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Smoothening and Segmentation of ECG Signals Using Total Variation Denoising –Minimization-Majorization and Bottom-Up Approach

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Abstract: An ECG Signal records electrical activity of heart. It includes information on heart's rhythm and is useful for diagnosis of heart related diseases. It encounters with various artifacts during acquisition and transmission. The unwanted signals/noises present in ECG signals disturb the clinical information present in it. This paper tries to reduce unwanted signals through Majorization-Minorization approach to optimize total variation in the signals. The denoised signal is then segmented using bottom up approach. The results show significant improvement in signal to noise ratio and successful segmentation of sections of ECG signals.

Keywords: ECG Signal, Total Variation, Majorization –Minimization, Bottom –Up approach.

1. Introduction

The Electrocardiogram (ECG) is a graphical representation of electrical signals generated by heart. These signals are time varying and are result of expansion and contraction of heart muscles. The surface ECG is obtained by recording the potential difference between two electrodes placed on the surface of the skin. A single normal cycle of the ECG represents the successive atria depolarization/repolarization and ventricular depolarization /repolarization which occur with every heartbeat[1]. These can be approximately associated with the peaks and troughs of the ECG waveform labelled P, Q, R, S, and T as shown in Fig. 1.

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Fig. 1 An ECG Signal

Any disorder in heart rate or rhythm or change in the morphological pattern of ECG is an indication of arrhythmia. Real signals encounters with noise. Noisy signal results in inaccurate diagnosis of disease. So there is a need to denoise the signals. Each wave of ECG is clinically important. Signal segmentation may also not be accurately analysed. Therefore, reducing noise is an important issue. This has become increasingly important in Cardiac related issues. Filters not only can reduce unwanted noise and short-term components of a signal, but also increases the processing time[2].

Rest of the paper is organized as follows: In section 2, we give the required background related to ECG smoothening and Total Variation Denoising (TVD) using Majorization-Minorization (MM) approach. In section 3, we describe signal segmentation and how Bottom –Up approach is applied for signal segmentation. Section 4 deals with the implementation and results obtained. The final section is concluded with discussions regarding the presented approach.

2. ECG Smoothening

The signal encounters various types of artifacts during acquisition, transmission and storage. The noises introduced are due to power line interference (PLI), body movement's, electrode contacts, electromagnetic field interference, respiration movements[1] etc. Presence of noises in ECG signals degrades the signal quality and thus affects the visual diagnosis and feature extraction. Several denoising techniques are available in literature. Many researchers have used digital Infinite Impulse Response filters[3] (IIR) filters to reduce the effect of PLI noise and baseline wander from ECG signals. In some related works, filtering approaches based on time-frequency, wavelet transform have been proposed. Median filters, Empirical Mode Decomposition (EMD), Non-linear Bayesian filtering techniques were also used to reduce noises present in ECG signals. Statistical techniques like Principal Component Analysis[4] (PCA), Independent Component Analysis[5, 6] (ICA), Neural Networks[7] have also been used to extract clinically important signals.

TVD using MM is an optimized approach for noise reduction and preservation of sharp edges of signals[7]. TVD estimates the signal *x(n)* by solving the optimization problem :

$$\arg\min\left\{F(x) = \frac{1}{2}\sum_{n=0}^{N-1}|y(n) - x(n)|^2 + \lambda\sum_{n=1}^{N-1}|x(n) - x(n-1)|\right\} \quad (1)$$

where *x(n)*- piecewise constant signal, *y(n)*-noisy signal, *n* represent number of samples.

The first term represents the mean square error between the noisy signal and the reconstructed signal. The