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Short Communication

Exact Wavelet Threshold Determined by the ACF of Denoised ECG Signals

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ABSTRACT

The heartbeat signal monitored by wearable sensors can detect cardiovascular diseases in real time, which is one of the deadliest diseases in the world. However, it is contaminated by noise, seriously affecting the accuracy of diagnosis. This article proposes a real-time and accurate wavelet thresholding method that utilizes normalized autocorrelation functions to accurately estimate electrocardiogram signals, *i.e.,* accurately estimate noise. Compared to traditional wavelet thresholding methods, it can effectively remove various types of noise, especially actual noise. The method can adaptively process complex noise without parameter adjustment, overcoming the shortcomings of existing methods that cannot accurately obtain wavelet thresholds in real time. The method can optimize the parameters of other filters besides various wavelet transforms to enhance the SNR of periodic signals more effectively.

Keywords: Biomedical analytical methods; Electrocardiography; Autocorrelation; Wavelet transform

INTRODUCTION

Heartbeat signal is one of the most important indicators for the diagnosis of cardiovascular diseases, so it is crucial to measure and analyze Electrocardiogram (ECG) signal accurately. However, the accuracy and reliability of ECG signals are severely degraded due to various interferences, such as additive Gaussian white noise, baseline drift noise, electrode motion noise and muscle artifact noise [1]. Therefore, accurately removing noise from ECG signals has become an important issue in the current research field. The wavelet transform has been widely used to process nonstationary biomedical signals [2,3]. However, the traditional wavelet thresholding method based on noise estimation or signal feature estimation makes it difficult to obtain an accurate threshold to remove complex real noise. Thresholding methods based on artificial intelligence can obtain accurate thresholds, but require heavy computation and reduce the real-time performance of ECG signal processing.

DESCRIPTION

We propose a fast iterative accurate wavelet thresholding method for its Non-Zero-Order Periodic Peaks (NZOPP) of the normalized Autocorrelation Function (ACF) [4]. The main idea of the method is that noise has no correlation while ECG signal has correlation. Therefore, the NZOPP value is positively correlated with the Signal-to-Noise Ratio (SNR), with a higher NZOPP value representing a cleaner signal. The method does not require parameter fine-tuning but can obtain more accurate thresholds than traditional wavelet thresholding methods and does not require a large amount of data training compared to artificial intelligence methods that can remove noise in real time. It is experimentally validated using a variety of ECG signals from different databases, each containing a specific type of noise such as additive Gaussian white noise, baseline drift noise, electrode motion noise and muscle artifact noise [5]. Although this method is only marginally better at removing additive white noise from ECG signals, it is far superior to conventional methods at removing true noise. The SNR can be improved by several or even thousands of times when removing baseline drift and power line noise. This is because this method can not only accurately distinguish additive Gaussian white noise that is significantly different from the spectrum of the electrocardiogram signal, but also accurately distinguish real noise that resembles to the spectrum of the electrocardiogram signal [6]. It is worth noting that, in practical applications, the SNR and noise standard deviation cannot be obtained due to the unavailability of accurate clean signal and noise levels for evaluating the denoising quality, whereas the proposed method

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is able to evaluate the denoising quality and thus improve the SNR of the signal based on the autocorrelation characteristics of the denoised signal alone.

CONCLUSION

This method overcomes the deficiency of existing wavelet thresholding methods that cannot accurately obtain the threshold value in real time, without manual parameter adjustment and heavy computations. The method is not limited to the threshold of the traditional discrete wavelet transform, but also applies to other parameter optimization (such as wavelet threshold function, number of decomposition layers, etc.), as well as other wavelet transforms (such as the static wavelet transform, dual-tree complex wavelet transform, lifting wavelet transform, etc.) and is also widely applicable to other filters (such as non-local mean filter, bilateral filter, mode-variant decomposition and singular value decomposition, etc.). The disadvantage is that since the method is based on the NZOPP of the ACF, it is only applicable to the assessment of denoising quality of periodic signals (e.g., electroencephalogram signals, heartbeat signals, rolling bearing signals, pulsed radar signals and image periodic textures, etc.). This method improves the SNR of ECG signals and provides better support for the diagnosis and treatment of cardiovascular diseases.

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