A Non-Linear Approach to ECG Signal Processing using Morphological Filters

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ABSTRACT

Analysis of the Electrocardiogram (ECG) signals is the pre-requisite for the clinical diagnosis of cardiovascular diseases. ECG signal is degraded by artifacts such as baseline drift and noises which appear during the acquisition phase. The effect of impulse and Gaussian noises is randomly distributed whereas baseline drift generally affects the baseline of the ECG signal; these artifacts induce interference in the diagnosis of cardiovascular diseases. The influence of these artifacts on the ECG signals needs to be removed by suitable ECG signal processing scheme. This paper proposes combination of non-linear morphological operators for the noise and baseline drift removal. Non flat structuring elements of varying dimensions are employed with morphological filtering to achieve low distortion as well as good noise removal. Simulation outcomes illustrate noteworthy improvement in baseline drift yielding lower values of MSE and PRD; on the other hand high signal to noise ratios depicts suppression of impulse and Gaussian noises.

Keywords: Baseline Wander, Gaussian Noise, Impulse Noise, Measure of Percentage Root Mean Square Difference (PRD), Morphology, Non-Flat Structuring Element

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1. INTRODUCTION

Electrocardiography (ECG) is an interpretation or account of the electrical activity of the heart over the period of certain time, which is detected by electrodes attached to the outer surface of the skin. This recording is called Electrocardiogram which particularly shows the plot of surface bio-potentials. The examination of these provides information about cardiac abnormalities which can even lead to death. The ECG device detects and amplifies the electrical charges present on the skin caused by depolarization of the heart muscle during each heartbeat. The orderly progression of a wave of depolarization is detected as very small rises and falls in voltages which can be displayed as wavy line on the display device. A single normal cycle of ECG represents the consecutive atrial and ventricular depolarization and repolarization during every heartbeat which is associated with the peaks and troughs of ECG waveform (Dupre et al., 2005; Fathima et al., 2012; Karthik et al., 2013, Labate et al., 2013). ECG signals are frequently plagued by impulse and Gaussian noise in diverse forms. Power line interference of 50/60 Hz is a common artifact corrupting the raw ECG which appears as a sinusoidal wave (Gupta et al., 2010; Lay-Ekuakille et al., 2013). Another artifact is baseline wander, where the baseline (of ECG waveform) starts to drift up and down in a sinusoidal pattern due to respiration. One more significant artifact is Electromyographic noise (EMG) where muscle contraction signals interfere with the ECG. Baseline correction and noise elimination forms an important module in preliminary analysis of ECG signals (Lay-Ekuakille et al., May 2013; Sep 2013). It is important to limit the distortion by the baseline correction and noise suppression algorithms for further analysis such as QRS detection and temporal alignment for proper diagnosis. This highlights the significance of pre-processing module to catalyze the procedure of computer-aided disease diagnosis (Bhateja et al., 2010; 2011; Mar 2013; May 2013; Jun 2013; Aug 2013) to facilitate the subsequent detection of cardiovascular disease. Computer based diagnosis have been demonstrated fertile for various other diseases especially which are based on accumulation of fluid (M. Khan et al., 2007; S. Urooj et al., 2010; 2011). In this regard, the reliability issues of the computer-based biophysical model reported in (S. Urooj et al., May 2011; Jun 2011; 2012) are of great importance. Multiresolution techniques in wavelet domain for ECG signal conditioning include wavelet packet, multi-wavelet, bionic wavelet and lifting wavelet (Sayadi et al., 2007; Srivistava et al., 2011). Techniques employing mathematical morphology for noise and baseline removal in ECG signals include works of Chu et al. (1996), Sun et al. (2002), Lay-Ekuakille et al. (2008), Liu et al. (2011) and Casciaro et al. (2012) for removal of above mentioned artifacts. The rest of this paper is organized as follows. A review of related works in the domain of ECG signal conditioning is presented in Section 2. The proposed morphological filtering scheme is described in Section 3. The results are presented and discussed in Section 4; lastly, the conclusions are drawn under Section 5.

2. ECG SIGNAL PROCESSING TECHNIQUES

In recent years, much of research work has been done towards development of the techniques for reduction of baseline wander and suppression of noise in ECG signals. Traditional methods for ECG signal conditioning include: high-pass and band-pass filtering (Peri et al., 1995). However, these filters have sharp cut-off frequency which causes the distortion of the ST segment and QRS complex and cannot track with the changing characteristics of time varying ECG signals. The temporal averaging filter adopted for noise removal requires a large number of time frames for effective noise reduction (He et al., 2006). Also, the linear filtering adopted for removing the baseline wander from ECG signals in the frequency range of 0.5 Hz introduces the ringing effect (Gibbs phenomenon) on the ECG signal analysis (Dashan 2010). Other methods involving FIR and IIR filters were
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