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Review

Wavelet-based electrocardiogram signal compression methods and their performances: A prospective review

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ABSTRACT

Cardiovascular disease (CVD) is one of the most widespread health problems with unpredictable and life-threatening consequences. The electrocardiogram (ECG) is commonly recorded for computer-aided CVD diagnosis, human emotion recognition and person authentication systems. For effective detection and diagnosis of cardiac diseases, the ECG signals are continuously recorded, processed, stored, and transmitted via wire/wireless communication networks. But long-term continuous cardiac monitoring system generates huge volume of ECG data daily. Therefore, a reliable and efficient ECG signal compression method is highly demanded to meet the real-time constraints including limited channel capacity, memory and battery-power of remote cardiac monitoring, ECG record management and telecardiology systems. In such scenarios, the main objective of the ECG signal compression is to reduce the data rate for effective transmission and/or storage purposes without significantly distorting the clinical features of different kinds of PQRST morphologies contained in the recorded ECG signal. Numerous ECG compression methods have been proposed by exploiting the intra-beat correlation, inter-beat correlation and intra-channel correlation of the ECG signals. This paper presents a prospective review of wavelet-based ECG compression methods and their performances based upon findings obtained from various experiments conducted using both clean and noisy ECG signals. This paper briefly describes different kinds of compression techniques used in the one-dimensional wavelet-based ECG compression methods. Then, the performance of each of the wavelet-based compression methods is tested and validated using the standard MIT-BIH arrhythmia databases and performance metrics. The pros and cons of different wavelet-based compression methods are demonstrated based upon the experimental results. Finally, various practical issues involved in the validation procedures, reconstructed signal quality assessment, and performance comparisons are highlighted by considering the future research studies based on the recent powerful digital signal processing techniques and computing platform.

Contents

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1. Introduction

Recent developments in digital technologies, sensors, efficient signal processing tools and wireless communication technologies enables to store and transmit biomedical signals for diagnosing patients diseases. Nowadays cardiovascular disease (CVD) is one of the most widespread health problems with unpredictable and life-threatening consequences in developing and developed countries in the world. The electrocardiogram (ECG) signals are widely used for detecting different kinds of heart diseases [1–8]. For effectively detecting and diagnosing CVD problems, long-term multi-channel ECG signals are recorded with different sampling rates and bit resolutions. The ECG signals, for example, received from recording systems such as 12-lead ECG, the vector cardiography (VCG) high-resolution ECG, exercise ECG are digitized at the sampling rate ranging from 100 to 1000 Hz with resolution between 8 and 12 bit per sample [1–18]. The amplitude of the recorded ECG signal on the skin is from 0.1 mV to 5 mV [1–10]. The recording of the electrical field generated by the His and Purkinje activities produces a signal in the ECG with an amplitude range of about 1–10 μV which is useful for identification of conduction abnormalities [2]. The frequency extends from 0.05 Hz to 130 Hz [3,10–12]. In ECG signal, notches and slurs may be superimposed on the slowly varying QRS complexes. The recommendations of the committee on electrocardiography of the American heart association suggest a conversion rate of 500 Hz with a 9-bit resolution [1]. The amount of ECG data depends upon the sampling frequency, sample width, the number of leads and record duration. Thus, the long-term ECG monitoring system generates large amount of cardiac data. Recently, miniaturized wearable ECG recorder enables both recording and transmission of ECG data via well-established telecommunication networks to the specialist diagnostic center [13–15]. In practice, sample rates from 100 Hz to 1000 Hz are used with 8–16 bit resolution per sample [1,10,16–18]. The data rate has become approximately 11–22 Mbits/h/lead. For the CVD analysis, multi-channel ECG signals are continuously recorded for 12–72 h to monitor ischemia, ventricular and supra-ventricular dysrhythmias, conduction abnormalities, QT interval and heart rate variability [2–8]. Hence, ECG record management system and telecardiology application requires reliable and efficient compression techniques for storage and continuous transmission purposes [34].

In general, single-channel and multi-channel ECG signal recording systems are used for effective analysis and diagnosis of cardiovascular diseases. Under long-term multi-channel recording conditions, ECG signals may exhibit three types of signal correlations: the intra-beat, the inter-beat and the inter-channel/lead. Figs. 1–3 illustrate different types of signal correlations. The intra-beat correlation represents the correlation between the successive

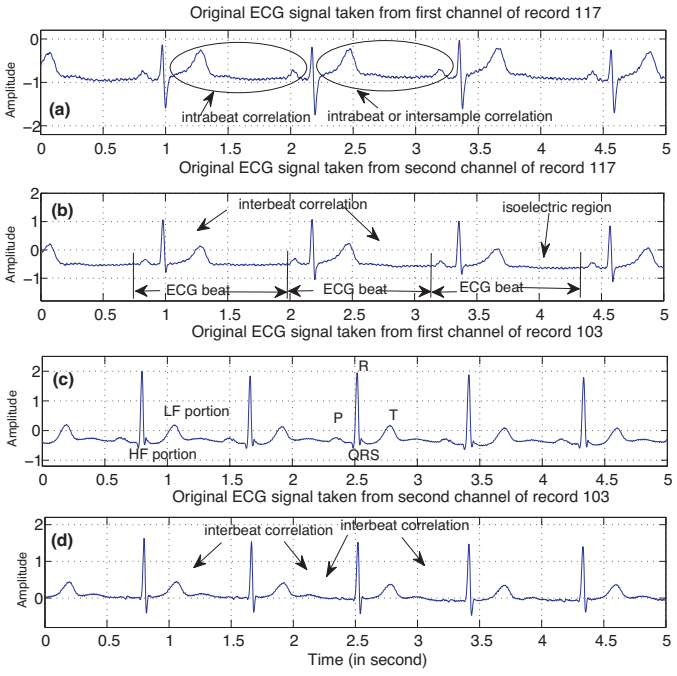

Fig. 1. Illustrates the ECG signal correlations such as intra-beat and inter-beat and low-frequency (LF) and high-frequency portions.