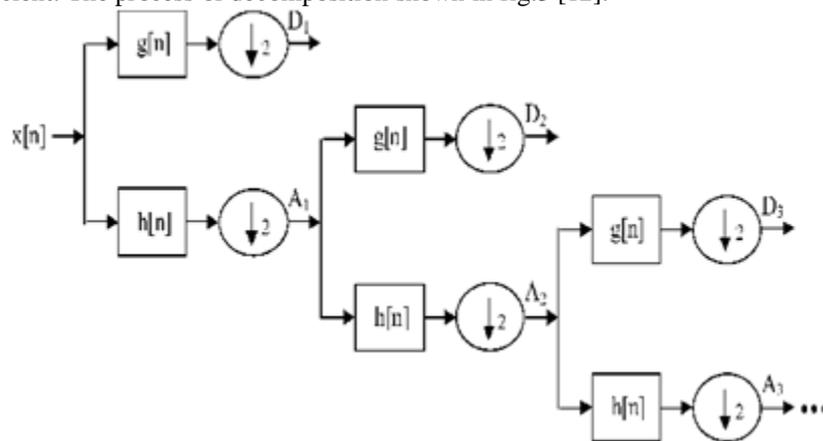


Fig. 5. Sub-band Decomposition of Discrete Wavelet Transform Implementation;  $g[n]$  is the high pass filter,  $h[n]$  is the low pass filter

The general equation for the DWT signal is written as [29]

$$X[a, b] = \sum_{n=-\infty}^{\infty} x(n) \varphi_{a, b}(n) \quad (2)$$

Where  $x(n)$  is the input signal to be transformed and [29]

$$\varphi_{a, b}(n) = \frac{1}{\sqrt{a}} \varphi\left(\frac{n-b}{a}\right) \quad (3)$$

In DWT, the function represents a window of finite length, where 'b' is a real number known as window translation parameter and 'a' is a positive real number named as dilation or contraction parameter.

Since DWT satisfies the energy conservation law and original signal can be properly reconstructed via employing it, DWT popular in ECG denoising and feature extraction technique.

### C. Daubechies Wavelet $D_p$

Daubechies wavelets are family of orthogonal discrete wavelet transform and characterized by maximal number of vanishing moments for a given support. Daubechies orthogonal wavelets from D2-D20 are commonly used and D4, D6, D8 are the most common. The index number refers to the number of moments. The number of vanishing moments is equal to the half of the number of coefficients.

### D. Thresholding

Significant wavelet coefficients from different levels are selected to reconstruct the denoised signal. Selection of those wavelet coefficients is done through thresholding process [28]. There are two types of thresholding method are used in Wavelet Transform soft and hard thresholding. Let  $T$  denotes the threshold. The hard threshold signal is  $x$  if  $|x| > T$ , and is 0 if  $|x| < T$ . the soft threshold signal is  $s(x) = (x - T)$  if  $|x| > T$  and is 0 if  $|x| < T$ . performance of the denoising process depends on the type of thresholding method [28].

## IV. METHODOLOGY

The methodology is defined in the following steps:-

- A signal is loaded.
- A signal is smoothened by median filter with different corresponding neighborhood values.
- Transform the signal using DWT.

- To achieve an adaptive threshold compute the maximum value of the transform coefficients.
- Then thresholding is applied to remove the noise present in the signal.
- Apply inverse transform to get the reconstruct signal.
- After that PSNR and MSE are computed to compare the wavelet used.

### V. PERFORMANCE PARAMETERS

- Mean Square Error (MSE) – it is estimated between the de-noised ECG signal and original ECG signal given by equation [12].

$$mse = \frac{1}{N} \sum (k(n) - l(n))^2 \quad (4)$$

- Peak Signal to Noise Ratio(PSNR) – it is defined as the ratio of the variance of the noise free signal to the mean squared error between the noise free signal and de-noised signal. PSNR given by equation [12].

$$psnr = 10 * \log_{10} \left( \frac{255^2}{\left(\frac{1}{N}\right) \sum (k(n) - l(n))^2} \right) \quad (5)$$

### VI. RESULTS

To evaluate our denoising algorithm we have proposed a new adaptive method using wavelet transform. We have used two different ECG data records of 7200 samples with same sampling frequency. The data base has been collected from MIT-BIH arrhythmias data base taken from physionet. Baseline wandering noise is used as the noise source and embedded in the ECG signal. The db (Daubechies) mother wavelet function is used in the DWT process for this work. We have considered the 3<sup>rd</sup> level decomposition for this algorithm; it depends upon the filtering process. The MATLAB software is used for the processing. The resulting waveforms are shown for wavelet db2 below and their resulting PSNR and MSE values are shown in table given below for median filtering for their different neighborhood values for signal decomposition.

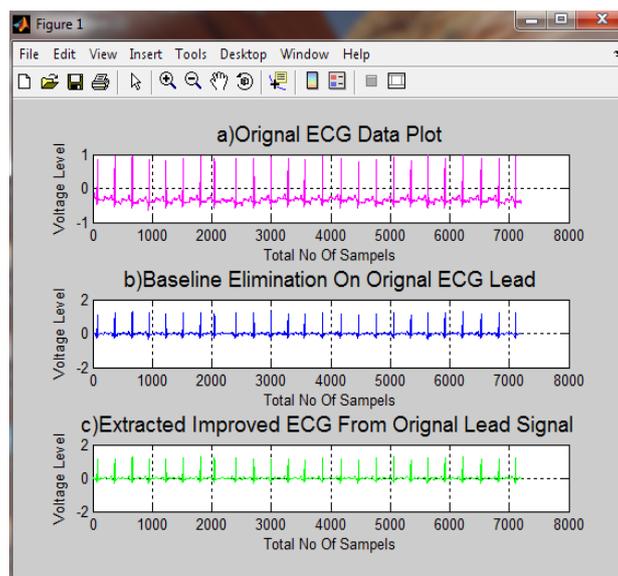


Fig. 6. ECG\_1 (original signal, noised signal, reconstructed signal)

Table I MSE Value For Sample 1

Corresponding neighborhood of median filter	[1 1]	[2 2]	[3 3]
Before Denoising	0.0736	0.1998	0.3501
After Denoising	0.3191	0.1631	0.0724

Table II PSNR Value For Sample 1

Corresponding neighborhood of median filter	[1 1]	[2 2]	[3 3]
Before Denoising	59.4622	55.1246	52.6892
After Denoising	53.0909	56.0058	59.5348

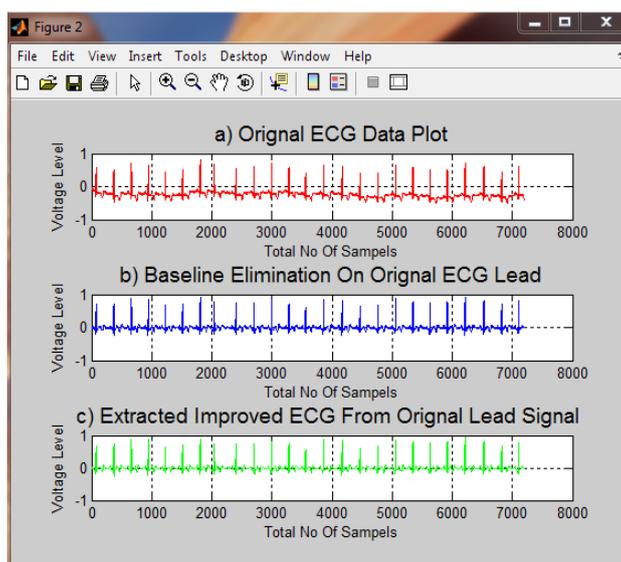


Fig. 7. ECG\_2 (original signal, noised signal, reconstructed signal)

Table III MSE Values For Sample 2

Corresponding neighborhood of median filter	[1 1]	[2 2]	[3 3]
Before Denoising	60.7133	56.5204	54.0351
After Denoising	54.3739	57.2924	60.8290

Table IV PSNR Value For Sample 2

Corresponding neighborhood of median filter	[1 1]	[2 2]	[3 3]
Before Denoising	0.0552	0.1449	0.2568
After Denoising	0.2375	0.1213	0.0537

## VII. CONCLUSION

In this work we have analyzed a very important signal, the electrocardiography by applying an advanced filtering tool called discrete wavelet transform. A new threshold and Bayesian shrinkage functions are used to de-noise the noisy ECG signal efficiently to keep it distortion free and smooth. From simulation result we can observe that the wavelet transform can remove the noise effectively and improve the PSNR and reduce the RMSE. The experimental results indicate that the proposed method is better than traditional de-noising method in the aspect of remaining geometrical characteristics of ECG signal and in improvement of PSNR and MSE. From our result we evaluate that the more precise value of error is calculated by taking [3 3] neighborhood values for median filtering than the DWT gives the best result after denoising the signal as compares to before denoising. When we taking [1 1] neighborhood value than it shows the results are given by DWT are not good after denoising. It means that the more precisely we calculate the error than the wavelet gives the best performance.

## ACKNOWLEDGEMENT

We sincerely extend our thanks to each and every member of the staff in the Department of Electronics & communication, College of Baddi University of Emerging Science and Technology, who guided us and rendered their full cooperation.

## REFERENCES

- [1] Donoho D.L., "De-noising by soft-Thresholding", IEEE Trans. Inform. Theory, vol. 41, no. 3, pp. 613-627, May 1995.
- [2] Mehmet Ustundag, Muammer Go kbulut, Abdulkadir Sengur, Fikret Ata, "Denoising of weak ECG signals by using wavelet analysis and fuzzy thresholding", Net Model Anal Health Inform Bioinforma, 2012.
- [3] Xu Huang, Sheikh Md. Rabiul Islam and Dharmendra Sharma, "Wavelet Based De-noising Algorithm of the ECG Signal Corrupted by WGN and Poisson Noise", International Symposium on Communications and Information Technologies, pp. 165-168, 2012.

- [4] P. Ghorbanian, A. Ghaffari, A. Jalali, C. Nataraj, "Heart Arrhythmia detection Using Continuous Wavelet Transform and Principal Component Analysis with Neural Network Classifier", *Computing in Cardiology*, pp. 669-672, 2010.
- [5] Gordana Cornelia, Reiz Romulus "ECG Signal Processing Using Wavelets".
- [6] JS Sorensen, L Johannesen, USL Grove, K Lundhus, J-P Couderc, C Graff, "A Comparison of IIR and Wavelet Filtering for Noise Reduction of the ECG", *Computing in Cardiology*, pp. 489-492, 2010.
- [7] Ms.Yamini, S.Bute, Prof. R.W. Jasutkar, "Implementation of Discrete Wavelet Transform Processor for Image Compression", *International Journal of Computer Science and Network*, vol. 1, issue 3, June 2012.
- [8] Zhi-Dong Zhao Yu-Quan Chen, "A New Method for Removal of Baseline Wander and Power Line Interference in ECG Signal", *Machine Learning and Cybernetics, International Conference*, 10.1109/ ICMLC, 04 March 2009.
- [9] Karishma Qureshi, Prof. V. P. Patel, "Efficient Data Compression of ECG signal using Discrete Wavelet Transform", *International Journal of Research in Engineering and Technology*, vol. 2, issue 4, pp. 696 – 699, April 2013.
- [10] Hari Mohan Rai and Anurag Trivedi, "De-noising of ECG Waveforms based on Multi-resolution Wavelet Transform", *International Journal of Computer Applications*, vol. 45, no.18, pp. 25-30, May 2012.
- [11] Mrs.S.O.Rajankar and Dr. S.N. Talbar, "An Optimized Transform for ECG Signal Compression", *ACEEE Int. J. on Signal & Image Processing*, vol. 01, no. 03, pp. 33-36, Dec. 2010.
- [12] Inderbir Kaur, Rajni, Gaurav Sikri, "Denoising of ECG Signal with Different Wavelet", *International Journal of Engineering Trends and Technology*, vol. 9, no.13, pp. 658-661, March 2014.
- [13] S.Z. Mahmoodabadi, A.Ahmadian, M.D. Abolhasani, "ECG feature Extraction using Daubechies Wavelets", *Proceeding of the fifth International conference on Visualization*, *Imaging and Image Processing*, pp-343-349, Sept. 7-9, 2005.
- [14] S.A.Choukari, F.Bereksi-Reguing, S.Ahmaidi and O.Fokapu, "ECG signal smoothing based on combining wavelet Denoising levels". *Asian Journal of Information Technology* 5(6), pp 666 - 77, 2006.
- [15] M.Kania, M.Fereniec, R. Maniewski, "Wavelet Denoising for Multi Lesd High Resolution ECG Signal", *Measurement Science Review*, vol. 7, section 2, no. 4, pp-30-33, 2007.
- [16] Abdel-Rehman, Al-Quwasm, Khaled Daqrouq, "ECG signal enhancement using Wavelet Transform", *WSEAS Transaction on Biology and Biomedicine*, issue 2, vol.7, pp-62-72, April 2010.
- [17] TAN Yun-fu, Du Lei, "Study on Wavelet Transform in the Processing for ECG Signals", *World conference on Software Engineering, IEEE*, p 515-518, 2009
- [18] S A Chouakri, F Bereksi-Reguig, S Ahmaidi, O Fokapu, "Wavelet Denoising of the Electrocardiogram Signal based on the Corrupted noise estimation", *Computers in Cardiology, IEEE* vol.32,pp 1021-1024 , 2005
- [19] Rohit Shag, Rakesh Sharma, Varun Setia, "Wavelet Thresholding for Image De-noising", *International Conference on VLSI communication & Instrumentation*, pp 20-24, 2011.
- [20] Fayyaz A Afsar and M. Arif, "Robust Electrocardiogram Beat classification using Discrete Wavelet Transform", *IEEE*, 978-1-4244-1748-3/08, pp.-1867-1869, 2008.
- [21] Abed Al Raouf Bsoul, Soo-Yeon Ji,Kelvin Ward and Kayvan Najarian, " Detection of P, QRS and T components of ECG using Wavelet Transformation", *IEEE* ,78-1-4244-3316-2/09,pp.1-5, 2009.
- [22] SYamini, S.Bute, Prof. R.W. Jasutkar, "Implementation of Discrete Wavelet Transform Processor for Image Compression", *International Journal of Computer Science and Network*, vol. 1, issue 3, June 2012.
- [23] Zhi-Dong Zhao Yu-Quan Chen, "A New Method for Removal of Baseline Wander and Power Line Interference in ECG Signal", *Machine Learning and Cybernetics, International Conference*, 10.1109/ ICMLC, 04 March 2009.
- [24] Nagendra H, S Mukherjee and Vinod Kumar, "Wavelet Based Non Linear Thresholding Techniques for Pre Processing ECG Signals", *International Journal of Biomedical and Advance Research*, pp. 534-544, 2013.
- [25] G.Aruna, Ch.Hima Bindu, BT Madhav "Denoising of Electrocardiogram Data with Wavelet Transform & Thresholding", *International Journal of Scientific & Engineering Research*, vol. 5, issue 12, December-2014.
- [26] Anas Fuad Ahmed, "A Comparative Study of ECG Signal Compression Techniques Using Various Transforms", *International Journal of Advanced Research in Computer Science and Software Engineering*,vol. 5, issue 6, pp 60-64, June 2015.
- [27] Juhi Sharma, Prof. Neha Verma, "ECG Signal De-Noising Techniques: A Review",*International Joournal Of Engineering Research and General Science*, vol. 4, issue 1, Jan.-Feb. 2016.
- [28] Chitrangi Sawant, Harishchandra T. Patil, "Wavelet based ECG signal De-noising", *First International Conference on Networks & Soft Computing*,2014.
- [29] Seena V, Jerrin. Yomas, "A Review on Feature Extraction and Denoising of ECG signal using Wavelet Transform", *2<sup>nd</sup> International Conference on Devices, Circuits and System*, 2014.
- [30] www.physionet.org