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Multiscale Analysing Methods in Electrocardiogram Signal Processing and Interpretation

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Abstract

Multiscale analysis is a fundamental theoretical approach in several engineering disciplines including signal and image processing and interpretation. This paper presents briefly the use of multiresolution and multiscale analysis as wavelet transform and spectral analysis in detecting and interpreting specific features of electrocardiogram (ECG) signals. The continuous wavelet transform based scalogram and the power spectral density based periodogram are presented as valuable tools in arrhythmia detection and interpretation. Specific signals from dedicated databases are used; the computational tasks are performed in Matlab environment using suitable toolboxes.

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Keywords: Multiscale analysis; wavelet transform; periodogram; scalogram.

1. Introduction

The analysis of the electrocardiogram signals has been the main issue of many scientific works since last twenty years. These works have introduced various computational tools for signal processing for different purposes.The electrocardiogram as non-invasive record of electrical activity of the human heart is a widely used signal in order to detect, trait, predict and prevent different diseases. This paper deals with the multiscale time-frequency domain transforms of these signals in order to find various scale or frequency related features connected to diseases.

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Any change from the normal electrical activity of human heart (sequence of electrical impulses) is called arrhythmia. Unfortunately, there are a large number of cardiac arrhythmias that could be life threatening, among these the most important are ventricular fibrillation (VF), ventricular tachycardia (VT) and atrial fibrillation (AF). In case of theirs occurrence it is important to detect them, to recognize them and immediately restore the normal heart rhythm. Sometimes there is no consistently identifiable fiducial point in the ECG, and analysis of the normal clinical features is not possible. In such cases, it is usual to exploit the changes in frequency characteristics that are present during arrhythmias [6], [7]. These arrhythmias have specific features in terms of signal processing parameters, ventricular fibrillation is characterized by continuous bands in the range of 2-10 Hz; ventricular tachycardia is characterized by two distinct bands: the first is in the range of 2-5 Hz and the second is in the range of 6-8 Hz; and atrial fibrillation is determined by a low frequency band in the range of 0-5 Hz. These parameters can be detected, measured and evaluated through signal processing procedures in order to observe, treat and prevent arrhythmias.

This paper presents the theoretical background of scalogram, and power spectral density through wavelet and Fourier transforms [1], a procedure to compute them [2] and also the obtained results in arrhythmia detection. Finally the conclusions bring the synthesis and mark out further working directions [6].

2. Multiscale procedures in electrophysiological signal analysis

2.1. Power spectral density. Periodograms.

Power spectral density (PSD) is a measure of a signal's power value in the frequency domain. Usually, the PSD is computed from the frequency spectrum of a signal, it provides a useful way to characterize the magnitude versus frequency content [1]. In a general form, the PSD is the average of the Fourier transform magnitude squared, over a large time interval

$$S_x(f) = \lim_{T\to\infty} E\left\{ \frac{1}{2T} \left| \int_{-T}^{T} x(t) e^{-j2\pi ft} dt \right|^2 \right\} \tag{1}$$

The power spectral density describes how the power of a time series is distributed with frequency. Mathematically, it is defined as the Fourier transform of the autocorrelation sequence of the time series. The linear spectral density is simply the square root of the power spectral density, and similarly for the spectrum, a power spectral density (PSD) expressed in V^2/Hz , it is the average power is distributed as a function of frequency. Variations of fixed frequencies would appear in PSD as distinctive sharp peaks. From a computational point of view PSD and autocorrelation form a Fourier transform pair.

2.2. Continuous Wavelet Transform. Scalograms.

The wavelet transform is calculated by taking the inner product between the original signal and the so called basis functions. The result is a set of coefficients which measures the similarity between the analyzing and analyzed signal. This set of coefficients indicates how close the signal is to the basis function. In the case of wavelet analysis the basis functions are scaled (stretched or compressed) versions of the same prototype function, called the mother wavelet. Mathematical backgrounds about of wavelet transform can be founded in [3], [4]. The continuous wavelet transform (CWT) of signal x is defined as convolution between the analyzed signal and combination of a set of basis functions, obtained by means of dilation a and translation b of a mother wavelet [3].

$$W_a x(b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{+\infty} x(t)\, \psi\left(\frac{t-b}{a}\right) dt \tag{2}$$