MECHATRONIC DESIGN AND DEVELOPMENT OF A ROBOTIC ARM

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To my beloved mak, abah and family, for your love and continuous support.

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ABSTRACT

In this study a small scale robot arm was developed based on the actual rig. The parameter from the model is used in the simulation process. Simulation algorithm was developed and implemented within the Simulink environment. The analysis is done by the implementation of different type of control scheme and disturbances to the robot arm. The results from the simulation are used and compared with experimental results. It is proven that a robot arm having a PD-AFC scheme is very robust and stable compare to PD control.

ABSTRAK

Dalam kajian ini, sebuah lengan robot berskala kecil telah dibina berdasarkan lengan robot yang asal. Data – data dan ukuran dari model robot ini digunakan di dalam proses simulasi. Algoritma simulasi dibangunkan dan simulasi dijalankan di dalam Simulink. Analisis dijalankan dengan mengaplikasikan skema kawalan dan gangguan yang berbeza kepada lengan robot. Hasil analisis dan kajian dari simulasi dibandingkan dengan keputusan secara praktikal. Terbukti bahawa lengan robot yang menggunakan skema PD-AFC adalah lebih stabil berbanding dengan kawalan PD sahaja.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

l	-	length of link
θ	-	joint angle of link
T	-	joint torque
$-m_i\dot{v}_{ci}$	-	inertial force of link
$\rho_{acrylic}$	-	mass density per unit area for acrylic
m	-	mass of link
$\dot{v}_{ci}$	-	linear acceleration
g	-	gravitational acceleration
$N_{i-1,i}$	-	rotational motion of the arm
$I_i\omega_i$	-	gyroscopic torque
f	-	force
K_p	-	proportional constant
K_i	-	integral constant
K_D	-	derivatives constant
a	-	acceleration
m_{mot}	-	mass of motor
h	-	thickness of link
v	-	volume of link
k_{tn}	-	motor torque
I	-	moment of inertia
a	-	width of plate
b	-	length of plate
k	-	spring stiffness
V_{cut}	-	end point linear velocity,
$D(t)$	-	desired position

$Y(t)$	-	measured position
$E(t)$	-	error
$C(t)$	-	controller response
$E(n)$	-	current error
$E(n-1)$	-	previous error
$T(s)$	-	sampling period

LIST OF ABBREVIATIONS

P	Proportional
I	Integral
D	Derivative
PID	Proportional-Integral-Derivative
PD	Proportional-Derivative
AFC	Active Force Control
PD-AFC	Proportional-Derivative-Active Force Control
RR	Rotation-Rotation
AFCAFL	Active Force Control and Fuzzy Logic
AFCANN	Active Force Control and Neural Network
ALCAIL	Active Force Control and Iterative Learning
AFCAGA	Active Force Control and Genetic Algorithm
IDE	Integrated Development Environment
PC	Personal Computer
PCM	Pulse Coded Modulation
PWM	Pulse Width Modulation
I/O	Input/Output

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This project is basically the continuation of previous research with some modification and the use of different approaches. Previously, the focuses are on the interfacing and control of a single link arm (Soong, 2001), experimental aspect of interfacing and experimental aspects of single link arm (Goh, 2003) and the implementation of Active Force Control (AFC) to a two-link robot arm (Pitowarno, 2002).

A robust and stable performance of a robot arm is very important as it deals with working environment and disturbances. For example, in manufacturing, process such as welding, cutting and spraying demands a highly robust and stable system. Study on kinematics (Lee, 1983), static, dynamics (Lee, 1983), robot control scheme (Astrom, 1995) and trajectory planning (Taylor, 1979) are very important, and there are a lot more consideration needs to be considered in robot analysis. These factors are important in order to have high quality product.

Many robot control methods had been introduced such as Proportional-Integral-Derivative (PID) control, (Astrom, 1995), Adaptive Control, (Petros Ioannou, 1991), Hybrid Control, Intelligent Control and AFC (Musa, 1998).

PID control is the most widely used control scheme. It is very robust and stable for a relatively low speed and very little disturbance robot operation. The

combination of the controller depends on the needs of the system. It can be Proportional alone or, the combination of Proportional with Integral (PI), Proportional with Derivative (PD) or PID control.

Nowadays, most robot system will have these classical controls and it is being upgraded with the implementation and combination with modern type of control scheme such as, Active Force Control, Intelligent Control, Adaptive Control and Hybrid Control. These control scheme will overcome the problem arise in PID control and produce more stable and robust system. Therefore, the existence of internal or external disturbance can be compensated.

1.2 Research Objectives

The objectives of the research are:

i. To model and simulate a robot arm with different control schemes and operating conditions.
ii. To develop a physical robot arm and use a microcontroller as the driver.

1.3 Research Scopes

The scopes of this project are:

- Simulation using two different control schemes and operating conditions.
- Development of small scale rig.
- Make use or PIC Microcontroller as the main component of the system.
- Development of an open loop system.
- Improving the system by upgrading it to a closed loop system.

- Development of the program both, for open and closed loop system.
- Test the rig.

1.4 Research Methodology and Strategy

The research methodology of the project can be described as follows:

- Literature review on robot areas, control scheme, microcontroller, software and hardware.
- Study on existing rig, measure and obtain all the parameters needed in order to design a small scale rig (length of link 1 and link 2, density, ρ of acrylic, mass of motor 1 and 2 and mass of link 1 and link 2).
- Study on PIC Microcontroller (set up, advantages and the specification).
- Study on the software in order to do simulation and testing (MATLAB 6.5, Simulink 5.0, MPLAB IDE 7.0, PiCC Lite 8.02 and IC Prog).
- Study on control scheme and identify the problem and other related issues (PD Control and AFC).
- Test the robustness and stability of the system by introducing different type of disturbances (simulation).
- Make use of microcontroller which acts as the driver, controller and analogue to digital converter.
- Perform experiment, compare, analyze and discuss the results.

This project was carried out within two semesters. The flowchart of the project is shown in Figure 1.1:

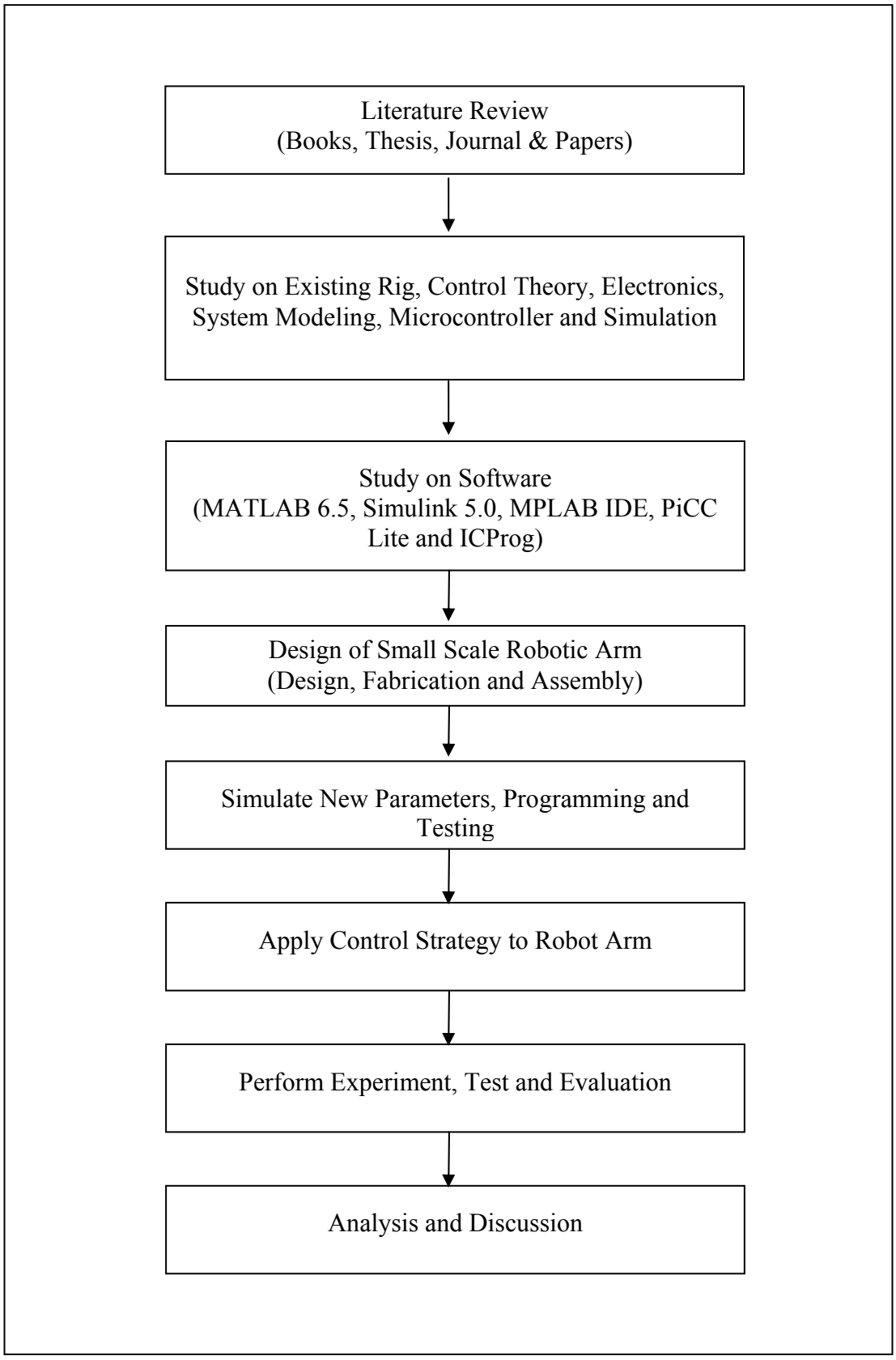

Figure 1.1: Project's flowchart

1.5 Expected Results

This project produces results that show the stability and robustness of the proposed control scheme on a small scale two degree of freedom rigid robot arm.

1.6 Organization of Thesis

This report is basically divided into six main chapters. In Chapter 1, the general idea of the project is stated. Introduction, project scope, methodology and expected results are described in this chapter. Chapter 2 describes the fundamentals of robot, dynamic analysis of robot arm, control scheme and other related topics. Chapter 3 describes the simulation process with different operating conditions. Chapter 4 gives the development of the robot arm and it includes design, fabrication and programming. Chapter 5 presents the simulations and experimental results. The final chapter (Chapter 6) describes the conclusions and recommendations of the project.