UNIVERSTI TEKNIKAL MALAYSIA MELAKA

SYSTEM RESPONSE FOR LIGHTWEIGHT ROBOT ARM

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotics and Automation) (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "System Response for Lightweight Robot Arm" 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 UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotics and Automation) (Hons.). The member of the supervisory is as follow:

....

(Puan Nur Aidawaty Rafan)

ABSTRAK

Laporan ini membincangkan hasil kerja tindak balas sistem untuk lengan robot jenis ringan (ITRobot). Kerja-kerja penyelidikan mengenai identifikasi untuk model lengan robot jenis ringan yang terdapat dalam kajian adalah sangat jarang dan terhad. Kebanyakan laporan penyelidik ialah mengenai lengan robot jenis berat yang biasanya digunakan dalam industri pembuatan. Aplikasi baru begitu juga prestasi baru dari segi kelajuan tinggi, kestabilan yang tinggi dan ketepatan yang tinggi boleh dicapai dengan tindak balas sistem yang lebih baik. Tindak balas sistem adalah salah satu unsur dalam sistem identifikasi (SI) teknik. Instrumen yang sesuai dan prosedur analisis digunakan untuk mendapatkan input dan output. Objektif projek ini adalah untuk menentukan tindakan frekuensi sistem untuk lengan robot jenis ringan dan untuk menganalisis kelakuan dan ciri-ciri lengan robot ringan menggunakan Jelmaan Fourier Pantas (FFT). Hasil bagi simulasi diperolehi dengan menggunakan alat SimMechanics yang terdapat dalam perisian MATLAB manakala bagi eksperimen adalah menggunakan peralatan robot iaitu lengan robot jenis ringan. Analisis untuk kedua-dua eksperimen berdasarkan margin gandaan, margin fasa, dan FFT. Menurut peraturan kebiasaan, margin gandaan adalah 4-10 dB manakala margin fasa 30^0-90^0. Kesemua hasil dapatan telah disusun dalam bab keputusan dan perbincangan. Penambahbaikan untuk melanjutkan kajian mengenai system identifikasi (SI) untuk lengan robot jenis ringan juga telah di nyatakan.

ABSTRACT

This report presents the work done on system response for lightweight robot arm (ITRobot). The research works on the identification of the lightweight robot arm models found in the literature are very limited. Most researchers study on the heavyweight types of robot arm that commonly applied in the manufacturing industry. New application as well as new performance in terms of high speed, high stability and high precision can be obtained by designing a system with good transient response properties. System response is one of the main elements in system identification techniques. A suitable instrument and analytical procedure is used to obtain the input and output of system. The objectives of this project are to determine the frequency response of the system for lightweight robot arm and to analyse the behavior and characteristics of lightweight robot arm using Fast Fourier Transform (FFT). The results for simulation are obtained by using SimMechanics toolbox that is available in MATLAB software while for experimental analysis is using the robot hardware which is lightweight robot arm. The analysis for both experiments is based on gain margin, phase margin, and FFT. According to the rule of thumb, gain margin is 4-10 dB while phase margin is 30^0-90^0. The results were compiled in the results and discussion chapter. It is recommended to do further studies on system identification for lightweight robot arm.

DEDICATION

To my beloved parents,

Mohd Razali bin Awang and Amikalsom binti Hamzah

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First and foremost, all praise to The Almighty, who made this accomplishment possible. I seek His mercy, favor and forgiveness.

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TABLE OF CONTENT

Declaration	
Approval	
Abstrak	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of Content	v
List of Tables	viii
List of Figures	ix
List Abbreviations	xi

CHAPTER 1: INTRODUCTION

1.1	Background	1
1.2	Problem statement	4
1.3	Objective	5
1.4	Scope of project	5
1.5	Significance	6
1.6	Outline	6

CHAPTER 2: LITERATURE REVIEW

2.1	Introduction	7
2.2	Type and application of robot	7
2.3	System identification	14
2.4	Summary	17

CHAPTER 3: METHODOLOGY

3.1 Introduction 18

3.2 Overview 18

3.3 Project Implementation 19

3.3.1 Literature Study 20

3.3.2 Identification of Frequency Response and bandwidth of system 20

3.3.3 Numerical and Experimental Validation 26

3.3.4 Data Analysis and Report Writing 30

3.4 Gantt Chart 33

3.5 Summary 34

CHAPTER 4: DESIGN

4.1 Introduction 35

4.2 Offline and Online Experiment 36

4.3 Summary 46

CHAPTER 5: RESULT AND DISCUSSION

5.1 Introduction 47

5.2 Result and Discussion 47

5.2.1 Offline Experiment (Numerical) 47

5.2.2 Online Experiment (Experimental) 50

5.3 Summary 57

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion 58

6.2 Recommendation 59

6.3 Sustainability 60

REFERENCE 61

APPENDICES

A PSM 1 Gantt chart 66

B Overall Gantt chart 67

LIST OF TABLES

2.1	Table of comparison of each type of robot configurations	10
3.1	Table of instrument list	20
3.2	Table of joints names	22
5.1	Table of result of experiment (offline)	48
5.2	Table of result of experiment (online)	50
5.3	Rule of Thumb of Gain Margin and Phase Margin	51

LIST OF FIGURES

1.1	Lightweight Robot Arm	2
2.1	Basic configurations of Robot	9
2.2	Basic robot motion	9
2.3	PANDI-2	13
2.4	PANDI-1	13
2.5	A simple closed loop system	14
2.6	Algorithm for Modeling and System Identification	15
2.7	Block diagram of overall system	17
3.1	Flow chart of project development	19
3.2	Lightweight Robot Arm (ITRobot)	22
3.3	Degree-Of-Freedom	22
3.4	Base DC Servo Motor	23
3.5	Voltage Regulator	23
3.6	Driver Box	24
3.7	Micro Box	25
3.8	System Identification Block Diagram	26
3.9	Flowchart for System Identification	28
3.10	Fast Fourier Transform (FFT) Plot	30
3.11	Bode diagram	31
3.12	Gantt Chart Overall	33
4.1	Block diagram of overall system	35
4.2	ITRobot Open Loop	37
4.3	ITRobot Close Loop	38
4.4	Robot Controller Block	38
4.5	Before Optimization	39
4.6	After Optimization	40
4.7	Final Simulation Model	41
4.8	Robot Dynamic Block	41
4.9	Robot Hardware	43
4.10	Final Hardware Model	44

4.11	Selected side used for online experiment	45
5.1	Window error that pop up during simulation	49
5.2	Error in command window of MATLAB	49
5.3	Bode response diagram FRF System (Simulation time=100 s)	52
5.4	FFT diagram of output (Simulation time=100 s)	52
5.5	Bode response diagram FRF System (Simulation time=90 s)	53
5.6	FFT diagram of output (Simulation time=90 s)	53
5.7	Bode response diagram FRF System (Simulation time=80 s)	54
5.8	FFT diagram of output (Simulation time=80 s)	54
5.9	Bode response diagram FRF System (Simulation time=70 s)	55
5.10	FFT diagram of output (Simulation time=70 s)	55
5.11	Bode response diagram FRF System (Simulation time=60 s)	56
5.12	FFT diagram of output (Simulation time=60 s)	56

LIST OF ABBREVIATIONS

CIM	-	Computer Integrated Manufacturing
DOF	-	Degree-Of-Freedom
FPE	-	Akaike's Final Prediction
FFT	-	Fast Fourier Transform
LSE	-	Least Square Estimation
FFS	-	Finite Fourier Series
FKP	-	Fakulti Kejuruteraan Pembuatan
UTeM	-	Universiti Teknikal Malaysia Melaka
DAQ	-	Data Acquisitions System
DC	-	Direct Current
SI	-	System Identification
FRF	-	Frequency Response Function
FDIDENT	-	Frequency Domain System Identification Toolbox
SISO	-	Single-Input/Single-Output
PID	-	Proportional-Integral-Derivative
PSM	-	Projek Sarjana Muda
RAM	-	Random Access Memory
PWM	-	Pulse Width Modulation
IO	-	Input/Output
dB	-	Decibel

CHAPTER 1

INTRODUCTION

1.1 Background

Robots are mostly used to replace human power such in applications that are dangerous, high precision or in routine and repeated works. They actually can do a better job compared to human. Robot arm is one of the type of robot which works similarly to a human arm. According to Rehiara et al. (2010), a robot arm or also called a manipulator is composed of a set of joints separated in space by the arm links, and it looks like human's wrist and elbow. In most robotic applications, robot can be subjected to a variety of external forces such as due to the disturbances, interaction with work piece, and collision with obstacles. The performance of the robot controller in this type of situation is critical to the success of the overall operation. Due to imprecision, it is difficult to control the robot motion to do an appropriate job perfectly. The imprecision can happen during the robot motion or operation and it might be caused by its own structure on the control algorithm. The dynamic parameters of the robot also cannot be brought together into the robot model because of the imprecision. In order to get a good robot model, the knowledge of the robot parameter values should be in line to the robot system in detail.

System identification is widely used in engineering and non-engineering areas which gives a possibility to construct a model from experimental data. A lightweight robot arm (ITRobot) available in Computer Integrated Manufacturing (CIM) laboratory Faculty of Manufacturing UTeM will be used as a physical structure of this system. It consists of 6 degree of freedom (DOF) that allows it to move freely like a human arm. Lightweight robot arm actually used in industrial such as for pick-and-place, assembly, and packaging applications. Figure 1.1 shows the lightweight robot arm that used in this project.

Figure 1.1: Lightweight Robot Arm

System or process identification is the field of mathematical modeling systems from test or experimental data. According to Zhu (2001), the input-output data are usually collected from an identification test or experiment that is designed to make measured data maximally informative about the system properties. According to Mikles and Fikar (2007), there are several procedures to estimate transfer function of the system. The steps in conducting the system identification are as follows:

i. The determination of the model structure that usually comes from the empirical experience about the process or information from some basic experiments.
ii. The parameter estimation procedure are basically depends on the type and characteristics of the process input as well as the desired model structure.

iii. The model verification should consider some of the criteria. A suitable model should agree with the experimental data, it should describe the process accurately, and it should meet the purpose in which it was obtained for. Besides, it can be verified whether the parameters obtained are within the physical limits and the possibility to reduce the model and to compare it with the original model to see if a simpler model suffices.

There are three ways to define a mathematical model in system identification that is white box modeling, grey box modeling and black box modeling. All the types are different with each other in term of the parameters status and the way to get the model. In order to get a good model, a model should be validated by using the suitable software. MATLAB System Identification Toolbox has provided two kinds of model validation that is by using the residual analysis plots or Akaike's Final Prediction (FPE) criterion. According to Eric and Simon (2004), the Akaike information criterion is a popular method for comparing the adequacy of multiple, possibly non-nested models. Both of the validation types provided by the software are used for a different way. Lennart Ljung (2010) states that the residual analysis plot types can be used for either time domain or frequency domain input-output data and consist of whiteness test and independent test meanwhile Akaike's Final Prediction (FPE) provide a measure of model quality by simulating the situation where the model is tested on different data set.

The system identification is basically to obtain a transfer function of a given system. A system is an object in which variables of different kinds of interact and produce observable signals. The observable signals that are of interest are called output. External signal that can be manipulated by the observer are called inputs. Other external stimuli are called disturbances and are divided into those are directly measured and those that are only observed through their influence on their output. The approaches for the system identification can be divided into two types that are direct method and indirect method. In order to achieve the stability on a system, the model of transfer function that develops must meets the requirements. Many of the other researchers that doing the studies and research in the field of the robot arm for example (Bulent, 2001) that studied about possibility to used two cooperating SCARA manipulator while doing a job, (Mustafa, 2006) which implemented fuzzy and neural network for control 3-DOF robot manipulator, (Rasit, 2004) presented a neural network for solving 3-joint robot inverse kinematics, and (Toshio, 2005) introduced a neural network in case is of robotic arm on-line learning.

1.2 Problem statement

Recently, robot manufacturers have increased development effort towards new application such as machining, laser welding, laser cutting and multi-robot collaboration which puts new forward performance requirements on robots. The requirements here which mean high speed, high stability and high precision, can be satisfied by involving advances model-based control schemes. The previous system response that developed do not meet the new performance requirement for applications nowadays.

Main factor that contribute to the instability for robot arm is the friction which is commonly a combination of viscous and Coulomb friction. According to Olsson et al. (1998), Coulomb friction also known as kinetic friction where the velocity is independent and always present. Its friction component is only dependent on the direction of motion in such way that is in direction opposite of the velocity. The properties of the surface in contact and normal forces influence the magnitude of the Coulomb friction. Virgala and Kenderova (2013) states that the viscous friction is dependent of the velocity where at zero velocity, the viscous friction is zero and vice-versa. Robot arm that actuated by the motor are sufficient to regard the robot joint friction as a static nonlinear function of the joint velocity with Stribeck effect. Another factor that result on the instability of the arm robot motion is the vibration which according to Itoh and Yoshikawa (2003) is the insufficiency of the torsional stiffness of the geared reduction mechanism. This insufficiency usually induces transient vibrations that mainly related to the eigenvalues of the mechanical parts in the lower-frequency range when the motor starts or stops.

The transfer function of a system is the relationship of the systems output to its input, represented in the complex Laplace domain. Transfer function is a representation of the linear time invariant dynamic system that fully describes a control system where the order, type and frequency response can all be taken from this specific function. The Bode response plots show the stability of the system when the loop is closed. So, the system identification technique will be applied to determine the system response for the system. Lightweight robot arm that is used for simulation and analysis. Validation and verification of the results is to ensure that the system response obtained viable and practically feasible.

1.3 Objective

The objectives of this study are:

i. To determine the frequency response of the system for lightweight robot arm.
ii. To analyse the behavior and characteristics of lightweight robot arm using Fast Fourier Transform (FFT).

1.4 Scope of Project

The scopes of the project are as follows:

i. Experimental work on Lightweight Robot Arm is conducted without load
ii. Numerical and experimental work is by using MATLAB/Simulink software
iii. Analyse frequency response of system using SimMechanics.
iv. Data analysis in term of stability and Fast Fourier Transform (FFT)
v. Involve one servo motor at the base part only (Turntable servo)

1.5 Significance

The findings of this study will contribute to the benefit of society considering that system identification plays an important role in science and technologies nowadays. The benefits from this research can be in term of industry and knowledge. For industries aspect, the demands on the high and new performance of applications can be achieved successfully if the good system identification is conducted to a system. As a result, a next level of applications for instance material handling, machining and surgery can be implemented broadly. The theory and methodology in this studies can be used for further research that related to the control system applications. Thus, a new method to conduct a system identification can be proposed perhaps by the next researcher.

1.6 Outline

This report consist of five main chapters that are introduction, literature review, methodology, design, and result and discussion.

i. Chapter 1 consists of problem statement, objective, scope of project, and significance that clearly stated.
ii. Chapter 2 covers literature review of a journal that related to field in order to identify studies, models, and case studies that supporting this project.
iii. Chapter 3 is a methodology which compile all the idea on how this project conducted and supported with the overview, flowchart of the project, validation and analysis technique and Gantt chart for this project.
iv. Chapter 4 is designs of model for block diagram that related to the robot system for both experiment which offline and online that used in this project.
v. Chapter 5 contains of result and discussion where result that obtained from experiment are briefly discussed and explained supported with some analysis according to the objective that need to be achieved.
vi. Chapter 6 covers about the conclusion and recommendation for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers the literature review that is divided into two section. The first section is the type of robot and their applications in the industrial field. This section covers on the lightweight robot arm supported with the characteristics and structures of the lightweight robot arm. Furthermore, the next section is system analysis which discussed the function and technique that commonly used by researchers to obtain system response of a system. System response leads to the variety of application and at once enhance the performance of the system.

2.2 Type and Application of Robot

Robots utilised for automation in a way that humans have specified. They are built to serve the people. This shows robot as a nice machine serving humans is however, not shared by everyone. According to Asimov (1950), in order to make the robots behave more nicely, the robot should obey "The three laws of robotics".

i. A robot may not injure a human being or, through inaction, allow a human being come to harm.
ii. A robot must obey orders given it by human beings except where such orders would conflict the First Law.
iii. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

An industrial robot is a programmable, multi-functional manipulator designed to move materials, parts, tools, or special devices trough variable programmed motions for the performance of a variety of tasks. Robots are mostly used to replace workers in such dangerous, high precision or in routine and repeated works where it's often do a better job than human according to Rehiara et al. (2010).

There are several types of robot in terms of shapes and sizes. This happen because of varies of the tasks that need to be performed by the robots to replace a human power. They are capable of various arm manipulation and they possess different motion systems. The classification is based on the physical configuration of the robot itself. Four basic configurations are identified with most of the commercially available industrial robots are:

i. Cartesian configurations: It consists of three orthogonal slides that parallel to the *x*, *y* and *z* axes of the Cartesian coordinate system. By appropriate movements of these slides, the robot is capable of moving its arm at any point within its three dimensional rectangularly spaced work space.
ii. Cylindrical configurations: Robot body is a vertical column that swivels about vertical axis. The arm consists of several orthogonal slides which allow the arm to be moved up or down and in and out with respect to the body.
iii. Polar configurations: Also called "spherical" coordinate because the workspace within which it can move its arm is a partial sphere. The robot has a rotary base and a pivot that can be used to raise and lower a telescoping arm.
iv. Jointed-arm configurations: It is combinations of cylindrical and articulated configurations. This is similar in appearances to the human arm. The arm consists of several straight members connected by the joints which are analogous to the human shoulder, elbow, and wrist. The robot arm is mounted to a base which can be rotated to provide the robot with the capacity to work within a quasi-spherical space.

Entire basic configurations are illustrated in the Figure 2.1 and Figure 2.2 below.

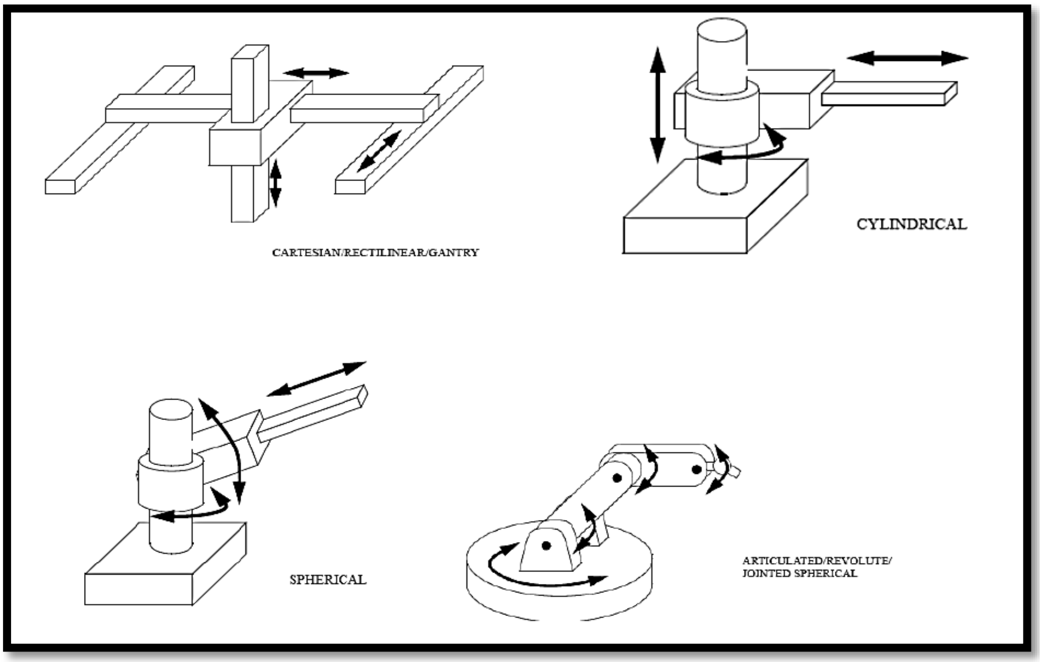

Figure 2.1: Basic configurations of Robot (Source: http://elearning.vtu.ac.in/11/enotes/CompIntManf/unit8-nan.pdf)

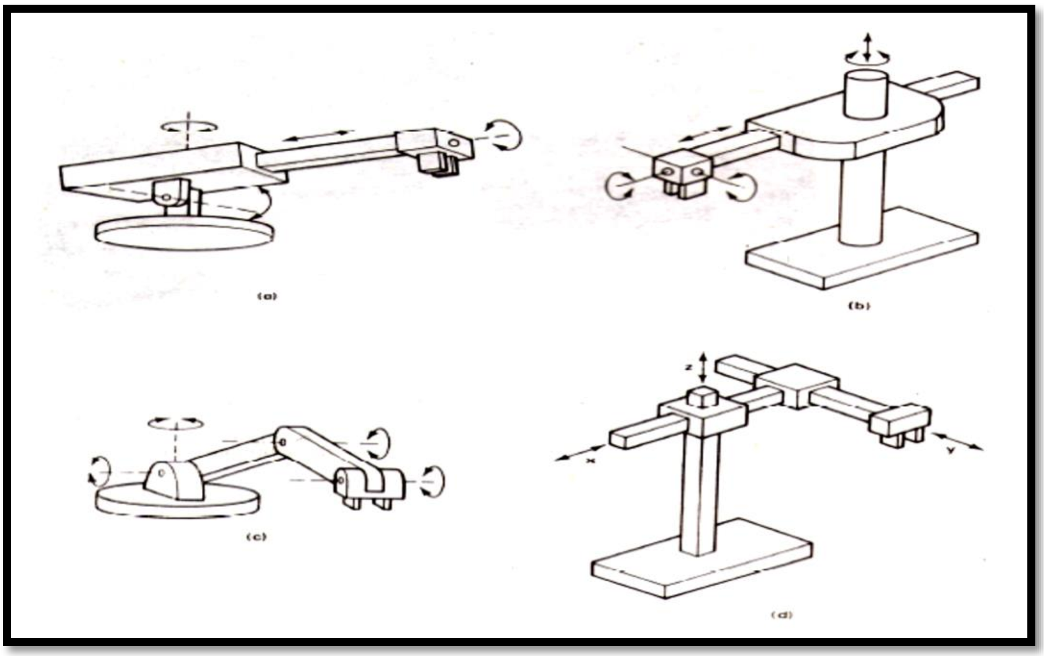

Figure 2.2: Basic Robot Motion (Source: http://elearning.vtu.ac.in/11/enotes/CompIntManf/unit8-nan.pdf)