An algorithm study of electrocardiogram signal denoising by using wavelet transform method

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Abstract. In order to remove the noise interference in Electrocardiogram (ECG) signal, an optimal denoising algorithm based on wavelet transform is proposed. To make use of the multi-resolution feature of wavelet transform, it is adaptive to signal and can reduce the complexity of denoising algorithm, and ensure the ECG main information features are not lost. The results show that this method can effectively denoise ECG signal and is suitable for biological signal processing with low signal noise.

1. Introduction

In recent years, the incidence of cardiovascular disease is increasing, which seriously threatens human life and health. Accurate and timely diagnosis and recognition of arrhythmia is the key to effective prevention and treatment of cardiovascular diseases. Electrocardiogram (ECG) is an important indicator of human heart health, which can provide an important basis for doctors to prevent and diagnose heart diseases [1-2].

ECG is an effective means of diagnosis and prevention of various diseases. These noises will seriously affect the amplitude characteristics of collected ECG signals, thus leading to misdiagnosis by doctors to different degrees. In recent years, researchers have proposed many algorithm for ECG signal noise problems, such as wavelet algorithm and the Empirical Mode Decomposition (EMD) algorithm, the algorithm to a certain degree in addition to most of the noise signal, but because of ECG signal and noise signal spectrum overlap between areas, as a result, this part is difficult to filter out noise, often in removing noise or loss of useful information in ECG signal at the same time, thereby reducing the clinical value of ECG signal [3].

In ECG signal acquisition process by all kinds of jamming signal, power frequency interference from the power system (50 to 60 Hz), measuring electrode and the body appear caused by poor contact electrode contact noise and baseline drift caused by breathing (less than 1 HZ) and human skin electric potential changes caused by electrical interference (5-2000 Hz) and so on, these noise late seriously affect the accuracy of ECG signal classification and recognition [4], therefore in the prophase of the original ECG signal preprocessing, it is important to suppress noise.

Wavelet denoising technology, due to its various excellent characteristics, has attracted the attention of many researchers, which greatly widens the range of wavelet denoising. These researches will greatly enrich the theory of wavelet denoising and promote the greater development of wavelet denoising
technology. Wavelet analysis is a rapidly developing new field of mathematics, which has both a profound theoretical basis and a wide range of applicable values [5]. Wavelet analysis, which is derived from signal field, is a milestone in the development history of Fourier analysis, and is the crystallization of the method of modulation and analysis in the field of mathematics.

This paper is based on wavelet transform and ECG signal as the research object. Through wavelet separation theory and noise reduction theory, simulation and field application results show that this method can suppress noise based on the maximum limit of original signal characteristics [6]. By comparing the denoising results of traditional wavelet threshold method with that of traditional wavelet threshold method under the same condition, we can get the conclusion that the denoising results of this method are better than that of traditional wavelet threshold method.

2. Wavelet denoising
The basic idea of wavelet threshold denoising is: the following model is used to represent a denoising One-dimensional signal of sound:

\[ F(t) = s(t) + n(t) \]

Where \( s(t) \) is the original signal and \( n(t) \) is the Gaussian white noise. Wavelet transform forms wavelet basis by scaling and translation of wavelet generating function and scale function, which can realize multi-scale refinement analysis of original signal and has good time-frequency analysis characteristic [7].

Wavelet algorithm is used to perform multi-layer wavelet decomposition of the original ECG signal. Input signal is divided into two parts of high frequency and low frequency by each layer decomposition. Then the decomposed low frequency signal (approximate signal) is decomposed at the next layer decomposition.

3. Algorithm implementation
Wavelet transform is a time-scale method for signal analysis. It has the characteristics of multi-scale resolution analysis and the ability to represent the local characteristics of signal in time domain and frequency domain. By means of stretching and shifting transformation, the refinement of ECG signals on different scales can be achieved, and the local characteristics of ECG signals in time domain and frequency domain can be reflected in different frequency bands at the same time, highlighting the different characteristics of ECG signals [8].

Wavelet decomposition and reconstruction method is a simple principle of wavelet denoising method, it is mainly using the wavelet multiresolution analysis feature with baseline drift and myoelectricity interference shall be carried out in accordance with the sampling frequency decomposition of ECG signals, different frequency of ECG signal with noise is decomposed into different frequency band signal,
Different from Fourier transform, wavelet decomposition uses wavelet basis to decompose the signal, that is, the signal is decomposed through translation, expansion and other transformations of the basis signal. The following figure 1 shows the general characteristics of wavelet decomposition. It can be observed from the figure1 that the wavelet basis corresponding to a10 is larger, while the wavelet basis corresponding to d10~d1 decreases successively, and the more decomposition layers, the more detailed division of corresponding frequency components.

![Wavelet decomposition diagram](image)

In practical application, the selection of small wave base, decomposition scale, threshold and coefficient processing method of wavelet threshold denoising method is difficult, and there is no uniform and fixed selection standard. There are many different options for specific signals, and the denoising effects may vary widely. So, how to choose these elements correctly appears crucial.

In the process of signal processing by means of wavelet transform, the selection of wavelet basis function is very important. Symmetry and antisymmetry are equivalent to linear phase and generalized linear phase because they are bandpass filters in signal processing. If a bandpass filter is not linear phase or generalized linear phase, it distorts the passing signal. In order to avoid signal distortion, spline wavelets with tight support, symmetry and antisymmetry properties are selected in this experiment.

Repeated experiments and simulations show that the spline times increase and the curve becomes smoother and smoother, but the effect of noise removal is weakened due to the increase of bandwidth. After balance consideration, cubic b-spline wavelet is selected as wavelet basis function to decompose and synthesize ECG signal. Polynomial of cubic B spline wavelet is as follows:

### 4. Simulation results

The available databases include MIT-BIH ECG Database, AHA(American Heart Association) arrhythmia ECG Database, Common Standards for Electrocardiography (SCE) Database, ST-T Database, PTB ECG Database in Germany, and the Prediction Challenge Database in The United States. Because MIT-BIH arrhythmia database is free and open, and the labeling quality of samples is high and detailed, this paper chooses MIT-BIH arrhythmia database as the data source. The sampling frequency of ECG signals in mit-bit standard database is \( f_s = 360 \text{ Hz} \). The chart given in the following experiment is the simulation result of no. 100 ECG data. A section of no. 100 ECG signal was intercepted for study, starting from 20s, and the signal length was \( N = 2048 \) points.
The principle of wavelet de-noising method is simple. When dealing with ECG signal, the frequency band of interference signal is set to zero directly, and the characteristic band of ECG signal is...
reconstructed to obtain the de-noised ECG signal. When the noise frequency band and signal frequency band do not overlap and the noise frequency band range is known, the wavelet decomposition and reconstruction method is very good filter effect. Since ECG interference basically covers the whole frequency band of ECG signal, it is small Wave decomposition and reconstruction can remove most of the ECG interference.

As can be seen from figure 5, wavelet noise reduction can remove the noise of ECG signals very well. Although the wavelet noise reduction effect is very good, it affects the side value of R wave, which is the focus of the next research.

5. Conclusion
The wavelet denoising method to eliminate noise of ECG signals, the experiments show that the denoising method for ECG signal noise suppression is a very effective, after eliminate noise keep the basic waveform characteristics of the ECG signal, choose the adaptive threshold value method is adaptive, suitable for non-stationary denoising of ECG signals processing, compared with the traditional ECG signal denoising method has obvious advantages. Although the wavelet noise reduction effect is very good, it affects the side value of R wave, which is the focus of the future research.

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