KINEMATIC STUDY OF 6 DEGREE OF FREEDOM ROBOT BASED ON STEPPER MOTOR

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Submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (with Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Kinematic Study of 6 Degree of Freedom Robot Based on Stepper Motor" is the results of my own research except as cited in reference.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Broad-based) (Hons.). The member of the supervisory committee is as follow:

…………………………….

(Dr. Silah Hayati Binti Kamsani)

ABSTRAK

Memandangkan dunia terus bertambah dalam teknologi, revolusi industri robot dan sektor-sektor lain semakin berkembang. Di Malaysia, institusi teknikal dan vokasional adalah penyumbang utama modal insan mahir dalam ekonomi revolusi robot. Bagi itu, adalah perlu untuk melibatkan pelajar dengan membuat robot baru yang berpatutan. Kajian ini adalah mengenai perkembangan dan pengiraan manipulator robot 6 paksi khas yang dibuat untuk tujuan pendidikan dan latihan. Tetapi untuk pembangunan robot, projek ini hanya tertumpu pada pemasangan elektrik yang mungkin melibatkan kuasa, arus dan voltan. Selepas pembangunan robot dilakukan, pengiraan akan melibatkan perwakilan Denevit-Hartenberg untuk kinematic ke hadapan dan songsang yang melibatkan 4 parameter, sudut(θ), twist pautan(α), pautan offset(d) dan Panjang pautan(a). Pengiraan kehadapan adalah apabila robot bergerak misalnya 60° untuk paksi pertama, hasilnya akan berbeza dari segi yaw, padang dan roll dan x,y dan z. Tetapi untuk pengiraan songsang, output akan berbeza dimana perubahan yaw, padang dan roll dan x,y dan z akan mengubah sudut putaran bagi setiap paksi. Pengiraan yang terlibat adalah dalam bentuk matriks (4x4). Oleh itu, pemasangan robot yang lengkap dapa memainkan peranan dalam pendidikan dan latihan

ABSTRACT

As the world keep improving in technology, the revolution of robotic in industry and other sectors are keep growing. In Malaysia, technical and vocational institution (TVET) are the major contributors of skilled human capital in robotic revolution economics. As for that, it is necessary to engage students by creating new affordable robot. This study is about the development and calculations of 6-axis robot manipulator made for education and training. But for the development of the robot, it focuses on electrical assembly which may involve the power, current and voltage. After the development of the robot is done, the calculation will involve the Denevit-Hartenberg representation for forward and inverse kinematics which involved 4 parameters, angle(θ), link twist(α), link offset(d) and link length(a). The forward calculation is when the robot moves for example 60° for 1-axis, the result will be different in terms of yaw, pitch and roll and x, y and z. But for inverse calculation, the output will be different which the change in yaw, pitch and roll and x, y and z will change the angle of rotation for each axis. The calculation involved will be in matrices form (4x4). Therefore, the complete assembly of the robot should be able to assume a role in education and training.

DEDICATION

To my,

Beloved father, Zamri Bin Puteh Mahadi

Beloved mother, Zabidah Binti Arshad

Appreciated brothers and sister, Noraliza, Shukrihizzan, Yuzzairi, Syafiqa, Nurdiana and Alia

For giving me the best of moral support, money, cooperation and understandings

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LIST OF ABBREVIATION

DOF	-	Degree of freedom
DH	-	Denavit Hartenberg
PSM	-	Projek Sarjana Muda
FKP	-	Fakulti Kejuruteraan Pembuatan

CHAPTER 1
INTRODUCTION

1.1 Background

The fourth industrial revolution (IR4.0) has begun. This fourth industrial revolution is all about connectivity where the internet of things (IoT) is widely used. Industry 4.0 is very relevant and is increasingly important in making for a variety of reasons Immerman (2017). According to office portal of Ministry of International Trade and Industry of Malaysia Hasbullah (2018), there are 9 pillars of industry 4.0 and one of the pillars is Autonomous Robots. The development of robot has been widely used in industries especially in manufacturing industries. For instance, the manufacture of national cars such as Proton and Perodua. In statistics between 2008 and 2011, about 500,000 to 750,000 new jobs were created due to the robotic industry. This growth is due to increased productivity in manufacturing companies, Colzani (2013). As Malaysia is moving towards industry 4.0, the Ministry of Higher Education (MOHE) is stepping up its efforts in mainstreaming Technical and Vocational Education (TVET) to compete with the challenges of the 4^{th} Industrial Revolution. The reason is to provide the golden challenges and opportunities arising from the development of digital technologies affecting the job market especially in terms of "high skills". The targeted students involved in TVET program are from Polytechnics, Community College, Vocational College and Public University. So, it is a good idea to engage students to learn more in this area by creating robotic platform, so they are directly involved in Industry 4.0. There are 4 types of autonomous robots which are programmable, non-programmable, adaptive and intelligent. But only programmable and non-programmable is focused due to industry demand and use. Famous example of programmable and non-programmable robot is pick and place 6-axis articulated robot arm.

1.2 Problem Statement

Mainly, the 6-axis articulated robot arm often found in heavy industry. The common robot's manufacture such as FANUC from Japan, ABB from Switzerland and others. However, the robots are large which normally hold a heavy load and need a precise position. Moreover, the price and maintenance works will cost very expensive. Because of that, the institution will need to think twist due to limited budge. The second problem statement is the design of the robot. Robotic manufacturers of most industries such as KUKA, ABB, MOTOMAN and FANUC provide robot education packages based on their smallest robot. However, due to their rigid structure, strict security measures need to be followed. It will generate high momentum when it contacted with human since it used metal material. The last problem statement is the electric motor for training robot. Most training robots use servo motor as actuator. This is because it has advantage where it uses a closed feedback system. Closed feedback systems have encoder and sensor. When something goes wrong, the sensor will detect and send a signal to the encoder. The encoder will be triggered and consequently will cause the servo motor to stop working. This is very good in terms of safety factor. But stepper motor is another alternative to be used as an actuator to replace the servo motor. One of the reasonable reasons to choose stepper motor is because of its accuracy which using pulses.

1.3 Objectives

The objectives of this project include:

a) To develop the a 6-axis robot arm for TVET educational purpose
b) To calculate the forward and inverse kinematic of 6-axis robot arm

1.4 Scope

This study is conducted at Universiti Teknikal Malaysia Melaka (UTeM) because it is one of the public universities in Malaysia involved in the TVET educational program. Other than that, the study will be focus on the 6-axis robot electrical assembly. Furthermore, the payload will use not more than 1-kg load in this experiment. The size for the 6-axis articulated robot is as large as desktop table. So, below 1 kg payload is very suitable to balance the weight of the robot and the payload. The programming Arduino and AR2 are software that will be using to give signal to robot arm. The last is kinematic calculation will be using Denevit-Hartenberg convention for forward and inverse kinematic

1.5 Significant of Study

The finding of the study can benefit to the students, industry and country. As for the students, through automated robot learning students will be exposed to software where it is to run the robot. For instances, programming Arduino and Proteus Simulation Software. Both software is not only limited to robot functioning but also used in industry as well. With these, the industry does not need to bother to import expertise within or outside the country as will lead to cost budget. Fresh graduates will cost low amount of budget to use the software operating the machine. Thus, at the same time high productivity can be generates. They can also learn to use Solid works or Catia software to make the design of the robot into 3D views. With these knowledges, the institution will advertise many courses and they targeted freshie from the high school to further studies at their place. At the same time, the institution can generate more money and the popularity among the high school students to further their studies will be increase significantly. Beside from institution, companies such as small and medium enterprises (SMEs) under the ministry of international trade and industry Malaysia do not have a huge allocation to buy large-scale robots. Moreover, the resulting productivity for small company is low and less. Thus, with the lightweight of pick and place 6-axis articulated robot arm which the company can afford to buy and the productivity will soar upwards at the same time. Employees will also be exposed to the use of robotic technology where the robot will be used to help them improve the productivity line. And someday, the robot may only use apps from smartphone to perform specific task where it is called Internet of Thing (IoT). This will help the government’s intention to bring the country’s 4.0 industry to be achieved indirectly.

1.6 Organization of report

Chapter 1: Introduction – This chapter discuss about the background of the study which is introduction to industry 4.0 and TVET program to enhance the skills of Malaysian especially to young generation. For that, the institution wanted to engage students with robots. But the problem is that the robot use in industry are too large and very expensive. The institution has limited budget to purchase it for training robot. Therefore, a small-scaled 6-axis robot is seen as suitable for use in an educational purpose. After the 6-axis robot arm developed, the inverse and forward kinematic analysis will be discussed

Chapter 2: Literature Review – The first sub chapter is introduction to industrial robotics where it separated into types of industrial robot, main components of robot and applications of robot for environment. The second sub chapter is classification of robot based on how axis. The third sub chapter is the focus of 6-axis articulated robot arm since this project is about the development of 6-axis robot arm for educational purpose. Next, stepper motor as the actuator for 6-axis robot arm is the fourth sub chapter. And the last is the kinematic study for forward and inverse will be last subtopic for chapter 2

Chapter 3: Methodology – This chapter is about the method that going to use for the chapter 4 and 5. The first is about the flow chart for assembly parts of electrical components which is the step by step need to be taken for chapter 4. Next is the software that will be used for commanding which are Arduino and AR2. After the development of the robot arm, forward and inverse kinematics will be calculated

CHAPTER 2

LITERATURE REVIEW

This chapter covers the research topic and the previous studies from articles and internet sources by other researchers based on their research about. It included Industrial Robotics background, 6-axis Articulated Robot Arm, Actuators, Electric motor, Stepper Motor, Arduino and Raspberry Pi with touchscreen HDMI. All of this is discussed in this topic.

2.1 Industrial Robotics

The word "robot" comes from the Czech word "Robotnik" meaning "to slave" (McKewen, 2016). Through evaluation, industrial robots are defined as multi-functional manipulator designs to perform special tasks such as transferring materials, parts and tools through input programmed motions. Robots are typically used as substitutes for human workers. As such, robots can give high consistent performance, repetitive accuracy and capable to do a heavy works load and dirty environment. Additionally, robots are reprogrammable to reflect changes in production and cycle.

2.2 Classifications of Industrial Robots

Industrial robot commonly refers to the robot arm used in manufacturing factories. (Bouchard, 2014) stated that it can be classified according to certain criteria such as robotic arm geometry, types of robotic arm, types of movement (degrees of freedom) and joints.

2.2.1 Types of Industrial Robots

Each industrial robot types have the specific elements that make them best suited for different applications based on task given (Marquiss, 2018). Speed, size and workspace are 3 components that make them different each other. Within the knowledge the designers can pick a suitable robot for their process

a) Cartesian – Also known as rectilinear or gantry robot. This robot has 3 linear joints that moves in different axes (X, Y and Z). It is the best for pick and place due to advanced position and repeatability. Example of pick and place operation is picking up and moving bottles in production line. Cartesian robots are fairly inexpensive to make due to simple design and structure

b) Cylindrical – Similar as Cartesian in their axis of rotation. Linear and rotary are two moving actuators cylindrical robots. Basically, it moves; up and down, and around a cylindrical pole. Because of its rotation element, it can be placed in the middle of workspace. It simply where the load is picked up, rotated and then placed.

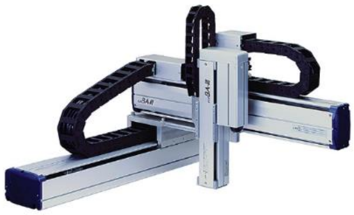
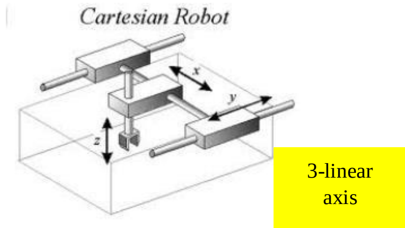
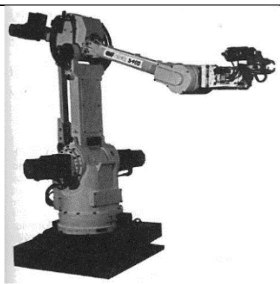
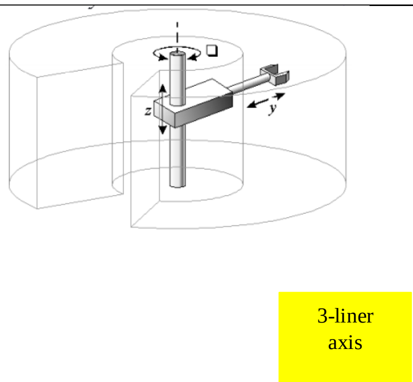
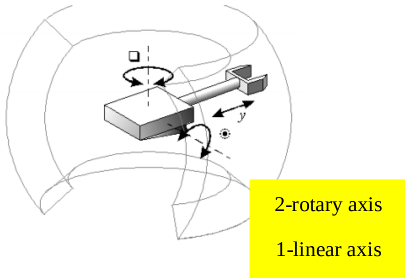
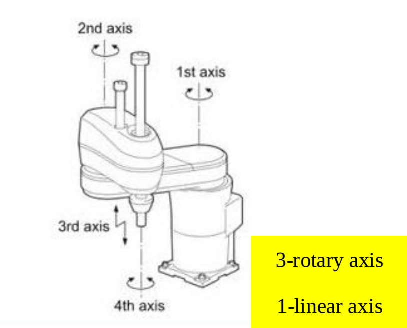
c) Spherical – Known also as Polar robot, it is similar to but more complex than Cartesian or Cylindrical. The arm robot is connected to a base via twisting joint by performing spherically shaped work area. This can perform the three-dimensional space task movement. As articulated are more performance, the Spherical robot become less popular nowadays.

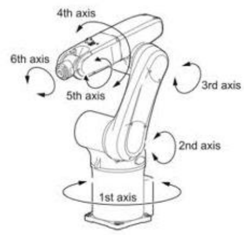
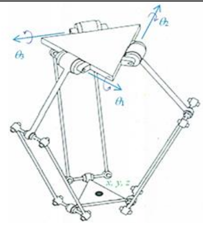
d) SCARA – Is an acronym that stands for Selective Compliance Assembly Robot Arm. It offers a complete solution equipped with X, Y and Z and rotary motion in one package. SCARA is also faster than Cartesian or Cylindrical robot. High speed and/or high precision in industries including automotive, medical, food and pharmaceutical are very suitable for SCARA robot (Heney, 2017).

e) Articulated – Also known as 6-axis robot. Usually found typically very large and used for job assembly. These arm act exactly like a human arm which can pick up a material and move them from one place to another. 6-axis robot arm can be quick as SCARA robot but along with the complicated programming coding.

f) Delta – The latest design which is faster and most expensive one. They have a unique structure and working envelope which can move at the very high speed. The application is the same as 6-axis which is pick-and-place. The design is more complicated than 6-axis or SCARA robot but can produce high precision.

Table 2.1: Types of Industrial Robot with pictures, degree of freedoms and joints

	Example of Robot	**Degree of Freedoms**	**Joints**
Cartesian			3-prismatic joints
Cylindrical			2-prismatic joints 1-revolute joint
Spherical			2-rotary joints 1-prismatic joint
SCARA			2-parallel joints

Articulated		 6-rotational axis	3-rotrary joints
Delta		 3-rotary axis 1-linear axis	

2.2.2 Main Components of Industrial Robot

In industrial robot, there are 5 main components (Controller, Arm, End Effector, Drive, Sensor)

a) Controller – Act as the brain of robot and can operate all the parts together. It can make the robot connected to other systems which is work as a computer. A set of instructions is running by the controller and written in code called a program. The Windows operating system are used that as interface for today's robot.

b) Robot arms – Within the robot arm, the shoulder, elbow and wrist move and twist at the exact spot. Each of the joints act as the degree of freedom which to range of the arm robot moving. Usually, a simple robot consists of 3 degree of freedom in 3 ways: up and down, left to right, forward and backward. But for industry applications usually use 6 degree of freedom.

c) End effector – Exactly mimic to human's hand. This part is direct contact with the materials or things. Some robots can set different of task by reprogrammed. Example of end effector is gripper, magnets, a vacuum pump, etc.

d) Drive – It acts as an engine or motor to moves the links into specific positions. The general use in industrial robot is hydraulic, pneumatic or hydraulic. The drive use depends on the task or order that gives by the controller.