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Comparative Analysis of Wavelet Thresholding Techniques with Wavelet-Wiener Filter on ECG Signal

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Abstract

The electrocardiogram (ECG) records the electrical activity of the heart muscle and displays this data as a trace on a screen or on paper .This data is then interpreted for identification of a particular malfunctioning of the heart. Before the identification of a particular disease the ECG signal is first de-noised, as the raw ECG signal is contaminated with various other signals called artefacts. This is the crucial step as the signal has to be extracted from the noisy signal, without losing much of the valid information. In this paper, wavelet transform technique is considered for de-noising the ECG signal. The ECG signal is de-noised using different threshold techniques like hard, soft, SURE shrink, hybrid shrink and compared with the wavelet based wiener filter. The performance of these techniques is analysed. It is observed that there is a trade- off between the bias and variance in case of hard, soft, sure shrink , hybrid shrink whereas, in case of wavelet- wiener filter, bias and variance reduces simultaneously and gives a minimum MSE.

*Keywords:*MSE, bias, variance, Savitzky-Golay filter, wiener filter,shrinkage.

1. Introduction

The ECG which is recorded is a non-stationary signal obscured with various noises like Power-line interference, Base-line wander, Electrode contact noise, Motion artefacts, EMG etc. The frequency spectrum of the ECG signal ranges from 0.05 to 100 Hz. And the frequency spectrum of the EMG which is overlapped is in the range from 20 to 200 hz. It is of primary interest to recover the true signal from the noisy ECG signal. The ECG signal should be clean and clear as possible so that accurate decisions can be taken by the physicians. To de-noise the ECG signal various kinds of time domain and frequency domain filters are implemented. But when compared to other filters like adaptive (LMS and RLS), Savitzky-Golay, wavelet transform techniques can better de-noise the ECG signal [1]. Wavelet transform has been an efficient tool for a variety of applications including estimation, classification and compression. Here the wavelet transform is used for estimating the true signal from the corrupted signal. The noisy signal is decomposed into different levels and the signal energy is concentrated in a small number of large wavelet coefficients and the noisy components are concentrated in a large number of small wavelet coefficients for which

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threshold is applied . The noisy wavelet coefficients are discarded / reduced and the true signal is estimated by reconstructing the signal from the remaining wavelet coefficients. The signal to be considered is modelled as a vector in R^N space. Let x, s, n denote $N \times 1$ column vectors. The noisy signal can be written as

$$x(i) = s(\frac{i}{N}) + n(i) \qquad i = 1,2,......N. \tag{1}$$

With $x(i)$ is the i[th] sample of the noisy signal, $s(\frac{i}{N})$ is the i[th] sample of the true signal, n(i) a zero mean white Gaussian noise of variance σ.

Let W denote the $N \times N$ orthogonal wavelet transform matrix. Applying wavelet transform to Eq. (1) becomes

$$y = \theta + z \tag{2}$$

Where, $y = Wx, \theta = Ws, z = Wn$

θ is the true signal wavelet coefficients, y is given noisy observations . The true signal s is compactly represented into a small number of large wavelet coefficients in θ.similarly, the wavelet transform map n noise terms to z noise wavelet coefficients.

Now the wavelet transform estimates the signal by shrinking the small entries of y (no signal) while retaining the large entries of y (where the signal is). On the other hand, ideal Wiener filter is the optimal filter to obtain the minimum MSE. The new algorithm given by [3] is the wavelet domain based wiener filter. In this algorithm, the wavelet shrinkage estimate is used as a means to design wavelet-wiener filter. The unwanted EMG signal components are best suppressed using DWT technique [2].

There are various de-noising algorithms which are used to de-noise the signal and to obtain an uncorrupted signal. In this paper, noisy ECG signal is de-noised using hard, soft, sure shrink, hybrid shrink and wavelet wiener filter. The de-noised signal is tested for MSE, bias squared, variance. Better results are achieved using wavelet-wiener filter because both bias-square and variance decreases simultaneously and maintain the minimum MSE.

2. Wavelet thresholding techniques

In wavelet shrinkage, the shrink/retain operation is to reduce the small amplitude (noise) wavelet coefficients to zero. A suitable threshold value is chosen such that pure noise coefficients may pass the threshold and discarded. And the signal is estimated from the remaining wavelet coefficients [4]. If the chosen threshold value is small then some of the noisy wavelet coefficients cannot pass the threshold and thus the estimated signal may still contain noise terms. On the other hand, if the chosen threshold is large then the signal is over smoothened, which may lead to the loss of valid signal information. Thus the optimal threshold value selection is an important criteria to get minimum MSE [5].

The wavelet shrinkage function determines how the thresholds are applied to the data. There are two basic wavelet shrinkage functions.

2.1 Hard threshold

This method was proposed by Dohono. This is a linear function in which, it discards coefficients below a threshold value τ, that is determined by the noise variance.

The hard threshold filter coefficients are given from [6],

$$h_h(i) = \begin{cases} 1, & if\ |y(i)| > \tau; \\ 0, & otherwise \end{cases} \tag{3}$$

It is basically a “keep or kill” procedure. In this scheme, spurious ‘blips’ and discontinuous appear in the output when noise terms does not pass the threshold [5].

2.2 Soft threshold

This method was also proposed by Dohono. This is a non-linear function which is similar to hard threshold but it shrinks the large magnitude wavelet coefficients above the threshold. This causes the output to be more smoothened and continuous when compared to the hard threshold. The soft threshold filter coefficients are given from [6]