Comparison of Fractional- and Integer-Order Filters in Filtration of Myoelectric Activity Acquired from Biceps Brachii

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Abstract. This study assesses the viability of filtration of myoelectric signal using fractional-order filters. We acquired raw EMG signal from *m. biceps brachii* during isometric maximal voluntary contraction from ten test subjects; tested conventional and fractional Butterworth filters of two order groups; and compared the results in terms of offline filtration.

Keywords: myoelectric activity, electromyography, fractional order filters, fractional calculus, noninteger-order systems.

1 Introduction

Fractional order systems (FOS) have recently attracted scientists, especially biomedical engineers who study biological signals such as electrocardiographic (ECG), electromyographic (EMG) or electroencephalographic (EEG) signal [1], which may be because the stochastic nature of these signals is well modeled by fractional order systems [2]. Moreover, biological signals are susceptible to multiple sources of noise, such artifacts resulting from moving muscles or heartbeat activity [1] which require filtration. Thus, a proper filtration is crucial for maintaining high quality of the signals.

The electromyographic (EMG) signal is a manifestation of the electrical activity resulting from muscle contraction and neural drive. During muscle contraction a volume current propagates within the tissues covering the muscle fibers and eventually reaches the surface of skin (thus it is called surface EMG) [1]. The bandwidth of the EMG signal lies between 20 and 450 Hz, which corresponds to the frequency range of the firing of motor units - the fundamental functional units of the muscle - as a result of the neural activity that drives muscle contraction [1]. To maintain high quality of the signal, a maximally flat frequency response in the pass band and steep roll-off slopes are desirable. Butterworth filters, while sacrificing the steepness of the slopes, have the flattest pass band, which is the reason for their wide use. In this paper we test the feasibility of using Butterworth-like fractional order filters in place of conventional, integer-order.

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This paper is organized as follows: Section 2 describes the experiment from which raw EMG data was acquired, filter design scheme, the process of signal filtration and statistical analysis of the filtered signal spectra; Section 3 presents the results from each of the aforementioned steps; Section 4 contains key discussion points; Section 5 explains the observations; and Section 6 provides guidelines for future research.

2 Methods

This section covers the used methods of signal acquisition, filter design, signal filtration and statistical analysis of obtained results.

2.1 EMG Signal Acquisition

We conducted an experiment on 10 healthy subjects of both genders aging from 16 to 60 years. All subjects gave their informed consent prior to the experiment. Each subject's skin was prepared for measurement according to the recommendations of the SENIAM project [3]. Two Ag/AgCl electrodes were placed on the surface of the right *biceps brachii* muscle, midway between the *medial acromion* and *fossa cubit* [3]. The reference electrode was placed on top of the styloid process of the ulna (an electrically passive region). Bipolar signal was acquired using REFA 72 (TMSi, Oldenzaal) reference amplifier with 2048 Hz of sampling frequency. For each subject, six measurements of maximal voluntary contraction (MVC)[1] were taken. Each measurement supplied us with raw EMG signals. The experiment was conducted at *Roessingh Research and Development*, Enschede, The Netherlands.

Fig. 1. SENIAM recommendations on the location of EMG electrodes. The 'x' represents the location of the electrodes on top of the *m. biceps brachii* [source: [3]]

[1] MVC corresponds to the peak activity of the muscle during maximally forceful contraction.