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Denoising Of Electrocardiogram Data With Wavelet Transform & Thresholding

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Abstract— Electrocardiography (ECG) signals are important in medical engineering to determine the condition of the heart. The proper **processing** of ECG signal and its accurate detection is very much essential for easy diagnosis. Generally ECG gets corrupted by noise and human artifacts. The denoising of this signal is very important issue in medical field. In this proposed work concentrated on denoising of ECG signal from white Gaussian noise using wavelet transform. Initially the noisy signal is transformed using wavelet transform to generate approximate and detailed coefficients. These detailed coefficients are thresholded by soft thresholding to remove the white Gaussian noise. At last IDWT (Inverse Discrete Wavelet Transform) is applied on thresholded detailed coefficient and approximated coefficients to generate denoise ECG signal. Finally the performance of proposed method is evaluated with SNR (Signal to Noise Ratio) value, RMSE (Root Mean Square Error) value and correlation value and compared among various wavelet families.

Index Terms— Introduction, Electrocardiogram, Discrete wavelet transform, Proposed method, Denoising process, Results, Conclusion

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1 INTRODUCTION

An Electrocardiogram (ECG) is a test used to determine the condition of the heart. This activity is recorded on graph sheets by placing the electrodes on specific locations of the body of a person. Electrocardiogram (ECG) is the outcome of electrical potentials in heart. It is recorded by placing electrodes on the skin and it consists of various points in it and those are P-QRS-T. The original ECG signal from recorded of human body is always corrupted by several sources of noises. Noise and then signal is reconstructed. The noise reduction in electrocardiography signals is one of the important problems, which appear during the analysis of ECG data. ECG signal is non-stationary biological signal in nature and plays a big role in diagnostics of human diseases. Therefore the electrocardiography signals need an effective denoising [2]. We are using wavelet transform to remove noise from the ECG signal because of its good localization properties. The threshold values are used to smooth out or to remove some detailed wavelet coefficients of the original signal. The obtained noiseless signal is then reconstructed in time domain using the modified coefficients.

Abdel-Reman, et.al., [5] used the high pass filtering for noisy signal before reconstruction by inverse discrete wavelet transform (IDWT).This algorithm is very robust for noise removal and it does not smoothens QRS complex. Ruchitha Goutham, et.al, [6] have demonstrated the application of DyWT for QRS complex detection. Naregalkar Akshay, et.al., [7] demonstrated the application of UWT for base line wonder removal and QRS morphology detection in LABVIEW environment. Antonio, et.al, [8] Used wavelet transform to detect the R-wave and wavelet segmentation approach for the extraction of ECG features.
In Nagendra H , et.al., 9] is used different types of wavelet transforms for the processing of ECG signals.In Galya Georgieva-Tsaneva.,et.al., [10]is used denoising of electrocardiogram with methods of wavelet transform .In Reema , et.al., [11] used denoising of ECG signal with wavelet transform and soft thresholding.

2 ELECTROCARDIOGRAM

An electrocardiogram (ECG) is a simple, painless test that records the heart's electrical activity. To understand this test, it helps to understand how the heart works. With each heartbeat, an electrical signal spreads from the top of the heart to the bottom. As it travels, the signal causes the heart to contract and pump blood. The process repeats with each new heartbeat. The heart's electrical signals set the rhythm of the heartbeat. An ECG shows:

How fast your heart is beating. Whether the rhythm of your heartbeat is steady or irregular. The strength and timing of electrical signals as they pass through each part of your heart [15]

Heart is a muscle tissue that pumps blood into body [12]. The electrocardiogram (ECG) is the recording of the heart's electrical potential versus time [13].Internal conduction system of heart is responsible for the generation of ECG.ECG signals are as given below.

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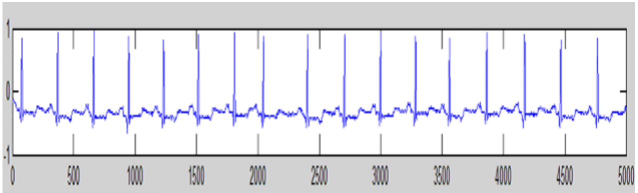

Fig. 1 Original ECG signal

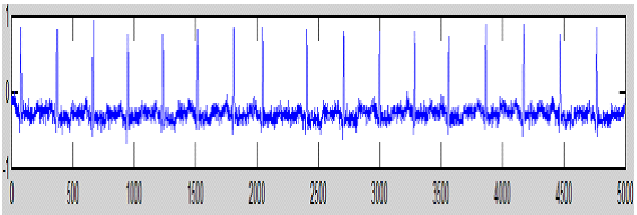

Fig. 2 Noisy ECG signal

Deflections shown in ECG reflect the electrical activity of heart causing muscle contraction [1].P-QRS-T, each of these points have particular and fix amplitudes and frequencies.

3 DISCRETE WAVELET TRANSFORM

Wavelet is a mathematical microscope used for the analysis of signals and images. It is the time-frequency approach for the analysis of signals [3].Wavelet transforms are based on small wavelets with limited duration [3]. The wavelet transform decomposes signals over dilated and translated wavelets [3].A wavelet is function ϕ which belongs to L^2(R) with a zero:

$$\int_{-\alpha}^{\alpha} \phi(t)dt = 0 \qquad (1)$$

The forward DWT coefficients for sequence f (n):

$$w(j_0,k) = 1/\sqrt{m} \sum_n f(n)\phi_{j,k}(n) \qquad (2)$$

$$w(j,k) = \frac{1}{\sqrt{m}} \sum_n f(n)\psi_{j,k}(n) \qquad for j >= j_0 \qquad (3)$$

The $\phi_{j0,k}(n)$ and $\psi_{j,k}(n)$ in these equations are sampled versions of basis functions $\phi_{j0,k}(x)$ and $\psi_{j,k}(x)$.

In accordance with the complementary inverse DWT is

$$f(n) = \frac{1}{\sqrt{m}} \sum_k w\phi(j_0,k)\phi_{j0,k}(n) +$$

$$\frac{1}{\sqrt{m}} \sum_{j=j_0}^{\alpha} \sum_k w\psi(j,k)\psi_{j,k}(n) \qquad (4)$$

Normally, we let $j_0 = 0$ and select m to be a power of 2. [16]

4 PROPOSED METOD

1. Read ECG signal from [4].
2. Add white Gaussian noise on above signal.
3. Apply DWT on noisy ECG signal using various wavelet families like Haar ,db2, db4, db6, db8 etc…..
4. Let consider detail coefficients (d) of the wavelet coefficients for denoising process.
5. The following denoising process is applied over detail coefficients (d) to remove the noise.
6. Apply inverse DWT to the above values to achieve less noisy ECG signal.

5 DENOISING PROCESS

The denoising process on noisy image initially computes threshold value by using following equations:

$$m = \frac{\max(d) + \min(d)}{2} \qquad (5)$$

$$s = \frac{m}{0.6745} \qquad (6)$$

$$\text{Threshold} \quad t = s\sqrt{2\log N} \qquad (7)$$

Where N is size of the signal. Now apply threshold conditions below

$$d_{ij} = dij \text{ if } d_{ij} >= t \qquad (8)$$

$$0 \text{ Otherwise}$$

The flow chart of the proposed method is given below

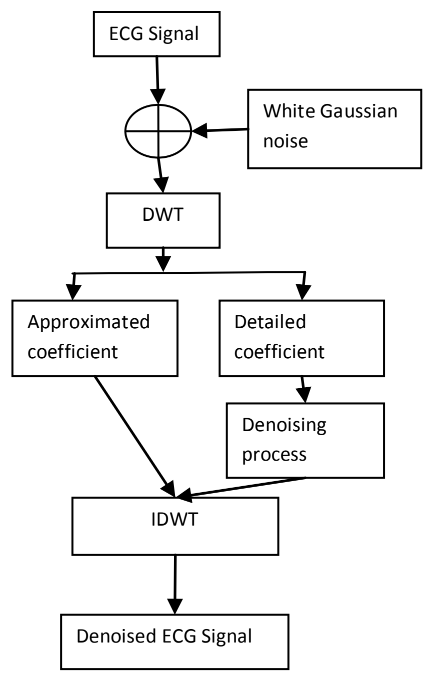

Fig. 3 Flow Chart of Proposed Method

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6 RESULTS

This paper proposes a new relation to finding the threshold value. Evaluation of many signals for validity is required. The proposed algorithm is tested on AHA (American Heart Association) ECG database [14]. This database contains a set of ECG data records sampled at a rate of 360 Hz with 11 bit resolution over a 10 mV range. The studied original ECG signal (with the number of a sample points N=1024) is shown in Figure 4. In this research the orthogonal wavelet functions: Haar, Daubechies: Db4, Db6, Db8, Db10, Db12 and Db20 are studied. Gaussian white noise is added to the original signal. The noisy ECG signal is shown in Figure 5. DWT is applied to the noisy signal. After determining the threshold value equations (6 to 8) the wavelet detail coefficients are filtering. The Inverse DWT is applied on the resultant approximate and detail coefficients, and denoised signal estimate is obtained. The reconstruction denoised ECG signal is shown in Figure 6.

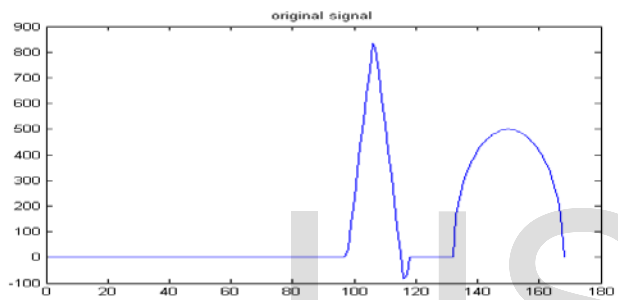

Fig: 4 Original ECG signal

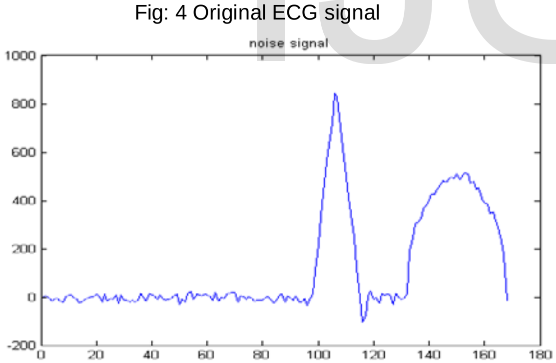

Fig:5 Noise ECG signal

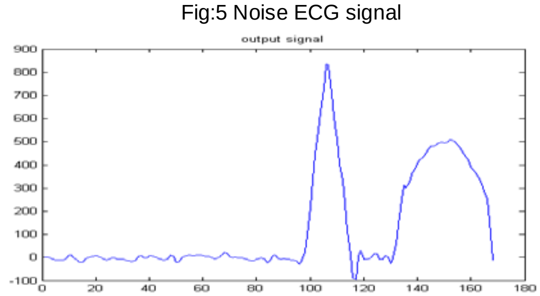

Fig: 6 Denoised ECG signal with proposed method.

The effectiveness of the proposed denoising process for different orthogonal wavelet basis functions has been tested is compared with existed method .the performance of proposed method is computed with SNR value, RMSE value and correlation value and compared with proposed method along with all wavelet families (shown in table).

Table 1: Denoising results of different wavelet basis using proposed method with Correlation Coefficient

wavelet family	Correlation Values	
	Existing Method[11]	Proposed Method
haar	0.9969	**0.9971**
db2	0.9981	**0.9984**
db4	0.9984	**0.999**
db6	0.9984	**0.9983**
db8	0.9981	**0.9985**
db10	0.9982	**0.9984**
db12	0.9983	**0.9986**
db20	0.9986	**0.9982**

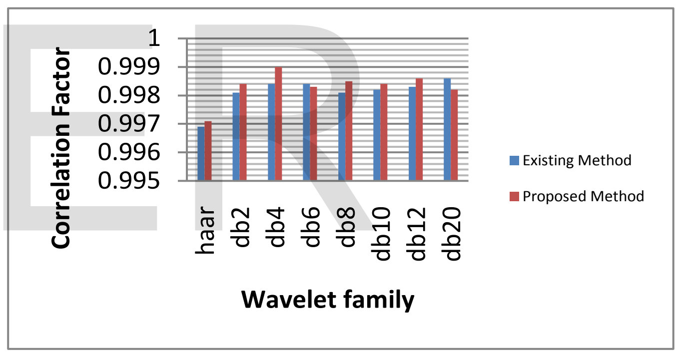

Fig 7: The Graphical representation of Table 1.

In the above graphical representation X-axis is wavelet family (haar, db2, db4, db6, db8, db10, db12 & db20) & Y-axis is correlation factor. The correlation function is defined as:

$$corr(A/B)=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(A_{i,j}-\bar{A})(B_{i,j}-\bar{B})}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(A_{i,j}-\bar{A})^{2}(B_{i,j}-\bar{B})^{2}}} \quad (9)$$

The value of correlation function towards 1 shows the better result for proposed method.

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Table 2: Denoising results of different wavelet basis using proposed method with Signal to Noise Ratio

wavelet family	SNR Values	
	Existing Method[11]	Proposed Method
haar	21.4476	**22.5066**
db2	20.9816	**22.6881**
db4	22.5586	**22.0377**
db6	22.0115	**20.7055**
db8	22.3797	**22.548**
db10	21.4459	**21.3946**
db12	20.3712	**24.2568**
db20	23.0253	**22.6116**

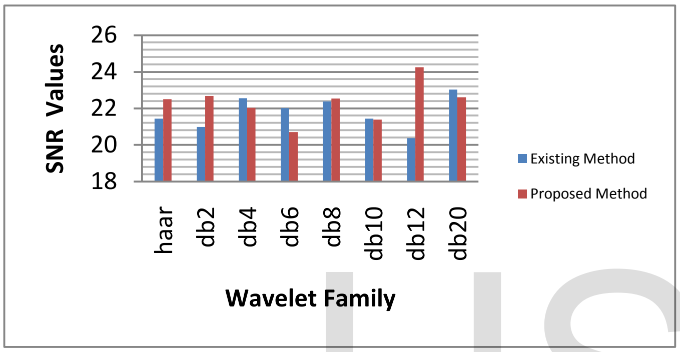

Fig 8: Graphical representation of Table 2.

In the above graphical representation X-axis is wavelet family (haar, db2, db4, db6, db8, db10, db12 & db20) & Y axis is SNR value. The SNR function is defined as:

$$SNR(dB) = 10 * \log_{10}\left[\frac{\frac{1}{M \times N}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)^2}{\frac{1}{M \times N}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left(f(m,n) - g(m,n)\right)^2}\right] \quad (10)$$

The higher value of SNR is shows the better result for proposed method.

Table 3: Denoising results of different wavelet basis using proposed method with Root Mean Square Error

wavelet family	RMSE	
	Existing Method[11]	Proposed Method
haar	0.7648	**0.0346**
db2	0.7315	**0.6734**
db4	0.2759	**0.2745**
db6	1.7243	**1.6437**
db8	0.947	**1.848**
db10	0.4849	**0.2992**
db12	1.057	**0.53**
db20	0.3875	**0.6337**

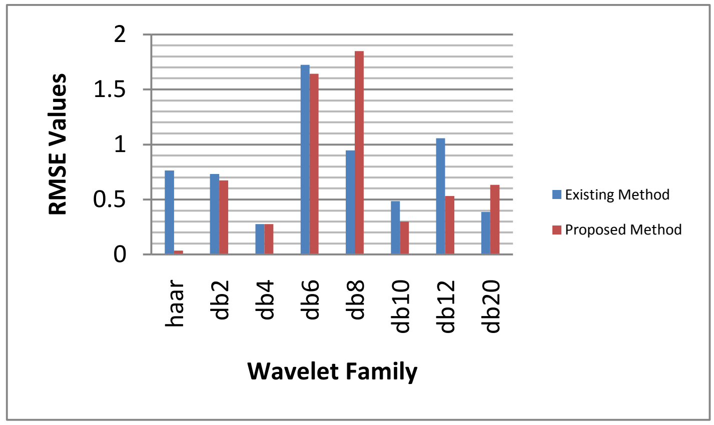

Fig 9: The Graphical representation of Table 3.

In the above graphical representation X-axis is wavelet family (haar, db2, db4, db6, db8, db10, db12 & db20) & Y-axis is RMSE. The RMSE function is defined as:

The RMSE for the reference image R and fused image F (both of size $M \times N$) are defined as follows.

$$RMSE = \sqrt{\frac{1}{M \times N}\sum_{m=1}^{M}\sum_{n=1}^{N}\left[R(m,n) - F(m,n)\right]^2} \quad (11)$$

Where $R(m,n)$ and $F(m,n)$ are the pixel value at position (m,n) of R and F, respectively. Smaller the values mean the better image quality.

7 CONCLUSION

The denoising of ECG signal with Discrete Wavelet Transform is proposed effectively in this paper. This work concentrated on computation of new threshold value to effectively filter out the Gaussian noise .With this the obtained denoised noised signal is more qualitative .The performance of proposed method is compared with existed method by computing SNR,RMSE and correlation value. The tabulated value shows the improperness of the proposed method. The Extension of this work is possible with changing of thresholding with advanced methods and working with multiscale wavelet coefficients.

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