UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MODELING AND SIMULATION OF 3 DEGREE OF FREEDOM OF ROBOT MANIPULATOR

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Mechanical Engineering (Automotive) with Honours.

By

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Laporan ini dikemukakan sebagai
memenuhi sebahagian daripada syarat penganugerahan
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MAY 2011

SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive)"

Signature: ……………………………

Supervisor: ……………………………

Date: ……………………………

2nd SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive)"

Signature: ……………………………

Supervisor: ……………………………

Date: ……………………………

DECLARATION

"I hereby, declared this report entitled "Modeling and Simulation of 3 Degree of Freedom Robot Manipulator" is the results of my own research except as cited in references.

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Author: ……………………………………

Date: ……………………………………

DEDICATION

Especially to my beloved parents and family

ACKNOWLEDGMENTS

I would like especially thanks to my beloved supervisor En. Fauzi bin Ahmad. Thanks to him who always gives advises when I face crisis in doing the project. Moreover he is willing to spend his precious time to guide me when I faced problems. Next, I also feel grateful with En. Khairol Annuar who guides me in modeling robot arm. I am so appreciates that facility in UTeM because it provides a useful free webpage that I can read many references journal. The journals really help me a lots in this project. Next, I would like to thank my panels Dr. Musthafar and En. Rodly that give me advises during my presentation in seminars. Finally, there is no word to thank to my beloved family members and friends that give me support during the period to complete this final year project.

ABSTRACT

This project is about modeling and simulation of a 3 degree of freedom (DOF) of robot manipulator. This project will be carried forward for further research on pitch rejection research. To model the robot manipulator, many journals have been studied to find out the mathematic derivation to model a robot arm. They are kinematic model and inverse kinematic of 3-DOF robot manipulator. The forward and inverse kinematic will be presented in this study and they will be validated. The robot manipulator will be combined with a 7-DOF vehicle model to do pitch rejection control. PID control is used in cancelling the vibration that suffered by the robot manipulator. The effectiveness of the controller that is used in this study will be discussed detail in this thesis.

ABSTRACK

Projek ini tentang model dan simulasi bagi 3 darjah kebebasan lengan robot. Projek ini akan dibawa kepada masa depan untuk perkajian tentang penolakan putaran. Untuk memodel lengan robot, terbitan matematik akan diperlukan. Terbitan matematik ini adalah kinematik, dan invers kinematik . Model kinematik dan invers kinematik akan menyampaikan dalam tesis ini. 3 darjah kebebasan lengan robot ini akan menggabung dengan 7darjah kebebasan kereta model untuk membuat kawalan penolakan putaran. PID akan digunakan dalam menolakkan getaran yang ditanggung oleh lengan robot itu. Keputusan akan dibincangkan dan ditujakkan dalam tesis ini.

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LIST OF SYMBOLS

d_i	=	The link offset, is the algebraic distance along Z_{i-1} to the point where the common perpendicular to axis Z_i is located
a_i	=	The link length, is the length of the common perpendicular to axes Z_{i-1} and Z_i
Θ_i	=	The link angle, is the angle around Z_{i-1} that the common perpendicular makes with vector X_{i-1}
α_i	=	The link twist, is the angle around X_i that vector Z_i makes with vector Z_{i-1}
Q	=	Joint space
W	=	Cartesian Space
R	=	Orientation of robot arm
X,Y,Z	=	Coordinate position of robot arm end-effector
q	=	Joint angle

LIST OF ABBREVIATION

DOF	-	Degree of Freedom
PSM	-	Project Sarjana Muda
DH	-	Denavit Hartenberg
$C\theta_1$	-	Cos θ_1
$S\ \theta_1$	-	Sin θ_1

CHAPTER 1

INTRODUCTION

1.1 Overview

A robot is an electromechanical device with multiple degrees-of-freedom (dof) that is programmable to accomplish a variety of tasks. Usually robot is used to help human or substitute human to conduct work. The applications of robot are jobs that are dangerous for humans, repetitive jobs that are boring, stressful, or labor-intensive for humans and menial tasks that human not willing to do. There are laws for robotics which proposed by Asimov.

Law 0: A robot may not injure humanity or through inaction, allow humanity to come to harm.

Law 1: A robot may not injure a human being or through inaction, allow a human being to com to harm, unless this would violate a higher order law.

Law 2: A robot must obey orders given to it by human being s, except where such orders would conflict with a higher order law.

Law 3: A robot must protect its own existence as long as such protection does not conflict with a higher order law.

The U.S is the second largest robot user behind Japan (Kumar, 2001). Japan installed more robots annually in 1990-1992 than the total U.S installed in the 32 years from 1962-1992. Annually sales of robots peaked at 80,000 in 1990 and then fell to 56,000 in 1993. Annual growth rate in 1995 – 2000 was around 15 % excluding Japan. This shows that robot become much more important to us for future development because robot already play an important role in these advance country.

1.2 Problem Statement

There is a need for the robot manipulator but the cost is too high for a student to do research on it. So the best way is model the robot manipulator in a simulink software before constructing or buying a robot manipulator. Moreover simulink software is inexpensive compare to a robot manipulator.

1.3 Background of the study

This project is going to model and simulate a 3 degree of freedom of robot manipulator with simulink software. The robot manipulator in this project will be carried forward to do further research by combining with a vehicle simulator to do research on vibration rejection. This robot manipulator is designed to help human for pick and place a dangerous item, for example explosive bomb. So modeling and simulate a robot manipulator is a necessary.

Modeling and simulating a robot in simulink software is really a good method because we could model a real robot and see the reaction of the robot when inserting different input. Hence we could make prediction with strong prove. Moreover, modeling the robot can easily change the design of the robot. For example, manipulate parameter of the robot so that we could see the result and make decision to get the best design.

Hence the simulink software is really a big useful tool for engineer because they can help them reduce their work in analysis and save time save money.

1.4 Objectives and Scopes of Study

This project's objective is to model and design a robot manipulator that can be combined with vehicle dynamic simulator for vibration rejection research.

There are two major scopes in the project which are:

- Mathematic derivation of 3 degree of freedom (DOF) robot manipulator.
- Modeling of 3 degree of freedom robot manipulator into simulink software MATLAB.
- Modeling a 7-DOF ride model vehicle.
- Combined 7-DOF ride model with 3DOF robot arm to do pitch rejection on robot arm.

1.5 Significance of the Study

This project is the fundamental research that will be very important for future research on developing a vibration rejection simulator robotic arm. Hence the data of in this project is very helpful for the future analysis. By having the model of the robot arm, they could easily manipulate the parameters of the robot arm and hence create a design of robot arm which can be used in the further research.

1.6 Methodology

I will combine the methodology for robotic simulation by Grajo *et al.* (2007) and proposed methodology by Velarde-Sanchez *et al.* (2010) so that the flow can be efficient. The items of the methodology are define the problem, design the study, mathematical model and Matlab & Robot toolbox. Following is the chart of methodology Matlab-Simulink.

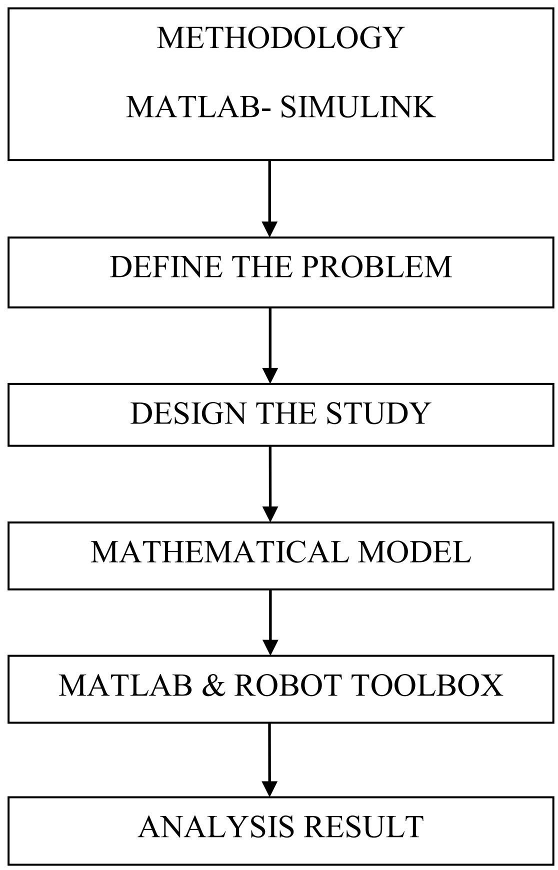

Figure 1.1: Chart of Methodology MATLAB - Simulink

1.6.1 Define the problem

Problem identification is defined during the preliminary analysis of problems' background. Since this project will be carried forward as vibration rejection purpose so it is impossible for a student to construct the robot arm because the cost is too high and inefficient. So modeling and simulate the robot in a software is a better choice. Moreover simulink has a lot of advantages, it is wise to do modeling and simulink before constructing or buy a robot because it can save cost and time.

1.6.2 Design the study

This project is distributed into PSM1 and PSM2, so basically in PSM1 I will more focus on research on how to model and simulation a robot arm and most of the time is doing literature review, find the methodology to solve the problem in the project, decide the type of robot arm joints and some mathematics derivation. In PSM2 mathematic derivation will be completed. Then it is model into simulink software- MATLAB and manipulate the parameters of robot arm to get the best design. The robot arm model will be combined with a 7DOF ride model to do pitch rejection control. Finally, make analysis on the result and complete the report.

1.6.3 Mathematical model

The 3 degree of freedom robot manipulator in this project is RRR robot arm, which has 3 revolute joints. So basically, the mathematical models are kinematic model, inverse kinematic model of robot manipulator and 7-DOF vehicle ride model. So in PSM 1 the mathematic derivation will be completed until forward kinematic and PSM 2 is inverse kinematic, 7-DOF ride model and pitch rejection control.

1.6.4 MATLAB & Robotic toolbox

Amongst the simulink software of robot, I chosed MATLAB as the tool to model the robot arm. The MATLAB is a powerful tool as mathematic model. There is a Robot's toolbox in MATLAB is specially designed for modeling and simulating the robot. In the robot toolbox, I could model the robot arm with visual robot arm model. The pitch rejection control will be done in MATLAB.

1.6.5 Analysis result

According to Dragon *et al*. (2002), they have compared their result with Robotic toolbox in MATLAB. In this project, I will compare my mathematic model in MATLAB result with Robotic Toolbox in MATLAB. The result in MATLAB shall similar with the result of the Robotic Toolbox in MATLAB. If the result is similar that means the method I model the robot in MATLAB is successful. The modeling in ride model will be validated with result in CarSimEd similink software. The pitch rejection control is compared with model before controlled and after controlled hence analysis the graphs with several condition and position.

1.7 Structure and Layout of the Thesis

This report consists of 7 chapters and organized as follows: the first chapter is the introduction of this project. This chapter will show the overview of robot, problem statement, objectives and scopes of the study, methodology of the research and the structure and layout of this report. The second chapter is literature review. In this chapter, it will give some brief explanation on the basic knowledge of robot as an introduction to the reader. Moreover in this chapter contains literature review of the previous researches which later will be the references of my project to model and simulate the robot manipulator in MATLAB simulink software and Robotics Toolbox. Chapter three contains the mathematic derivation of forward kinematic of 3-DOF robot manipulator and the modeling in MATLAB and Robotics Toolbox. Chapter four contains the mathematic derivation of inverse kinematic of 3-DOF robot manipulator and validation the result with forward kinematic. Chapter five contains a mathematical derivation and simulink model of 7-DOF ride model. Chapters six, the combination of 3-DOF robot arm with 7-DOF ride model, pitch rejection control and result analysis. Final chapter is the conclusion and recommendation of this project.