ECG Signal De-noising with Asynchronous Averaging and Filtering Algorithm

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ABSTRACT

In this study, a new algorithm is proposed—Asynchronous Averaging and Filtering (AAF) for ECG signal de-noising. R-peaks are detected with another proposed algorithm—Minimum Slot and Maximum Point selecting method (MSMP). AAF algorithm reduces random noise (major component of EMG noise) from ECG signal and provides comparatively good results for baseline wander noise cancellation. Signal to noise ratio (SNR) improves in filtered ECG signal, while signal shape remains undistorted. The authors conclude that R-peak detection with MSMP method gives comparable results from existing algorithm like Pan-Tomkins algorithm. AAF algorithm is advantageous over adaptation algorithms like Wiener and LMS algorithm. Overall performance of proposed algorithms is comparatively good.

Keywords: Adaptive Algorithms, Asynchronous Signal Averaging, Baseline Wander Noise, ECG Signal, EMG Noise, Pan-Tomkins Algorithm, R-Peak Detection

INTRODUCTION

ECG is contaminated with noises mainly, 1) baseline wander noise due to heavy respiratory activity, 2) EMG (Electromyogram) noise due to electrical activity of skeletal muscles, 3) electrode motion artifact due to the physical movement of electrode that cause changes in the skin-electrode potential. The frequency range of ECG signal varies from 0.05-150 Hz and voltage levels of 0.5-4mV. EMG signal has frequency range between 1-5000Hz and voltage levels of 0.1-5mV. Thus EMG signal causes distortion of ECG signal and induces random noise in it. The spectrum of EMG overlaps the spectrum of ECG signals hence it is hard to distinguish the peaks of ECG signal and peaks of noisy signal. The presence of undesired interferences cause serious problem in the ECG diagnosis.

There are well known methods for removing these interferences (Kenneth, 2007). They are also known to have limitations as analyzed by researchers. Linear digital filters performs very well when spectra of signal and noise do not significantly overlap but when they do,
conventional filtering schemes fail to give good performance.

One of the popular techniques is adaptive noise cancellation, where the reference signal is motion (accelerometer) signal for adaptation and filtering of stress ECG signal (Raya & Sison, 2002). Therefore the performance of adaptive filtering depends on particular reference signal which have strong correlation with the noise and artifacts presence in corrupted ECG signal. In (Valtino, Thompkins, & Nquyen, 1996) linear filter bank have been used for noise cancellation and ECG signal enhancement.

This paper shows AAF algorithm which includes signal averaging and filtering for separating a repetitive (random) signal from noise without introducing signal distortion. This method is very straight forward which comparatively improves SNR by preserving original shape of the different waves (P-,Q-,R-,S-,T-wave) in ECG signal. In (Lravanian & Tung, 2002), a novel algorithm based on signal averaging and filter residue method has been proposed for filtering.

**ECG SIGNAL DE-NOISING**

Aim is to improve ECG signal de-noising method by dividing it in two stages, first stage involves QRS complex detection and second stage is filtering. In the first stage, this paper introduces MSMP and second stage filtering with AAF for ECG signal averaging.

**Asynchronous Averaging and Filtering Method (AAF)**

Signal averaging is a technique for combining the signals (images) recorded from various sources. Signal averaging is applied in varies applications to improve SNR of periodic signal mixed with random Gaussian noise. In cardiology, its main application is in the detection of ventricular late potential (Freedman, Gillis, Keren, Soderholm-Difatte, & Mason, n.d.). Generally signal averaging technique is implemented wherein:

1. Noisy ECGs are time aligned with the mean or median ECG signal
2. Signal and noise are uncorrelated
3. The nature of noise is random with a mean of zero is true.

Then averaging distorted signal m times improves SNR by a factor of \( m^{\frac{1}{2}} \) only when the random noise level of each portion of waveform has same characteristic and variability of waveform pattern is small (Herrera-Bendezu, Denys, & Reddy, n.d.) and (Alperin & Sadeh, 1986).

Signal averaging is based on the some characteristics of the signal and the noise like:

1. Signal waveform should be periodic
2. Noise must be random (not periodic) and uncorrelated with the signal
3. Temporal position of each signal waveform must be accurately known (Valtino, Thompkins, & Nquyen, 1996).

AAF algorithm is basically a modified moving average filtering method. It includes two stages for two types of noise (EMG and baseline wander noise) cancellation. First M-point averaging for EMG noise cancellation and second double mean averaging for baseline wander cancellation.

**M-Point Averaging of ECG Signal**

The m-point arithmetic averaging of signal gives the random noise cancellation from the signal. So m-point averaging of ECG signal before and after the QRS complex for removing the random Gaussian noise (EMG noise) present only between the R-R waves has been utilized, therefore QRS complex isn’t included in averaging method.

Let \( y(n) \) represent the realization of signal
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