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Comparison of ECG Denoising Threshold Estimators through Wavelet Packet Analysis

Imtiyaz Ahmad Wani[1], Dr. Afroz Ahmad.[2]

[1]*Research Scholar Department of Mathematics, MANUU, Hyderabad, (India)*
[2]*Assistant Proffesor, Department of Mathematics, MANUU, Hyderabad, (India)*

ABSTRACT

We present in this paper denoising algorithm which is based on thresholding and selection of wavelets. We denoise an ECG signal by applying wavelet packet due to its localization characteristics in order to decide the optimal selection of threshold value. As in literature a number of thresholding methods are proposed. Keeping all of them in view, we have applied hard and soft thresholding methods and compared its results with a thresholding method in which commulative frequency and energy of signal is taken into consideration.

Keywords: ECG Dinoising, wavelet, wavelet packet, wavelet transform, thresholding,

I.INTRODUCTION

The heart activity of human being is represented by electrical signal known as Electrocardiogram (ECG). It provides a way of detecting several types of disease like cardiac arrhythmia, myocardial infarct, angina, ischemia [1], [2]. ECG is generated by heart's electrical activity from SA Node then atrial depolarization followed by ventricular depolarization and ventricular repolarization. An ECG normally consists of set of waves namely P, Q, R, S and T wave along with some segments, intervals and QRS Complex as shown in the Fig 1.

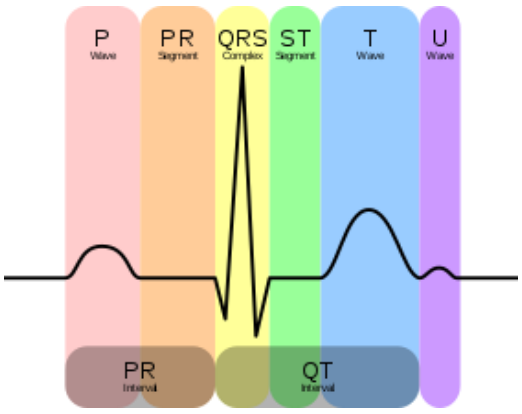


fig 1

QRS complex is however most important wave characterized by ventricular contractions. Among different automatic feature extraction of ECG signal, QRS complex is its dominant feature. The detection of QRS complex can be done easily by Trainer in cardiology only if there would not be differences in morphologies of

normal and abnormal QRS complexes. Also due to the presence of noise from many sources again makes it more complex to analyse. The noisy signal sources are power line interference, the electromyogram (EMG) noise and the baseline wandering [3],[4]. So the primary support to clinical analysis of ECG signal is to make ECG signal free from noise. For this purpose lot of methods and techniques were applied for denoising signals like digital filtering, adaptive methods and wavelet transform methods [5] [6]. Due to non- stationary behaviour of ECG signal, the digital filtering and adaptive methods are not applicable for ECG as they do good analysis in stationary signals. As ecg signal is weak than noisy signal therefore wavelet transforms works well for denoising it. Also research in denoising of signals came in conclusion that denoising a signal is more better in frequency domain than in time domain[7]. Wavelet Transform is frequency representation of a signal which represents a signal in terms of wavelet coefficients. Therefore wavelet based techniques are most preferred for denoising the ECG Signal[8].

II.WAVELET TRANSFORM

A wavelet is a waveform having effectively limited duration that has an average value of zero. Fourier analysis consists of breaking up a signal into sine waves of various frequencies. In the similar fashion wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or mother) wavelet. Thus signal with sharp changes might be better analysed with an irregular wavelet than with smooth sinusoid. Two functions play an important role in wavelet analysis: one is called scaling function ϕ and another is called wavelet ψ. With the help of these functions, a family of functions can be generated that can be used to break up or reconstruct the given signal. Sometimes ϕ is called father wavelet and ψ is called mother wavelet.

Mathematically, Morlet et al. (1982a,b) defines wavelet as a function $\psi \in L^2(R)$ which satisfies the condition:

$$C_\psi = \int_{-\infty}^{\infty} \frac{\left|\hat{\psi}(\omega)\right|^2}{|\omega|} d\omega < \infty$$ Where $\hat{\psi}(\omega)$ is the Fourier transform of $\psi(t)$

Based on the idea of wavelets as a family of functions constructed from translation and dilation of a single function ψ called the mother wavelet, we define the mother wavelets by:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}} \psi\left(\frac{t-b}{a}\right),\ a,b \in R,\ a \neq 0$$

Wavelet transform has localization, multi-resolution and decomposition properties, which makes it a powerful tool in many signal processing. Denoising a signal through wavelet transformation is based on thresholding. In [9] two approaches have been proposed to threshold the resulting wavelet coefficients. One is known by hard thresholding and another is known as soft thresholding. The hard and soft threshold values can be calculated using the equations 1 and 2 given below:

$$f_h(D) = \begin{cases} D & \text{if } D \geq thr \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

And

$$f_s(D) = \begin{cases} D - thr & \text{if } D \geq 0 \\ 0 & \text{if } D < 0 \\ D + thr & \text{if } D \leq -thr \end{cases} \quad (2)$$

The threshold value [7] in equations (1) and (2) is calculated as:

$$thr = \sigma\sqrt{2\log N}$$

where σ is the standard deviation of the noise and obtained from detail coefficients w_k at finest level, by the formula:

σ =median $\{(|w_k|:k=1,2,\ldots n/2)\}/0.6745$

conservation of energy[10] of a signal and the concept of commulative frequency will also play an important role in defining threshold value. However, it is critical in wavelet thresholding to choose an appropriate threshold value [11]. A number of the methods reported in literature that provides the threshold values are also available like Universal threshold proposed by Donoho[12] is one of the most popular and widely used method in wavelet thresholding. Sure shrink threshold is based on stein's unbiased risk estimation (SURE).Hybrid thresholding technique is also available which is also based on SURE And Universal thresholding which is proposed by Donoho and Johnstone.

In this paper results of hard thresholding, soft thresholding and a technique where threshold value is taken from concept of conservation of energy of signal in terms of commulative energy profile.[10]

III.PROPOSED METHOD

step 1. A noisy ECG signal is first decomposed with the help of wavelet transform at level 2 into approximation and detail coefficients.

step 2. Obtained threshold value from detained coefficients

step 3. Now apply the wavelet packet for denoising the ecg signal at the threshold value obtained in step 2. As wavelet packet is generalization of wavelet transform. The time frequency resolution ratio is enhanced due to more exact local analysis feature of wavelet packet threshold denoising method. In wavelet packet analysis the detail of signal (ECG) is further decomposed which not possible in wavelet transform.

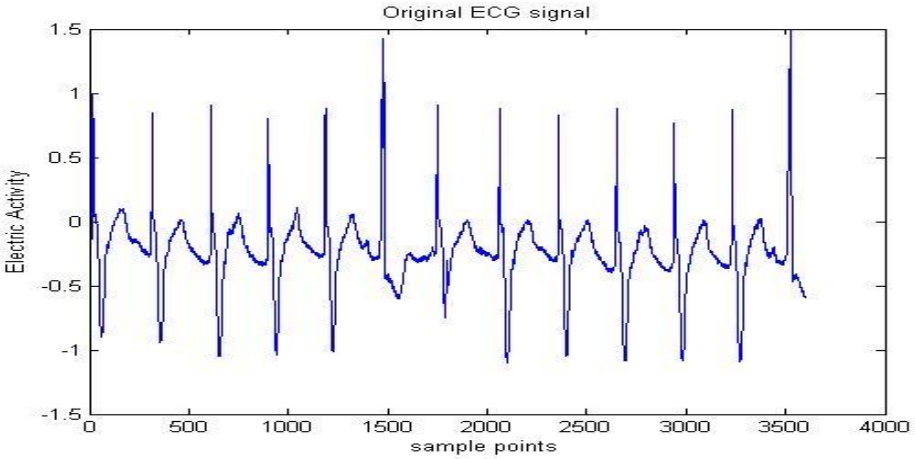
step 4. Reconstruct the denoised ECG signal by inverse wavelet transformation through matlab 2009 wavelet tool box.

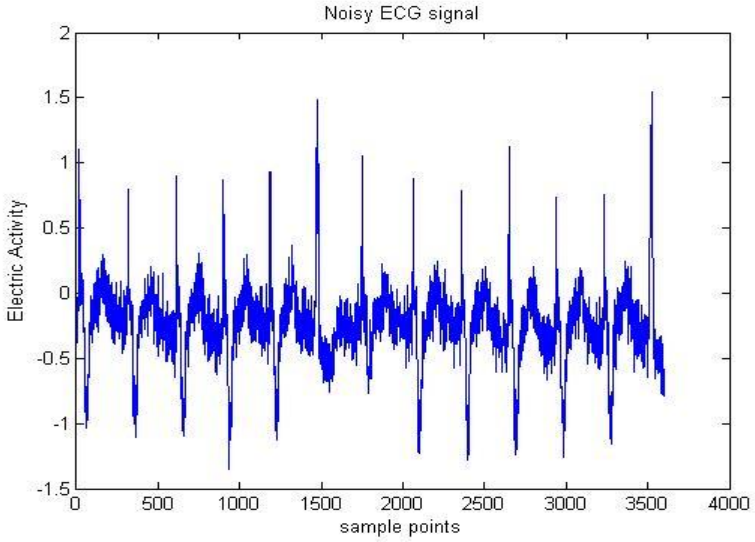
step 5. Compare the results of SNR

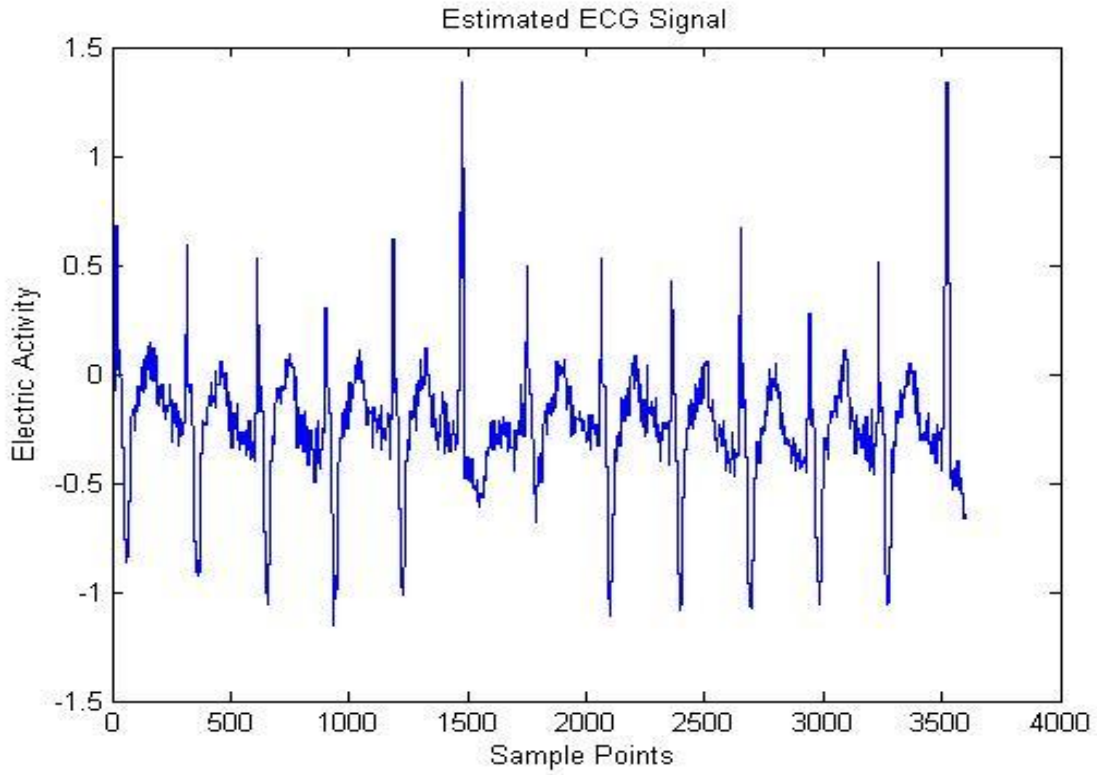
$$SNR = 10\log_{10}\frac{\sum_{i=1}^{N}(y(i)-x(i))^2}{\sum_{i=1}^{N}(\hat{x}(i)-x(i))^2}$$

$$MSE = \frac{1}{N}(\sum_{i=1}^{N}(\hat{x}(i)-x(i))^2)$$

Where y(i) and x(i) are noisy ECG and Original ECG signal and $\hat{x}(i)$ is the estimated ECG signal.







IV.TABLE 1 OF ANALYSIS

Wavelets	Soft threshold		Hard threshold		Thresholding by commulative frequency	
	SNR	MSE	SNR	MSE	SNR	MSE
db2	5.2590	0.0239	5.6070	0.02281	5.6094	0.0227
db4	5.5590	0.0230	5.3436	0.0234	5.7737	0.0222
Symlet	5.6073	0.0228	5.6422	0.0217	5.8060	0.0224
Coef2	5.5873	0.0233	5.5850	0.0239	5.7730	0.0230
Bior1.1	5.4361	0.0236	5.7069	0.0221	5.7098	0.0230

V.CONCLUSION

Denoising is an important issue for researchers to remove noise from any important signals. In the similar fashion denoising ECG signal is essential for patient's heart disease detection for accurate treatment. Wavelet thresholding is very prominent tool for signal denoising besides other existing methods. In the present paper, the proposed method gives us comparative study of thresholding in which SNR and MSE is computed. This simulation is done with the help of matlab 2009. In this comparative study in table 1, all thresholding estimators gives us best result. But commulative energy profile gives us better result than soft and hard thresholding but to obtain its threshold value for thresholding is quite time consuming than in hard and soft thresholding. Once

denoising is done then rhythm, rate, axis, P wave, PR interval , Q wave, QRS complex, QT interval, ST segment and T wave of heart can be analysed and required interpretation can be laid done.

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