EMG CONTROLLED SYSTEM OF 4-DOF ROBOTIC ARM

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DECLARATION

I declare that this thesis entitled "EMG CONTROLLED SYSTEM OF 4-DOF ROBOTIC ARM is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	
Date	:	

APPROVAL

I hereby declare that I have checked this report entitled “EMG CONTROLLED SYSTEM OF 4-DOF ROBOTIC ARM” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Electromyography (EMG) provides an alternative way of providing signal responses from the muscle. As such, the recent trend in developing myoelectric devices have spark the interest in this specific field of study. This is because the traditional controllers lack in certain parts which reduce the utilization of limbs to control devices mainly the robotic arm. However, noise such as crosstalk, motion artifact, ambient noise and inherent noise have become a major issue when handling EMG signals. The preparation of electromyography requires more attention in terms of muscle group selection, electrode placement and condition of the surrounding as it will affect the signal output. The aim of this study was to develop a 4 degree-of-freedom (DOF) robotic arm that can be controlled using EMG signals. The correlation between the EMG signal and the robotic arm are required to identified to analyze the performance of robotic arm. Review on the actuator, electromyography methods and microcontroller are done to evaluate the techniques used from past researches. The methods of this project include identification the error percentage of the actuator, classification and validation of EMG signals based on hand gestures, the correlation between the characteristic of the EMG signals with the functionality and performance of the robotic arm. The experiment showed that the actuator produced minor percentage error and does not affect the robotic arm accuracy significantly. The sampling rate and arm position affect the EMG signal output. In addition, the controllability of the robotic arm was low because the motors are controlled independently. The objectives of the project are achieved as the EMG-controlled robotic arm has been successfully developed. The robotic arm is still available for improvement by adding multiple channel sensor and implementing a wireless system.

ABSTRAK

Elektromilogi (EMG) menyediakan cara untuk mendapatkan bacaan isyarat daripada otot. Sehubungan dengan itu, penghasilan peranti myoelektrik telah menarik minat terhadap bidang ini. Hal ini kerana pengawal yang sedia ada mempunyai kekurangan yang menghadkan kadar penggunan anggota badan untuk mengawal pergerakkan peranti terutamanya tangan robotik. Walau bagaimanapun, isyarat EMG adalah terdedah kepada gangguan seperti pertembungan isyarat dari otot yang lain, pergerakkan otot dan radiasi daripada peranti elektrik. Penyediaan elektromilogi memerlukan lebih perhatian terutama pada pemilihan kumpulan otot, penempatan elektrod pada tubuh badan dan keadaan persekitaran kerana ia akan menggangu isyarat EMG. Tujuan utama projek ini ialah untuk membuat tangan robotik yang mempunyai empat darjah kebebasan yang dikawal menggunakan isyarat EMG. Hubungan antara isyarat EMG dan tangan robotik perlu diketahui untuk mengkaji prestasi tangan robotik. Kajian semula tentang mesin penggerak, teknik elektromilogi dan mikropengawal dilaksanakan untuk menilai teknik yang digunakan dalam kajian lepas. Antara kaedah yang digunakan ialah mengenalpasti tahap keberkesanan mesin penggerak, pengkelasan dan pengesahan isyarat EMG berdasarkan isyarat tangan dan mengenal pasti hubungan diantara ciri isyarat EMG dengan fungsi serta prestasi tangan robotik. Hasil eksperimen ini menunjukkan bahawa mesin penggerak mempunyai peratus kesilapan yang kecil dan tidak menggangguu ketepatan tangan robotik. Tambahan pula, kadar pengambilan sampel dan kedudukan tangan mempengaruhi isyarat EMG. Tahap kawalan tangan robotik pula adalah rendah kerana mesin penggerak perlu dikawal satu persatu. Objektif projek ini telah dicapai kerana tangan robotik yang dikawal menggunakan isyarat EMG dapat dihasilkan. Tangan robotik boleh lagi diperbaiki dengan menambahkan jumlah pengesan dan mengimplimentasikan sistem tanpa wayar.

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LIST OF SYMBOLS AND ABBREVIATIONS

EMG	-	Electromyography
DOF	-	Degree of freedom
FDS	-	Flexor digitorum superficialis
V	-	Voltage
A	-	Ampere
bits	-	Binary digits
θ	-	Angle

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CHAPTER 1

INTRODUCTION

1.1 Overview

This section contains five parts which are project background, motivation problem statement, objectives and scopes. The project background highlights on some key aspects and fundamental of electromyography (EMG). The motivation discusses on the purpose of conducting the project based on the recent trend that associates with myoelectric devices. The problem statement discusses the problem regarding the preparation and development of EMG controlled devices. The objectives are sets of goal that needs to be achieved at the end of this project and is associated with limitation from the scope.

1.2 Background

Electromyography (EMG) has been commonly used in biomedical and clinical application. EMG is a process of measuring electrical activity in the muscles. An EMG signal[1] is basically the summation of all the action potential recorded from the muscle fiber. The motor units[2] which is made up of muscle fiber exhibits electrical properties when muscles undergoes contraction. The raw EMG signal is measured in terms of voltage and typically displayed in waveform. Figure 1.1 shows an example of EMG signal waveform.

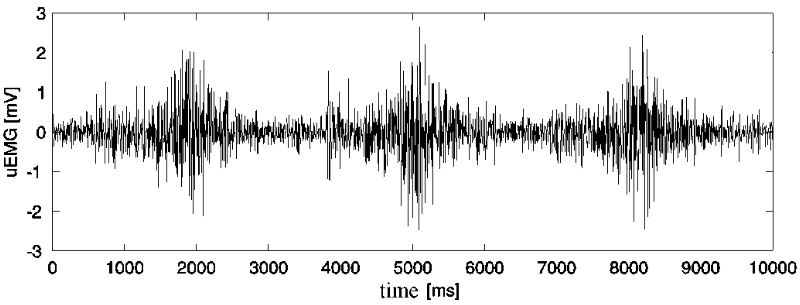

Figure 1.1 Example of EMG signal waveform

There are two known methods of extracting EMG signals which are the invasive and non-invasive methods. The invasive method uses wired electrodes that is inserted into the muscle’s fibers. The non-invasive method uses surface electrodes that are placed on the skin surface. The methods still use the same concept of recording EMG signal despite using different technique. The non-invasive method has been the more popular approach because the method is easier to conduct. However, both .techniques still share a common problem which is the EMG signals are highly exposed to noise [3]

There are several processes required before the EMG signal is readable. Pre-processing is the initial step in EMG signal data acquisition. The process includes amplification, filtration, rectification and analog to digital conversion. The EMG signal amplitude usually ranges from 0-10mV and the frequency ranges from 0 -500 Hz. The parameters depend of the type of electrode used. Signal that have been processed are transferred to the computer for real-time signal monitoring.

1.3 Motivation

In recent years, the usage of EMG signal for automation control, prosthetics and robotic arms has been more frequent. EMG signals have been used mostly in clinical application to diagnose muscles disorders in the past. Multiple researches have been conducted which aims to control devices using EMG signals. Table 1.1 shows a list of projects that have implemented electromyography in their device system.

Table 1.1 List of recent projects related with electromyography

Year	Projects
2015	Bilateral rehabilitation using an EMG-controlled robotic hand exoskeleton[4]
2016	Intelligent wheelchair controlled by EMG [5]
2017	EMG-controlled prosthetic hand with sensory system[6]
2018	Gait Robotic Exoskeleton[7]
2019	Robotic Arm movement using EMG signals[8]

The sudden interest in this field of studies is because the potential EMG signals have not yet been fully explored. The advantage of electromyography is that the signal is produced naturally by the movement of body parts. Controlling a device mainly a robotic arm would be more interactive compared to the standard controller because it utilizes the movement of the human body parts. In addition, this will also provide a more fluid control over the devices because traditional controllers restrict the movement to a certain body segment.

Lack of physical sensation of controlling a manipulator is also one of the factors that lead researches towards the usage of EMG signal. Most of the robotic arms are currently controlled by mechanical controllers and vision controllers. Examples of these controllers are joystick, buttons and image processing-based controllers. Both mechanical and vision controllers can control the robotic arm but lacks control over the transmission of force to the manipulator. EMG signals enable the user to control the devices via gesture which is influenced by the amount of force exerted by the muscle.

Hence, conducting this project will help in improving the control over myoelectric devices mainly the robotic arm. The behavior of manipulator based on the EMG signal from performing limb movement is the main aspect that is used to determine controller functionality and efficiency. The study on EMG-based controller will also help in overcoming the limitation of the previous controller.

1.4 Problem Statement

Electromyography exhibit several issues that affect the outcome of the signal. The placement of electrode is one of the main concerns of electromyography. Both method, invasive and non-invasive electromyography requires accurate positioning in order to get a quality EMG signal. The muscle group[9] needs to be identified initially before applying the electrode. The effect of electrode misplacement is cross talk which leads to misinterpretation of EMG signals.

Another problem when using electromyography is that the EMG signals are easily exposed to noise. Some examples of the noises are motion artifact, ambient noise and inherent noise. The motion artifact[10] produces the most noise compare to the other noises. Motion artifacts is the involuntary movement of the body that causes the muscles to contract randomly. This leads to the interference of the contact between the muscle fiber and the electrode.

The controller requires to read EMG signal which then will be transmitted to the actuator to produce movement. The EMG signals have an infinite value which mean that the signals produced are random and hardly the same for the same gesture. The signals need to be allocated into a certain range value for the controller to distinguish the gesture. This process requires proper EMG signal classification as the signal will also be affected by noise.

The precision of the robotic arm also needs to be considered. This is more focused on the selection of actuators as they handle the rotational movement of the robotic arm. Some of the motors may have major defects which will cause the motors to have a higher percentage error. A higher error will reduce the performance rate of the robotic arm as well as make it harder to manipulate. Hence, there are several problems in developing an EMG controlled robotic arm which are the electrode placement, noise exposure, classification of EMG signals and accuracy of the robotic arm.

1.5 Objectives

1. To design and develop a functional 4-DOF robotic arm that is controlled using EMG signals
2. To perform analysis on the operation of the Robotic Arm based on the characteristic of EMG signal collected from the forearm.
3. To test the effectiveness of the actuators based on the instruction given by the controller

1.6 Scopes

1. Developing a 4 degree of freedom (DOF) robotic arm with base, shoulder, elbow, wrist and gripper motion.
2. The movement of the robotic arm is controlled using EMG signals that are collected from the upper limb
3. The system will use a microcontroller to process the input and output data.
4. Surface electrodes will use to collect EMG signals that is interfaced by a single channel EMG sensor
5. A total of five actuators will be used to actuate the robotic arm joints.
6. The robotic arm forward kinematic will be developed using the DH convention method.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This section discusses on the review of information from other journals and papers. The topic that is reviewed are actuator, electromyography and controller. The actuator consists of three parts which are servo motor, DC motor and stepper motor. The electromyography section consists of three parts which are invasive electromyography, non-invasive electromyography and electrode placement. Lastly, the microcontroller section consists of three parts which are Arduino UNO, Raspberry Pi and Arduino Mega 2560. The summary of the reviews is discussed in in the final section of this chapter.

2.2 Actuator

An actuator is a device that convert energy into motion. The actuators are required to move the robotic links and joints in order to replicate the real human limbs. Different types of actuator have their own advantage and disadvantages. Three types of actuator will be discussed in this part which are servo motor, DC motor and Stepper motor.

2.2.1 Servo Motor

The servo motor is a type of rotary actuator that can have a precise control over angular position. There are two types of servo motor, a DC servo motor and an AC servo motor. Both types operate on PWM (Pulse Width Modulation) which is activated when a pulse is sent to its respective output pins. The motor can produce high torque which can generate enough force to move medium weighted loads. The servo motors are commonly used in robotic applications. Figure 2.1 shows a typical servo motor.

Figure 2.1 Servo motor

Several research projects have used the servo motor for its ease of control. The robotic arm in [11] used servo motors as actuators which is controlled using internet connection. The angle of rotation is inserted into the program and transferred to the controller. The manipulator was able to rotate based on the value given by the researchers. The voiced controlled prosthetic arm[12] is another example of servo motor application. The prosthetic consists of six standard servo motors which are controlled by human speech. It is possible to generate a range of PWM signals by classification of different voice sample.

Servo motors also have a very high accuracy in terms of angle rotation. It uses a close loop negative feedback system using a potentiometer to return the current angle of the servo motor. In paper [13], the servo motor is used to actuate the gripper which used a geared system. The gripper is locked when the servo reached the desired angle. Another example of servo motor accuracy is the chess playing robot[14] which uses servo motor to lower down the end effector. The servo motor pushes the manipulator tip to reach the top of the chess piece without overshooting.

The servo motors in general have high torque, high accuracy and easy to control in which is suitable for a control operation. The common rectangular shape of a servo motor is also an advantage for some cases as it is easier to install it in the system. Any standard microcontroller with PWM output can control a servo motor.

2.2.2 DC Motor

A DC Motor is a rotary actuator that converts electrical energy into mechanical energy. The motor main components are axle, rotor, commutator, field magnets, and