FACULTY OF ELECTRICAL ENGINEERING

DEVELOPMENT AND CONTROL OF EXOSKELETON (UPPER LIMB) FOR MOBILITY SUPPORT

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BACHELOR OF ELECTRICAL ENGINEERING
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DEVELOPMENT AND CONTROL OF EXOSKELETON (UPPER LIMB) FOR MOBILITY SUPPORT

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Electrical Engineering (Control, Instrumentation and Automation) with Honours

Faculty of Electrical Engineering

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment Bachelor of Electrical Engineering (Control, Instrumentation & Automation).

Signature : .....

Supervisor Name : .....

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DECLARATION

I declare that this thesis entitled “Development and Control of Exoskeleton (Upper Limb) for Mobility Support” 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.

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ABSTRACT

Mobility support is the movement of an object to support itself**.** This project concerns about the mobility support of exoskeleton (upper limb).The development of upper limb focuses on the human arm which is important for the supportive movement. Human arm is the main mobility of the upper limb part of the body. This project is develop to control the assistive human arm robot that will be support for the elderly and disabilities people to move their hands. So, mobility mechanism will be develop to help these people to move their arm. Arm robot will be modelled in this paper by determining it using the physical modelling. The physical modelling will be create based on the mathematical modelling. A design of the arm model is developed using the computer aided design (CAD) software, Solidworks and simulated with MATLAB. MATLAB software is used to control the movement of human arm. A plug-in software called as Simmechanics will be export the model from the Solidworks and import to the MATLAB. The imported model is then direct to the extension file of MATLAB, Simulink. The arm model which is appears as the Simulink output will be run. A controller which is PID and PD controller is added to the Simulink output to control the movement of human arm. The human arm movement is analyzed based on the output performance of the controller. The best performance of controller will selected to put on the human arm model.

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ABSTRAK

Sokongan mobiliti adalah pergerakkan sesuatu objek untuk memberi sokongan kepadanya. Projek ini membicangkan mengenai sokongan mobiliti daripada eksoskeleton (bahagian atas anggota badan manusia) .Bahagian anggota badan yang diberikan tumpuan ialah lengan manusia. Lengan manusia merupakan pergerakan utama anggota badan bahagian atas badan. Projek ini dijalankan bertujuan untuk mengawal lengan manusia. Lengan manusia dibantu oleh sebuah model robot yang akan menjadi sokongan kepada warga kurang upaya untuk menggerakkan tangan mereka. Jadi, model robot tersebut ini akan digunakan untuk membantu orang kurang upaya supaya lengan mereka dapat bergerak. Sebuah model robot yang menyerupai lengan manusia akan direka di dalam projek ini dengan menggunakan model fizikal. Model fizikal direka terlebih dahulu melalui model matematik. Satu reka bentuk model lengan akan direka dengan menggunakan perisian reka bentuk bantuan komputer (CAD) iaitu Solidworks. Satu perisian komputer simulasi iaitu MATLAB akan digunakan dalam projek ini. Simulasi MATLAB digunakan untuk mengawal pergerakan lengan manusia. Satu perisian plug-in yang dikenali sebagai Simmechanics digunakan untuk mengeksport model lengan dari Solidworks dan diimport kepada MATLAB. Model lengan yang diimport kemudiannya akan terus dihantar ke fail sambungan MATLAB Simulink. Model lengan yang muncul sebagai keluaran Simulink akan dijalankan. Dua buah alat kawalan iaitu pengawal PID (*Proportional-Integrator-Derivative*) dan pengawal PD (*Proportional-Derivative*) ditambah kepada keluaran Simulink yang berbeza untuk dijadikan sebagai sebuah sistem bagi mengawal pergerakan lengan manusia. Pergerakan lengan manusia dianalisis berdasarkan prestasi pengawal PID dan

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pengawal PD tersebut. Presetasi alat kawalan yang lebih baik dipilih untuk diletak pada model lengan manusia.

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CHAPTER 1

INTRODUCTION

This chapter describes the mobility support of the exoskeleton (upper limb). The project emphasizes on the development and control of assistive exoskeleton which is upper limb part for mobility support. The project brief's explanation will be explain in the project background. The problem statement and motivation relating to this project will be explain in this chapter .Finally, objective and scope are listed accordingly.

1.1 Project Background

Exoskeleton used to support and defends human or animal's body [1]. The region in an animal extending from the deltoid region to the hand, including the arm, axilla and shoulder called as upper extremity [2]. The upper limb enables to grip, write, lift and throw among many other movements. The upper limb has been shaped by evolution, into a highly mobile part of the human body. The upper limb has developed for stable mobility support. This project focuses on the development of assistive human robot arm which is suitable for mobility support. Human arm refers to the structures part extended from shoulder to the elbow.

An arm is an internal mechanical structure which has joints that correspond to the human arm. By wearing the exoskeleton arm, mechanical power can be transmitted to the human arm as a result of the physical contact between the two [3]. People are unable to do their daily activities without an arm. This is the reason why arm is very useful to people.

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The movement of the upper limb or upper extremity will be control using Proportional-Integral -Derivative (PID) and Proportional-Derivative (PD) controller. PID controller are common technologies used nowadays in order to design a controller. PD is a controller type which is from PID division. The other controller type from PID is Proportional-Integral (PI) controller. The PID controller only able to control low torque and speed which is can be define as simple system and it using manual panel of controller interface. PID controller are design to eliminate the need for continues operator attention. The integral term is most effective at low frequencies, the proportional term are at moderate frequencies and integral term are at high frequencies. The profits from the integral term is the reduction of steady state error and the differential term improve the receptiveness stability.

The project presents about the development and control of exoskeleton (upper limb) for mobility support. An assistive robot arm is created to test and develop a mobility support. The project focuses on the movement of human arm. The aim is to help injured and disabilities people to move their arm. People with these problems are the main subject for this project.

1.2 Motivation

Upper limb and arm movement disorders had given the motivation to develop a system for the movement of upper extremities to train its normal movement and give more control freedom in strength and speed. The controller which is attach on the joint of shoulder and elbow is a sophisticated system to study. Thus, more knowledge will be enhanced in engineering aspects. In general, this project uses the advance techniques in designing the model, creating the 3D model in Computer Aided Design (CAD) software. The development

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of model in related software enable engineers to investigate the movement of the model through the simulation in the controller software. Complete control system will be develop. It will benefit a lot since it use in the term of instrument and control engineering perspective.

1.3 Problem Statement

Strokes and arm injuries are the most factor that affects the movement of arm nowadays. Approximately 15 million people worldwide have a stroke each year. In a worldwide population, around 1 in 6 people in this world have a stroke in their lifetime [4]. Other than stroke, arm injuries are caused by cuts and laceration injuries. U.S. Bureau of Labor Statistics (BLS) reports that cuts and laceration injuries are the most common work injuries to the hands. The victims to the incidents accounted for 4,120 job transfer or restriction cases in 2012 [5].

In order to solve above problem, a mechanism was created to help affected people to move. So, the development and control of exoskeleton (upper limb) for mobility support has chosen in this project. This project is use to help people with minor stroke and arm injuries to move their affected body part to normal movement. So, the project is done by designing a wearable assistive arm model to activate disabilities arm. Next, if the patient is suitable to use the assistive model, it can train the arm to move in the good posture.

Many upgrading and modification have to be considered in order to achieve the target. So, the problem of the minor stroke and arm injuries is use as an approach to develop and control of human arm. This project will implement on how to investigate the development of an assistive upper limb exoskeleton component for specific mobility support.

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1.4 Objective

The project to be developed is to fulfill the configuration and specification of development and control of upper limb or human arm. An assistive human arm model should be develop in the beginning part of the project. Due to shortage of budget, the human arm are able to design using the software tools The software tools that are used in this project is CAD software, Solidworks and simulation software, MATLAB.

The objectives of this project are used as a benchmark to make sure the progress can be carried properly. The "**Development and Control of Exoskeleton (Upper Limb) for Mobility Support**" project objectives can be defined as listed below:

1. Design human arm model using CAD software, Solidworks and transfer to MATLAB via Simmechanics.
2. Develop and design control system of human arm model using Proportional-Derivative (PD) controller and Proportional-Integral-Derivative (PID) controller using simulation software, MATLAB.
3. Validate PID and PD controller performance on human arm model.

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1.5 Scope

In order to accomplish the objective of this project and enhanced the effectiveness of this system, few scopes has been considered. The scope of this project is to develop and control the upper extremities exoskeleton that can interfaced using Solidworks and MATLAB software. The scopes are shown as the flowchart in the figure 1.1:

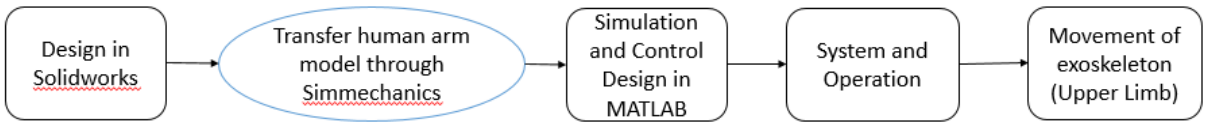

Figure 1.1: Scope of the project

Based on the figure 1.1, the development of exoskeleton (upper limb) model which is human arm begins by the designing a model in Solidworks .The designed of human arm model is transferred to the MATLAB by using the Simmechanics plug-in software.The simulation and control of human arm model happens in the MATLAB software. The system and operation of the model becomes complete as the controller in MATLAB able to control the movement of the model designed in Solidworks.The movement of exoskeleton (upper limb) is completed. The control design in this project is focusing on the PID and PD controller. The scope of the project also involve on the controlling variable value on PID and PD controller. This project focusing on the controlling of human arm movement on sholuder joint and elbow joint.

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1.6 Organization of Thesis

The organization of this report is arrange as below:

- **Chapter 2,Literature Review:** This chapter discuss the article of the current and previous research to enhance an idea to do the project
- **Chapter 3, Methodology:** Methodology is one of the chapter discuss the process path of the project until the objectives is achieved. In this chapter, the development of this project is written from designing of human arm in Solidworks until the analysis of human arm movement in the MATLAB.
- **Chapter 4, Result and Discussion:** This chapter shows result of software development and simulation of human arm. In this chapter, the result are also based on objectives stated in the chapter 1.This project will show the result from designing of human arm model, transferring the model via Simmechanics. Finally, testing and simulation of human arm model in MATLAB. The analysis of human arm model is discuss in this chapter as well. The model is analyze based on its trajectory value and error. The value of the arm model trajectory will be discussed as well in this chapter.
- **Chapter 5, Conclusion:** This chapter summarize all the project flow from beginning to end. The result obtained also discussed in this chapter .Further project development will be tell in this chapter.

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CHAPTER 2

LITERATURE REVIEW

In this chapter, the mobility assistive robot based human arm will be first topic to review. In order to develop the upper extremities, degree of freedom and modelling of human arm are also review in this chapter. Phases to develop human arm by using Solidworks and MATLAB will be clarify in the development of automation modelling part. Finally, the basic concept of PID controller is presented as well in this chapter.

2.1 Mobility Assistive Robot based Human Arm

Falling among the elderly or patients can be avoid by providing a mobility assistive robots which has the ability of physical and equilibrium support [6]. To overcome this situation, a Mobility Assistive Robots (MAR) is developed by joining features. An example of features are robot also derived with challenges in terms of safety. They have to operate in close interaction with humans especially for elderly or patients with cognitive and or physical disorder [7]. This project use to develop an assistive robot of exoskeleton (upper limb) for mobility support. A controller is design in controlling an arm robot. The movement of arm robot refers to the human arm. An example can be made based on the above statement is the development of the proposed rehabilitation robot called as NTUH-ARM. The rehabilitation

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robot provides 7 degree-of- freedom (DOF) motion. The robot runs as a subject to an inherent mapping between the 7 DOFs of the robot arm and the 4 DOFs of the human arm [8].

The mobility assistive robot is focuses on the development of arm robot. The movement of the arm robot are referring to the human arm.

2.2 Degree of Freedom of Human Arm

Human arm are the body parts of human body that able to move in seven degrees of freedom (7 DOF).The seven degrees freedom of human arm includes 3 in the shoulder joint, 1 in the elbow joint and 2 in the wrist. The shoulder joint consists of shoulder adduction/abduction (add/abd), extension/flexion (ext/flx) and lateral/medial (lat/med) rotation. In elbow joint, the flexion and supination/pronation (sup/pron) occurs in the forearm. Next, wrist extension/flexion (flx/ext) and adduction/abduction (add/abd) occurs at wrist joint while supination/pronation (sup/pron) of the forearm is formed by ulna and radii bones in the forearm. Elbow joint and wrist joint are located in the forearm [9]. Figure 2.1 illustrate the seven degrees of freedom (7 DOF) of human arm movement.

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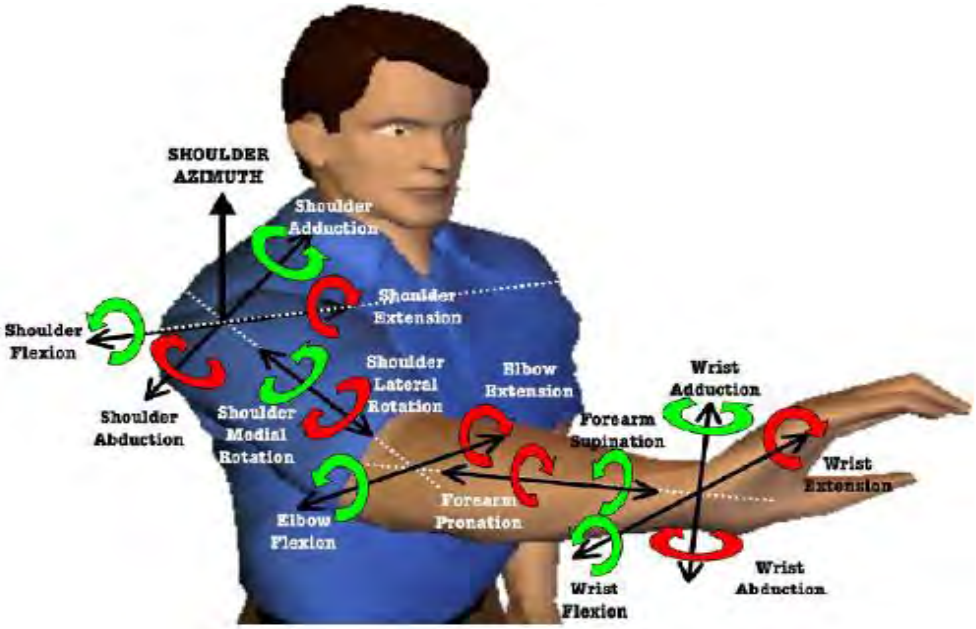

Figure 2.1: 7 DOF in a human arm [9].

The human arm have an abilities to move into basic four degrees of freedom (4 DOF).Four Degrees of freedom includes the shoulder abduction / adduction. Shoulder flexion / extension and internal / external rotates as well as the elbow flexion / extension motion [10]. Four basic degrees of human arm are shown in figure 2.2.

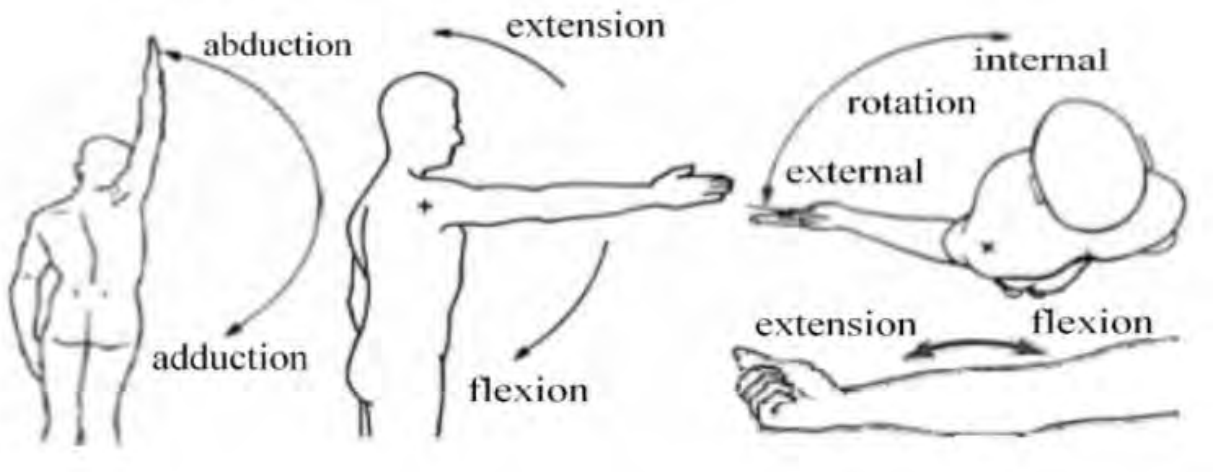

Figure 2.2: Four basic degrees of freedom of the arm .a) Adduction/Abduction b) Flexion/Extension c) External/Rotation/Internal d) Extension/Flexion [10]

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