

Decomposition of Surface EMG Signals into Single Fiber Action Potentials by Means of Neural Networks

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ABSTRACT

The paper describes a neural network approach to decomposing surface EMG signals into a multitude of single muscle-fiber action potentials (SFAP's). This decomposition is to yield the signal forms of the SFAP's and to allow for localizing the particular SFAP's relative to the recording (surface) electrodes. The goal of this approach is to allow the physician and the medical researcher to observe the wave-forms (of the electrical activity) and to localize SFAP's below the surface of the skin in a non-invasive manner and without discomforting the patient, as is important for several neurological diagnostic purposes. The approach utilizes a Hopfield neural network and is based on work by Sosa and Hopfield [1] on the decomposition of Gaussian sum probability distribution functions (p.d.f.'s) into individual p.d.f.'s. This utilization is facilitated by the nature of SFAP's that they can be considered to be each the sum of three base functions, the base functions having the form of a Gaussian p.d.f. function [2]. Localization is facilitated by correlating the resultant SFAP's as obtained from a (small) array of surface EMG electrodes.

1. INTRODUCTION

This paper is concerned with the decomposition of surface EMG signals into single muscle-fiber action potentials (SFAP's). Such decomposition should enable the physician or the medical researcher to observe the time behavior of SFAP in a non-invasive manner and without discomforting or affecting normal function of the patient, for diagnostic purposes.

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[2]. Furthermore, when an array of surface EMG electrodes is engaged (three or more) one can localize a given fiber relative to these surface electrodes via correlating the various reconstructed sequences of SFAP signals. The decomposition approach of the present work is based on using Hopfield neural networks rather similarly to the approach of [1]. Localization is to be performed by conventional signal means. Once decomposition has been accomplished, by correlating SFAP sequences and observing their amplitude values. Once SFAP's have been obtained, individual motor unit action potentials (MUAP's) can also be reconstructed, noting the relationship between MUAP's and their respective SFAP's.

2. Physiological Fundamentals

Surface EMG signals are the outcome of a multitude of SFAP's as observed at the skin's surface (at the surface electrode's location). MUAP's are the summation of SFAP's of those fibers that belong to a particular motor unit as in Fig. 1. Typically, in muscle location such as the deltoid or the trapezius, some 10-15 muscle fibers are innervated by a single motor neuron. Due to differences in propagation distances to the record fibers along the motor neuron and noting the finite (slow) velocity of propagation of SFAP action potentials (AP's), different SFAP's of the same motor unit are displaced in time from one another, though being otherwise perfectly synchronized sequence-wise. Hence, the SFAP is the most basic signal waveform existing due to an AP that can be observed outside the fiber or the cell, where as the MUAP is a combination (summation) of several such SFAP's. The SFAP is thus the building-block for the purpose of decomposition of the present approach. This SFAP as measured anywhere outside the fiber (on or below the skin) can still be reconstructed in terms of a summation of 3 base functions of the form of $F(t)$:

$$F(t) = \sum_{i=1}^3 K_i \exp \left[- \left(\frac{t - t_i}{\tau_i} \right)^2 \right] \quad i = 1, 2, 3 \quad (1)$$

t denoting time, with different K_i , t_i and τ_i , taking both positive and negative values, with K_i being larger than K_1 and K_2 and of opposite sign to K_1 and K_2 ; for any given SFAP [2]. We observe that the form $K_i \exp(-x_i^2)$ is the form of a

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