CONTROLLER DESIGN OF MULTIFUNCTIONAL PROSTHETIC HAND

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Supervisor's Declaration

"I hereby declare that I have read through this report entitle 'Controller Design for Multifunctional Prosthetic Hand' and found that it has comply partial fulfilments for awarding the Degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)".

Signature:
Supervisor's Name: Dr Rozaimi Bin Ghazali
Date:

Student's Declaration

"I hereby declare that this report entitles 'Controller Design for Multifunctional Prosthetic Hand' is 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:
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Date:

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Prosthetics hand is replacement of original hands that lose or damage because of war, trauma, accident or congenital anomalies. However, problems often occur on a prosthetics hand when dealing with the control capabilities and devising functional. Thus, an advanced with control approach is required to improve the performance in terms of quality control in prosthetics hand and also enhance existing capabilities to the optimum level. This project presents the development of an enhanced prosthetics hand since the conventional prosthetic hand are incapable to functioning as a real human hand. The main objective of this project is to create a functional prosthetics hand at upper limb, which will focus on position of human hand particularly using the movement of finger instructions. In this project, an intelligent controller is proposed to realize accurate force control with high performance. A mechanical hand designed according to the physiological alignment of muscle and attempted to control the pre-recorded movement of an actual hand. In addition, performance of prosthetics hand can be assessed through the existing issue, whether is in visual or data. Firstly, the relationship and mathematical model of the position of flex signals using system identification technique will be developed. Then, Fuzzy-PID Controller is designed. Finally, evaluation on the effectiveness of the controller design will be conducted with the flex signal for the developed prosthetic hand. It is expected that the prosthetics hand will move and functional like a real hand using the flex signals and Fuzzy-PID Controller to track the desired movement of finger in prosthetic hand. The fabrication and design development of the prosthetics hand will solve the problem for people with disabilities to continue their routine life on grasping an object with an appropriate position. As a conclusion, the Fuzzy-PID controller that has been developed to control the performance of prosthetic hand model is outperform better controller than PID and Fuzzy controller, where it's improve the transient response and steady state error especially eliminate the overshoot and higher accuracy based on comparison of performance for the three different controllers.

ABSTRAK

Tangan prostetik adalah penggantian tangan asal yang disebabkan kehilangan atau kerosakan fizikal kerana kesan dari perang, trauma, kemalangan atau kecacatan kongenital. Walau bagaimanapun, kebiasaanya masalah sering berlaku pada tangan prostetik yang sedia ada terhadap keupayaan kawalan dan keupayaan merangka. Oleh itu, kemajuan terhadap pendekatan kawalan amat diperlukan bagi meningkatkan prestasi dari segi kawalan untuk tangan prostetik dan juga meningkatkan keupayaan sedia ada ke tahap yang optimum. Projek ini membentangkan pembangunan bagi tangan prostetik yang lebih efisien seperti tangan manusia sebenar. Objektif utama projek ini adalah untuk mewujudkan tangan prostetik yang pelbagai fungsi pada anggota badan yang akan memberi tumpuan kepada kedudukan pada tangan manusia terutamanya menggunakan arahan isyarat Flex. Dalam projek ini, pengawal pintar dicadangkan bagi merealisasikan ketepatan pada kawalan kedudukan pada tahap yang optimum. Satu tangan mekanikal direka mengikut penjajaran fisiologi otot dan cuba mengawal pergerakan yang telah dirakam daripada tangan yang sebenar. Selain itu, prestasi tangan prostetik boleh dinilai melalui maklumat yang sedia ada sama ada dari segi visual atau data. Projek ini mewujudkan hubungan dan matematik model berdasarkan kedudukan isyarat Flex menggunakan teknik pengenalpastian system. Kemudian, Pengawal Fuzzy-PID direka. Akhir sekali, penilaian ke atas keberkesanan reka bentuk pengawal akan dijalankan dengan menggunakan isyarat Flex terhadap tangan palsu. Tangan prostetik akan berfungsi seperti tangan sebenar menggunakan Flex dan Pengawal Fuzzy-PID untuk mengesan daya menggenggam tangan berdasarkan dikehendaki oleh pengguna. Pembuatan dan reka bentuk pembangunan tangan prostetik yang akan menyelesaikan masalah untuk orang kurang upaya untuk meneruskan kehidupan rutin mereka di menggenggam objek dengan kedudukan yang sesuai. Secara keseimpulan, pengawal Fuzzy-PID digunakan untuk mengawal prestasi model tangan palsu merupakan pengawal yang lebih baik daripada pengawal PID dan pengawal kabur di mana ia meningkatkan sambutan fana dan ralat keadaan mantap terutamanya dapat menghapuskan terlajak dan ketepatan yang lebih tinggi berdasarkan perbandingan prestasi bagi tiga pengawal yang berbeza.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Recent years, the number of cases requiring assistance in daily life has been increased for physical disability. The physical disability is the people who suffer from permanent disability or loss of a limb or limbs as a result of disease, trauma, accident, disability congenital and so on. For the activities and movements of daily life, they will facing many difficulties and hardships [1]. Therefore, most of them need help from their family's members both in terms of physical or mental support. However, some patients who have lost limbs had the desire to do anything without problems and they expect to rely on prosthetics hand to help them in their daily lives. Prosthetics devices are the tools that commonly used in medicine in the era of technology and it is quite easy for patients who are fitted with artificial limbs. Advances in prosthetic devices should be expanded aggressively where many studies that need to be improved so that the development of robotic artificial limbs can achieve great advances and their availability at a high level [1], [2].

The development of prosthetic hand is a very demanding endeavour which is essential to support the daily activities of amputated people. Design criteria for prosthetic hands are cosmetics, comfort, controllability and also low power consumption. The purpose of a prosthetic hand control system is to interpret the limited set of control signals available to the user in a way that maximizes the amount of available actions without requiring too much of the user's attention. The function of controller also affected in the design of prosthetic hand where efficiency of prosthetic hand which must attain a real ability of human hand [2].

One type of control, namely fuzzy control has appeared as one of the most popular controller explored and means of research in industrial process where they do not depend on traditional techniques. Fuzzy logic used in the fuzzy control logic system which had a closer link with human thinking and natural language. Fuzzification, defuzzification strategies and fuzzy control rules are used in fuzzy reasoning mechanism. Various fields of application ranging from automatic train operation system shows the cost effectiveness of using fuzzy logic control. Control engineers can use fuzzy logic to develop control strategies in the application area characterized by dynamic low- order non- linearity is poor.

However, the control approach contains weakness due to lack of quantitative data on the input and output relationship. Besides that, it is difficulty to develop fuzzy rules and also membership functions and fuzzy output can be interpreted in several ways to make the analysis difficult. In addition, it must expertise to develop a fuzzy system and requires lot of data. It does not deliver the results not convincing and programs have been conducted for each individual patient. Therefore, clinical applicability and use of the software is difficult without pre - programmed for different pathologies and clinical basic training to use the program.

To optimize a particular control system, many industrial implement a proportional-differential-integral (PID) controller arrangement can be adjusted. For controller design, PID is the easiest design controller compared to existing controllers. Thus, PID is the most commonly used controller in industry. Addition, many industries use controller either PID or improved version PID controller. The serial controller, parallel controller and mixed controller are basic type of PID controller. The design velocity algorithm, which also known as incremental algorithm used PID controller algorithm. In the industry, PID controllers are the most common control method to use in real applications [3].

There are many unique elements and advantages of fuzzy logic controller and PID controller over another controller such as PD controller and PI controller. The main advantages of fuzzy logic controller it is intuitive knowledge base design and flexibility. Consistency, redundancy and completeness also part of validation can be checked in rule bases. PID controller has all the necessary dynamics: proportional gain controls the effect of reducing error and derivative gain control the effect of reducing the overshoot. While for

integral gain act to improving the transient response and increasing the stability of the system [4]. However, PID controller, it has some drawbacks, when unique processes are required to perform the task when PID controllers are significantly limited in their capabilities. PID controller is capable of measuring a variety of input and calculates the difference between them.

To reduce vulnerability in existing controls on the PID controller and Fuzzy controller where the combination between the two controllers was created to accommodate all the weaknesses that exist. In addition, it also allows them to control the prosthetic hand directly and easily. Therefore, patient can to do things with their own wishes and also act alone independently. Now, it is interesting to know the detailed parts of the controller either fuzzy logic or PID controller and study the method to be used for tuning in the same time and then apply this method during the process of designing controller for prosthetic devices.

1.2 Motivation

Prosthetics hand developed widely in medical field with many several of implementation as the controller. Many types of controllers available for use to control the performance of the system such as intelligent controller. Intelligent controller is combination of one or more controller such as Fuzzy Logic, Artificial Neuron Network and other. While, controller commonly used in industrial such as PI, PD, PID and so on. For this research, combination of Fuzzy Logic and PID controller that are used that will affect the result of this analysis. Without a proper or a well-developed of system, the control of prosthetic hand will either have disturbances on great amount of which leads to the significant effect in the performance of the system.

1.3 Problem Statement

It has been addressed in much research that the causes of the dissatisfaction are low cosmetic value, functionality and controllability of prosthetics hand [4]. Research areas regarding prosthetic control in general are aimed at:

I. Controller design: Most embedded controllers of position control are used separately on prosthetics hand.
II. Processing these signals to get information out of them: Number of researchers has used simple classifiers focusing on simplicity and robustness while others use methods involving fuzzy logic and neural networks to extract information from voltage signals [4].
III. Performance of controller: Performance of controllers are differ based on the type of controllers.

1.4 Objective

Purpose of this project is to create a prosthetic hand at upper limb, which will focus on human hand in position movement particularly using the flex sensor based finger instructions. Below are the objectives that must to achieve to complete this project:

I. To develop a functional prosthetics hand hardware.
II. To design an intelligent controller that capable to control the position by using the combination of Fuzzy controller and PID controller.
III. To evaluate the performance of PID controller, Fuzzy Logic controller and Fuzzy-PID in the prosthetics hand in simulation.

1.5 Project Scope

This project will focus primarily on the controller of prosthetic hand and has a limitation during develop this project. Below are the limitations that be applied in this project:

I. The design of prosthetic hand will be focused on one fingers only.
II. The data from flex system will be collecting at the prosthetic finger.
III. Data input from the flex signal must be a voltage signal to a reference data.
IV. In the mechanical design of prosthetic hand, CAD software will be utilized.
V. MATLAB software will be implemented in collecting the data and controller design process.
VI. A combination of fuzzy logic and proportional-integral-derivative (PID) controller will be used to control the feedback and minimize the error.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter contains the overview of prosthetic hands, PID controller, Fuzzy logic controller, Fuzzy-PID controller and the overview of the research that related to the project**.**

2.2 Prosthetic Hand

This part explained about the main components related with prosthetic hand for this research: development of prosthetic hand and selection of tool.

2.2.1 Development of Prosthetic Hand

An electromyography method (EMG) is a medical method that rendered by the medical field to measure muscle reaction to anxious stimulation. Electromyograph instrument is used to perform EMG techniques to produce the record of the so-called electromyograph. An electromyograph sense the electrical signal generated by muscle cells when these cells tense.

A myoelectric prosthetics hand using EMG signals or possible of voluntary muscle contraction in the rest of one's body to the skin to control the movement of the prosthesis, such as elbow flexion, open hand, finger cap or wrist supination/pronation (rotation). This prosthesis using a neuro-muscular system of the human body to manage the rest of the functions of an electric-powered prosthetic [5]. This contrasts with the switch electric prostheses, which requires ropes and cables driven by the movement of the body to move or

operate a switch that controls the movement of the prosthesis or a completely mechanical. It has a jack hang person by taking electrodes placed on the flexors and extensors of extension and extension movements respectively. Advances in technology myoelectric in current years has made it the top end of forged components are far superior to the governing body equivalent [2].

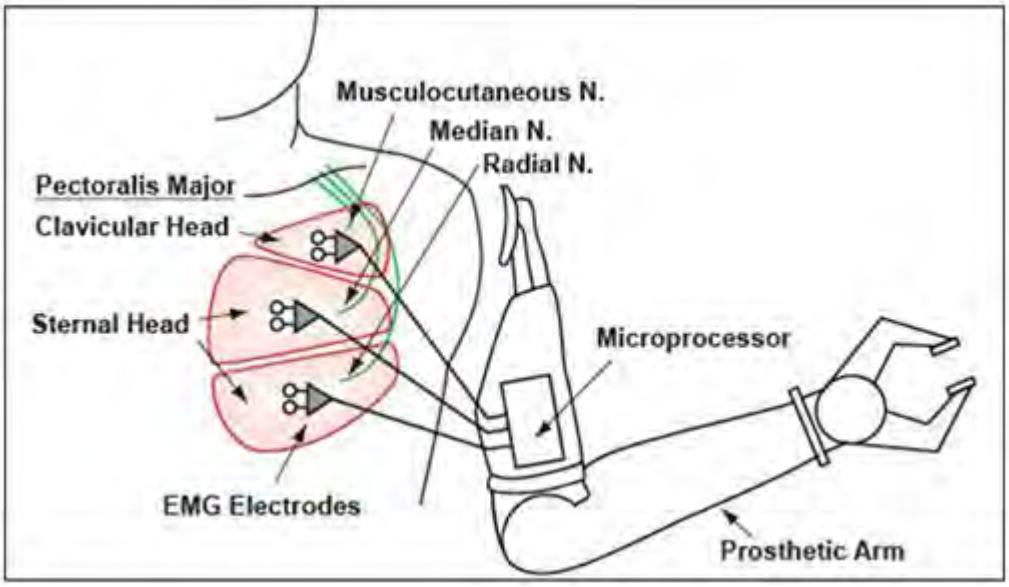

Figure 2.1: Electromyography Method in Prosthetic Hand

In Figure 2.1 shows pectoral muscles have the four main brachial nerves (musculocutaneous, median, radial & ulnar) after be transferred where it are little functional use to a person with shoulder disarticulation. After the nerves are communicate to distinct regions of pectoral tissue by anastomosis, conventional surface electrodes can monitor these restored sources of neural signals that now correspond to musculature that would have been distal to the amputation (elbow, wrist, and hand).

The movement of a prosthetic arm requires amenities control system for controlling the movement consists of three main parts: the input signal, motor driver part and motor control algorithms. Part processing the input signal include real-time data and also its buffer part. Additionally, it measure electromyograph signals from the hands of the forearm muscle subject and generate a stable flow of root mean square (RMS) value [1]. The next movement of the arm can be determined by using the range of RMS value. After that, motor control will be determine the motor movement based on the range of RMS value and device driver

acts to control the performance of motor. By using correct selection of threshold and fitness level, any type of exercise can be successfully trained in the application.

2.2.2 Selection of Tool

The selection tool is a very important component to complete a project or to obtain more specific data based on hardware physical model. Selection of tool should be selected properly to expedite the process of getting data running smoothly. Thus, instruments like servo motor, flex sensors, Arduino and others are also accounted in this research. The use of servo motors in the prosthetic hand industry is particularly widespread. Characteristic in automatic control of DC servo motor has played a key role in the electromechanical engineering world. For sensor, it plays a crucial role in robotics where it implicated in the special aids such as prosthetic hand. Besides that, sensors is also used to measure the current state of the system. Robotic industries require good sensors with high degrees of precision, reliability and repeatability. One of the sensors used in industry, namely, flex sensor is such an instrument, which accomplish the above task with great degree of accuracy. The movement of position finger in robotic hand can be efficiently controlled using microcontroller. This work is an educational based concept as robotic control is an exciting and high challenge research work in recent year.

2.2.2.1 Servo Motor

Servo motor is a rotary actuator or linear actuator that produce specific control of three term: angular or position, velocity and acceleration. Thus, servo motor consists of a DC motor coupled to a sensor for position feedback. In addition, the servo motor also requires a fairly sophisticated controller which is designed to be used with servomotors for achieving better performance.

Figure 2.2: Servo Motor

2.2.2.2 Power Supply

Power supply is a key element in the development of various type of electronic applications. Power consumption in the servo motor requires stable voltage to move the servo motor. In prosthetic hand, it used 5 servo motor with the capacity of 6Kg/cm where each servo motor consume approximately 1Amp at 5Volt supply. Thus, the consumption of 5-6 Amps will be needed for 5 servo motor. So the challenge in the design of servo motor is to design a larger power supply that can deliver enough current without effecting the servo motor.

2.2.2.3 Servo Driver

Servo driver is a heart of the servo motor. Servo motors require continuous pulse width modulation (PWM) signals to achieve continuous angle settings. Besides that, it requires microcontroller circuit to control the servo simultaneously. Capability of microcontroller in servo controller that can generate constant PWM pulse that will set need desired angle without affecting any other motor in the same time. The PWM pulse should also be continuous angle else it can make the angle sustainability will get loose cause the servo motor moving not properly.

2.2.2.4 Flex sensor

Flex sensor in other word known as bend sensor. This sensor capability is to sensing any kind of minute bend in its structure. Flex Sensor that be produced achieves better form-factor on a thin flexible substrate. This sensor produces a resistance output correlated to the bend radius when the substrate is bent. Theoretically, the smaller the radius then the higher the resistance value. This carbon layer is divided into small sections and connected together in series by conductive layer.

Figure 2.3: Flex Sensor

2.2.2.5 Arduino

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Thus, Arduino hardware is an open-source circuit board with a microprocessor and input/output (I/O) pins for communication and controlling physical objects. The board will be typically be power-up via USB or an external power supply which enough supply provided to other hardware, sensors and other component. Arduino also has an open-source software interface which is similar to C++. This interface that called (IDE) allows users create the coding, compile, and then upload it to Arduino for standalone use in prototyping and projects. Many design of Arduino hardware that be developed from Arduino team. One of them is current version of the Arduino hardware reference design is called the "Mega". It provides four basic functional elements:

- An Atmel "ATmega2560" AVR microcontroller
- Power supply for 5V or 3.3V.
- A USB-to-serial converter for loading new programs onto the board
- I/O headers for connecting sensors, actuators, expansion boards, etc

Figure 2.4: Arduino Mega

2.2.2.5.1 Power (USB / Barrel Jack)

Every Arduino board needs a way to be connected to a power source. The Arduino UNO can be power-up from a USB cable coming from the computer or a wall power supply that is terminated in a barrel jack. Average of power consumption in Arduino is less than 20 Volts. The recommended voltage for most Arduino models is between 6 and 12 Volts.

2.2.2.5.2 List of Pin

Each pin on the Arduino had different functions. In addition, there is the Arduino pin that is where the wire is connected to a circuit that may build together a breadboard and some wires. Each pin can be used as input and output to complete the circuit.

GND: Abbreviation for 'Ground'. There are several GND pins on the Arduino, any of which can be used to ground the circuit.

- **5V & 3.3V**: For 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the Arduino running between of 5 or 3.3 volts.