Multiscale Processing of Multichannel Electrocardiogram Signals

A

Thesis submitted

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By

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Abstract

This thesis documents our investigations on processing of multichannel electrocardiogram signals using multiscale principal component analysis (MSPCA). There are three broad contributions. First, wavelet based denoising methods are proposed and evaluated for noise cancellation. The proposed denoising methods are based on relative subband energy of the signal and its Gaussianity from real data. Higher order statistics at different wavelet subbands provides significant information about the statistical nature of the data in time and frequency. The fourth order cumulant, Kurtosis, and the Energy Contribution Efficiency (ECE) of signal in a wavelet subband are combined to assess the noise content in the signal. The proposed methods show improved performance over soft threshold, hard threshold and SURE methods when applied to ECG signals.

Second, multiscale principal components analysis (MSPCA) is investigated for compression of multichannel electrocardiogram signals. If all the channels of a standard 12-lead ECG are subjected to wavelet transform with the same decomposition level and mother wavelet, it is expected that, at the same wavelet scale the inter-lead correlation may be much higher. The correlations across the ECG channels at the same wavelet scales are investigated using scatter plots and correlation coefficients. The higher correlations between multichannel ECG signal-components at similar wavelet scales help reduce dimension and remove redundant information present in signals. Using covariance method for PCA, it is found that the proposed method perform data dimension reduction without introducing distortion on clinical information. Multichannel compression is implemented using uniform quantizer and entropy coding of MSPCA coefficients. Third, clinical entropy (Centropy) is proposed based on an information theoretic approach to eigenvalue matrices resulted from MSPCA. It is shown that Centropy can effectively quantify the distortions in the clinical components in an ECG signal.

The major contributions of the work reported in this thesis includes,

1. Denoising using Higher Order Statistics in Wavelet Subbands.
2. Denoising based on Kurtosis based Noise Variance and Multiscale Energy.
3. Multiscale Principal Component Analysis (MSPCA) for multichannel ECG processing and ECG data compression.
4. Clinical Entropy based Principal Component Analysis (PCA) and MSPCA for multichannel ECG Signals.

The other contributions are,

1. Multiscale multivariate energy contribution efficiency for multichannel ECG.
2. Denoising multichannel ECG using Multiscale PCA.
3. Quality controlled denoising of multichannel ECG signals using Multiscale PCA.
4. Multiscale Distortion Measure for Multichannel Electrocardiogram.

Keywords: Multichannel electrocardiogram, Denoising, Principal Component Analysis, Multiscale Principal Component Analysis, Distortion Measure, PRD, WWPRD, WEDD.