UNIVERSITI TEKNIKAL MALAYSIA MELAKA
(UTeM)

DESIGN AND SIMULATION OF ROBOT SPRAY PAINTING

Thesis submitted in accordance with the partial requirements of the
Universiti Teknikal Malaysia Melaka for the
Bachelor of Manufacturing Engineering (Robotics and Automation) with Honours

By

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I hereby, declared this Bachelor's Project entitled "Design And Simulation of Spray painting Robot" is the result of my own research except as cited in references.

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APPROVAL

This Bachelor's Project submitted to the senate of UTeM and has been accepted as fulfilment of the requirement for the Degree of Bachelor of Manufacturing Engineering (Robotics and Automation) with Honours.

The members of the supervisory committee are as follows:

....

Mr Hafidz Fazli B. Md Fauadi

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ABSTRACT

The design and simulation robotic spray painting robot is discussed particularly in the matter of the kinematic analysis and the trajectory planning of the robot spray painting. The discussed matters in this project are the kinematic analyses which are proceeded using methods and software. In the method task, the kinematic analyses are analyzed using forward kinematics and the trajectory planning analysis. On the other hand, the softwares that are used in this paper are the matlab and mathcad. The design and simulation were carried out using the workspace 5.0 design software. In calculating the kinematic analysis, the software to be use the matlab software. The project is conducted to determine a workspace that will be place with the robot spray painting.

DEDICATION

For my beloved parents:

Saipollah Hassan

Faridah Samoh

And for my adored brother and sisters:

Farashafina Saipollah

Farashafira Saipollah

Muhammad Saifuddin Saipollah

Farashafida Saipollah

Farashafilia Saipollah

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My thesis supervisor, Mr Hafidz Fazli B. Md Fauadi of which we had a good working relationship, and who offered tremendous help and encouragement,

My family, who inspired me whether through the storm and carry on,

My friends and peers who are good companions in times of need.

Wassalam.

Mohd Shafiq Saipollah

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

D-H	-	Denavit-Hartenberg
MATLAB	-	Matrix Laboratory
PLC	-	Programming Logic Controllers
DOF	-	Degrees of Freedom
SCARA	-	Selective Compliant Articulated Robot Arm
ISO	-	International Organization for Standardization
CNC	-	Computer Numerical Control

CHAPTER 1

INTRODUCTION

1.1 Background of project

The term industrial automation is generally defined by ISO as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. In the studies of the robotics, the scopes are related to the practice of study, design and the use of the robot system in a certain manufacturing sectors. The definition normally relies on the priority of the robot itself. Typical applications of robots include welding, painting, ironing, assembly, pick and place, packaging and palletizing, product inspection, and testing. These processes are all accomplished with high endurance, speed, and precision (ISO Standard 8373:1994)

The benefits of applying robots in an industrial sector are the ability to boost up the productivity of the industry especially in automation sector. In an industrial sector, an automated process is very important where, the automated process stated can be refer as panting, screwing, assembling and welding. Every manufacturing factor has its own translation of automated processes and the process defer in each one of them.

Another popular and efficient use for robots is in the field of spray painting. The consistency and repeatability of a robot's motion have enabled almost perfect quality to the finished goods while at the same time wasting no paint. In fact, the spray painting is seems to be optimizing the proper applications of robotics. In other word, it helps to relief the human operator from a hazardous substance from the spray nozzle, perform a very skillful job continuously, while at the same time increasing work quality, uniformity, and cutting costs.

The project consists of a simulation of spraying robot that would adapt the facts that applying robot in an industrial sector would accomplish high endurance, speed and preciseness. The system of the project is able to perform repeatable motion and work, in order to position the truth about the benefits of applying a robotic system in a manufacturing sector. (Shimon ,1999)

1.2 Problem Statements

In general, the use of applying a layer coat of paint or any other kind of substance, which, covers up partial or entire product, are to extend the life of the good or product, to give an extra credit on the product's looks or finishing. As we know, the consumers will be attracted to the product if the products are well fashioned or in other word colorful and bright. In order to produce a skillful panting job continuously without compensate more time, a design of a robotic automation system should be placed in the production line. The result of robotic paint automation would not downgraded the finished good, in fact, the use of a robotic spraying automation would give a similar finish to all products and the output of the productivity can be increased enormously.

In this case, the consistency and the repeatability of the robot motion itself are placed in a good benefit, where the use of robotic spraying automation on finish goods can be done faster and with a lower cost without losing the quality of the finish goods. The facts that robot spraying automation keeps a lower cost is supported by the facts that, amount of paint that are used in a single product is fixed with out any lost of paint. As we know, a robotic automation system would be a high capital expenditure but, the products that are produced with a great quantity and quality would return back the cost of the robotic automation itself. (Shanon, 1999)

1.3 Objectives

The objectives of this project are to design and simulate a spraying robot that will be applied in a production line in an industry. The understanding of the system should be sufficient during this paper. The objective is carried out through a simulation with the reason that the cost might be too expensive for a student to carry out. A robot system simulation is a lot more portable and would help ease the student to comply. The objectives o this project conduction is stated below:

i. To design a suitable spraying robot to adapt in a certain workplace
ii. To propose a suitable robot work cell for the spraying task

1.2 Scope of Study

The scope of study is based on the objective of the project. Simulation of the spraying robot automation is carried out based on the specific task of the project. In this project, the specific task is defined as the spray paint of the furniture door .The designs of the simulation are depending on the work piece and the work environment. The method is to handle an offline programming simulation.

1.3 Conclusion

On the end of the introduction chapter, a brief understanding of robot definition, benefits, advantages and the purpose of the project is properly introduced. The objective of the project is clearly defined in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the discussions are more about the previous researched that have been done. In the never-ending effort of the humanity to simplify their daily work, came the birth of the automatic manufacturing. Automatic manufacturing has become an important motivation to develop more flexible automated manufacturing techniques, where the original idea to gain more production rate for an industry (Olsson, 2002).The discussion on how a robotic spraying automatic would boost up a production rate and how simulation can help overcome the paint constrains

Robotics technology embraces multiple disciplines such as structural mechanics, material physics, power electronics, computer science, software engineering, etc. The continuous progress and discrete breakthroughs in respective discipline have altogether contributed to a remarkable improvement in performance of industrial robots (Olsson, 2002) .A robot is cheaper, can move faster and more accurate, with higher payload and is more reliable than ever before.

The transition time has been reduced through the use of robot simulation systems, often referred as CAR (Olsson, (2002). The robot task can in this way be simulated using a virtual model of the work cell at a time where only digital prototypes of the work piece exist. The risk of technical failure for a transition can be reduced. The robot task description can even be transferred to the robot system to reduce the very time-consuming robot programming phase (referred as off-line programming).

2.1.1 Etymology of Robot

The word robot was 1st to be released as a printing medium in March 1942, by Isaac Asimov in a short film called 'runaround' as a science friction story. The structure of the electrical parts is called electronics while the designs of the frames are called robots. (Robotic, 2008, www.wikipedia.org/wiki/Robotics#Etymology)

2.1.2 History of Robot

Computer controlled industrial machine tools such as CNC falls into the robot category and can be defined as a robot as well but in some people resist to call CNC as robot and are defined as CNC machines only. (John J. Craig, 1989) Robots are primarily concerned with generating specific motion of the robot joints, simultaneously allowing tooling or sensors to perform certain functions, either when the arm is moving or at specific operational configurations. The arm and attached tooling may perform the operations themselves (such as painting) or carry parts to other devices which perform the operations.

Newer technologies are concerned with robot interactions with parts such that interaction forces and torques can be controlled. This technology will permit more robot applications in assembly, which promises to be a growing application arena for robotics.

2.2 Fundamentals of Robot

Robots usually have joints to position the tool and joints to orient the tool. Gross positioning is accomplished by the inner (primal) joints, while orientation is accomplished by the outer (distal) joints.

When classifying a robot type, the primal joints are used, it being understood that the orientation joints can be added to give the orientation flexibility required. Thus, the figures which follow show only the first three joints in the robot type classification. At the beginning of this section, the robot workspace is mentioned. A workspace of a robot is a three-dimensional collection of points which the wrist of the robot can reach. However, when the joints corresponding to the three major axes have different combinations, the robot work-space is different. Therefore the classification of industrial robot manipulator is often done to the first three joints corresponding to the major axes, though there are many other classification method based on control manners, application, and kinematic structural. The following are the four different geometric configurations of robots. (Zhihong, 2003)

2.2.1Articulated Robot

An articulated robot has three rotary joint that makes the robot able to have more degree of freedom. The designed structure has relative large wok-space. An articulated robot is known as RRR (Zhihong, 2003)

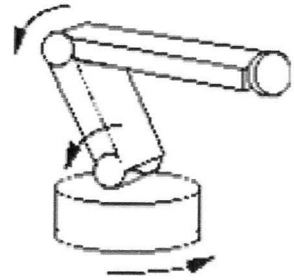

Figure 2.1 – Revolute or Articulated Robot: RRR

Source: Edward Red

2.2.2 Spherical Robot

A spherical robot such as the above figure has two rotation axes and one prismatic axis and the robot is called RRP. The degree of freedom on this robot is less than the articulated robot, since the joints for the robot are limited. (Zihiong,2003)

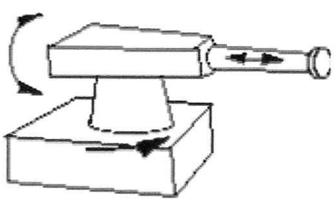

Figure 2.2 Spherical Robot: RRP

Source: Edward Red

2.2.3 Cylindrical Robot

Cylindrical robot has a single rotary joint and two prismatic movements where the work-space of the robot is actually a two concentric cylinder with the same heights. (Zihiong, 2003)

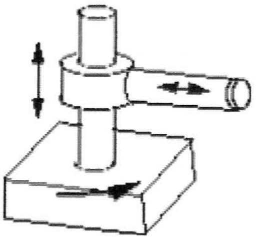

Figure 2.3 Cylindrical Robot: RPP

Source: Edward Red

2.2.4 Rectangular Robot

The figure above shows us the rectangular or prismatic robot which it is the most common features in any robot. The joints are built from the prismatic joint and the advantages of the robot are simple, and easy to be re-position. (Man Zihiong,2003)

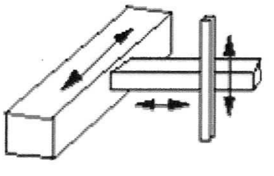

Figure 2.4 Rectangular or Prismatic Robot: PPP

Source: Edward Red

2.2.5 Supporting Technologies

Robots are only functional when there are technologies of the decade installed onto the robot. There are a lot of gadgets that can be adapted onto a robot. The types of technologies that are commonly integrated with a robot are vision systems, end-of-arm tooling and special compliance/manipulation devices, welding technologies, optical devices such as lasers, sensors such as acoustical or other type proximity sensors. Other than that, wrist sensor which capable of measuring wrist's forces and torques. A control software and hardware, such as AC/DC motors, encoders, tachometers, and amplifiers are other examples of gadgets that can be integrated onto the robot system to improve flexibility.

When certain technologies are installed onto the robot configuration, there are lots of advantages that the robot can obtain and with the integration of the technologies onto the robot, the robot gain greater flexibility, are able to reprogrammable, adjustable kinematics dexterity and others. While others technologies helps the robot to reduce accidents and casualties in the workplace. (Edward Red)

2.3 Robot Kinematics

Robot kinematics is the study of the motion of the robot. In the study of kinematic, the analysis of a certain position, velocity and acceleration of the joints and link are calculated to find the relations on the robot by assigning the parts of robots or joint in the frames orders. Each frame are representing a moveable part in a robot. Every joints that are moving will be named and will be calculated the movements of the robot. In order to be simple, the calculations are dealt with a single manipulator arm at times.

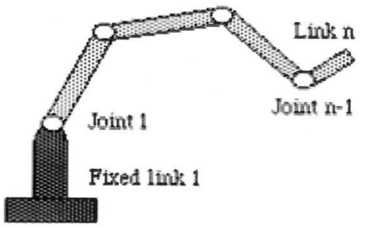

Figure 2.5 Serial of Joints Manipulator

(Source: Red,2002)

Above are a serial of joints manipulator that have four degree of freedom. The numbers of degree of freedom of a kinematic chain are labeled each one by the type of joints and number of joints. Each joint contributes a single degree of freedom and the degree of freedom of a single robot is determined through the number of degree of freedom of the robot. Even though many robots have joints which are configured serially, many robots have other joints which actually actuate the primary joints. For example many robots use 4-bar linkages to actuate the primary joints. Sometimes these joints are referred to as the actuation joints. (Zihiong,2003)

2.3.1 Forward Kinematics

Forward kinematics are homogeneous transformations to relate the joint variables on the position and orientation of the robot end effectors to the robot base frames. The orientation and position can be computed or calculated using the D-H algorithm. For the serial links of a robot the pose of a tool at the end of the robot can be determined by the equation (Red,2002)

$$\mathbf{T = H^1 \, H^2 \, H^3 ... Hn} \qquad (1)$$

where =**T** locates the tool relative to the robot base frame and **G** locates the tool relative to the last joint/link frame.

The joint frames are described relative to each other by **H** and are a function of the joint angle if a rotational (revolute: R) joint or the joint translation if a sliding (prismatic: P) joint. Note that the joint frames relative to the previous joint frame as described by **H** are usually oriented such that the rotation or translation takes place about the joint z axis. (Red,2002)

In forward kinematics the amount of translation or rotation is specified directly and the tool is commanded to the pose described mathematically by **T** since each **H** is known. Forward kinematics is used in teach pendant programming to describe the pose of the tool once one or more joint values are changed by jogging the robot through the teach pendant interface.

2.3.2 Rotation Transformations

Rotation transformations can be described as two frames which occupy the same origin can be transformed into the each other by rotating the axes of either x, y or z until the frames are mutual. When the frame needs to be rotated at the x axis, the formula is state as below:

$$\mathbf{R}(x,q) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$ **(Source:Zhihong,2003)** (2)

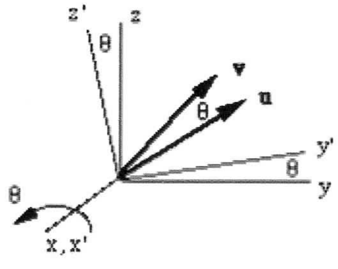

Figure 2.6 Rotation of a vector

(Source: Red,2002)

We designate the rotated frame by the x'y'z' axes and the original frame by the xyz axes. The effect of rotating **u** to **v** is to change its coordinates with respect to the xyz axes but not with respect to the x'y'z' axes.