Denoising of ECG signal using thresholding techniques with comparison of different types of wavelet

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Abstract- This paper deals with the study of ECG signals using wavelet transform analysis. The Electrocardiogram (ECG) shows the electrical activity of the heart and is used by physicians to inspect the heart’s condition. Examination of ECG is not easy, it is a tuff task, if noise is added with signal during acquirement. In this paper, denoising techniques for ECG signals based on Decomposition will be compared. Firstly different wavelets will be applied like Haar,dbN and Symlet wavelet. Then thresholding technique will be applied for getting denoised signal.

Keywords – ECG, Wavelet, Denoising, Thresholding.

I. INTRODUCTION

The electrocardiogram (ECG) is a graphical recording of the electrical signals generated by the heart. The signals are generated when cardiac muscles depolarize in response to electrical impulses generated by pacemaker cells. Upon depolarization, the muscles contract and pump blood throughout the body. The ECG reveals many things about the heart, including its rhythm, whether its electrical conduction paths are intact, whether certain chambers are enlarged, and even the approximate ischemic location in the event of a heart attack (myocardial infarction).

It has been used extensively for detection of heart disease. ECG is non-stationary bioelectrical signal including valuable clinical information, but frequently the valuable clinical information is corrupted by various kinds of noise. The main sources of noise are:

- power-line interference from 50–60 Hz pickup and harmonics from the power mains; baseline wander caused by variable contact between the electrode and the skin and respiration; muscle contraction form electromyogram (EMG) mixed with the ECG signals; electromagnetic interference from other electronic devices and noise coupled from other electronic devices, usually at high frequencies. The noise degrades the accuracy and precision of an analysis. Obtaining true ECG signal from noisy observations can be formulated as the problem of signal estimation or signal denoising. So denoising is the method of estimating the unknown signal from available noisy data.

Raw ECG data contain some noise and artifact components that alter the expression of the ECG trace from the ideal structure described previously and render the clinical interpretation inaccurate and misleading; consequently, a preprocessing step for improving the signal quality is a necessity. It is therefore important to be familiar with the most common types of noise and artifacts in the ECG and address a method which can compensate for their presence before proceeding to the feature extraction step.

In recent years wavelet transform (WT) has become favorable technique in the field of signal processing. Donoho et al [1][2] proposed the denoising method called “wavelet shrinkage”; it has three steps: forward wavelet transform, wavelet coefficients shrinkage at different levels and the inverse wavelet transform, which work in denoising the signals such as Universal threshold, SureShrink, Minimax.
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De-noising using traditional DWT has a translation variance problem which results in Pseudo-Gibbs phenomenon in the Q and S waves, so the following algorithms tried to solve this problem: used cyclic shift tree de-noising technique for reducing white Gaussian noise or random noise, EMG noise and power line interference[3].

The performance of ECG analyzing system depends mainly on the accurate and reliable detection of the QRS complex, as well as T- and P waves. The P-wave represents the activation of the upper chambers of the heart, the atria, while the QRS complex and T-wave represent the excitation of the ventricles or the lower chamber of the heart. The detection of the QRS complex is the most important task in automatic ECG signal analysis. Once the QRS complex has been identified a more detailed examination of ECG signal including the heart rate, the ST segment etc. can be performed [4].

Wavelet thresholding de-noising methods deals with wavelet coefficients using a suitable chosen threshold value in advance. The wavelet coefficients at different scales could be obtained by taking DWT of the noisy signal. Normally, those wavelet coefficients with smaller magnitudes than the preset threshold are caused by the noise and are replaced by zero, and the others with larger magnitudes than the preset threshold are caused by original signal mainly and kept (hard-thresholding case) or shrunk (the soft-thresholding case). Then the denoised signal could be reconstructed from the resulting wavelet coefficients. These methods are simple and easy to be used in de-noising of ECG signal. But hard thresholding de-noising method may lead to the oscillation of the reconstructed ECG signal and the soft thresholding de-noising method may reduce the amplitudes of ECG waveforms, and especially reduce the amplitudes of the R waves. To overcome the above said disadvantages an improved thresholding de-noising method is proposed [5][6][7][8].

ECG signal is easy to be contaminated by random noises uncorrelated with the ECG signal, such as EMG, baseline wandering and so on, which can be approximated by a white Gaussian noise source[9].

II. PROPOSED ALGORITHM

The general de-noising procedure involves three steps. The basic version of the procedure follows these steps:

1. Decompose
2. Choose a wavelet; choose a level \( N \). Compute the wavelet decomposition of the signal \( s \) at level \( N \).
3. Threshold detail coefficients
4. For each level from 1 to \( N \), select a threshold and apply soft thresholding to the detail coefficients.
5. Reconstruct
6. Compute wavelet reconstruction using the original approximation coefficients of level \( N \) and the modified detail coefficients of levels from 1 to \( N \).

1 Decomposition of signal

1.1 Multiple-Level Decomposition

The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components. This is called the wavelet decomposition tree.
2 Wavelets Chosen:

2.1 Haar Wavelet-

Any discussion of wavelets begins with Haar wavelet, the first and simplest. Haar wavelet is discontinuous, and resembles a step function. In mathematics, the **Haar wavelet** is a sequence of rescaled “square-shaped” functions which together form a wavelet family or basis.

The technical disadvantage of the Haar wavelet is that it is not continuous, and therefore not differentiable. This property can, however, be an advantage for the analysis of signals with sudden transitions, such as monitoring of tool failure in machines. [2]

2.2 dbN

These wavelets have no explicit expression except for db1, which is the **Haar** wavelet. However, the square modulus of the transfer function of $h$ is explicit and fairly simple. Ingrid Daubechies, one of the brightest stars in the world of wavelet research, invented what are called compactly supported orthonormal wavelets -- thus making discrete wavelet analysis practicable.
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2.3 Symlet Wavelets: symN

In \( \text{symN} \), \( N \) is the order. Some author’s use \( 2N \) instead of \( N \). Symlets are only near symmetric; consequently some authors do not call them symlets.

3 Thresholding Techniques

3.1 Thresholding

Thresholding is one of the most often used processing tools in wavelet signal processing. It is used in noise reduction, in signal and image compression, and sometimes in signal recognition. The four types of thresholding we
use are (1) hard thresholding, (2) soft thresholding, (3) quantile thresholding, and (4) universal thresholding. The choice of thresholding methods depends on the application. We discuss each type here briefly.

3.2 Hard thresholding

Hard thresholding sometimes is called gating. If a signal (or a coefficient) value is below a preset value, it is set to zero. That is,

\[ y = \begin{cases} x, & \text{for } x \geq \sigma \\ 0, & \text{for } x < \sigma \end{cases} \]

where \( \sigma \) is the threshold value or the gate value.

3.3 Soft thresholding

Soft thresholding is defined as

\[ y = \begin{cases} f(x - \sigma), & \text{for } x \geq \sigma \\ 0, & \text{for } x < \sigma \end{cases} \]

The function \( f(x) \) generally is a linear function (a straight line with slope to be chosen). However, spline curves of third or fourth orders may be used to effectively weight the value greater than \( \sigma \).

3.4 Quantile thresholding

In certain applications, such as image compression, where a bit quota has been assigned to the compressed file, it is more advantageous to set a certain percentage of wavelet coefficients to zero to satisfy the quota requirement. In this case, the setting of the threshold value \( \sigma \) is based on the histogram and total number of coefficients. The thresholding rule is the same as hard thresholding.

3.5 Universal thresholding

In some noise removal applications in which the noise statistics is known, it may be more effective to set the threshold value based on the noise statistics. For example, Donoho and Johnstone [8] set the threshold value to be

\[ \sigma = \sigma_0 \sqrt{\frac{2\log(l)}{l}} \]

where \( \sigma_0 \) is the standard deviation of the noise and \( l \) is the cardinality of the data set. This threshold value can be used in either hard or soft thresholding as shown earlier.

IV. CONCLUSION

A wavelet based method for denoising of ECG signal is proposed in this paper. In the proposed method firstly three different wavelets Haar, dbN and Symlet will be taken of original input signal.then different thresholding technique will be applied. In order to identify the performance of denoising, two simple measures that is PSNR and MSE were investigated and results discussed.

REFERENCE


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