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A Localized ECG Cancellation Method for Preserving EMG Information in Trunk Muscle Analysis

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Abstract

Surface electromyography (sEMG) signals from the trunk region are often distorted by the electrical activity of the heart (ECG), particularly when analyzing low-amplitude EMG responses. Existing methods for resolving this problem through ECG cancellation often lead to the deterioration of noiseless portions of the signal. In this paper, we propose an original ECG cancellation method that aims to limit the deterioration of sEMG information. Instead of directly removing the ECG, our method consists of two main steps: ECG localization and selective ECG cancellation based on detected heart pulses. The localization phase effectively extracts the ECG contribution using a combination of discrete wavelet transforms (DWT) and independent component analysis (ICA). Subsequently, a novel algorithm based on the fast Fourier transform (FFT) leverages the quasi-periodic properties of the ECG to accurately detect the positions of heart pulses. We conducted extensive simulations to evaluate the proposed method in terms of relative errors, coherence, and accuracy under different levels of ECG interference. Additionally, we assessed the method using correlation coefficients computed from paraspinal muscle EMG signals obtained from 12 healthy participants. The simulation and real data results demonstrate that our proposed method accurately detects pulse positions, efficiently removes ECG from EMG signals even in heavily overlapped scenarios, and effectively limits EMG deterioration.

Keywords: ECG Cancellation, Quasi-periodic Signals Detection, Discrete Wavelet Transforms, Independent Component Analysis.

I. Introduction

Surface electromyography (sEMG) is a non-invasive and cost-effective method widely utilized in clinical and research settings to study various aspects of muscular activities, including neuromuscular diseases. However, before interpreting the acquired signals, post-processing is necessary due to the susceptibility of sEMG electrodes to various artifact sources such as movement artifacts, power line interferences, and interference from other devices or body parts. Consequently, artifact cancellation is a crucial topic in biomedical signal processing.

When recording muscular activities in the thoracic or trunk region, sEMG signals are significantly contaminated by the electrical activity of the heart muscles (ECG). Separating the heart's contribution from the muscle activity is challenging because their frequency spectra overlap. EMG signals typically range from 10 to 500 Hz, with the most power between 20 and 200 Hz, while ECG signals span from 0 to 100 Hz, with power diminishing after 35 Hz [1]. The corruption caused by cardiac artifacts is particularly detrimental when analyzing low muscular activities, such as studying the effects of spinal manipulation therapy on human physiological responses [2-4]. In these experiments, sEMG electrodes placed on

Cardiac artifacts clearly corrupt muscular responses. This corruption is more damaging if the signals to analyse are low muscular activities, as for example, it is the case in studies about the impacts of the spinal manipulation therapy on the human physiologic responses [5]. In those experimentations, sEMG electrodes recorded spine erector spinae muscles (close to

ccurately detects pulse positions, efficiently removes ECG from EMG signals even in heavily overlapped scenarios, and effectively limits EMG deterioration

VI. Conclusion

In conclusion, this paper presents an original ECG cancellation method designed to preserve EMG information in trunk muscle analysis. The proposed method focuses on localizing and selectively canceling the ECG contribution, aiming to minimize the deterioration of the desired EMG signals. Through the combination of discrete wavelet transforms (DWT), independent component analysis (ICA), and a novel algorithm based on the fast Fourier transform (FFT), the method accurately detects the positions of cardiac pulses and efficiently removes the ECG from the EMG signals, even in scenarios where the two signals strongly overlap. Extensive simulations were conducted to evaluate the performance of the proposed method, considering relative errors, coherence, and accuracy metrics under varying levels of ECG interference. Furthermore, real data obtained from a study on spinal manipulation effects were used to assess the method's performance in a practical setting. The results from both simulation and real data experiments demonstrate the effectiveness of the proposed method in accurately detecting pulse positions and limiting the deterioration of the EMG signals. By preserving the EMG information while removing the ECG, the proposed method offers a valuable tool for researchers and clinicians in studying muscular activities in the trunk region. The ability to mitigate the distortion caused by cardiac artifacts enhances the accuracy and reliability of EMG analysis, particularly in cases where low-amplitude EMG responses are of interest. Future research may focus on further refining the method and exploring its applicability in other contexts beyond trunk muscle analysis.

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