A STUDY IN INDUSTRIAL ROBOT PROGRAMMING

YUSMARNITA BINTI YUSOP

KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: A STUDY IN INDUSTRIAL ROBOT PROGRAMMING

SESI PENGAJIAN: 2004/2005

Saya YUSMARNITA BINTI YUSOP
(HURUF BESAR)

mengaku membenarkan tesis (~~Sarjana Muda~~/Sarjana /~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Kolej Universiti Teknologi Tun Hussein Onn.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[✓]	TIDAK TERHAD	

Disahkan oleh

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat Tetap:
KM 16 JALAN PARIT LAMPONG,
KAMPUNG TEHEL,
77200 MELAKA.

PM. DR. ZAINAL ALAM HARON
Nama Penyelia

Tarikh: 22 NOVEMBER 2004

Tarikh: 22 NOVEMBER 2004

CATATAN:
* Potong yang tidak berkenaan.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai atau TERHAD.
♦ Tesis dimaksudkan sebagai tesis bagi Ijazah doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).

" I hereby declare that I have read this thesis and acknowledge it has achieved the scope and quality for the award of the Degree of Master of Electrical Engineering."

Signature	:	....
Supervisor	:	PM. DR. ZAINAL ALAM HARON
Date	:	NOVEMBER 2004

A STUDY IN INDUSTRIAL ROBOT PROGRAMMING

YUSMARNITA BINTI YUSOP

A thesis submitted in partial fulfillment of the requirements for the award of the Degree of Master of Engineering (Electrical)

Kolej Universiti Teknologi Tun Hussein Onn

NOVEMBER 2004

"No part of the study was covered by copyright. References of information obtained from other source are specially quoted; otherwise the rest of the information presented through this study is solely worked and experimentally carried out by the author."

Signature : ....

Author : YUSMARNITA BINTI YUSOP

Date : NOVEMBER 2004

I dedicate this to you,
mum and dad
for your undivided love and support
for making me the person
I am today.

ACKNOWLEDGEMENT

I would like to take this opportunity to extend my deepest gratitude to all these who have assisted me in making this project a success. A special note of thanks goes to my supervisor, PM. Dr. Zainal Alam Haron for his patience and guidance throughout the course of this project.

I would also like to take this opportunity to thank all the technicians who have played a role in accomplishing this project.

Not forgetting also to my lovely family and all my dearest friends who have never failed to lend a helping hand when I needed them. Thank you all.

ABSTRACT

This project is concerned with learning the technology and programming of servo controlled industrial robots. A Mitsubishi RV-2AJ articulated robot was used in this project. The project work is divided into two parts: In the first part of the project the author familiarized herself with the operation and programming of the robot's manipulator and controller hardware by carrying out some laboratory experiments. A set of laboratory sheets were produced from this exercise. In the second part, the author studied the mechanics of software control of the robot. A user-defined trajectory planning routine based on the cubic spline fitting function has successfully been developed in this project.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Multi-axis machines are used in a variety of applications: pick-and-place operations, welding, machining, etc. Such machines can be divided into two units: the physical mechanism composed of links and actuators, and the control system. The number of actuators present in the mechanical system depends on the number of independent machine axes, or degrees of freedom. For example, a typical articulated six degree of freedom manipulator contains six rotating actuators. A five-axis high-speed CNC machining centre would contain three linear actuators and two rotating actuators.

A motion task given to the machine must ultimately be represented as a reference signal, which is sent to the control system. The control system acts to make the machine track the reference signal by activating the appropriate actuators. If the reference signal changes too quickly, given the dynamic limitations of the machine, the tracking of the reference signal will be poor, regardless of the control system design. Computer algorithms are designed to calculate an appropriate reference signal based on the desired task path and time-related limits (such as speed and acceleration). This reference signal is the trajectory, and can be defined as a locus of points in operational or joint space on which a time-law has been specified [1]. The generation of an appropriate trajectory is the problem that is being investigated in this thesis.

The path along which the trajectory is defined can be point-to-point; namely, the machine is required to move between the two points but is not given any fixed intermediate path. This type of path is useful in manipulator pick-and-place operations. A path can also be completely specified through use of geometric functions. This type of path is commonly used in CNC machining applications or in manipulator applications when obstacles are present, or when it is necessary to ensure that the end effector follows a specific path. Herein it is assumed that the path definition is provided, and the problem of path planning is not specifically addressed.

The control of the machine motion can be divided into two parts: motion planning and motion tracking. Motion planning involves generating the path and its time law, providing the controller's reference signal. Motion tracking, on the other hand, is concerned with improving the tracking of the reference signal. Motion planning is often done off-line, typically when the trajectory generation algorithms are computationally intensive. However, it is often desirable to generate trajectories on-line so that changes can easily be made to the machine's trajectory, increasing the system's overall robustness and adaptability. For example, a manipulator may require the ability to recompute its trajectory on-line in order to avoid an unexpected obstacle that lies along a path on which it is currently moving [2]. In an automated robot workcell, a high level scheduler feeds a series of tasks to a manipulator in terms of waypoints, approach points and stop points. The manipulator must execute the task by generating paths and trajectories to these points and then following these trajectories using a control law. Use of an on-line planner reduces manipulator setup time and downtime, since the time required to plan the trajectories is shorter.

In industrial applications, it is common to use simple PID control laws, which do not take into account the system's nonlinearities, to track a reference signal. To compensate for tracking errors introduced by the system's nonlinearities, a more complicated controller must be used [3, 4, 5]. Alternatively, it is possible to design a trajectory that takes the system's nonlinearities into account and thus provides a reference signal that can be more easily tracked by common industrial controllers [6,7].

1.2 Industrial Motivation

Increased productivity is an important industrial consideration. When a multi-axis machine limits the task speed, decreasing the machine's overall motion time will increase productivity [6, 3]. In addition, improving the tracking accuracy of the machine is always desirable since it results in more repeatable products or operations.

Tracking a purely time-optimal trajectory with a simple controller will saturate the actuators resulting in poor tracking, vibrations in the machine and increased machine wear [8, 9, 10, 11, 12, 13]. Specialized controllers have been developed in order to provide better tracking of time-optimal trajectories. However, it is unlikely that they will be widely implemented in industry due to their complicated form. Purely time optimal trajectories have been modified to take into account further limitations of the actuators, for example jerk or torque rate limits, thereby avoiding controller saturation and resulting in improved tracking accuracy [15, 7, 14]. Herein, trajectories that are planned with jerk or torque rate limitations are termed smooth trajectories.

There exists a need for a *smooth* trajectory generation algorithm that can easily be integrated into existing industrial systems, that is, be implemented using a typical industrial controller. Such an algorithm should be applicable on-line, provide adequate dynamic limitations, and allow the specification of the speeds at all the way-points.

1.3 Problem Definition

There are four types of robot operation control included in this system which is joint interpolation, linear interpolation, circular interpolation and continuous path.

a) Joint interpolation

The robot moves with joint axis unit interpolation to the designated position. The robot interpolates with a joint axis unit, so the end path is irrelevant.

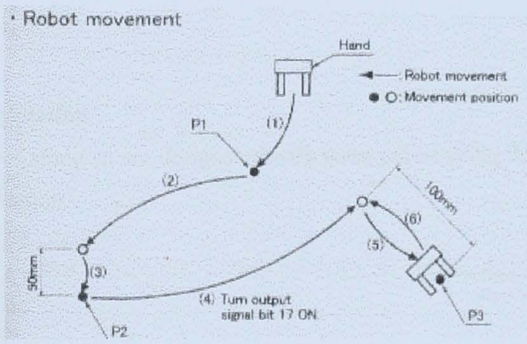

Figure 1.1: Joint Interpolation

b) Linear interpolation

For the linear interpolation type of control, the end-effector is programmed to move a sequence of discrete points in the workspace. In between points, no control required over either speed of the individual axes or the path of the end-effector. Fig.1.2 shows that the speeds is reduced and almost stop in front of the target position. After moving to the target position, the speed for moving to the next target position starts to be accelerated.

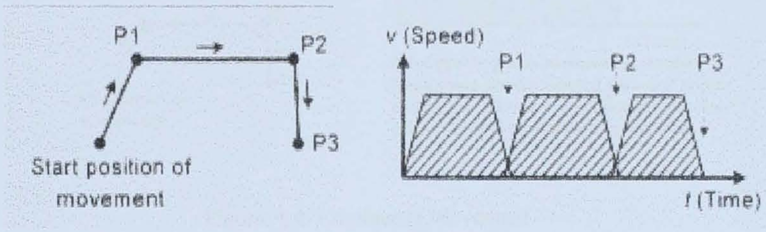

Figure: 1.2: Linear Interpolation

c) Circular interpolation

The robot moves along an arc designated with three points using three-dimensional circular interpolation.

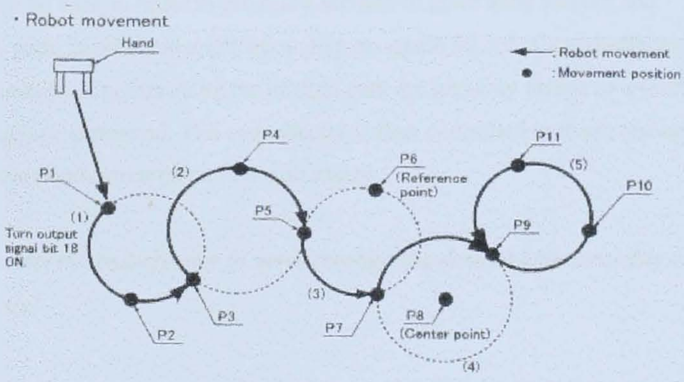

Figure: 1.3: Circular Interpolation

d) Continuous path

In the continuous operating mode, the speed is reduced in front of the target position, but it does not stop completely. The speed for moving to the next target position starts to be accelerated at that point. Therefore, **it does not pass through each target position**, but it passes through the neighborhood position.

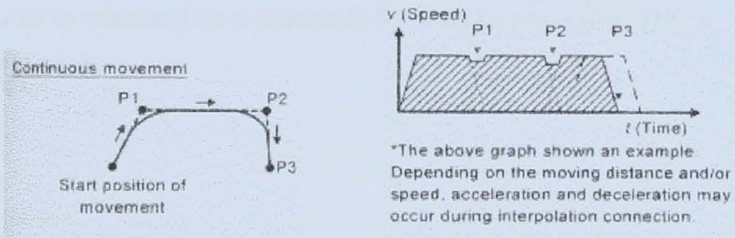

Figure: 1.4: Continuous Movement

The drawback of the existing operation control methods stated in previous section are does not preserving continuity in the first and second derivatives at the interpolation point. The first derivative represents continuity in the velocity and the second derivative represents continuity in the acceleration. Several trajectory planning methods can be used in order to provide a method of generating smooth and continuous path. In practical application, to plan a path for robot's end-effector to follow, a number of points along the desired path are given by means of a teach-box or a robot language command. The end-effector is then controlled to move through or pass by these points smoothly and continuously.

How to control the end-effector to move through the desired path smoothly and continuously?

To solve the stated problem, this project proposed an approach to constrain smoothness and continuity based on cubic spline trajectory planning algorithm. Cubic splines offer several advantages. First, it is the lowest degree polynomial function that preserving continuity in the first and second derivatives at the interpolation points. Second, low-degree polynomials reduce the effort of computations and the possibility of numerical instabilities. The feasibility of the method is illustrated by experimental results with an articulated robot (Mitsubishi RV-2AJ) located at KUITTHO's Automation Lab.

1.4 Research Objectives

This project is divided into two parts. For Part I, the objective of this work is to familiarize with the Mitsubishi RV-2AJ robot operation and control. Instead of to familiarize with the robot operation and control, a further objective is to produce a set of laboratory sheets as a reference material to the students or lecturers in future work. Furthermore is to learn MELFA robot programming languages, MOVEMASTER Command and MELFA-BASIV IV Command.

For Part II, the objective is to write a user-defined trajectory planning routine based on cubic spline fitting function using MATLAB. At the end of this project, this work aims to produce a cubic spline trajectory that will generate smooth and continuous path.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

With a pressing need for increased productivity and the delivery of end products of uniform quality, industry is turning more and more toward computer-based automation. At the present time, most automated manufacturing tasks are carried out by special-purpose machines designed to perform predetermined functions in a manufacturing process. The inflexibility and generally high cost of these machines, often called hard automation systems, have led to a broad-based interest in the use of robots capable of performing a variety of manufacturing functions in a more flexible working environment and at lower production costs.

The word robot originated from the Czech word *robota*, meaning work. Webster's dictionary defines robot as "an automatic device that performs functions ordinarily ascribed to human being." With this definition, washing machines may be considered robots. A definition used by the Robot Institute of America gives a more precise description of industrial robots: "A robot is a reprogrammable multi-functional