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Performance Analysis of New Hybrid Thresholding Filter on Biological Signals

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Abstract— **To estimate the biological signals from noisy environment wavelet shrinkage method is popularly used. Hard and garrote filters are existing filters in this method. A new hybrid thresholding filter is designed in this paper for remove the noise present in the signal. This filter is applied to ECG signals corrupted with white Gaussian noise. FDR method and Hypothesis method are used for calculate the threshold value for thresholding filter. The results of hybrid thresholding filter are compared with existing filters using Signal to Noise Ratio (SNR) and Mean Square Error (MSE). From the results, it is clear that the new hybrid thresholding filter performs better than both existing hard and garrote filters with FDR method and Hypothesis method.**

Keywords— **Wavelet Transform, denoising, new hybrid thresholding filter, ECG signal, FDR method, Hypothesis method.**

I. INTRODUCTION

From past few years collecting data or signals is increases rapidly. It is also applicable to biological signals. During collecting signals, noise is added to the signal. Due to the noise the signal information will be lost. Regression is necessary for these biological signals. There are so many methods for remove the noise. In those methods parametric and non parametric regression are different types. In non parametric regression wavelet transform is widely used technique. In this wavelet shrinkage method is very popular for regression [3], [4].

A new hybrid thresholding filter is considered in this paper. This filter is applied on detailed coefficients for denoised biological signal using FDR method and Hypothesis method. The results are compared with existing hard and garrote filters.

II. WAVELET SHRINKAGE METHOD

Wavelet shrinkage method is used to remove the noise present in the biological signal [5]. During this method the noisy biological signal is passed through wavelet transform. It decomposes the signal into detailed coefficients [2]. These coefficients are modified using thresholding filter. In thresholding filter, the threshold value is calculated using thresholding method. FDR method and Hypothesis method are considered as thresholding methods. These modified detailed coefficients are passed through inverse wavelet transform [6]. It reconstructs the coefficients into noiseless biological signal [8]. Coiflet wavelet is selected for wavelet transform and inverse wavelet transform.

A. FDR method

The min FDR (minimizing false discovery rate) method was introduced by B. Vidakovic for one-dimensional data. It determines the same threshold value for all thresholding filters by remaining the expected value of the fraction of detailed coefficients incorrectly included in the reconstruction below a given part *p.* Given the M detailed coefficients (e_n, n = 1, 2... M), first it computes x-values [1], [9].

$$x_n=2[1-\Phi\ (|e_n|/\sigma)]$$

Where Φ (.) is the cumulative distribution function and σ is an estimation of the standard deviation. Then x_n values are ordered as

$$x_{(1)}\leq x_{(2)}\leq x_{(3)}\ldots\leq x_{(M)}$$

from n = 1, let i be the major index value then

$$x_{(i)} \leq \frac{i}{M}\,p$$

The threshold value is obtained as

$$\lambda=\sigma\ \Phi^{-1}(1-(x_{(q)}/2))$$

B. Hypothesis method

The threshold estimation in this method is independent of thresholding filter used. It calculates level dependant thresholds after performing wavelet transformation on the signal [1],[9].

Let the detailed coefficients e are M in number at a particular level and assume that they are normally distributed.

$$V^{\delta}_{M}=\{\Phi^{-1}[((1-\delta)^{1/M}+1)/2]\}^{2}$$

Φ ( ) is cumulative distribution function. Where δ is error probability parameter. Then calculte the largest of the squared detailed coefficients at that level, represented by $e^2_{(M-1)}$ and compare it to the above value V^{δ}_{M}. If

$$e^2_{M}/\sigma^2> V^{\delta}_{M}$$

Where, σ is the standard deviation, e^2_M is preserved signal. Next repeat the process with the square of second largest detailed coefficient $e^2_{(M-1)}$. If

$$e^2_{(M-1)}/\sigma^2> V^{\delta}_{M-1}$$

The procedure carries on until at some point the bth largest detailed coefficient satisfies

$$e^2_{(b)}/\sigma^2> V^{\delta}_{b}$$

The threshold at that level is then set as $\lambda = \alpha\ e^2_{(b)}$. The recommended value for δ is 0.05.

C. Thresholding Filters

Thresholding filters are used to apply the threshold value. In this paper Hard and Garrote filters are consider.

Donoho and Johnston proposed hard thresholding filter. A threshold value is selected by adopting some sort of threshold rules. Hard thresholding sets any coefficient below or equal to the threshold to zero. The coefficients above this threshold value are retained [7]. The hard thresholding "H (e, λ)" is denoted by

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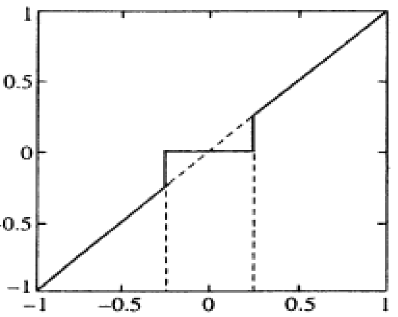
$$H(e, \lambda) = e \text{ for } |e| > \lambda$$
$$= 0 \text{ otherwise}$$

H (e,λ)



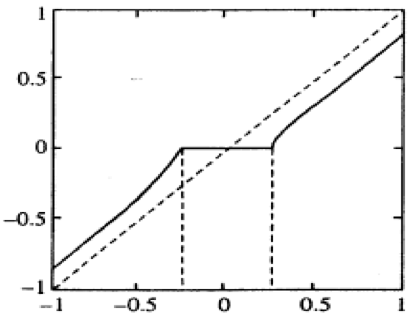
-λ λ e

Fig. 1: Hard Thresholding Filter

Garrote filter [1] is defined as

$$G(e,\lambda) = \left(e - \frac{\lambda^2}{e}\right) \text{ for all } |e|>\lambda$$
$$= 0 \quad \text{otherwise}$$

G (e,λ)



-λ λ e

Fig. 2: Garrote Thresholding Filter

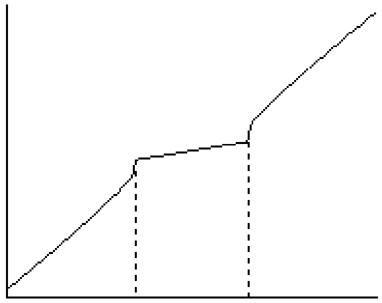
e represents wavelet coefficients and λ represents threshold value.

III. HYBRID THRESHOLDING FILTER

Hybrid thresholding filter is newly desined filter in this paper for modifying the detailed coefficients. This filter is designed from taking the mean of hard and garrote filters for more than threshold value. 20 % of detailed coefficient value is considered for less than threshold value [1]. This is shown as

$$H(e,\lambda) = \frac{\left(e - \frac{\lambda^2}{e}\right) + e}{2} \text{ for all } |e| > \lambda$$
$$= 0.2{*}e \quad \text{otherwise}$$

H (e, λ)



-λ 0 λ e

Fig. 3: Hybrid Thresholding filter

e represents detailed coefficients and λ is the threshold value.

IV. RESULTS AND DISCUSSION

The results are obtained using hard filter, garrote filter and new hybrid thresholding filter on noise effected ECG signal are placed in this section. The length of the ECG signal is 1024 and it is contaminated with gaussian noise of different noise standard deviation values are simulated. Coiflet wavelet is used in wavelet transform which is used to decompose the noisy signal into detailed coefficients. These detailed coefficients are modified using thresholding filter. In thresholding filter the threshold value is fixed using FDR method and Hypothesis method. The inverse wavelet transform is used to reconstruct the modified detailed coefficients into denoised signal. MSE and SNR parameters are used to compare the results.

$$\text{MSE} = \frac{1}{t} \sum_{i=1}^{t} \left(n(i) - \hat{n}(i)\right)^2$$

$$\text{SNR} = 10 \log_{10} \frac{\sum_{i=1}^{t} n(i)^2}{\sum_{i=1}^{t} \left(n(i) - \hat{n}(i)\right)^2}$$

t represents number of samples, n(i) is original signal and $\hat{n}(i)$ is denoised signal. The simulation process is repeated 100 times then takes the average values of MSE and SNR. This process is performed on different ECG signals and same results are obtained. This simulation is implemented in MATLAB environment. The MSE and SNR values of ECG signal for standard deviation 10, 20 and 30 using existing filters and new hybrid thresholding filter with FDR method and Hypothesis method are shown in Table 1 and Table 2. The original ECG signal and denoised ECG signals using new hybrid thresholding filter with FDR method and Hypothesis method are shown in Figures 4-7. The comparison of MSE and SNR values of FDR method and Hypothesis method are shown in Graph 1-4.

For standard deviation 10, MSE value is 44.3586 and SNR value is 25.9515 are obtained for denoised ECG signal with hard thresholding filter and MSE is 51.5357 and SNR is 25.3013 are obtained with garrote thresholding filter using FDR method. Using new hybrid thresholding filter, MSE is 37.5629 and SNR is 26.6671 are obtained (Table 1). From the above values, it is clear that the new hybrid thresholding filter performs better than both hard and garrote thresholding filter. The same performance is obtained for standard deviation 20 and 30 (Table 1).

Using hypothesis method, for standard deviation 10, MSE value is 47.1969 and SNR value is 25.6818 are obtained for denoised ECG signal with hard thresholding filter and MSE is 57.2465 and SNR is 24.8462 are obtained with garrote thresholding filter. Using new hybrid thresholding filter, MSE is 40.3936 and SNR is 26.3553 are obtained (Table 2). From these results, the new hybrid thresholding filter performs better than existing thresholding filters. The same performance is obtained for standard deviation 20 and 30 (Table 2).

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Table 1: Values of MSE and SNR for different thresholding filters using FDR method

	σ =10		σ =20		σ =30	
	MSE	SNR	MSE	SNR	MSE	SNR
Noisy signal	100.7220	22.3778	401.1091	16.3766	898.9865	12.8711
Hard filter	44.3586	25.9515	130.9982	21.2515	279.0602	17.9664
garrote filter	51.5357	25.3013	169.2912	20.1488	345.0665	17.0549
Hybrid filter	37.5629	26.6671	120.1216	21.6238	253.1261	18.3921

Table 2: Values of MSE and SNR for different thresholding filters using Hypothesis method

	σ =10		σ =20		σ =30	
	MSE	SNR	MSE	SNR	MSE	SNR
Noisy signal	100.7220	22.3778	401.1091	16.3766	898.9865	12.8711
Hard filter	47.1969	25.6818	137.9133	21.0357	278.0868	17.9872
garrote filter	57.2465	24.8462	173.7035	20.0385	351.7135	16.9792
hybrid filter	40.3936	26.3553	126.8601	21.3914	253.6594	18.3821

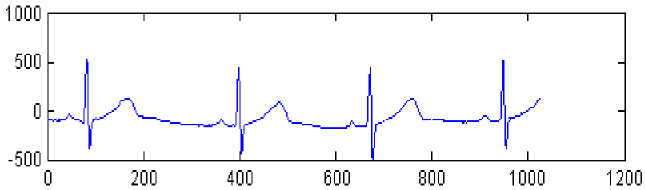


Fig. 4: Original ECG signal

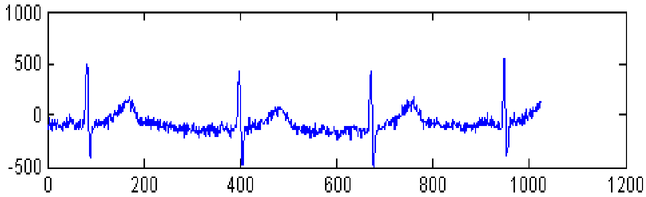


Fig. 5: Noisy effected ECG signal

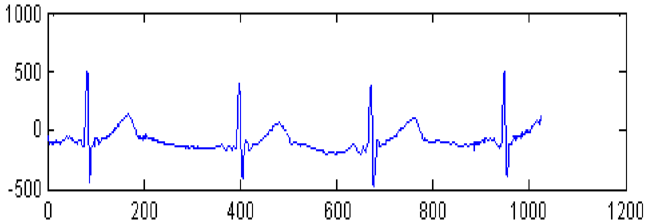


Fig. 6: Denoised ECG signal using new hybrid thresholding filter with FDR method

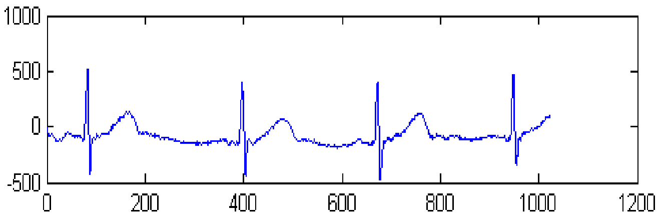
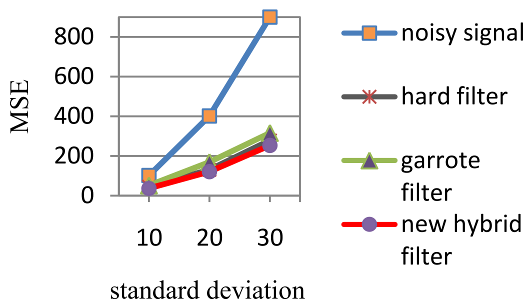
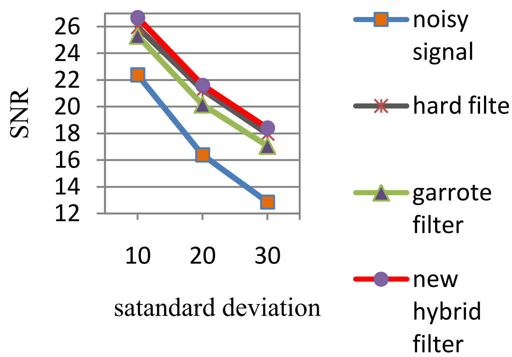


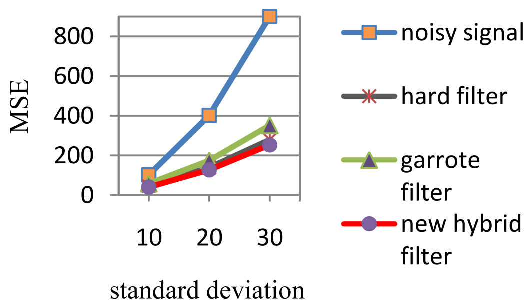
Fig. 7: Denoised ECG signal using new hybrid thresholding filter with Hypothesis method



Graph 1: MSE values comparison of different filters in FDR method.



Graph 2: SNR values comparison of different filters in FDR method.



Graph 3: MSE values comparison of different filters in Hypothesis method

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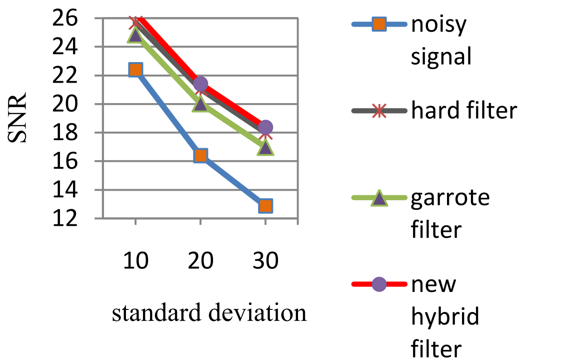

Graph 4: SNR values comparison of different filters in Hypothesis method

V. CONCLUSION

A new hybrid thresholding filter is proposed in this paper for denoise the noisy biological signal. The performance of this filter is evaluated by using ECG signals. These results are compared with existing hard filter and garrote filter. From the results, the hybrid thresholding filter performs better than existing filters with FDR method and Hypothesis method.

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