

Denoising of ECG Signal with Different Wavelets

Inderbir Kaur^{#1}, Rajni^{#2}, Gaurav Sikri^{#3}

¹Research Scholar, Department of Electronics and Communication Engineering, SBSSTC, India

²Associate Professor, Department of Electronics and Communication Engineering, SBSSTC, India

³Assistant Professor, Department of Electronics and Communication Engineering, LLRIET, India

Abstract— ECG signal gives vast information about the heart's activity. But it often gets contaminated with noises hence needed to be denoised. In this paper Discrete Wavelet Transform is used to denoise the signal. It also shows a comparison between wavelets used through the performance parameters.

Keywords— Electrocardiogram (ECG), Wavelet Transform.

I. INTRODUCTION

The Electrocardiogram (ECG) is a simple and reliable investigation method that provides a large amount of information about the heart [1]. Electrocardiogram is the electrical activity of the heart. It is a graphical demonstration of the deviation of bio-potential versus time. The leads are placed on precise locations of the body of the person to record ECG either on graph paper or on monitors. The human heart contains four chambers i.e., Right Atrium, Left Atrium, Right Ventricle and Left Ventricle. The upper chambers are the two Atria's and the lower chambers are the two Ventricles. Under healthy condition the heartbeat begins at the Right Atrium called Sino Atria (SA) node and a particular group of cells send these electrical signals across the heart. This signal travels from the Atria to the Atrio Ventricular (AV) node. The AV node connects to a group of fibers in Ventricles that conducts the electrical signal and transmits the impulse to all parts of the lower chamber, the Ventricles. To ensure that the heart is functioning correctly this path of propagation must be traced accurately [2].

II. ECG WAVEFORM

The ECG signal is distinguished as a combination of P Q R S T U waves. The P wave represents the sequential activation (depolarization) of the upper chambers of the heart i.e. right and left atria. Then it is followed by the QRS-complex that illustrates the ventricular depolarization. T wave is present at the end of each single-cycle ECG signal, and the return to its resting state-ventricular repolarization is depicted by T- wave. There is another wave known as U-wave which may be present in the ECG signal but its origin is not clear [3]. The typical ECG wave is shown in figure 1:

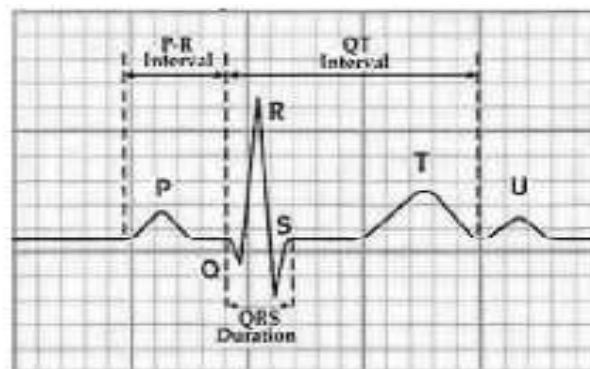


Fig1. ECG waveform [4]

One of the elementary subjects in analysis of ECG signal is the detection of QRS complex. The Q, R and S are three typical points in the QRS complex. It is examined as the most prominent waveform and is used as starting point for further analysis or processing. QRS complex is not difficult to detect but in case of noisy or highly variable signals the accurate level of detection decreases [5]. A typical ECG signal has the amplitude values as following: P-wave 0.25 mV, R-wave 1.6mV, Q-wave 25% of the R-wave, T-wave 0.1 to 0.5 mV; the time interval values: PR-interval 0.12-0.2s, QRS complex 0.04 to 0.12s, and QT interval < 0.42s and the usual range of heart beat is 60-100 beats/min [6].

III. WAVELET TRANSFORM

Wavelet Transformation is a linear process that involves the decomposition of a signal into components that appears at different scales (or resolutions) [7]. The Wavelet Transform is two- dimensional in time and frequency and allows the analysis of data in both domains at the same time. It provides a time- frequency graphical representation of the ECG signal at different scales with different resolutions [8].

There are two types of Wavelet Transform: Continuous & Discrete Wavelet Transform

A. Continuous Wavelet Transform:

The CWT is formally written as:

$$CWT(m, n) = \int_{-\infty}^{+\infty} x(t)\varphi * (m, n)dt \quad \dots\dots\dots (1)$$

where x(t) represents the analyzed signal, m and n symbolize the scaling factor (dilatation/compression coefficient) and translation along the time axis (shifting coefficient),

respectively, and the superscript asterisk depicts the complex conjugation.

B. Discrete Wavelet Transform:

The DWT is formally written as:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi(t - b)/a \dots\dots\dots (2)$$

The DWT is used because of major advantage that it provides good time resolution at high frequency and better frequency resolution at low frequency [9]. The method of multiresolution decomposition of a signal $x[n]$ is shown in figure 2. Each step of this method contains two digital filters and two down samplers. The first filter, $g[n]$ is the discrete mother wavelet that is high-pass in nature, and the second, $h[n]$ represents its mirror version, low-pass in nature. The down sampled outputs of high-pass and low-pass filters give the detail, D_1 and the approximation, A_1 , coefficients respectively. The approximation, A_1 is further decomposed and this process continues as shown in figure 2:

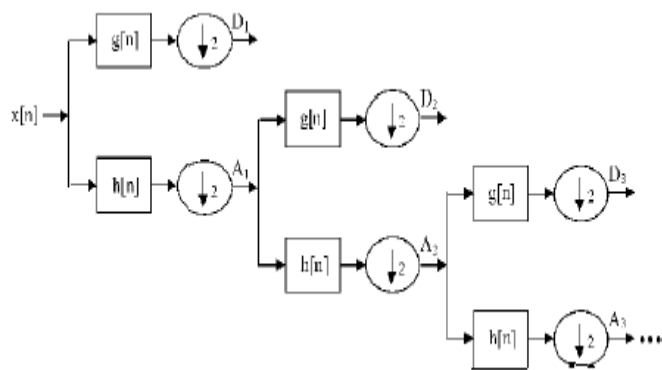


Fig 2. Decomposition of ECG signal [10]

IV. NOISES IN ECG SIGNAL

ECG recordings, used for cardiovascular diagnosis are obtained by a non-invasive procedure that is a rapid and risk-free method. The proper analysis of information extracted from ECG recording requires accurate detection of waveform morphologies [11]. This electrophysiological signal gets often contaminated by different noise sources such as muscle noise, respiration, or electrode artifacts [12]. The various noises introduced in ECG signal are:

A. Powerline interference

In case of current sources electromagnetic field is generated that acts as noise in ECG signal. It is represented as a 50 or 60 Hz sinusoidal interference along with the generation of harmonics. Such noise is narrowband in nature and it makes it difficult the analysis and further processing of ECG signal [13].

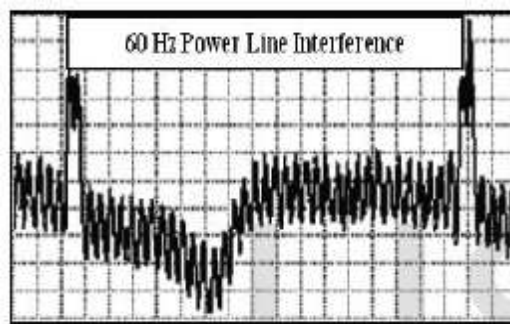


Fig 3. 60 Hz Powerline interference [14]

B. Contact noise

Whenever there is loss of contact between the electrode and the skin, contact noise occurs. It leads to disconnection of the measurement system and generates large artifacts. The characteristics of this noise signal comprise of the amplitude of the first transition, the amplitude of the 60 Hz component and the regular time of the decay [14].

C. Baseline wander

Baseline wandering is one of the noise artifacts that have an effect on ECG signals. This wandering is caused by:

- Movement of the patient or breathing
- Vibrations near to patient and machine
- Vibrations of the mobile phone or drill machine
- Any metallic item present near the chest or near electrode.
- Improper placement of electrodes.

Baseline wandering noise can change certain characteristics of the ECG signal; hence it should be removed for further processing [15].

D. Muscle tremor/noise

The heart is not the only that produces considerable electricity. When your skeletal muscles undergo vibration, the ECG is bombarded with seemingly random activity. The word noise does not refer to sound but rather to electrical interference. Muscle noise or tremors are often a lot more delicate than that shown in figure 4 [16].

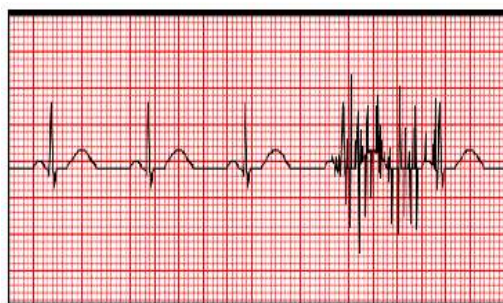


Fig 4. Muscle tremor

V. METHODOLOGY

The methodology is defined in following steps:

- Random noise is generated and added to the signal.

$$P = q + r \quad \dots\dots (3)$$

q= original signal
r= random noise
- Baseline drift is removed using the smoothening filter.
- Then the signal is decomposed at the 10th level of decomposition.
- Then thresholding is applied to remove all the noises present in the signal.
- Different wavelets are used for the Wavelet Transform method.
- Evaluation measures i.e. SNR, PSNR, MSE, PRD are computed to compare the wavelets used.

VI. PERFORMANCE PARAMETERS

- Signal to Noise Ratio (SNR):

k (n) = original signal
l (n) = denoised signal

$$snr = 10 * \log_{10} \left(\frac{\text{var}(l(n))}{\text{var}(k(n) - l(n))} \right) \quad \dots\dots (4)$$

- Peak Signal to Noise Ratio (PSNR)

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

- Mean Square Error (MSE)

$$mse = 1/N \Sigma(k(n) - l(n))^2 \quad \dots\dots (6)$$

- Percentage Root Mean Square Difference (PRD)

$$prd = \sqrt{\Sigma(k(n) - l(n))^2 / \Sigma(k(n))^2} * 100\% \quad \dots\dots (7)$$

VII. RESULTS

The data used for denoising process is MIT-BIH Arrhythmia database taken from Physionet. The data is sampled at frequency of 360 Hz and is stored in a 212 format [17]. The MATLAB software is used for the processing. The sample number 116 in text form is used for denoising. The resulting waveforms are shown for Wavelet bior3.1 below:

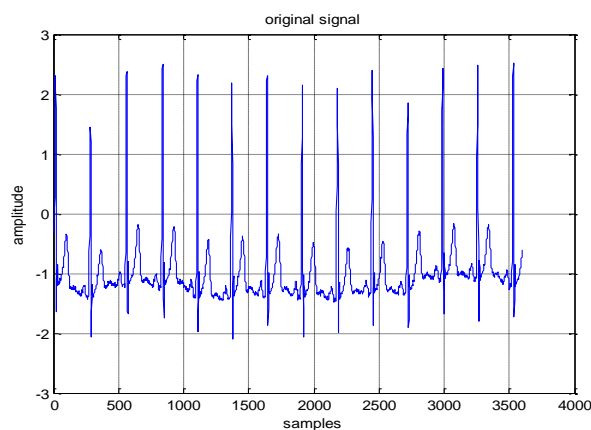


Fig 5. Original signal

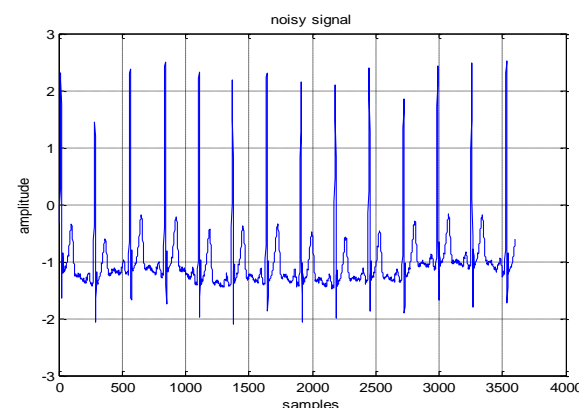


Fig 6. Noisy signal

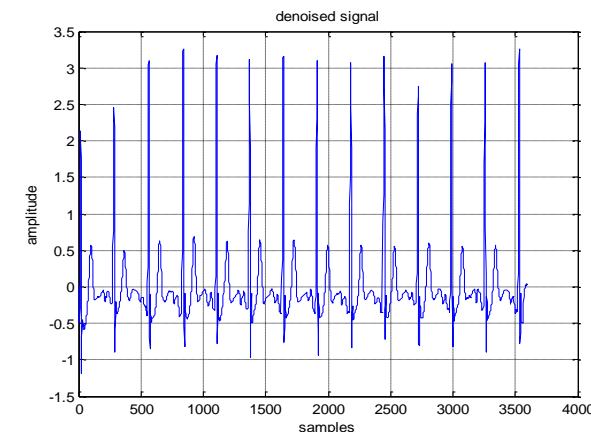


Fig 7. Denoised signal

The comparison between wavelets is shown in tabulated form as:

TABLE I

WAVELET	SNR (db)	PSNR	MSE	PRD (%)
Db1	8.9661	48.2239	0.9788	37.4283
Db2	8.9756	48.2212	0.9794	37.4521
Db3	9.0024	48.2216	0.9793	37.4480

Db4	9.0006	48.2214	0.9793	37.4497
Db5	8.9572	48.2178	0.9802	37.4812
Db6	9.0213	48.2250	0.9785	37.4189
Db7	8.9924	48.2230	0.9790	37.4359
Db8	8.9611	48.2195	0.9798	37.4660
Db9	8.9814	48.2132	0.9812	37.5211
Db10	8.8925	48.2098	0.9820	37.5498
Db12	8.8988	48.2099	0.9819	37.5489
Db20	8.8530	48.2103	0.9819	37.5456
Bior1.3	8.9394	48.2194	0.9798	37.4673
Bior2.8	9.1337	48.2240	0.9788	37.4276
Bior3.1	9.1534	48.2251	0.9785	37.4179
Bior3.7	9.1167	48.2211	0.9794	37.4528
Bior4.4	9.0002	48.2203	0.9796	37.4591
Bior5.5	8.8911	48.2172	0.9803	37.4858
Bior6.8	9.0178	48.2247	0.9786	37.4211
Coif2	9.0160	48.2201	0.9797	37.4613
Coif4	8.9799	48.2136	0.9811	37.5171
Sym2	8.9405	48.2207	0.9795	37.4563
Sym3	9.0028	48.2216	0.9793	37.4486
Sym4	8.9906	48.2190	0.9799	37.4711
Sym5	8.9915	48.2183	0.9801	37.4770
Sym6	8.9732	48.2196	0.9798	37.4656
Sym7	8.9535	48.2231	0.9790	37.4354
Sym8	9.0148	48.2199	0.9797	37.4629

VIII. CONCLUSION

In this paper we have shown comparison between Wavelets. According to performance parameters calculated it is shown that the Bior3.1 Wavelet is better than other due to higher PSNR, lower MSE and PRD than other wavelets.

REFERENCES

- [1] Jonas Carlson, Rolf Johansson, and S. Bertil Olsson, "Classification of Electrocardiographic P-Wave Morphology", *IEEE Transactions on Biomedical Engineering*, VOL. 48, NO. 4, pp 401-405, April 2001.
- [2] Rajni and Inderbir Kaur, "Electrocardiogram Signal Analysis - An Overview", *International Journal of Computer Applications*, Vol. 84, No 7, pp 22-25, December 2013.
- [3] Adam Jós'ko and Remigiusz J. Rak, "Effective Simulation of Signals for Testing ECG Analyzer", *IEEE Transactions on Instrumentation and Measurement*, Vol. 54, No. 3, pp 1019-1024, June 2005,
- [4] Jyothi Singaraju and K.Vanisree, "Automatic Extraction of ECG Features Using Discrete Wavelet Transform", *International Journal of Societal Applications of Computer Science*, Vol2, Issue 6, pp 418-423, June 2013.
- [5] P. Sasikala and Dr. R.S.D. Wahidabanu, "Robust R Peak and QRS detection in Electrocardiogram using Wavelet Transform", *International Journal of Advanced Computer Science and Applications*, (IJACSA), Vol. 1, No.6, pp 48-53, December 2010.
- [6] Vanisree K and Jyothi Singaraju, "Automatic Detection of ECG R-R Interval using Discrete Wavelet Transformation", *International Journal on Computer Science and Engineering (IJCSE)*, Vol. 3 No. 4, pp 1599-1605, Apr 2011
- [7] J.S. Sahambi, S.N. Tandonz and R.K.P. Bhatt, "Using Wavelet Transforms for ECG Characterization", *IEEE Engineering in Medicine and Biology*, pp 77-83, January/February 1997.
- [8] Mariana Moga, V.D. Moga and Gh.I. Mihalas, "Continuous Wavelet Transform in ECG Analysis. A Concept or Clinical Uses", *Educational Technologies and Methodologies*, 2005.
- [9] Upasani Dhananjay E. and Dr. R. D. Kharadkar, "Detection of Myocardial Infarction Using Wavelet Transform", *International J. Of Recent Trends in Engineering and Sciences*, Vol. 2, Issue 4, pp 103-107.
- [10] Ruqaiya Khanam and Syed Naseem Ahmad, "Selection of Wavelets for Evaluating SNR, PRD and CR of ECG Signal", *International Journal of Engineering Science and Innovative Technology (IJESIT)*, Volume 2, Issue 1, pp 112-119, January 2013.
- [11] Omid Sayadi and Mohammad Bagher Shamsollahi, "ECG Denoising and Compression Using a Modified Extended Kalman Filter Structure", *IEEE Transactions on Biomedical Engineering*, Vol. 55, No. 9, pp 2240-2248, September 2008.
- [12] Julien Oster, Olivier Pietquin, Michel Kraemer, and Jacques Felblinger, "Nonlinear Bayesian Filtering for Denoising of Electrocardiograms Acquired in a Magnetic Resonance Environment", *IEEE Transactions on Biomedical Engineering*, Vol. 57, No. 7, pp 1628-1638, July 2010.
- [13] V. Viknesh and P. Ram Prashanth, "Matlab Implementation of ECG signal processing", *IOSR Journal of VLSI and Signal Processing*, Vol.3, Issue 1, pp40-47, Sep-Oct 2013.
- [14] Snehal Thalkar and Prof. Dhananjay Upasani, "Review Paper...Various Techniques for Removal of Power Line Interference from ECG Signal", *International Journal of Scientific & Engineering Research*, Volume 4, Issue 12, pp 12-23, December-2013.
- [15] Mrs. V. R. Lele and Prof. K. S. Holkar, "Removal of Baseline Wander from ECG Signal", *International Conference on Recent Trends in engineering & Technology – 2013*, pp60-65, Feb 2013.
- [16] Amit Kumar Manocha and Mandeep Singh, "Improved Method for ECG Denoising Using Wavelet Transform", *2nd International Conference on Biomedical Engineering & Assistive Technologies*, pp 247-251, 6-7 December 2012
- [17] <http://www.physionet.org/>