DEVELOPMENT OF MEASUREMENT SYSTEM FOR INDIRECT HAND GRIP FORCE AND WRIST ANGLE FOR BIONIC HAND

FAZILLA BINTI MD AMIN TENG

A report submitted is partial fulfillment of the requirements for the degree of Mechatronic Engineering

Faculty of Electrical Engineering

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"I hereby declare that I have read through this report entitle "Development of Measurement System for Indirect Hand Grip and Wrist Angle for Bionic Hand" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature : ……..

Supervisor's Name : Dr Fariz bin Ali @ Ibrahim

Date : ……..……

I declare that this report entitle “Development of Measurement System for Indirect Hand Grip and Wrist Angle for Bionic Hand” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……..…….

Name : Fazilla binti Md Amin Teng

Date : ……

To my beloved mother and father

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ABSTRACT

In today's world, the number of physical disability people is increasing year by year. To overcome the problem, bionic hand is introduced. However, most of the bionic hands designed are complex and time consuming. Thus, in this project, a bionic hand with a designed measurement system is proposed. The first objective is to design and develop a measuring system that consist of preamplifier with DRL concept, band pass filter, full wave precision rectifier, smoothing circuit and also inverting amplifier in order to extract linear enveloped EMG signal. The second objective is to establish the relationship of EMG signal with hand grip force and wrist angle. An experiment is done which the angle considered are 60°, 90°, and 120° with the hand grip force of 20N, 60N and 100N to obtain the relationship. The last objective is to see the performance of the bionic hand in terms of repeatability and accuracy by using the designed measuring circuit. In terms of repeatability, the bionic hand is led to follow the actual human hand in terms of gripping and relaxed position to see the ability of the bionic hand to repeat and follow the human hand. From the results obtained, the bionic hand manages to yield the movement repeat ably. Finally, in terms of accuracy, the angle of each fingers of the bionic hand is test respect to the expected angle of bionic hand. From the results, the bionic hand considered as accurate as most of the fingers have lower percentage of error than 50%.

ABSTRAK

Dalam dunia hari ini, bilangan orang-orang kurang upaya fizikal semakin meningkat dari tahun ke tahun. Untuk mengatasi masalah ini, tangan bionik telah diperkenalkan. Walau bagaimanapun, kebanyakan tangan bionik yang direka adalah rumit dan memakan masa. Oleh itu, dalam projek ini, tangan bionik dengan sistem pengukuran yang direka telah dicadangkan. Objektif pertama projek ini adalah untuk mereka bentuk dan membangunkan sistem pengukuran yang terdiri daripada prapenguat dengan konsep DRL, penapis lulus jalur, gelombang penuh ketepatan penerus, melicinkan litar dan juga menyongsang penguat untuk mengekstrak linear menyelubungi EMG isyarat. Objektif kedua adalah untuk mewujudkan hubungan EMG isyarat dengan kekuatan genggaman tangan dan sudut pergelangan tangan. Satu eksperimen dilakukan yang dianggap sudut 60 °, 90 °, dan 120 ° dengan kuasa cengkaman tangan 20N, 60N dan 100N untuk mendapatkan hubungan. Objektif terakhir adalah untuk melihat prestasi tangan bionik dari segi kebolehulangan dan ketepatan dengan menggunakan litar mengukur direka. Dari segi kebolehulangan, tangan bionik diketuai mengikuti tangan manusia sebenar dari segi cengkam dan kedudukan santai untuk melihat keupayaan tangan bionik mengulangi dan ikut tangan manusia. Daripada keputusan yang diperolehi, tangan bionik berjaya menghasilkan pergerakan berulang yang berupaya. Akhir sekali, dari segi ketepatan, sudut setiap jari tangan bionik adalah ujian berkenaan dengan sudut yang dijangka tangan bionik. Daripada keputusan, tangan bionik dianggap sebagai tepat kerana kebanyakan jari mempunyai peratusan lebih rendah daripada kesilapan daripada 50%.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research background

Bionic in terms of medical definition is a comprising of artificial body parts that substitute a natural biological capability. Meanwhile in terms of engineering, bionic is an application of biological principles and design of engineering systems (especially in electronic systems). Referring to Touch Bionic *et al.* , the history of touch bionics began in year 1963 at Princess Margaret Rose Hospital in Edinburgh where it start with comprehensive research in developing a prosthetic solutions for patient that affected by Thalidomide as shown in Figure 1.1. In year 1993, David Gow who joined the Bioengineering Center at the hospital, developed a partial hand system that receive international publicity and years later he achieved international profile for the world's first electrically powered shoulder. In 2007, Touch Bionics of Livingston made the i-LIMB hand that had become the world's first commercially available bionic hand that has five individually powered fingers. [1]

Figure 1.1: Patient that suffer Thalidomide

1.2 Motivation and significant of the research

Referring to the *Perangkaan Sosial Negeri/Daerah 2013,* the Table 1.1 shows the number of registered person under the department of social welfare with disabilities in Malaysia from year 2008 to 2012. In this table it shows that the number of disability people is increasing year by year.

Table 1.1: Number of Registered person with disabilities in Malaysia, from 2008 to 2012

Jenis kecacatan *Type of disability*	**2008**	**2009**	**2010**	**2011**	**2012**
Jumlah *Total*	**248,858**	**283,577**	**314,247**	**359,203**	**445,006**
Penglihatan *Visually impaired*	22,856	26,158	27,840	31,924	40,510
Pendengaran *Hearing*	34,580	37,735	39,824	43,788	53,357
Fizikal *Physical*	83,070	94,346	105,020	123,346 [a]	148,461 [a]
Masalah pembelajaran *Learning disability*	96,246	109,743	120,109	134,659	165,281
Cerebral palsy	2,890	4,071	4,068	-	-
Pertuturan *Speech*	-	-	334	725	1,734
Mental	-	-	3,663	8,927	14,990
Lain-lain *Others*	9,216	11,524	13,389	15,834	20,673

[a] **Termasuk *Cerebral palsy***
Includes Cerebral palsy

Sumber: Jabatan Kebajikan Masyarakat Malaysia
Source: Department of Social Welfare, Malaysia

For physical disabilities, in year 2008 it shows that the number of patient registered is 83070, followed by 94346 in year 2009, 105020 in 2010, 123346 in 2011 and finally 148461 in year 2012. This physical disabilities includes patient that had lost their hands, hand paralyzed and so on. For patient that facing this problem of maimed hand, their daily activities become limited and difficult for them to adapt to the daily environment. This is because they will have a difficulty to perform basic movements such as holding an object or grasping an object. To improve their daily life activities, a bionic hand by using designed measuring circuit is proposed.

1.3 Problem statement

In today's world, there are more and more amputee who had lost their body part such as hand and leg. They don't have the capability to do things like a normal person does. To improve their living ability, a bionic hand is proposed to replace their lost hands or legs. This becomes the biggest issues that surround the design and development of prostheses. Satisfaction in modern prosthetics is depends on how close a prosthetic is to reach its ideal objectives. One product has been produced by the Touch Bionic's Company which is I-Limb Ultra. This I-Limb Ultra has 14 Degree of Freedom. With 14 Degree of Freedom, the bionic hand will have more joint and parts that need to assembly together. This makes the system of this bionic hand is complex, time consuming, expensive and also hard to control. Most of the bionic hand designs used muscle kit sensor which is more expensive, to extract the EMG signal as the primary controller to control the bionic hand. The measuring circuit to extract the EMG signal is designed and developed in the project rather than muscle kit sensor as the designed measuring system cost less money and the EMG extracted is smoother compared to muscle kit sensor as it does not have a smoothing circuit in it. Thus, in this project, a bionic hand of 10 degree of freedom with designed measuring circuit which is less complex, less expensive and not time consuming is done.

1.4 Objectives

The objectives of this final year project (FYP) are to:

1. Design and develop a measurement system to extract forearm EMG signal and interface the signal with designed bionic hand.
2. Establish the relationship between forearm EMG signal and hand grip force and use this relationship to predict the hand grip force exerted and joint wrist angles when forearm EMG signals are used as input.
3. Analyze the performance of the bionic hand in term of repeatability and accuracy by using the designed measurement system.

1.5 Scope

The scopes that cover in this final year project are:

1. The EMG signal that extracted from the electrodes that attached to hand is used as the input of the system.
2. The bipolar electrodes are used in order to extract the EMG signal from Flexor Digitorum Superficialis (FDS) muscle.
3. Mohamad Fakri bionic hand designed will be used as the test bed of this project.
4. The angle considered to establish the relationship between the forearm EMG signal are 60°, 90°and 120° with hand grip force considered of 20N, 60N and 100N.

1.6 Report outline

This report consists of 5 chapters which are Introduction, Literature Review, Methodology, Preliminary Results and conclusion and recommendation. In first chapter which is Introduction, it basically talks about the objectives of project. It covers the research background of the bionic hand, motivation and significant of the research, problem statement, scope and report outline.

In chapter 2, it talks about literature review which covers the theory and basic principle, test bed of the project and also reviews of the previous related works. In this theory and basic principle, its covers the basic theory of the anatomy of hand and electromyography. The test bed of this project is developed by Mohamad Fakri which it covers the mechanical design and component selection of the bionic hand. In this chapter also, several reviews of the previous related works which taken from the journals are compared to choose the best controller and muscles to used. From the review, summary is made.

In chapter 3, it talks about methodology that used to complete the project. A flowchart is provided to see the flow on completing this project. In this chapter, it covers the objectives of the project. The first part is design and development of measuring system for forearm EMG signal extraction and interfacing to robotic hand where it covers the design measurement system and constructing the circuit. The second part covers the second objective which is the establishment of the relationship between forearm EMG signal and hand grip force. In this section, it covers the muscle selection, experimental setup for signal extraction, and establishes of the relationship. The last part covers the last objective which is to analyze the performance in term of accuracy and repeatability. Accuracy test and repeatability test is done.

In chapter 4, it covers the results obtained from each experiment that had been done. Each of the experiment is done in order to achieve every objective in this project. Analysis and discussion is made based on the results that obtained.

Finally, in chapter 5, it covers the conclusion of the whole project. Recommendation is made for further improvement for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and basic principle

In this section, theory and basic principle that are related to the development of bionic hand. It covers the anatomy of human hand which it talks about the muscle in hands. This section also covers the introduction of electromyography signal, which talks about the benefits of EMG signal and the factor influence it. In this section also, it covers on the information for test bed of the bionic hand that is developed by Mohd Fakri. Finally, it covers on the previous work done in terms of bionic hand controller and muscle selection and the performance test of bionic hand.

2.1.1 Anatomy of human hand

Hand is a complex structure which adapted to perform unequalled array of movement. There are more than 60 different muscles in the hand in order to accomplish this such as Extensor Pollicis Brevis Muscle (EPB), Flexsor digitorum sublimis (FDS), Flexsor digitorum

profundus (FDP) and many more. However, there are two main contribution of muscle in gripping hand which are Flexsor digitorum sublimis (FDS) muscle and Flexsor digitorum profundus (FDP) muscle.

Referring to Innerbody *et al.* Flexor digitorum superficialis (FDS) is a large muscle that located along the bottom of the forearm from all the bones at the elbow to the four fingers as shown in Figure 2.1. It serves to flex or curl of the fingers. This muscle is divided into two distinct heads which are the radial and humeroulnar. [3] The median nerve and ulnar artery travel through these two heads. A flexor muscle is the one that decreases the angle between the two bones such as bending the arm at the elbow.

Figure 2.1.: Flexor digitorum sublimis muscle [3]

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2.1.2 Electromyography (EMG)

Electromyography which is also known as EMG, is an experimental technique that concerned with the development and analysis of myoelectric signals. Myoelectric signal is an electrical impulse that produces the contraction of the muscle fibers in the human body. By placing electrodes on the skin, the myolectric signals can be detected. Two electrodes are placed so that there is a voltage between them when the myoelectric signals are occurs.

Meanwhile, the third electrode is placed in a natural area where its output is used to cancel the noise that can interfere with the signals from the other two electrodes.

Electromyography (EMG) signal is a small electrical current that generated when there is a contraction of a muscle. Since the electromyography signal levels are too low to be captured directly by the computer, the signal is required to amplify to a TTL level that ranged between -5volts to +5volts. By amplifying the EMG signal, the computer can store and read the data in the file format. However, there are many critical factors that must be considered such as noise and artifact problems could distort the signal. Other than that, Additional DC current could also add offset to the EMG signal. Finally, the size of the device should be taken into consideration as the equipment will be attached to the forearm during the EMG recording.

Referring to Aditya Veer Singh Rana *et al*. the measurement of the electrical activity of the muscle in the hand is the results of a signal that generates in the brain which is transmitted through the nervous system to the motor neuron attached to the muscle fibers. The motor neurons resulting in a depolarization or repolarization wave throughout the muscle fiber. This wave creates action potential in the muscle fibers resulting in the movement of the electrical charge that produces an electrical signal in the muscle. This electrical signal can be picked up by the well-placed electrodes that attached on the surface of the skin. The received signal is EMG signal. The amplitude of EMG signal is depends on the amount of force delivered by the biceps. The stronger the contraction of the muscle the larger the amplitude of the EMG signal. [5]

Referring to Peter Konrad, *et al*. there are a lot of benefits of using Electromyography (EMG) such as it allows measurements of a muscular performance, helps in decision making for both before and after surgery, helps patients to find and train their muscle. Using EMG also will allow analysis to improve sport activities and detect muscle response in ergonomic studies. [6]