DEVELOPMENT FOR HAND GESTURE MOVEMENT OF AN EXOSKELETON HAND MODEL WITH CONTROLLER

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DECLARATION

I declare that this thesis entitled "DEVELOPMENT FOR HAND GESTURE MOVEMENT OF AN EXOSKELETON HAND MODEL WITH CONTROLLER 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 : MUHAMMAD AMMAR HAZIQ BIN ABU SAMAH

Date : 05/07/2021

APPROVAL

I hereby declare that I have checked this report entitled "DEVELOPMENT FOR HAND GESTURE MOVEMENT OF AN EXOSKELETON HAND MODEL WITH CONTROLLER" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :

Supervisor Name : DR HYREIL ANUAR BIN HAJI KASDIRIN

Date : 05/07/2021

DEDICATIONS

To my beloved mother and father for always support me and being my motivation to pursue my Bachelor's Degree and want me for the best and become a successful person.

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ABSTRACT

Nowadays, thousands of people across Malaysia that affect an accident cause them to lose all or part of their hands. The victims involved in the accident may have difficulty doing their daily activities like normal people or their previous lives. The development of the exoskeleton finger gesture is a function to help a person that lost all or part of their hand to regain the functionality of a regular hand. In order to develop an exoskeleton finger gesture, the three objectives need to be achieved, which are to develop the exoskeleton finger gesture by using SolidWorks Software, to control the exoskeleton finger gesture using PID controller in Simulink MATLAB Software and to verify the finger movement in exoskeleton finger gesture by comparing using transient response in PID controller via Simulink MATLAB Software. For this project, SolidWorks Software is used to design by considering the degree of freedom (DOF) in the finger gesture that only focuses on one finger, which the index finger. Also, the MATLAB software is used to control the finger gesture made in SolidWorks and compare the transient response from the different movement and gesture for exoskeleton finger gesture with regular hands to achieve this project. This project refers to the previous study, Range of Motion, to explain the DOF with the transient response in the PID controller [9]. The achievement for this project is successfully following required flexion-extension in the three DOF, which is MCP, PIP, and DIP joints in SolidWorks. Also, exoskeleton finger gesture able to achieve the desired movement by using PID controller and verified the similarities like regular hands with the transient response in three movements which is grip, low-grip, and no grip with the Steady State of Error, *Ess* is zero and the targeted Percentage of Overshoot, *%OS* is in minimal since its in range of 5%. Therefore, the PID controller is the best method for this project as an automatic process control that is Autotuned and easy to implement and quick to achieve the finding data in transient response so that the project can prove similarities like regulars. The recommendation for this project is to propose using optimization for manual tuning to increase the performance in Settling Time, *Ts*, which reduced the time taken for the joints of exoskeleton finger gesture is below 1 second and implement the various movements and gestures consider the movement in abduction and adduction. Hence, develop another four-finger to give the accurate result for exoskeleton finger gesture and compare performance between manual tuning with Autotuned or PID controller with Joint Torque to determine the suitability and better assistive hand model.

ABSTRAK

Pada masa kini, ribuan rakyat Malaysia yang terlibat dalam kemalangan telah menyebabkan mereka kehilangan semua atau sebahagian anggota tangan yang terlibat telah menyebabkan mereka sukar melakukan aktiviti harian seperti dahulu. Jadi, pembuatan pergerakan jari tangan exoskeleton yang berfungsi untuk membantu individu yang kehilangan semua atau sebahagian dari tangan mereka bagi mendapatkan fungsi yang sama seperti tangan biasa. Untuk menghasilkan pergerakan jari tangan exoskeleton, tiga objektif perlu dicapai iaitu untuk mencipta pergerakan jari tangan exoskeleton dengan menggunakan perisian SolidWorks, untuk mengawal pergerakan jari tangan exoskeleton dengan menggunakan kawalan PID pada Simulink MATLAB dan untuk mengesahkan pergerakan jari tangan exoskeleton dengan tangan manusia biasa dengan melihat tindak balas sementara di dalam perisian MATLAB. Seterusnya, untuk projek ini, perisian Solidwork digunakan untuk mencipta dengan menitik beratkan kategori segmen dan darjah kebebasan (DOF) pada model jari tangan iaitu fokus kepada jari telunjuk. Perisian MATLAB juga digunakan bagi mengawal pergerakan jari tangan yang direka melalui perisian Solidwork dan untuk membandingkan tindak balas sementara (Transient Response) pada beberapa pergerakan dan kawalan yang berbeza pada exoskeleton jari tangan dengan jari tangan manusia untuk menjayakan projek ini. Juga projek ini berpandukan dari hasil kajian lepas, iaitu melalui Julat Pergerakan (Range of Motion) untuk menerangkan darjah kebebasan pada tindak balas sementara menggunakan kawalan PID [9]. Projek ini telah berjaya berpandukan ukuran pemanjangan-lenturan pada ketiga-tiga sendi DOF, iaitu MCP, PIP dan DIP dengan perisian SolidWorks. Di samping itu, projek ini juga telah berjaya mengikuti pergerakan yang sama seperti tangan manusia menggunakan kawalan PID dan membuktikan persamaan jari tangan exoskeleton dengan tindak balas sementara pada tiga pergerakan yang berbeza, iaitu genggaman kuat, genggaman lemah dan tanpa genggam. Ini telah ditunjuk pada nilai Steady State of Error, E_{ss} pada kesemuanya adalah kosong dan target Percentage of Overshoot, $\%OS$ adalah pada sekitar nilai 5%. Oleh sebab itu, kawalan PID adalah cara yang terbaik untuk projek ini melaksanakan kawalan automatik (Autotuned) dan ianya juga mudah untuk digunakan serta mendapatkan keputusan yang sama seperti tangan manusia. Penambahbaikan pada projek ini adalah dengan mengemudi kawalan secara manual untuk mendapatkan Settling Time, T_s bawah pada 1 saat dan menambah beberapa jenis pergerakan dan jari tangan yang lain. Projek ini juga boleh membuatkan perbandingan antara kawalan secara manual dan automatik atau kawalan PID dan sensor sendi tork untuk mengenalpasti kawalan yang terbaik dan sesuai pada projek ini.

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LIST OF SYMBOLS AND ABBREVIATIONS

DOF	-	Degree of Freedom
MCO	-	Movement Control Order
WHO	-	World Health Organization
ADL	-	Activities in Daily Living
DIP	-	Distal Interphalangeal
MCP	-	Metacarpophalangeal
PIP	-	Proximal Interphalangeal
IP	-	Interphalangeal
CMC	-	Carpometacarpal
P	-	Proportional
I	-	Integral
D	-	Derivative

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CHAPTER 1

INTRODUCTION

1.1 Overview

Usually, an introduction is a start with the scenario of the project. For example, in the near future, the exoskeleton hand gesture plays an essential role for the patients that suffer losing part of their hands from an accident. Fortunately, Malaysia can develop the exoskeleton as an alternative method for the patient who cannot go to Replantation Surgery.

This project aims to focus on developing the index finger for exoskeleton finger gesture, which modeling in SolidWorks and controlling in MATLAB software. Hence, the transient response is a tool for this project to validate the similarities like regular hands.

1.2 Problem Statement

Lose all or some part of the hand that is still in minority cases in Malaysia because of the accident. However, this is still bad luck or bad news for the person that experienced it.

Replicating a hand again or recovering from losing hand is impossible; otherwise, the losing part of the hand (finger) can be reattached again through a surgery called Replantation Surgery. This surgery can be considered safe because it have a success rate high as 92% [1].

The proposed project aims to solve the patient who is unable to undergo the replantation surgery using another method, which is developing the exoskeleton finger gesture. Furthermore, the project is to identify whether exoskeleton finger gesture can have the same desired movement as regular hands by using a controller or without the controller. Hence, to analyse the accuracy for the exoskeleton finger gesture to have similar movement and gesture like the regular hands to have grip and hold for cylinder object.

1.3 Motivation

A thousand cases of an accident happened in Malaysia which 10,382 cases in 2020 in the first of 32 days start in March 2020 before the MCO. Also, the World Health Organization (WHO) stated the cases are more than a 1.2million per year globally, with 20 to 50 per cent having injured caused by accident [2].

In fortunate for Malaysia, that have good healthcare with a score of 95 out of 100 and get ranked first in Best Healthcare in the World category of the 2019 International Living Annual Global Retirement Index [3]. In other words, Malaysia's healthcare is advanced to cure diseases with good technical equipment and medical devices. Also, its have occupied an excellent medical team that responds to innovate the biotechnology such as genetic, artificial body's part, medical machine and so on.

The exoskeleton finger gesture is one of the innovations that the biotechnology medical team has developed. The model functions to help the patient regain or have the same functionality as a regular hand. This project presents the exoskeleton finger gesture that could be achieved like a regular hand by considered have the same movement and gesture for that the model can hold the cylinder object.

1.4 Objectives

The objectives of this project are:-

1. To develop the exoskeleton finger gesture by using SolidWorks Software.
2. To control the exoskeleton finger gesture by using PID controller via Simulink MATLAB Software.
3. To verify the finger movement in the exoskeleton finger gesture by comparing using transient response in PID controller via Simulink MATLAB Software.

1.5 Scope

There are several of scope that need to be considered to achieve the object of this project. The scope of this project focus to develop, control and verify the exoskeleton finger gesture by using SolidWorks and MATLAB software.

- Develop a human finger gesture that focus to one finger first which consist of 3 degree of freedom which to considered Distal Phalanx, Middle Phalanx, and Proximal Phalanx.
- Link SolidWorks to MATLAB-Simulink by export the design file in order to control the hand model via SimMechanics plugin.
- Verify the exoskeleton finger gesture with regular hands in the different movement and gesture for hold the cylinder object by using transient response in PID controller via Simulink MATLAB software.

1.6 Organization of Thesis

The organization are follow chapter by chapter which are:-

- **Chapter 2, Literature Review:** This chapter will discuss the essence and fundamental of the project by gain of the research.
- **Chapter 3, Methodology:** This chapter will interpret the method step by step from develop the finger gesture until verify the transient response in finger gesture via simulation for achieve the main objective of this project.
- **Chapter 4, Result and Discussion:** This chapter will show the result of project from modelling to comparing transient response for exoskeleton finger gesture with regular hands.
- **Chapter 5, Conclusion and Recommendation:** This chapter will give the summary from the project done whether the objective achieved or not and will state the improvement for the project to have better performance.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The literature review is essential to proceed with this project. The chapter is conducted based on reliable data, conference proceedings, and project-related journals. Hence, it will discuss various methods to achieve this project's objective and select the suitable method for exoskeleton finger gesture to be improved and relevant use in current and future development.

2.2 Project Background

This project refers to healthy males, 29 years of age, 71 kilograms, and 174 centimetres in height that volunteer to be subject in the research paper [4]. Therefore, two different finger gesture movements were chosen: index finger flexion-extension and wrist extension for analysis.

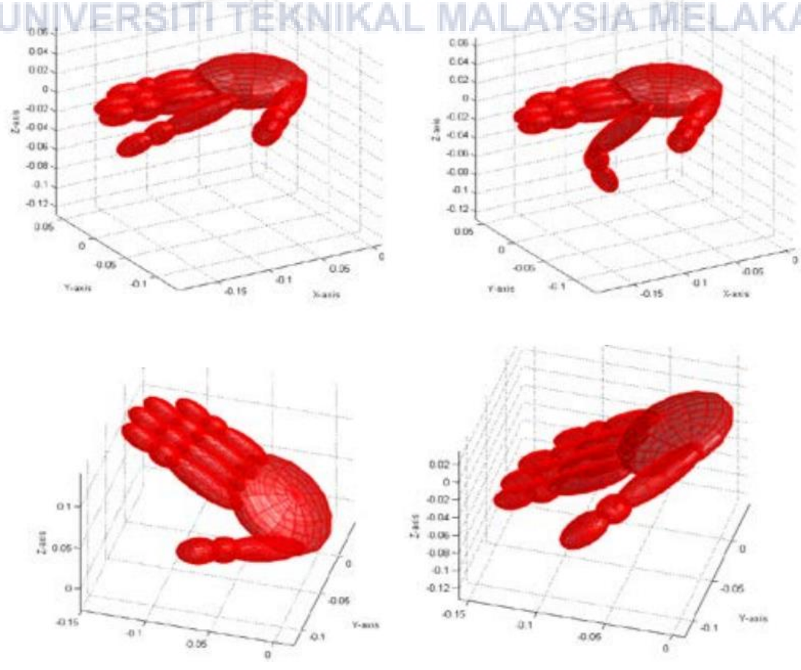

Figure 2.1: simulation view for the index finger and wrist movement [4].

Holding and gripping are an essential function to do everyday life tasks. The cylindrical grip is the most important in activities in daily living (ADL). Figure 2.1 above shows the simulation views for the index finger and wrist movement based on the research paper [4], which been analyzed for the index finger rotation by using passive reflective markers that placed on the five anatomical points that include the distal end of the distal phalanx, distal phalanx joint, middle phalanx joint, proximal phalanx joint, and wrist joint [5].

Furthermore, the exoskeleton finger gesture is a mechanical system device that can replace the human hand's skeletal structure. As a safety precaution, the exoskeleton hand gesture device must have manipulator segments based on the lengths of the human hand's fingers. Every model or system has a different feature or setting in the finger joint to prevent slipping while using it. Most of the hand movement in exoskeleton finger gesture is focused on three DOF for each joint of the fingers.

2.3 Degree of Freedom, DOF of Human Hand (finger)

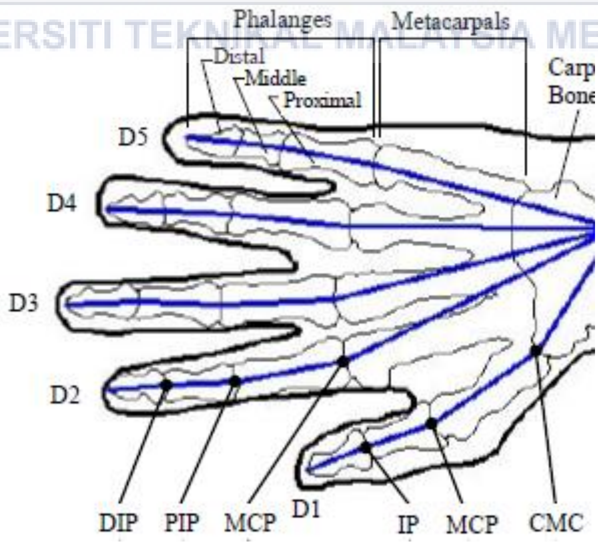

Figure 2.2: Bone structure of the hand in the top view [4].

Figure 2.2 shows the human hand consist of three DOF for each joint in each finger or digits (D) in the group bones of the phalanx. The three joint of DOF is in phalanx segment which is Distal, Middle and Proximal. Start from the end of the index finger, the specified name of the joint is named Distal Interphalangeal (DIP) joints, Proximal Interphalangeal (PIP) joints, and Metacarpophalangeal (MCP) joints [6]. The thumb finger has different names than other fingers, which start with Interphalangeal (IP), Metacarpophalangeal (MCP), and Carpometacarpal (CMC) joints.

Table 2.1 below will show the Anthropometric Properties that need to measure for the fingers by considering the segment, length, diameter, mass, and moment of inertia based on previous studies.

Table 2.1: Anthropometric Properties of the Digits based on previous studies[4].

Segment	Length (cm)	Diameter (cm)		Mass (g)	Moment of Inertia (g•cm²)
		P.e.	*D.e.*		
D1 distal phalanx	3.26	2.06	2.06	11.72	I_{xx}= 6.219 I_{yy}=I_{zz}= 13.49
D1 proximal phalanx	2.01	2.06	2.06	7.23	I_{xx}= 3.384 I_{yy}=I_{zz}= 4.351
D1 metacarpal	6.42	2.06	2.06	23.08	I_{xx}= 12.24 I_{yy}=I_{zz}= 85.42
D2 distal phalanx	2.69	1.64	1.64	6.13	I_{xx}= 2.061 I_{yy}=I_{zz}= 4.728
D2 middle phalanx	2.18	1.64	1.97	6.03	I_{xx}=2.492 I_{yy}=I_{zz}= 3.615
D2 proximal phalanx	5.68	1.97	1.97	19.27	I_{xx}= 9.349 I_{yy}=I_{zz}= 59.82
D3 distal phalanx	2.69	1.65	1.65	6.20	I_{xx}= 2.112 I_{yy}=I_{zz}= 4.798
D3 middle phalanx	2.57	1.65	2.0	7.27	I_{xx}= 3.076 I_{yy}=I_{zz}= 5.504
D3 proximal phalanx	5.22	2.0	2.0	17.69	I_{xx}= 8.847 I_{yy}=I_{zz}= 44.60
D4 distal phalanx	2.78	1.54	1.54	5.58	I_{xx}= 1.656 I_{yy}=I_{zz}= 4.427
D4 middle phalanx	2.35	1.54	1.87	5.80	I_{xx}= 2.143 I_{yy}=I_{zz}= 3.718
D4 proximal phalanx	5.06	1.87	1.87	14.99	I_{xx}= 6.554 I_{yy}=I_{zz}= 35.27
D5 distal phalanx	2.55	1.40	1.40	4.23	I_{xx}= 1.038 I_{yy}=I_{zz}= 2.814
D5 middle phalanx	1.69	1.40	1.65	3.34	I_{xx}= 0.981 I_{yy}=I_{zz}= 1.279
D5 proximal phalanx	3.96	1.65	1.65	9.13	I_{xx}= 3.109 I_{yy}=I_{zz}= 13.49

P.e. proximal end, D.e. distal end.

Furthermore, the Anthropometric Properties of the Palm also will be considered due to knowing the connection between the palm and the finger. Table 2.2 below will show the Anthropometric Properties based on previous studies [4].

Table 2.2: Anthropometric Properties of the Palm based on previous studies [4].

Segment	Parameter
Wrist width (cm)	6.22
Palm width on MCP of D2-5 (cm)	8.41
The length from wrist to MCP of D2 (cm)	7.18
The length from wrist to MCP of D3 (cm)	8.13
The length from wrist to MCP of D4 (cm)	7.48
The length from wrist to MCP of D5 (cm)	7.09
Tickness (cm)	3.02
Mass (g)	181.0
Moment of Inertia (g•cm^2)	**I*xx***=945.9 **I*xy***= **I*yx***=53.60 **I*yy***=995.9 **I*zz***=1666 **I*xz***= **I*yz***= **I*zx***= **I*zy***=0

The Anthropometric Properties segment for the palm is not used for this project because it required more time to precisely detail the model. The project only focused on similar appearance and functionality for exoskeleton finger gesture with regular hands.

2.4 Controller of the Mechanism

This subchapter will discuss the PID controller and other block diagrams as the method used for this project. It will briefly explain the background of PID, advantage and disadvantage, function for the block and the Range of Motion which is essential for this project to have indicator measurement similar to regular hands.

2.4.1 Proportional-Integral-Derivative (PID) Controller

The PID controller is a control loop mechanism commonly used in industrial control systems. The PID controller uses the difference value between the setpoint and the variable's process to calculate an error value.

The proportional, Kp, integral, Ki, and derivative values, Kd, are used in mathematical terms for the PID. The terms Ki and Kd are usually replaced by the terms Kp / Ti and Kp / Td in the standard form of the equation. Due to its represent the integration time and the derivative time, it were replaced because they have a clear meaning. Hence, the mathematical form for the can be expressed as,

$$U(t) = Kp\left[e(t) + \frac{1}{Ti}\int_0^t e(t')dt' + Td\,\frac{de(t)}{dt}\right]$$

The PID controller system also consists of the feedback loop along with the desired value for setpoint and measured value. Figure 2.3 below will shows the block diagram for the PID controller.