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The Application of Frequency Slice Wavelet Transform in ECG Signal Feature Extraction ⋆

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Abstract

According to the difference of time-frequency characteristics of ECG (electrocardiogram) signal and jamming signal, FSWT (Frequency Slice Wavelet Transform) is used to deal with the ECG signal denoising and feature extraction. FSWT algorithm has a good time-frequency aggregation and can freely choose the frequency range for signal reconstruction to extract characteristic information flexibly and accurately. Firstly, ECG signal is decomposed to get the whole time-frequency distribution characteristic by using FSWT and carries on the detailed analysis. Frequency section interval is determined according to frequency distribution characteristics of the jamming signal, disturbance signal is refactored and isolated through the time-frequency filter and the inverse transformation of FSWT. So it can realize the ECG signal denoising and feature extraction. The proposed algorithm is compared with wavelet threshold denoising method, Empirical Mode Decomposition (EMD) and average empirical mode decomposition (AIMF). The simulation results show that, the denoising effect of FSWT is superior to other methods for ECG signal, and gives the time-frequency distribution characteristics of ECG signal.

Keywords: ECG Signal; FSWT; Time-frequency Analysis; Feature Extraction

1 Introduction

Usually a normal ECG amplitude is in 10 μV-5 mV, and frequency range is within 0.15 Hz-150 Hz. While about 90% spectral energy of the ECG signal exist between 0.25 Hz-35 Hz. Due to the impact of human body, equipment, etc, the measured ECG signal is often accompanied by disturbances such as, (1) baseline drift, its frequency is less than 5 Hz; (2) the myoelectricity interference (EMG), the interference has a wide frequency range; (3) power frequency interference, its frequency is 50 Hz; (4) other random noise. Because of above interference, each wave band of correct identifying ECG signal the diagnostic results are all affected [1].

The time-frequency analysis method of ECG signal includes: Short-time Fourier Transform (STFT), wavelet transform, the EMD method, and so on. Wavelet transform has a good denoising effect only at the time of the correlation of signal and noise [2,3]. In the process of denoising,

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EMD exists endpoint effect and frequency aliasing phenomenon [4,5]. Hence, this paper introduce the Frequency Slice Wavelet Transform (FSWT) into the time-frequency analysis for ECG signal. FSWT itself is an effectual filter to noise [6]. FSWT can very clearly represent the characteristics of signal simultaneously in time and frequency domain. It can be controlled adaptively in separation by dynamic scale. The application of FSWT is focused on the damping vibration signal processing, signal filtering and signal segmenting, etc.

2 The Basic Principle of FSWT Algorithm

2.1 Frequency Section of the Wavelet Transform (FSWT) Algorithm

For signal $f(t) \in L^2(R)$, if $p(t)$ is a function of the frequency of the slice, its Fourier transform is $\hat{p}(\omega)$, the frequency slice wavelet function of $f(t)$ is defined:

$$W(t,\omega,\sigma,\lambda) = \frac{\lambda}{2\pi}\int_{-\infty}^{\infty} \hat{f}(u)\hat{p}^*\left(\frac{u-\omega}{\sigma}\right)e^{iut}du \tag{1}$$

in the formula, σ is the scale factor ($\sigma \neq 0$), λ is the energy coefficient ($\lambda \neq 0$), σ and λ for the function or a constant of ω and t, $\hat{p}(\omega)$ is the mother wavelet function form of $p(t)$ in frequency domain, $\hat{p}^*(\omega)$ is a the conjugate function of $\hat{p}(\omega)$, the wavelet function $\lambda p[(u-\omega)/\sigma]$ is the result of scale and translation transform of $p(\omega)$ in the frequency domain.

By type (1), the algorithm by introducing FSWT scale and translation for variable time-frequency window, introduced traditional FT with functions of time-frequency analysis. By using Parseval's theorem, type (1) can be translated to the time domain:

$$W(t,\omega,\lambda,\sigma) = \sigma\lambda e^{i\omega t}\int_{-\infty}^{\infty} f(\tau)[\sigma(\tau-1)]d\tau \tag{2}$$

In fact, even $p(t)$ and $\hat{p}(\omega)$ are known, according to Eq. (2), it is difficult to analyze in the frequency domain. Therefore, only when analysing the signal is concerned about $\hat{p}(\omega)$, and defined as a function of frequency slice [7,8]. We first give some special cases of $\hat{p}(\omega)$ or $p(t)$ as below: (a) $\hat{p}(0) \neq 0$ or $\hat{p}(0) = 1$; (b) $\int_{-\infty}^{+\infty} |\hat{p}(\omega)|^2 d\omega < \infty$; (c) $\hat{p}(\pm\infty) = 0$; (d) $|\hat{p}(\omega)| \leq \hat{p}(0)$ or $|p(t) \leq p(0)|$.

2.2 The Selection of Scale Factor

Order $\lambda = 1$, according to the principle of Morlet wavelet transform, $\sigma \propto \omega$, taking the scale factor $\sigma = \frac{\omega}{k},\ k > 0$, and

$$W(t,\omega,k) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \hat{f}(u)\hat{p}^*\Big(k\frac{u-\omega}{\omega}\Big)e^{itu}du \tag{3}$$

Introduce $k\frac{u-\omega}{\omega}$ into frequency slice function, ω, u and k is independent, we use it adjust the sensitiy of time and frequency, called resolution time-frequency coefficients. Eq. (2) can be changed:

$$W(t,\omega,k) = \frac{1}{k}\omega e^{i\omega t}\int_{-\infty}^{\infty} f(\tau)e^{i\omega\tau}p\Big[\frac{\omega(\tau-t)}{k}\Big]du \tag{4}$$