ECG Detection Using a Convolution Wavelet Algorithm for Denoising of Surface EMG

Hojun Yeom¹, Jinsook Roh², Ukjin Yoon³, Seng Bum Yoo³, William Z. Rymer³, Randall F. Beer³

¹Department of Biomedical Engineering, Eulji Univ., South Korea
²Sensory Motor Performance Program, Rehabilitation Inst. of Chicago, IL, USA
³Mediana Inc., Wonju, South Korea
hyeom@eulji.ac.kr

Abstract. We compared the performance of bandpass filtering methods, the commonly used mathematical morphology operator (MMO) method and the convolution-wavelet method (CNW) on both simulated and real sEMG data. The CNW showed better performance as compared to bandpass filtering and the MMO particularly for low signal-to-artifact ratios.

Keywords: convolution, wavelet, trunk muscle, EMG, ECG artifact.

1 Introduction

In this study, we assessed the effectiveness of the convolution wavelet method (CNW) in comparison to the previous methods.

2 Methods

We have to compare actual and known values of parameters with the values obtained using the new methods. Performance of the filters was first quantified as a function of signal-to-noise ratio in simulated noisy EMG signals and then with the addition of baseline drift and motion artifact.

Fig. 1. Simulated EMG signals with ECG signals in the condition (1) without environmental noise, (2) with baseline drift, and (3) movement artifacts.
Surface EMGs were recorded (Bagnoli 8, Delsys Incorporated, Boston, MA) from 14 muscles including pectoralis major (sternal fibers), while human subjects generated isometric force at the wrist, in 210 directions, homogeneously distributed in the three-dimensional force-space.

We compared the performance of 3 algorithms for detection of the QRS complex.

First, we used a bandpass IIR filter with cutoff frequencies of 5 and 20 Hz to detect the QRS complex. Second, the mathematical morphology operator (MMO) was used to identify the QRS complex[1]. Wavelet function was newly generated through convolution in the wavelet and scaling functions. This wavelet function removed noise again through convolution with the ECG signal and amplified the energy of the QRS complex. For optimally detecting the QRS complex through convolution, we decided on k value which the number of iterations computed, as k=3 [2].

\[
CNW(t) = \psi(t)_{k-3} * \phi(t)_{k-3}
\]

(1)

3 Results

Performance evaluation of each QRS complex detection algorithm was made on sensitivity (SE) and positive predictive values (P) through the statistical methods.

\[
SE(\%) = \frac{TP}{TP + FN}, \quad P(\%) = \frac{TP}{TP + FP}
\]

(2)

FN, FP, and TP represent the number of false negatives, false positives and total points, which indicates the total number of QRS complexes detected by the algorithm. We show the results of quantitative analysis of the three filtering algorithms in Table 1 and Fig. 2.

<table>
<thead>
<tr>
<th>SNR</th>
<th>BAND</th>
<th>MMO</th>
<th>CNW</th>
<th>BAND</th>
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<th>CNW</th>
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<td>FP</td>
<td>Se(%)</td>
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<td>FP</td>
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</table>

Table 1. Comparison of detection rates for various SNRs

SNR: signal-to-noise ratio; FN: false negative; FP: false positive; MMO: mathematical morphology operator; CNW: convolution wavelet.
Fig. 2. Comparison of three removal algorithm performances in Sensitivity associated with leaving the EMG in the ECG signal.

The BAND produced lower Sensitivity percent in the range from -5 dB to -25 dB. The BAND looks better than MMO in EMG+ECG and EMG + Baseline drift, however it produced lower Sensitivity percent that ranged from -5 dB to -25 dB in the case of EMG+ECG and motion artifact. The CNW method consistently produced higher sensitivity than the MMO and BAND.
The performance of the CNW algorithm for removal of the ECG artifact in a real sEMG signal. The CNW detected the ECG artifact completely, while eliminating the ECG artifact and reconstructing the average EMG template.

4 Discussion

The proposed processing steps include detection and reduction of the ECG signal with the CNW algorithm. The results of QRS complex detection with simulated and real data show a consistently higher percentage of accurate detection and thus we could retain the clean EMG signal.

References