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A flexible approach for segregating physiological signals

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ABSTRACT

The interpretation of Surface Electromyogram (SEMG) signals at multiple muscle points for different operations of arm was investigated. Myoelectric signals were detected using designed acquisition setup consists of an instrumentation amplifier, filter circuit, an amplifier with gain adjustment. Further, Labview softscope code was used to record the SEMG signal for independent movements. The whole system consists of bipolar noninvasive electrodes, signal acquisition protocols and signal conditioning at different levels. Feature extraction was done for exercising Statistic Measured Index method to evaluate the distance between two independent groups by directly addressing the quality of signal. Thereafter factorial analysis of variance technique was investigated to analyze the effectiveness of recorded signal. Finally the SEMG feature evaluation index based reported work is a step forward to develop more powerful, flexible, efficient applications leading to prosthetic design.

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1. Introduction

Surface Electromyography (SEMG) involves recording the action potentials that activate skeletal muscle fibers. The action potentials are initiated at the muscle fiber membranes and resemble electrical waves that pass along the fibers to stimulate muscle contraction. In most cases, the action potentials are detected with bipolar arrangement placed on the surface of the skin over the muscle. Thus, during muscle contraction, the action potentials travel through the tissue overlying the muscle and are picked up by the electrodes on the skin surface. Because these electrodes are not very selective, the surface EMG signal is generated by a summation of the action potentials from many muscle fibers. The SEMG is the recorded sequences of two principal bioelectric activities i.e. (a) propogation of motor nerve impulses and their transmission at the neuromuscular junctions of a motor unit, and (b) propogation of muscle impulses by the sarcolemma and the T-tubular systems resulting in excitation and contraction coupling [1].

In order to predict the effect of SEMG corresponding to voluntary muscle contraction, various models have been developed by researchers [2–6]. Although it has been shown that all the aforementioned properties of a model are important for interpreting real data, no model is available in the literature that includes all these characteristics. From the late 1990s, due to the availability of computer systems and software modules, the researchers focused on two main subjects: (a) the relationship between the myoelectric signals collected by surface electrodes and the working of muscles and the nervous system, and (b) new techniques to extract information about the central nervous systems strategy for controlling motor units [7–13].

The advancement of electromyography, combined with modern digital processing techniques, has strongly renewed researchers' interest in detecting upper-limb motion intentions for prosthetic control [14,15] but the difficulties in SEMG signal classification for prosthetic applications are the selection of electrode locations on the arm, signal processing and the extraction of a feature

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vectors which are able to classify several motions [16–21]. Among different methods to be used for the investigation of SEMG, the spectral estimation [22] plays a vital role, and the most widely used method for this is the Fourier transform. The application of the FFT requires a stationary signal, but the nature of the signal changes with contraction level and time which indicated that its nature is non stationary and non linear. Even when there is no voluntary change of muscle state, characteristics of signal changes due to the variation in the blood flow. Therefore, in order to analyze the characteristics of non stationary SEMG signal, more advanced and powerful computer aided signal processing algorithms need to be used both in time and frequency domain.

The objective of this present work is to acquire SEMG; its pre-processing; extraction of features (comparison of recorded data against two participated muscle locations); implementation of statistical technique; and finally the cross validation of results using different techniques for ensuring class separability among four exercised movements.

2. Methodology

2.1. Data collection protocols

The data collection protocols define the timing, content and other rules relating to the ascertainment and collection of data i.e. the conduct of assessments, at particular occasions. The timing of the assessments and the specific details of the procedure to be followed vary as a function of the kind of setting in which the assessment is being completed and the key clinical event that has prompted the completion of the assessment. The data collection protocol enables data to be collected for two main purposes:

- Firstly, the data will be used explaining the reasons for the utilization of signal;
- Secondly, the data will be used in evaluating the outcomes of the analytical studies;

Surface Electromyography (SEMG) measures the electrical impulses of muscles at rest and during contraction. As with other electrophysiological signals, an SEMG signal is small and needs to be amplified with an amplifier that is specifically designed to measure physiological signals. When SEMG is measured from electrodes, the electrical signal is composed of all the action potentials occurring in the muscles underlying the electrode. This signal could either be of positive or negative voltage since it is generated before muscle force is produced and occurs at random intervals. Hence, SEMG signals were collected noninvasively at skin surface from amputed male volunteers during the complete part of experiment [16,19].

Since the research work for electromyogram signal based acquisition system is an open challenge throughout the world and consequently there is no universal accepted acquisition system available for data detection, so in this reported work the self-designed sensor system was designed for acquiring signal. The complete block diagram for the whole system is shown in Fig. 1. During the experiment, the overall gain of the system was kept 5000 and all the volunteers were seated on adjustable chair with their feet flat on the floor to perform four predefined independent movements, as described in [23,24].

3. Feature evaluation

Though the aim is to investigate the recruitment of muscle fiber during voluntary contractions, hence the estimation of variation in the amplitude of signal is more appropriate and needs to quantify for interpretation of signals, so the evaluated parameters in terms of amplitude estimation (V_{RMS}) for identifying prominent locations on upper arm muscles corresponding to independent arm movements were calculated. A wide variety of features have been considered individually and in group [1,25] representing both electromyogram amplitude and spectral content. The list of extracted parameters is as follows:

- Root mean square (RMS), for amplitude estimation;
- Power spectral density (PSD), for accurately transforming the sequence of data points;
- Euclidean Distance (ED), and;
- Standard deviation (SD), for calculating Statistic Measured Index [23,24];

Since previous work suggested [26] different factors on which the quality of SEMG depends, hence in this investigation, maximum class separability was evaluated by root mean square value, standard deviation and Statistic Measured Index (SMI) index.

3.1. ANOVA method

The basic principle [16,19,24,27] is to test for differences among the means of the populations by examining the amount of variation within each of these samples, relative to the amount of variations between the samples. Eventually one has to make two estimates of population variance i.e. one based on between samples variance and other is based on within samples variance. Finally, two aforesaid estimates of population variances are compared against *F*-test as follows:

$$F = \text{Estimate of variance between samples}/\text{Estimate of variance within samples} \tag{1}$$

The standard one-way ANOVA hypothesis tests are valid under the following assumptions:

1. The treatment populations must be normal.
2. The treatment populations must all have the same variance.

4. Result

In first part, the raw signal from identified muscle locations with different independent motions was acquired using designed system and thereafter processing was done using classical filters and computer aided simulation

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