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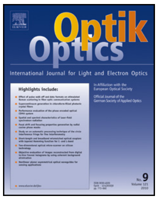

Development of sensor system with measurement of surface electromyogram signal for clinical use

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ABSTRACT

In this investigation, the study of surface electromyogram (SEMG) signals at different above-elbow muscles for different operations of the arm like elbow flexion/extension, abduction/adduction was carried out. The proposed study for measuring signal amplitude is based on subject's data (age, height, and weight) utilizing surface electromyogram-based body mass index. The whole system consists of surface electrodes, signal acquisition protocols, and signal conditioning at different levels. Labview Softscope was used to acquire the SEMG signal from the designed hardware. After acquiring the data from selected locations, interpretation of SEMG signals was done for the estimation of parameters using Labview algorithm. The different types of arm operations were analyzed using principal component analysis and analysis of variance for justifying the effect of the surface electromyogram signal for different motions. This paper provides researchers a good understanding of surface electromyogram signal with its analysis and will help them to develop more powerful, flexible, efficient applications leading to prosthetic design.

1. Introduction

The technology of surface electromyogram (SEMG) recording is relatively new and has been used in various aspects of biomedical applications and can be derived from muscles using single or multiple channels. EMG signals are generally divided into two main groups: surface and needle. Surface electromyogram signals have attracted remarkable attention in the design and manufacturing of artificial limbs. There are still limitations in detection and characterization of existing nonlinearities in the surface electromyography signal, estimation of the phase, acquiring exact information due to derivation from normality [1]. In order to utilize surface electromyogram as input to control assistive devices or prosthesis, the initial step is the processing of the surface electromyogram signal to extract features from it, and classify the signal for different types of desired motions [2]. Since the quality of the detected surface electromyogram signal determines the usefulness of the information extracted from the signal, so it is of high importance to maximize the quality of the acquired signal and this particularly depends on: (a) sensor location; (b) sensor characteristics; (c) electrode–skin interface; (d) cross-talk from other muscles; and (e) noise contamination.

Analysis of surface electromyogram signals with powerful and advanced methodologies is becoming a very important requirement in biomedical engineering. The main reason for the interest in surface electromyogram signal analysis is in clinical diagnosis and biomedical applications. Recent advances in technologies of signal processing and mathematical models have made it possible to develop advanced surface electromyogram detection and analysis techniques [3] and have been used in robotic devices and upper-limb prostheses but with limited function [4].

The process of surface electromyogram signals is the most common approach now a time used for controlling active prosthetic devices [5]. Voluntary muscle activity can be successfully detected by using appropriate filter algorithms which provides useful measurements of the signal amplitude. Various mathematical and Artificial Intelligence techniques have received extensive attention. The performance of various surface electromyogram signal analysis, along with hardware implementations, encouraged surface electromyogram applications related to prosthetic devices and human computer interactions [1,6,7]. In recent years, detecting upper-limb motion intention for prosthetic control attracted growing research [8], but the difficulties in surface electromyogram signal classification for prosthetic applications are the selection of electrode locations on the arm, signal processing and the extraction of a feature vectors which are able to classify several motions [9].

The main objective of this study is: (1) to present the design of multi electrode surface electromyogram detection system, since there is no universally accepted system available throughout; (2)

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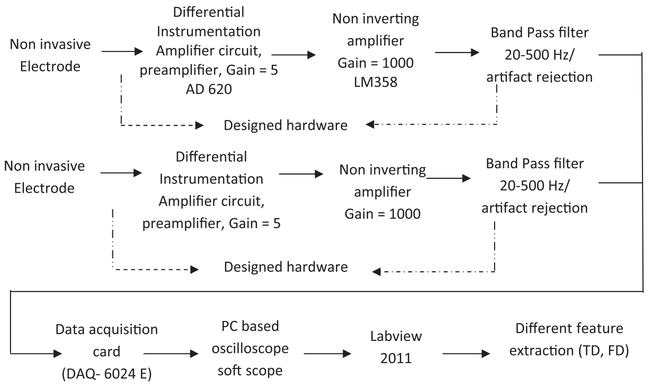

Fig. 1. Block diagram for dual channel SEMG acquisition.

to validate on experimental signals the methods proposed for different choices of the processing parameters; (3) computer-assisted recording and decomposition techniques; (4) to interpret the different arm motions; (5) to estimate the effect of surface electromyogram signal variations for different positions and motions, respectively; and finally (6) verifying the validity of the results. The study is organized as follows: in Section 2, the formal scheme of EMG acquisition and processing is presented. Section 3 describes the methodology used; Section 4 presents results regarding the extracted SEMG features, Section 5 describes statistical analysis and Section 6 gives the final conclusion.

2. SEMG signal detection system

The blocks (Fig. 1) of the surface electromyogram signal detection setup consists of a differential amplifier, noninverting amplifier, and filter circuit. Being noninvasive technique, acquisition of surface electromyogram is strongly influenced by the characteristics of the electrodes and their location on requisite muscles. According to researchers [5,10], the membrane potential in the muscle is about −90 mV with the range of measured surface electromyogram potential lying between 0 and 10 mV (peak to peak) with frequency range of 2–10 kHz having the most relevant information below 500 Hz.

In the next stage, interfacing was done to connect the surface electromyogram signal amplifier circuit to the computer through data acquisition card (DAQ). The process of digitization is defined by the concept of the sampling frequency, as it is critical in establishing the accuracy and the reproducibility of the signal. It is based on Nyquist frequency theorem i.e., signal must be sampled at no less than twice its maximum frequency. The process of sampling the surface electromyogram signal at less than 1000 Hz (samples/second) may distort the signal due to aliasing. Some of the noise from the detection and recording equipment cannot be eliminated, but can be reduced using high quality components. Ambient noise of about 50 Hz comes from power sources. Next, the noise from motion artifacts has most of its energy in the frequency range of 0–20 Hz and can be reduced by proper design of electrical circuit. As far as electrode configuration is concerned, bipolar is more appropriate than unipolar configuration since it eliminates the unwanted signal. This bipolar configuration serves as band pass filter whose bandwidth is a function of the spacing between the [11] detection surfaces.

3. Methodology

Five amputed male volunteers, age 22–31 year, weight 55–90 kg, height of 170–180 cm and body mass index (BMI) ratio shown in Table 1, participated in the complete part of this experiment. They were well informed of what the experiment was about. The surface electromyogram signal was recorded from two upper-arm muscles, the biceps (A) and triceps brachii (B) individually with maximum time of 3 s. Simple form of pre-gelled Ag/AgCl passive electrodes with bipolar configuration was used for signal acquisition.

Table 1
Demographic data of subjects.

Subject data					
ID No.	Age	Gender	Height (cm)	Weight (kg)	BMI (kg/m^2)
1	29	M	173	61	20.4
2	25	M	178	75	23.7
3	26	M	173	78	26.1
4	28	M	174	79	26.4
5	25	M	170	60	20.8

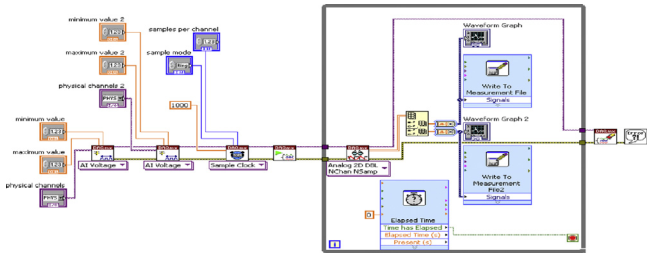

Fig. 2. Labview schematic for signal acquisition.

SEMG signals were acquired with the differential-mode operational amplifier in first stage having a gain of 5 and CMRR greater than 90 db. The surface electromyogram signal was again amplified by a non inverting amplifier 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 [12]. The inter-electrode distance was kept as 1 cm. Three electrodes were used for the signal acquisition. The sampling frequency used for the acquisition was 1000 Hz. The recorded SEMG signals were processed and analyzed with Labview. The block diagram for the whole system is as shown in Fig. 1. Labview-based code for acquiring the data is shown in Fig. 2.

3.1. Activities performed

Subjects were seated on a chair. Each subject was asked to perform four independent movements for different muscles activation.

- P1—Arm was in rest with downward position parallel to body, Elbow Extension (ee).
- P2—Hand was moved upside. This position is called flexion elbow (ef)
- P3—Arm was rotated in abduction direction (abd).
- P4—Arm was rotated in adduction direction (add).

The details of five subjects on which experiments were performed are given in Table 1. Fig. 3 depicts activities involved in complete process.

4. Result

The strength of surface electromyogram signal is a good measure of the strength of contraction of muscle. Further, the muscular