
# FACULTY OF ELECTRICAL ENGINEERING

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## THE INVESTIGATION OF THE POSITION CONTROL FINGER FOR REHABILITATION ROBOT USING 5DOF ROBOTIC ARM MANIPULATOR

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"I hereby declare that I have read through this report entitle "The investigation of the position control finger for rehabilitation robot using 5DOF robotic arm manipulator" and found that it has comply the partial fulfilment for awarding the degree of bachelor of Electrical Engineering (Mechatronics)"

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Date : 2 Jun 2016

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**A report submitted in partial fulfilment of the requirement for the degree of Mechatronics Engineering**

**Faculty of Electrical Engineering**

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## STUDENT'S DECLARATION

I Declare that this report entitle "The investigation of the position control finger for rehabilitation robot using 5DOF robotic arm manipulator" 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 : .....

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Date : 2 Jun 2016

To my beloved Mother (Faridah Bt Samakon) and Father (Allayarham Marikon Bin Marjo).

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# ABSTRACT

Robotic rehabilitation is widely use especially in application of finger rehabilitation. Every year, 15 million people worldwide suffer a stroke. Patient with stroke disease need long time and lot of rehabilitation training. Modern method nowadays, the robot rehabilitation method is use to give repetitive task and focus to targeted rehabilitation technique. This method will give the patient ability to do the rehabilitation training by their own even at their home. In this investigation is to position control of finger rehabilitation robot using 5 DOF robotic arm. The problem of control finger for rehabilitation is how to generate the trajectory generation in terms of angular position from initial and final of the robot during rehabilitation session. Moreover, the problem in term of different size and length of the human finger need to be consider as well as the movement of the robot need to same with actual human finger motion. The objective for this investigation is to investigate, design and evaluate the position control of finger rehabilitation robot using 5 DOF robotic arm using KUKA Youbot and VREP simulation software.This investigation focus on the simulation in VREP by using the KUKA Youbot robot. The finger that have been evaluate for this investigation is only for index finger. Based on the Cartesian space scheme method, this method able to determine the position of the end effector by using the quarter circular formula and parabolic equation. The methodology of this investigation is the quarter circular formula will determine the total path point to generate the smooth motion of the robot using MATLAB software. To determine the trajectory path of end effector for different length of human finger, the parabolic circular motion has been used in the VREP simulation software to observe and analysis the position, velocity and acceleration of the robot and it effect to the finger joints. This investigation able to control the movement of the finger rehabilitation robot with the different length of the patient's finger with the absolute error 0.067m for x-axis and 0.044m for y-axis. The accuracy for the 15 path point that use in this simulation is 97.2 percent. To reduce the force acting to the finger joints, the simulation need to use the joint velocity below 10 deg/sec and the acceleration 0.3 deg/sec^2. The simulation able to control the position of the index finger during rehabilitation session.

# ABSTRAK

Robot pemulihan semakin luas digunakan terutamanya dalam aktiviti pemulihan jari. Setiap tahun, lima belas juta orang diseluruh dunia menghidap penyakit strok. Pesakit dengan berpenyakit strok memerlukan jangka masa pemulihan yang lama dan latihan pemulihan yang banyak. Meggunakan kaedah moden zaman sekarang, kaedah robot pemulihan diperlukan untuk memberi tugas yang berulang – ulang kepada jari dan memfokuskan kepada teknik yang diperlukan sahaja. Melalui kaedah ini akan memberi pesakit keupayaan untuk melakukan latihan pemulihan dengan sendiri walaupun mereka berada di rumah sendiri. Dalam penyiasatan pada posisi pengawalan jari untuk robot pemulihan dengan menggunakan 5 sudut pada kebebasan robot tangan. Penyataan masalah untuk pengawalan jari adalah bagaimana untuk menjana trajektori untuk robot dalam keadaan kedudukan sudut dari kedudukan awal dan kedudukan akhir untuk robot bergerak pada sesi latihan pemulihan. Seterusnya, pemasalahan dari segi perbezaan saiz dan panjang jari manusia perlu diberi perhatian serta pergerakan robot hendaklah sama dengan pergerakan sebenar jari manusia. Objektif penyiasatan ini adalah untuk menyiasat, mereka dan mengesahkan untuk mengontrol kedudukan jari untuk proses rehabilitasi menggunakan 5DOF robot tangan dengan mengunakan robot jenis KUKA Youbot dan simulasi VREP. Penyiasatan ini berfokuskan pada simulasi di dalam VREP dengan mengunakan KUKA Youbot. Jari yang telah dikaji dalam kajian ini adalah jari telunjuk sahaja. Berdasarkan kaedah ruang kartesian, kaedah ini membolehkan untuk mendapatkan posisi pada hujung robot dengan mengunakan formula suku bulatan dan formua parabolic. Untuk metodologi pada penyiasatan ini adalah formula suku bulatan akan menentukan jumlah titik laluan untuk menjadikan pergerakan robot semakin lancar dengan menggunakan MATLAB. Untuk menentukan laluan trajektori pada hujung robot dengan pelbagai panjang jari, kaedah formula parabolic akan digunakan di dalam simulasi VREP untuk di perhatikan pergerakanya dan dianalisa data untuk posisi terbabit. Penyiasatan ini membolehkan untuk mengawal posisi pergerakan pada jari semasa sesi rehabilitasi dengan panjang jari berlainan dan kesalaha yang sbenarnya hanya 0.067m untuk paksi x dan 0.044m untuk paksi y.

ketepatan untuk lima belas titik laluan yang dipilih adalah 97.2 peratus. Untuk mengurangkan daya tolakan pada sendi jari, simulasi ini perlu untuk mengunakan kadar halaju dibawah 10 darjah/ s dan kadar pecutan sebanyak 0.3 darjah/s^2. Simulasi ini Berjaya mengawal posisi untuk jari telunjuk semasa proses rehabilitasi.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Motivation

Every year, 15 million people worldwide suffer a stroke. Of these, 5 million die and another five million are left permanently disabled [5]. Stroke in Malaysia is the third largest cause of death and estimated over 40,000 people are suffered in Malaysia. [6]. Loss ability by post stroke patient during movement their thumb and finger is critically issues observes by clinical and frequently reported by patient. The limited ability to activate the movement of finger and thumb extensor muscle is the main problem for the patient [1]. In order to increase the improvement finger and thumb movement, the targeted rehabilitation technique need to implement during rehabilitation session [2]. The targeted rehabilitation technique will make the recovery period faster.

The ability to identify and detect the actual position for the finger and thumb motion is beneficially tool in improve the finger and thumb movement. Robot based on the controlling human finger for post stroke patient can be used to control frequently the actual movement of the finger. Nowadays, due to shortage time during therapist session for rehabilitation, it is not possible for patient to receive long term rehabilitation. In order to improve the recovery for finger motion in short time, the rehabilitation for patient using robot allow them to independently carry out rehabilitation exercise [3]. The actual motion with the control finger motion during rehabilitation using repeatable motion generated by robot will able the patient recover in proper technique in future.

Furthermore, using robot application in Malaysia will solve the problem for the rehabilitation instructor to monitor the patients frequently, it will give patient an advantaged to create the ability to do repetitive practice task during rehabilitation session in order to give repetitive practice for physical therapy to patient without the present of instructor [4]. In addition, motion of robot can be controllable and able to quantify the recovery progress performance make them suitable to calibrate the rehabilitation motion with the recovery progress [5]. Using this advantage, the rehabilitation session will goes smoothly with no human error by physiotherapists. Robot based rehabilitation will improve rehabilitation session more efficient because the no of finger rehabilitation robot can use more than three in a time. Make the more patient able to receive physical treatment in a period of treatment without need extra energy of physiotherapist. The robot will increase the effeteness of finger rehabilitation in future.

## 1.2 Problem statement

The complex problem of control finger for rehabilitation is how to control the trajectory generation for initial angular position ($x_i$), final angular position ($x_f$), initial angular velocity ($v_i$), final angular velocity ($v_f$), initial angular acceleration ($a_i$), and final angular acceleration ($a_f$) for the 5 DOF robot to move during rehabilitation of index finger. If the initial angular acceleration is increase, the jerk of the 5DOF robot will increase. Moreover, when the decreasing of the initial angular acceleration ($a_i$), the jerk for robot will decrease, but the time taken to complete one cycle of the robot finger movement will increase. Therefore, how to compare the acceleration and jerk based on the human joint finger force limit.

Every people have different size of finger either long or short on their length and bigger or smaller on their size. The problem of to control the finger rehabilitation robot trajectory movement is different size and length of human finger. Furthermore, how to use the mathematical equation for the circular motion, parabolic circular motion and Cartesian space scheme to generate the movement of robot for the different finger length. How to

produce the movement from that equation so the movement of the finger will be the same as the movement of actual human finger motion.

The problem of control the accuracy of the robot is when the manipulator need to move the finger from initial position to the final position without produce much error and keep the finger joints will not getting hurt. The path description and generation for the trajectory of the robot need to synchronous with the of actual normal finger trajectory. This is because in motion of the patient finger during rehabilitation activity, the muscle need to generate like normal movement of the actual finger and the motion of path need to be specify during this investigation. The motion of path need to move the manipulator from the initial position to the final desired position.

## 1.3 Objective of the project

The objective of this project are:

1. To investigate the finger control for rehabilitation using 5 DOF robotic arm.
2. To Design the Angular position $(x_i, x_f)$, angular velocity $(v_i, v_f)$ and angular acceleration $(a_i, a_f)$ of the Finger rehabilitation robot using KUKA Youbot robot.
3. To evaluate the control of finger using 5 degree of freedom robot during the finger rehabilitation using V-REP software.

## 1.4 Project scope

This project will investigate the how to control the finger motion by using the fundamental of the trajectory generation subject. The 5 DOF robot used in the simulation is only KUKA Youbot and not using other type of 5 DOF robotic arm.

The focus to generated movement of the 5 degree of freedom robot can be simulate by using virtual robot experimentation platform software (VREP). The experimental tool to show the output for this investigation is by using V-REP software. Moreover, this

investigation is able to control the finger motion during rehabilitation with the different size and length finger of the human. This investigation only focus trajectory of human index finger in the V-REP simulation software.

The boundary of research by using VREP simulation software is the gravitational force acting on the KUKA Youbot might be different compare to the actual KUKA Youbot in real world. The different value of gravitational force might affecting the velocity and acceleration in the VREP might be different compare to the actual KUKA Youbot. Therefore, in this investigation, the velocity and acceleration just focus for the VREP simulation software.

In other to investigate the analysis of finger rehabilitation robot, the analysis for accuracy, percentage of error and absolute error is analyse based on the angular position of different finger length, angular velocity and angular acceleration joints for the trajectory of the 5 DOF robot and the force acting to the finger.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Theoretical Background

### 2.1.1 Robotic Rehabilitation

Nowadays, the development of robotic rehabilitation in other to help the patient in rehabilitation activity has increase in the biomedical engineering across the world. The robotic rehabilitation works in very complete task trajectory. This is because the robotic rehabilitation works in unpredictable environment and need to communicate with human ability to do some movement task in rehabilitation training. Robotic rehabilitation is more complex compare to industrial robotic manipulator.

In the biomedical engineering, there are many type of robot use in various task to rehab the patient like 3 DOF robotic arm use to move the movement of finger, the 7 DOF robot use for nursing robot [17] and pneumatic cylinder to generate the movement of finger. For those robotic manipulator, the trajectory movement is mostly generated by using trajectory planning. In the trajectory planning, there are two method basically used to generated the end effector trajectory. The method is joint space scheme and Cartesian space scheme.

There are several rehabilitation task involve to enhance the patient ability by the robot. The task training such as teaching with active assistance robot, training with passive assistance and training with no assistance robot. The modern technology was implement at the rehabilitation robot with the combination of the feedback sensor to analyse the ability

and performance of the patient during rehabilitation training session. The visual based movement also make the robot able to learn the behaviour of the patient ability make the robot to decide either down scale or up scale the movement of the rehabilitation training.

### 2.1.2 Background of finger rehabilitation robot Model

The anatomy of the human hand as shown in figure 2.1.1.1. The anatomy for human hand skeleton is consist of 27 bones. In this investigation, the focused is for index finger. For index finger, there have 3 joint and 4 bones for this finger skeleton. The joint consist of Distal Interphalangeal (DIP), proximal interphalangeal (PIP) and methacarpophalangeal (MCP) [14]. For the bones of index finger, there have distal phalanges, Middle phalanges, proximal phalanges and metacarpals. The related for this purposed into this investigation is, the MCP, DIP and PIP joint is need to consider on control of finger rehabilitation by using 5 DOF robotic arm.

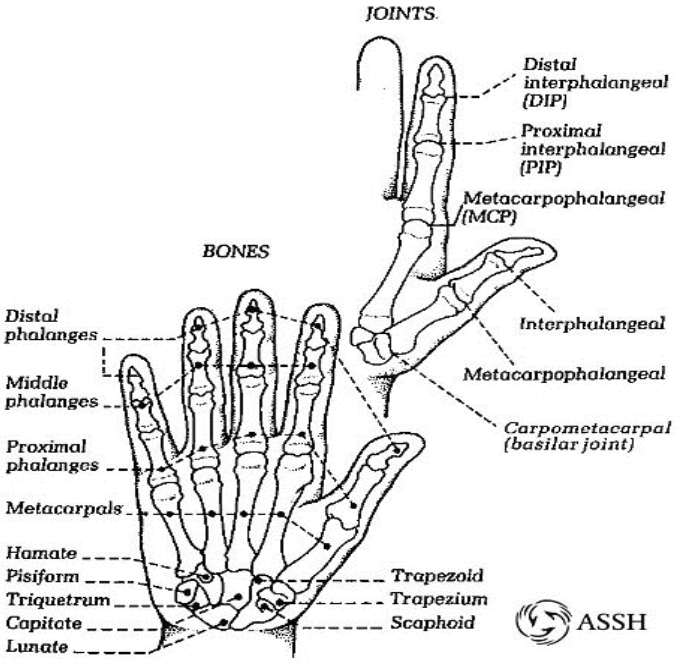


Figure 2.1.2.1: show the basic finger anatomy.

The rehabilitation for thumb finger, 5DOF robot is used to generate the movement of thumb finger. Furthermore, the motion is not focus on passive rehabilitation technique only, they also improve the rehabilitation technique by implement the finger motion with

hand wrist movement in other to improve the effectiveness for patient rehabilitation. The wrist movement is generated by using 2DOF robot [15].

To generate the finger movement, the actual data from human finger movement is implement in this investigation. The actual finger movement from the research [16] is likely movement in parabolic circular shape perimeter. The figure is shown in figure 2.1.2.2 below.

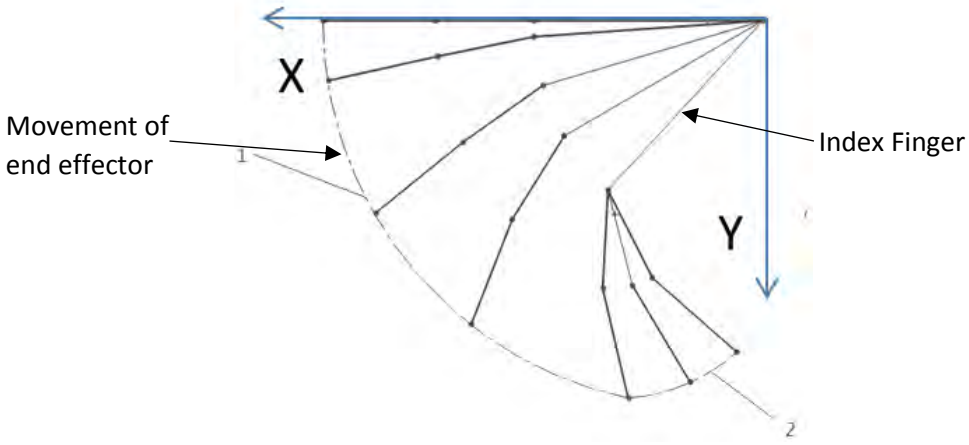


Figure 2.1.2.2: The finger trajectory movement

Finger rehabilitation investigation need several method to gain analysis from the finger motion, to compare and analyse the result from this investigation. Form previous study, the method that apply in rehabilitation activity is vital in terms of accuracy of the position, acceleration, velocity, and angle of each finger joint. This is because every parameter need to synchronise with the normal finger motion of human.

The method use in [9] is the method to generate the finger motion using the combination multi ginger haptic interface robot controlled by surface electromyogram (EMG). The movement of the finger is generated by robot using exoskeleton actuator and the electrical activity of muscle respond is monitor and recorded trough the detection of EMG. This will able to monitor and control every muscle activity by controlling the movement of robot. The EMG is used to measure the bioelectrical signal come from the voluntary contraction of muscle. This signal will give lot of information about a person's intent. It is useful method in other to find the actual normal finger motion in terms of contraction of muscle to be analysis and come out with the control system method [8].

During the rehabilitation for patients, the EMG system will estimate the joint angle of the patient finger. Joint angle is applicable to the robotic system. This is because to generate the finger motion, the angle for each joint in finger need to be estimated in actual position. The angle of joint will affect the muscle contraction. In addition, when the angle was determined, the calculation for different type of exercise can be calculate. This is helpful method in order to produce various exercise for the finger including flexion and extension. [9]. the finger motion for this system can be generated more than 3-directional motion

Furthermore, the hand rehabilitation support system based on self-motion control was developed [10]. The system was developed with the exoskeleton device that support using symmetric master-slave motion system that applicable for virtual reality environment. This is applicable for the patient that have one side hand or finger problem only. The motion is drive by healthy patient hand itself to control other hand that have problem to move.

The other application for robot rehabilitation for finger stroke is by using cable actuated rehabilitation system [11]. The system was developed to train each finger to move using cable loop linear displacement movement. The force from the movement will generated the movement of finger. This system have deferential sensing system and clutch system which allows every each finger movement independently using one actuator.

## 2.2 Trajectory Generation

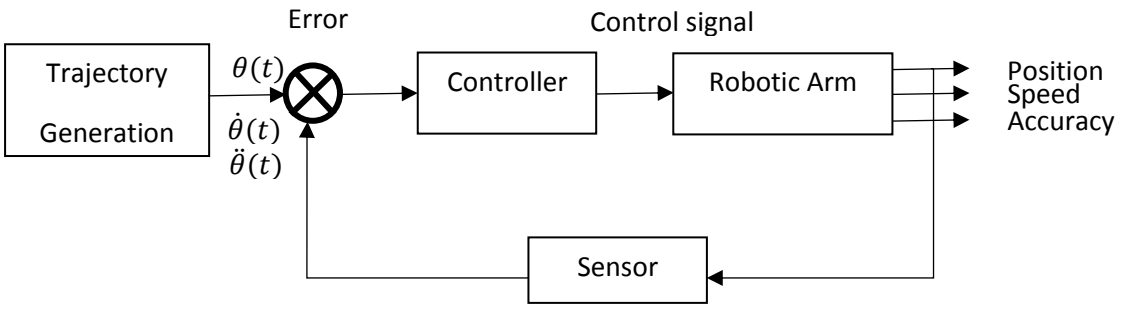


Figure 2.2.1: The Trajectory Generation Block Diagram.

Trajectory generation is the terms to describe the desired motion of a manipulator in multi-dimensional space. The terms trajectory is refer to the time, acceleration and velocity for every single degree of freedom for the manipulator. In investigation of control finger for

rehabilitation, we using the trajectory generation to specify the trajectory or path point in desired position to move the robot in the form of parabolic circular motion.

Using trajectory, the motion of every manipulator can easily generated through the specifying trajectory description for the desired motion. User can easily specify the desired goal position for the end effector to move the finger and let the system to determine the exact shape and path for the manipulator to move to the desired goal position. [11]. The movement for the finger rehabilitation robot depend on the initial position and final position that will define by the user. The trajectory motion for the parabolic motion of the robot will generated by the computer through the define point. Trajectory is computing on the digital computer. The trajectory point is computed at certain rate call path update rate. The rate is typically range between 60 and 2000Hz.

### 2.2.1 Joint-Space Scheme

The joint-space scheme method is to related the path and time and describe it in terms of function of joint angles. The path is commonly describe in terms of position and orientation for the tool frame {T} and station frame {S}. By using inverse kinematic method, each of this parameter is converted to the set of desired joint angle. When the n function pass through via point and end goal point, the smooth function will be determine. The time required for all the joint to move and reach through via point is need to be same resulting the in the Cartesian position of {T} at each of via point. [11]. The purpose for this method in this investigation of the finger control for rehabilitation is when the end effector move the finger, the trajectory parameter for the joints robot need to be control. This is because the synchronisation of the angular position, angular velocity and angular acceleration to the movement of the finger will give the best result for the finger control during this simulation.