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A technique for classification and decomposition of muscle signal for control of myoelectric prostheses based on wavelet statistical classifier

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ABSTRACT

Since surface electromyography is an electrical activity of superficial muscles and is an essential tool to investigate assessments protocols to be required for prosthetic design, so here, the wavelet transforms based interpretation of Surface Electromyogram signal for classifications of upper arm operations were investigated. The study presented methods of processing and analyzing Surface Electromyogram signal for upper arm motions for extracting accurate patterns of the signal. From these recorded signals, amplitude estimated features were extracted and explored significantly. Then a comparative study to evaluate the wavelet denoising for optimal motor unit action potential detection through the decomposition based on the different wavelet functions of Daubechies, Coiflet and Symmlets families were investigated and tabulated. Thereafter linear discriminating analysis pattern classifier approach was employed to analyze classification performance for different upper arm movements. Results inferred that Daubechies wavelet families were more suitable for the analysis of surface electromyogram signals of different upper arm motions and a classification accuracy of 85.0% was achieved. Finally data projection method of analysis of variance technique was implemented for the effectiveness of recorded surface electromyogram signals for class separability of upper arm motions.

1. Introduction

The recording and analyses of the bioelectric signals collected from the skin using non invasive bipolar electrodes can be widely used in biomedical applications for many reasons ranging from scientific curiosity to clinical diagnosis. The technologies of Surface Electromyogram recording is relatively new and have attracted remarkable attention in the design and manufacturing of artificial limbs. It is a non-invasive and pain-free technique for monitoring and assessing muscle force relation in humans performing voluntary contractions at different activities. The signals generated by most of the electrodes used to sense the bioelectric potentials of the human body are weak and are buried in noise. Though the bands pass filter determination is a compromise for removing interference noise in order to analyze the desired information from the Surface Electromyogram signal.

Since it is very difficult to separate the actual signal from the associated noise using the conventional analog signal processing techniques for proper interpretation, so now a time with the advancement in the high speed digital computers technology and advancement in sophisticated processing techniques [1] with human computer interaction based [2–11] mathematical models have made it possible to develop Surface Electromyogram detection and

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analysis algorithms to be used in robotic devices and upper-limb prostheses [12].

The relevant aspects to be covered under the development of arm constitutes two stage – first stage, the signal conditioning with controlling and second stage, its mechanical assembly. Electronic design consists of analog and digital signal processing and controlling circuit. Here in this investigation the first stage of experiment, the study for classification of upper limb motions has been analyzed. In literature, numbers of studies have reported that the results from surface electromyogram signals vary as these signals are influenced by the placement of the electrode(s). In fact, it is difficult to compare previous results due to non uniformity in muscle locations, electrode placements, acquisition set up, arm movements, number of subjects protocols and also due to different ways of analyzing, interpreting and presenting the results using simulated code. The work related to feature extraction and classification protocols for wrist operations from forearm muscle signal has been observed in literature [13].

As we are unable to compare the previous data representation results as stated above, so in this investigation Surface Electromyogram signals for different upper arm motions are measured from two muscles (biceps brachii and triceps brachii), and then the recorded signals of different arm motions are processed and decomposed into four levels using Discrete Wavelet Transform. Before evaluating surface electromyogram signal, the power spectral density (PSD) is appropriate to use since it provides information about the frequency contents in the signal. So electrode positioned mutual information group based theory for evaluation of processing techniques for dynamic contractions is proposed.

Although signal amplitude estimation can be done with many techniques, however different techniques of root mean square value, mean absolute value, simple square integral were evaluated to monitor signal variations to analyze the effectiveness of the surface electromyogram signal for class separability of upper arm motions. Further muscles location information values were used for analyzing the upper arm motions like elbow extension, elbow flexion, abduction and adductions [14].

Wavelet Transform in analysis of surface electromyogram signal is being studied since last decade, particularly in the engineering application such as the control of prostheses. This study is motivated by the fact that there is no universal mother wavelet which is applicable to all types of signals. The wavelet denoising technique is applied to remove different noises being caused while recording signal from the muscle of the subjects during voluntary contractions. The choice of right wavelet function becomes important to achieve the optimal performance [15]. Wavelet thresholding results in smoothing of the signal in the time domain or the frequency domain because each time frequency contribution of the original signal is considered locally in the time scale two dimensional domain. This technique is near optimal for a wide class of corrupted signals. In last part of study the data projection statistical method of analysis of variance is exercised for investigating the significance of recorded data and consequently the effectiveness of recorded surface electromyogram signal in a way to characterize the different upper arm motions for prosthetic designs, hence one way repeated factorial analysis of variance has been implemented.

Since the classification of upper arm motions from surface electromyogram signals is an open research to the researchers worldwide, so the objective of this present investigation evaluates properties of the surface electromyogram features through wavelet denoising family observation in signal classification and to examine a good features using statistical analysis to develop a system to assess effect of different voluntary contractions on muscle activities for the design of upper arm prosthetic arm.

The organization of the paper is as follows: the brief description of the proposed methodology and data collection procedure are discussed in Section 2. Section 3 presents the feature evaluation parameters used in this work. Experimental results and discussions are provided in Section 4.

2. Methodology

The different stages for classification of signal includes; recording of surface electromyogram signals of upper arm motions, feature extraction, decomposition using wavelet transform, feature reduction and classification of arm motions using one way repeated factorial analysis of variance (ANOVA) techniques.

2.1. Protocol for data collection

The membrane potential in the muscle is about −90 mV with the range of measured surface electromyogram potential lying between 0 to 10 mV (peak to peak) with frequency range of 2 to 10 kHz having the most relevant information below 500 Hz [17,3]. Surface electromyogram signals were acquired with the dual channel differential-mode operational amplifier (AD 620) in first stage having a gain of 5 and CMRR greater than 90 dB. The signal was again amplified by a non inverting amplifier (LM 358) in second stage with a gain of 1000. The purpose of the non-inverting amplifier was to provide fine tuning of the gain needed.

In experiment assembly, if active and reference electrodes were placed very close to each other, signal pick up was found almost same in both the electrodes with no difference between them. So, in order to extract spectral components that contain important information, signal processing electrodes placement as far as possible from each other in transverse direction is necessary [18]. The sampling frequency used for the acquisition was 1000 Hz. The recorded surface electromyogram signals were processed and analyzed with Labview® soft scope toolbox. Fig. 1 shows the block diagram of the whole process.

2.2. Electrode placement

The surface electromyogram signal was acquired from two upper-arm biceps and triceps brachii muscles simultaneously through non invasive electrodes placed on the