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EMD-DWT Based ECG Denoising Technique using Soft Thresholding

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Abstract**:** ***Now a days ECG signal plays an important role in the primary diagnosis and analysis of cardiac diseases and abnormalities present in the heart. Due to the presence of artifacts, the analysis of the ECG is difficult. Therefore, undesirable noise and signals should be removed or eliminated from the ECG in order to ensure proper analysis and diagnosis. Denoising is the process***

s used to separate original ECG signal from noise to obtain desired noise-free signal. In this paper to eliminate Additive White Gaussian Noise (AWGN) a hybrid approach EMD-DWT (Empirical mode Decomposition-Discrete Wavelet Transform) is used. To measure the performance RMSE, SNR, PSNR and CC values are used and all the simulations are carried out using MATLAB.

Keywords : AWGN, ECG, EMD-DWT, Thresholding.

I. INTRODUCTION

Electrocardiograph (ECG) is the representation of activities of the heart like muscle contraction and extraction. This ECG signal should be free from noise, for the proper diagnosis of the heart diseases. But, during the acquisition of the ECG signal and transmission of the signal, it is corrupted by the different types of noises like power line interference, baseline wander, Additive White Gaussian Noise (AWGN) and also due to the internal movements of the human body like Electromyogram (EMG). So the denoising should be performed on corrupted ECG signal, for proper diagnosis of heart diseases.

There are so many denoising techniques like Empirical mode decomposition (EMD) [9], Discrete Wavelet Transform (DWT) and soft Thresholding [3]. Filters like FIR and IIR [6], etc. Sharma et al. proposed a novel algorithm to denoise the ECG signal by removing Baseline wander and PLI using eigen value decomposition which gives good results than other existing techniques [1]. Jenkal et al. proposed an efficient algorithm to reduce noise from ECG signal using ADTF and DWT [2]. Savita Chandel et al. developed an algorithm using wavelet transform and soft thresholding to enhance the signal quality [3].Das et al. implemented a novel ECG signal denoising technique using S-transform which is evaluated on ECG signals from MIT-BIH database by considering SNR, RMSE and PRD values. The proposed method gives lower RMSE, PRD values and higher SNR values[4].Cuomo, S.et al. developed a novel ECG filtering technique which has boundary conditions that are used to eliminate the edge effects and this scheme is applicable for mobile devices. In this paper the author compared various noise free techniques[5].Blanco et al. proposed a new ECG enhancement technique by removing Baseline Wander noise using empirical mode decomposition(EMD).The proposed EMD based method provides good results than existing methods[6].

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II. RELATED WORK & PRELIMINARIES

A. Empirical Mode Decomposition

EMD is effective for analyzing nonlinear and non-stationary signals since it doesn't require previous knowledge of signals. EMD decomposes the signal into the Intrinsic Mode Functions (IMF's) [11]. The first three IMF's consists maximum amount of information, so we preserve the first three IMF's. The signal is decomposed into the IMF's by using the "Sifting process".

B. Discrete Wavelet Transform

The discrete wavelet transform is also one of the decomposition methods which are used for denoising of the signal. It consists of two filters, they are, Low-pass filter whose output is the approximation coefficients and the High-pass filter whose output is the detailed coefficients as shown in Figure 1. If 'N' is the length of the signal then number of levels in the DWT is given by $\log_2 N$.For each level from 1 to N, select appropriate threshold limit and apply soft or hard thresholding to the detail coefficients at some particular levels to best remove the noise.

III. METHODOLOGY

This article describes about signal preprocessing using a hybrid approach EMD-DWT using the following steps.

Step 1: Read the ECG samples from MIT-BIH database.

Step 2: Add Additie White Gaussian Noise with variance 0.01 to the original ECG sample to get noisy data.

Step 3: Decompose the noisy data by using Empirical mode decomposition which gives partially denoised signal.

Step4: Apply DWT on partially denoised signal using various thresholding techniques.

Step 6: Compare the results by evaluating the parameters RMSE, SNR, PSNR and CC values using the following equations.

$$RMSE = \sqrt{\frac{\sum_{i=0}^{N}[y(i) - x(i)]^2}{N}} \quad (1)$$

$$SNR = \sqrt{\frac{\sum_{i=0}^{N} x(i)^2}{\sum_{i=0}^{N}[y(i) - x(i)]^2}} \quad (2)$$

$$PSNR = 10X \log_{10} \sqrt{\frac{\max(x(t))}{\sum_{i=0}^{N}[y(i) - x(i)]^2}} \quad (3)$$

Where x is the input signal and y is the estimated signal.

The Correlation coefficient between two signals m and n is defined as:

$$Corr(m/n) = \frac{\sum_{i=1}^{N} m_i - \overline{m})(n_i - \overline{n})}{\sqrt{\sum_{i=1}^{N}(m_i - \overline{m})^2 (n_i - \overline{n})^2}} \quad (4)$$

Where m_i and n_i is the values of the variables m & n in a sample. $\overline{m}$ and $\overline{n}$ is the mean values of m & n.

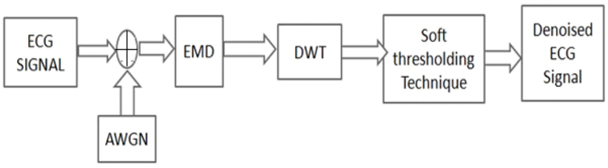

Fig. 1 Block diagram of Proposed Method

Figure 1 shows that the block diagram of the proposed approach for the removal of AWGN noise from ECG data and iIt clearly describes the step by step procedure.

IV. RESULTS AND DISCUSSIONS

This article presents the comparative analysis of EMD-DWT based approach to eliminate Additive White Gaussian Noise in ECG signal. Sample 208m is collected from MIT BIH Arrhythmia Database [11]. It consists of a collection of ECG data records with sampling rate 360 Hz, 11 bit resolution over 10 mV range which is clearly shown in Figure 2. After adding AWG noise with variance 0.01 is shown in Figure 3. Figure 4 &5 shows that the noise free ECG data using EMD and DWT. The proposed EMD-DWT outcome is clearly shown in Figure6. It gives good visual appearance then remaining techniques.

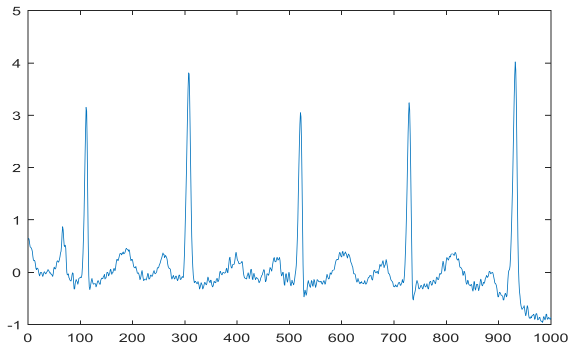

Fig. 2: Original ECG signal for sample 208m

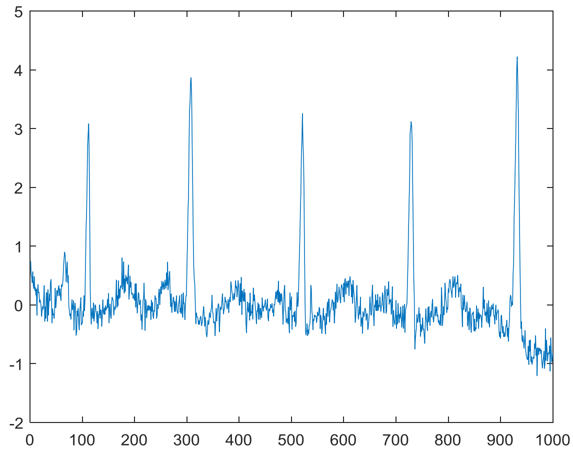

Fig. 3: AWG noisy ECG signal

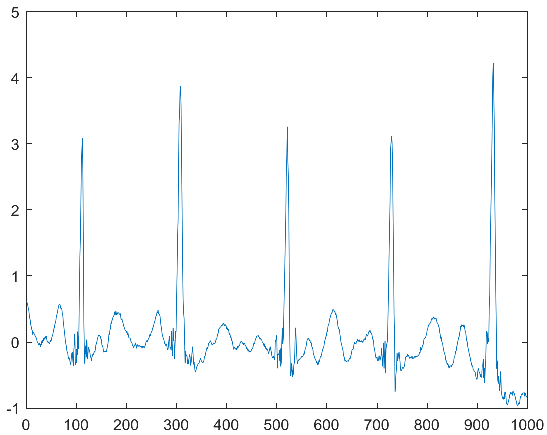

Fig. 4: Denoised ECG through EMD

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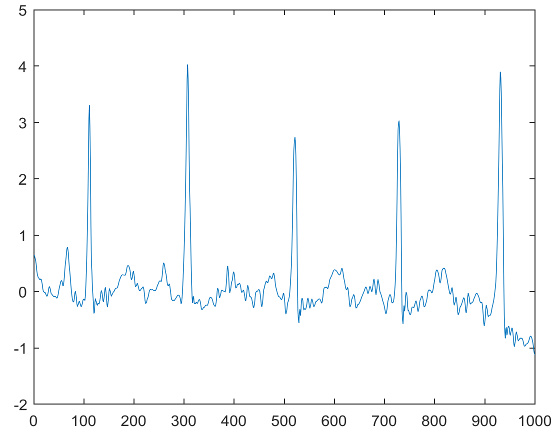

Fig.5: Denoised ECG through DWT

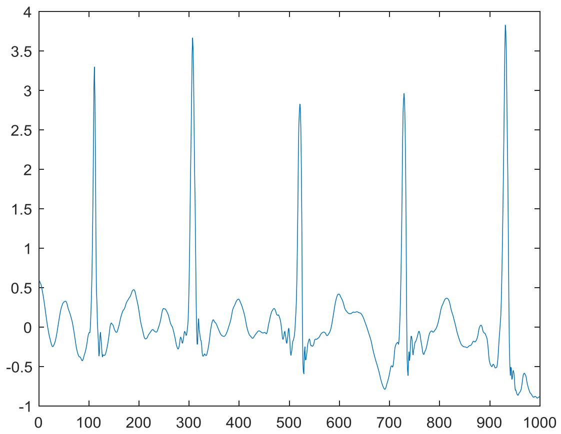

Fig.6: Denoised ECG through EMD-DWT

Table- I: Result analysis of EMD

Signal	RMSE	SNR	PSNR	CC
104m	0.1114	6.4454	11.0204	0.9091
105m	0.1170	6.1082	13.4142	0.9633
119m	0.0674	10.3327	15.7397	0.9936
208m	0.0846	5.9013	8.8459	0.9914
Average	**0.1920**	**7.5258**	**13.1574**	**0.9521**

The noise free ECG signal using DWT with various thresholding techniques such as rigrsure, minimaxi, heursure and sqtwolog in terms of SNR, RMSE, PSNR, CC values are shown from Table II to Table V. Among all thresholding techniques rigrsure threshold gives less RMSE, more SNR, PSNR and CC values.

Table -II: Result analysis of DWT using 'rigrsure'

Signal	RMSE	SNR	PSNR	CC
104m	0.0959	8.9746	14.2805	0.9855
105m	0.8308	9.4291	14.8357	0.9905
119m	0.0149	11.7524	14.6970	0.9932
208m	0.0792	9.1298	17.0548	0.9924
Average	**0.0683**	**9.8214**	**15.2170**	**0.9904**

Table- III: Result analysis of DWT using 'minimaxi'

Signal	RMSE	SNR	PSNR	CC
104m	0.1429	5.2403	12.5463	0.9446
105m	0.0994	8.6473	14.0542	0.9859
119m	0.1778	11.0079	13.9526	0.9902
208m	0.0812	9.0166	16.9417	0.9921
Average	**0.1253**	**8.4780**	**14.3737**	**0.9782**

Table- IV: Result analysis of DWT using 'heursure'

Signal	RMSE	SNR	PSNR	CC
104m	0.1188	6.0428	13.3487	0.9626
105m	0.0877	9.1941	14.6010	0.9895
119m	0.1805	10.9431	13.8878	0.9898
208m	0.1438	6.5370	14.4621	0.9757
Average	**0.1327**	**8.1792**	**14.0749**	**0.9794**

Table- V: Result analysis of DWT using 'sqtwolog'

Signal	RMSE	SNR	PSNR	CC
104m	0.1314	5.6048	12.9108	0.9541
105m	0.1602	6.5769	11.9838	0.9636
119m	0.2398	9.7109	12.6556	0.9835
208m	0.1227	7.2262	15.1513	0.9829
Average	**0.1635**	**7.2797**	**13.1753**	**0.9710**

Table VI to IX shows that the preprocessed ECG signal using EMD-DWT with various thresholding techniques. The proposed method using rigrsure threshold gives an outstanding performance than EMD and DWT.

Table- VI: Result analysis of EMD-DWT using 'rigrsure'

Signal	RMSE	SNR	PSNR	CC
104m	0.0745	8.0692	15.3752	0.9852
105m	0.0320	13.5616	18.9684	0.9985
119m	0.0496	16.5488	19.4935	0.9992
208m	0.0657	9.9387	17.8637	0.9948
Average	**0.0554**	**12.0295**	**17.9252**	**0.9944**

Table -VII: Result analysis of EMD-DWT using 'minimaxi'

Signal	RMSE	SNR	PSNR	CC
104m	0.0655	9.9514	17.8765	0.9948
105m	0.0738	8.1085	15.4144	0.9855
119m	0.0345	13.2417	18.6486	0.9982
208m	0.0511	16.4180	19.3627	0.9991
Average	**0.0562**	**11.9299**	**17.8254**	**0.9944**

Table- VIII: Result analysis of EMD-DWT using 'heursure'

Signal	RMSE	SNR	PSNR	CC
104m	0.0739	8.1031	15.4090	0.9855
105m	0.0333	13.3972	18.8041	0.9984
119m	0.0498	16.5333	19.4779	0.9992
208m	0.0657	9.9380	17.8631	0.9948
Average	**0.0556**	**11.9929**	**17.8885**	**0.9944**

Table- IX: Result analysis of EMD-DWT using 'sqtwolog'

Signal	RMSE	SNR	PSNR	CC
104m	0.0738	8.1122	15.4182	0.9855
105m	0.0343	13.2633	18.6702	0.9983
119m	0.0509	16.4371	19.3817	0.9991
208m	0.0652	9.9725	17.8975	0.9948
Average	**0.2242**	**11.9462**	**17.8419**	**0.9944**

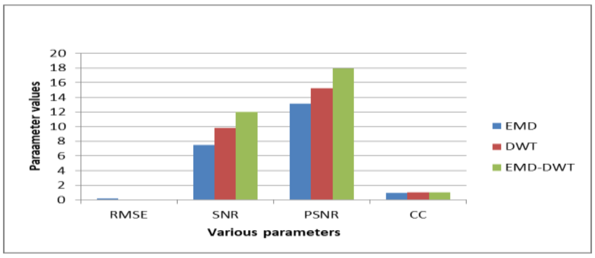

Fig. 7: Comparative analysis of EMD, DWT and Proposed methods

Figure 7 shows that the comparative analysis of ECG signal denoising methods using EMD, DWT and proposed EMD-DWT. The proposed hybrid approach gives better RMSE, SNR, PSNR and CC values than existing techniques.

V. CONCLUSION

In this paper a hybrid denoising approach which is the combination of Empirical Mode Decomposition (EMD) and Discrete Wavelet Transform (DWT) for the removal of AWGN is implemented. The qualitative as well as quantitative analyses are performed on a number of records from MIT-BIH Arrhythmia Database. The RMSE, SNR, PSNR and CC values for various ECG records obtained are compared with the EMD, DWT based filtering approaches and the proposed method. Hence proposed denoising method is observed to be more proposed denoising method is observed to be more effective than the EMD based and DWT based filtering methods.

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