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Research Article

Design of EMG Controlled Prosthetic Hand

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Abstract

The human hand has various movements and actions which is very essential for independence. Loss of hand reduces the caliber of life. The purpose of this project is to design a prosthetic hand that utilizes the myoelectric signals for controlling the movements such as Flexion, Extension, Pronation, Supination, hand grasp and release with reduced energy expenditure of the amputee and at reduced cost. The design involves developing the necessary EMG acquisition and processing circuitry, interfacing the output and programming the microcontroller for classification of various movements and developing the driving circuitry for rotation of the motors. Using this, amputees will be able to control the motors in the myoelectric prostheses by voluntarily contracting the muscles of their residual limb.

Keywords: Myoelectric prosthesis; Pronation; Supation; Hand g rasp; Hand release.

Introduction

The new devices are generated for communication between man and machine to develop better interfaces and control systems, closer to the human body. One particular case of interaction between man-machine is the prosthetic device. Rehabilitation of amputees with acquired limb loss as a result of workplace injuries is important for the affected people to have a normal life. Prosthetic application is an essential part of the rehabilitation process and the ability to return to work is enhanced when appropriate prosthetic devices are employed. In this work, EMG signal is used to control the prosthetic hand. Myoelectric technology uses electromyographic (EMG) activity, a form of electrical signal, from the voluntary movements of the stump muscles [1].

EMG signal, which acts as control signal for the flow of energy to the electric motor, is captured through surface electrodes [2]. The amplitude of the EMG signal is generally proportional to the contraction of the residual muscle. After amplification and transmission, the myoelectric control system activates the electric motor to operate the terminal device namely a prosthetic hand [3].

Electromyography (EMG) deals with the detection, analysis and utilization of electrical signals which originates from skeletal muscles. Electromyography is studied in the field of Biomedical Engineering and Bio mechatronics deals with the prosthesis using electromyography. Myoelectric signal is a kind of electric signal produced during muscle activation. It is produced due to small electrical currents which are generated by the exchange of ions within the muscle membranes. The EMG signal is detected with the help of electrodes. Electrical activity produced by the muscles of the human body can be evaluated using Electromyography [4]. Electromyography is the instrument which is used to obtain the EMG signal and the resultant record which obtained is known as electromyogram. The functioning of human body is a fascinating and intriguing activity.

Methodology

In this proposed work, the EMG signals that are generated from the muscles of the residual limb are recorded using surface electrodes and have been employed for the development of the prosthetic hand [5]. The EMG signal is measured on the skin surface at the microvolt level. These emissions that are picked up by electrodes and are amplified for use as control signals to the functional elements of

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the prosthesis. The flow chart for prosthetic design is shown in figure 1.

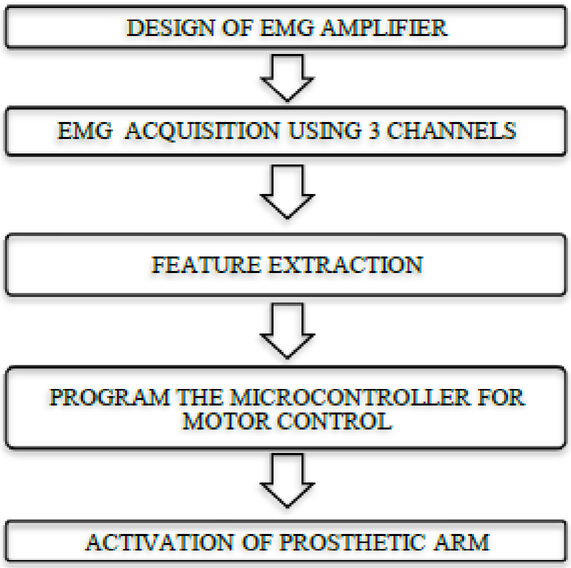

Fig. 1. Flowchart for prosthetic arm design

Implementation

The implementation of Prosthetic limb is divided into two parts namely, Electronic assembly and Mechanical assembly

a) Electronic Assembly

The Electronic assembly consists of three sets of EMG Amplifier and Signal Conditioning units. One set for Flexion/Extension, one set for Pronation/Supination and the other set for grasping movement of the hand [6]-[7]. The signals acquired from the muscles are very weak; therefore it has to be amplified for its efficient usage.

An instrumentation amplifier with variable gain is used for this purpose. The amplified signal is then fed to the signal conditioning unit which comprises a band pass filter and a full wave rectifier. The EMG signal being biphasic, has to be rectified to make it compatible within the (0-5) V range of the microcontroller. The features taken into consideration are implemented in the microcontroller for classifying the six movements of the upper limb namely Flexion, Extension, Pronation, Supination grasping and release of the hand [8] – [9]. Data was collected using two EMG channels. For the feature extraction the windowing was done using a disjoint windowing scheme, which consumes less computer resources due to its simplicity. Various feature sets have been extracted; Waveform length, Hjoth Time Domain (TD) Parameters, Slope Sign Changes, Number of Zero Crossings, Sample Skewness and Auto Regressive (AR) Model parameters were selected [10]. Microcontroller is used for the analysis and classification of those signals and in turn to control the mechanical part.

b) Mechanical assembly

The mechanical assembly consists of three motors, one for controlling Flexion and Extension movement of the elbow, one for controlling Pronation and Supination movement and the other for controlling the grasping and releasing of the hand.

Signal Acquisition

The EMG signals are picked up from the following muscles

Channel 1 - EMG from Biceps Brachii Muscle (For flexion and extension) [2] is shown in Fig. 2. Channel 2 - EMG from Pronator Teres Muscle (For pronation and supination) is shown in Fig. 3. Channel 3 - EMG from Brachio Radialis Muscle (For hand grasp and release) [3] is shown in Fig. 4

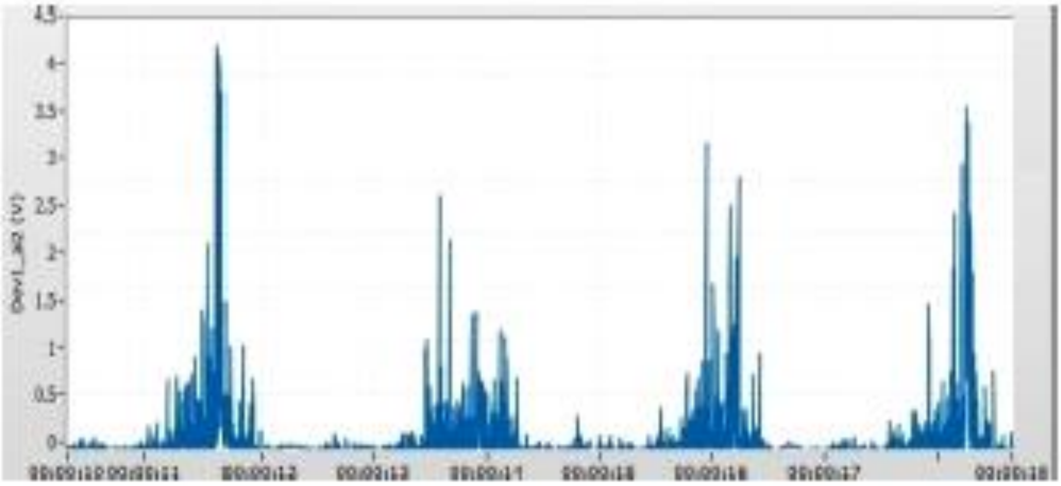

Fig. 2. EMG for Flexion and Extension

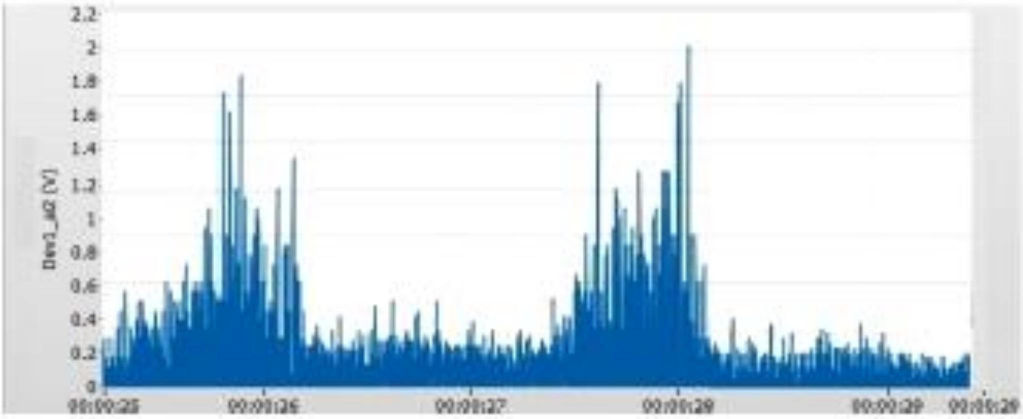

Fig. 3. EMG fronation and Supination

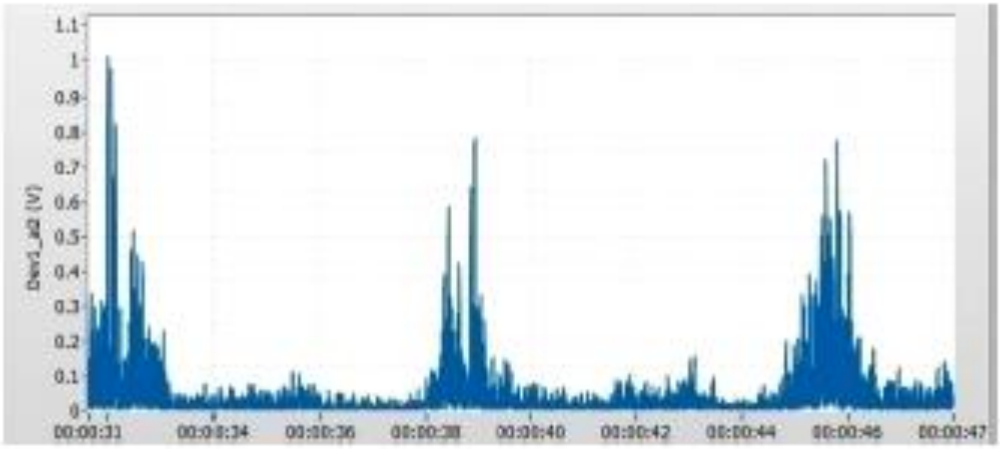

Fig. 4. EMG for Hand Grasp and Release

The three channel EMG signal obtained from the Amplifier circuit is brought into the microcontroller. The main objective of this article is to analyze critically different methods for EMG signal processing that could be exploited to improve the controllability and thus the usability of current hand prostheses. The motivation for this effort is the assumption that, even if current hand prostheses have many intrinsic limitations, their performance could be improved significantly by implementing better control techniques based on better EMG signal processing.

Feature extraction

The accessibility and the computational simplicity make time domain features the most popular tools for generating outputs for the myoelectric control system [4]. They are based on time-amplitude representation of the signal and features taken for analysis are

1. Mean:

The average value, or mean, of a signal x is calculated using the equation

$$V_{th} = \frac{1}{N}\sum_{n=0}^{N-1} x_n$$

It is computed over time duration of N samples.

2. Variance:

Variance is a measure of how values are distributed around the mean value.

The variance, or sample variance, of a signal x is calculated using the equation

$$\sigma_x^2 \stackrel{\Delta}{=} \frac{1}{N}\sum_{n=0}^{N-1} \left|x_n - \mu_x\right|^2$$

It is computed over time duration of N samples.

D. Programming the Microcontroller

The microcontroller is programmed to extract the features like variance, threshold value in order to classify the upper limb movements namely flexion, extension, pronation, supination and the grasping movement of the hand which will provide control signal in an exact manner to control the action of three motors.

Results and discussions

The analysis is done by extracting features such as the statistical parameters like mean and variance for the EMG signals of all three channels. The feature values obtained by considering the EMG signals while performing flexion, extension, pronation, supination, hand grasp and release movements are tabulated in table 1, 2 and 3.

Table 1. Analysis of Flexion/Extension

Subject	Position	Mean	Variance
1	Flexion	623	72
	Extension	701	77
2	Flexion	688	69
	Extension	710	79

Table 2. Analysis of Pronation/Supination

Subject	Position	Mean	Variance
1	Pronation	68	37
	Supination	115	20
2	Pronation	64	30
	Supination	116	21

Table 3: Analysis of Hand Grasp/Release

Subject	Position	Mean	Variance
1	Hold	117	8
	Release	131	14
2	Hold	115	6
	Release	141	16

Thus the difference in the time domain features calculated from the three channels are observed. Further, the difference in the individual signals has to be analyzed. Based on which, the movements has to be classified.

Conclusions

After classifying the six upper limb movements, the microcontroller provides an appropriate control signal for the actuation of motors in a smooth and controlled manner. The motors in-turn the controls Flexion/Extension Pronation/Supination and HandGrasp/Release movements. The designed low cost upper limb prosthesis has brought out an active motion at the elbow joint and it has been tested with 2 healthy subjects

Conflict of interest

Authors declare there are no conflicts of interest.

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