HYBRID POSITION/FORCE CONTROL

WONG KIAN ANN

Universiti Malaysia Sarawak
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BORANG PENYERAHAN TESIS

Judul: Hybrid Position/Force Control

SESI PENGAJIAN: 1996/97

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(HURUF BESAR)

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Alamat tetap: 6, Jalan Pangsan 3,
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Approval Sheet

This project report attached hereto, entitle "Hybrid Position/Force Control" prepared and submitted by WONG KIAN ANN in partial fulfilment of the requirements for the degree of Bachelor of Engineering with honours in Mechanical Engineering and Manufacturing Systems is hereby accepted.

Date: 21-11-98

(Dr. Ha How Ung)
Head Programme
Mechanical Engineering & Manufacturing Systems
Faculty of Engineering
Universiti Malaysia Sarawak

HYBRID POSITION/FORCE CONTROL

WONG KIAN ANN

Tesis Dikemukakan Kepada
Fakulti Kejuruteraan, Universiti Malaysia Sarawak
Sebagai Memenuhi Sebahagian daripada Syarat
Penganugerahan Sarjana Muda Kejuruteraan
Dengan Kepujian (Kejuruteraan Mekanikal dan Sistem Pembuatan)
Januari 1999

Dedicate to my beloved family.

My life will not be completed without them.

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Abstract

This project report presents a hybrid control scheme controlling the joint position and Cartesian contact force of a robot manipulator with inner computed-torque feedforward loop. The control scheme consists of two controllers: the proportional plus derivative position controller and the proportional plus velocity force controller. The controllers are designed based on the model reference control and orthogonal force/position constraints under the assumption of constant desired forces and slowly time-varying motion. Simulations studies performed on a 6 degree of freedom PUMA 560 robot model are presented.

Abstrak

Laporan project ini mempersembahkan sejenis teknik kawalan gabungan yang bertujuan mengawal gerakan tangan robot. Sistem kawalan ini terdiri daripada sistem kawalan kedudukan rujukan sendi dan sistem kawalan daya sentuhan rujukan Kartesian dengan bantuan loop suap-depan dalaman tork-berkomputeran. Sistem kawalan ini mempunyai dua sub-sistem iaiatu: pengawal kedudukan jenis berkadaran campur pembezean; dan pengawal daya jenis berkadaran campur halaju. Kedua-dua sub-sistem ini direkacipta berdasarkan konsep kawalan rujukan permodelan dan sifat ketentangan daya dan kedudukan berorthogonal dengan angapan bahawa daya ialah tetap dan gerakan adalah perlahan berbanding dengan masa. Simulasi komputer dijalankan dengan bantuan model robot jenis PUMA 560 yang mempunyai enam darjah gerakan bebas.

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Chapter 1

Introduction

This chapter describes briefly the active research fields in robotics technology. The study of today's robot applications and future robot applications are compared. From there, it is possible to identify the importance of implementing active compliant motion robot controller to improve its accuracy and stability. Finally, the project objectives are provided as a context for the detailed analysis of robot force control in subsequent chapters.

1.1 Robotics Technology

The word 'robot' was first coined by the Czechoslovakian playwright Karel Capek which means forced labour or serf [1]. Since in our childhood we saw robot cartoons and movies all around of us. In our mind, we often think of robot as a human like machine that is able to move, talk, fight and even fly! However, robot has a totally different meaning in the engineering world especially in the industrial field. The Robot Institute of America has defined robot as [2]:

> A programmable, multifunctional manipulator designed to move material, parts, tools, or specialised devices through various programmed motions for the performance of a variety of tasks.

From the above definition, a machine can be called a robot when it is able to reprogram and do multifunctional manufacturing task. However, this definition restricts robots to industrial applications only.

The study of robots is called 'robotics'. The term was coined and first used by the Russian born America scientist and writer Isaac Asimov [3]. When discussing about robotic systems, there are plenty of different areas that could be studied. Below are some major robotics field commonly see in reference books, magazines and research journals:

1. **Robot Mechanism Design** - This area mostly discuss some issues involving the design of the robot such as size, weight, speed and load capability. Mobile robot has been a hot topic in recent researches [7].
2. **Control of Robot** - A controller is needed to control the robot according to task specification. The issues involved in this field include stability, accuracy, and reliability of the robot control system such as PID, CTM, adaptive control, force control and etc. [4]. The present robot control researches are being in artificial intelligence, neural networks and fuzzy systems.
3. **Programming of Robot** - To control the robot, the robot has to be taught how to do the job. This lead to the development of robotics programming language such as VAL from Unimation, AR-BASIC from American Cimflex, and AML developed by IBM. The latest trend in robot

programming is Off-Line Programming Systems (OLP). OLP is defined as a robot programming language which has been sufficiently extended, generally by means of computer graphics, that the development of robot programs can take place without access to the robot itself [5].

4. **Robot Application** - In this field, the study is concentrated in industrial applications such as spot welding, spray painting, cutting, material handling, and assembly. The future trends will be in flexible manufacturing applications, bio-medical applications and multi-robot systems.

1.2 Today's Robot Applications in Manufacturing

For more detail investigations of the today's industrial robot applications in manufacturing, ABB robots were taken as a case study. ABB (Asian Brown Boveri) is one of the leading industrial robot manufacturers in the world. First ABB robot was introduced in 1974. ABB robots have been applied to various industrial applications including:

1. Material Handling
2. Welding
3. Spray Painting/Coating
4. Packaging and Palletising
5. Water Jet Cutting

1.2.1 Material Handling

For material handling task, the robot needs to move to a prescribed location, grasps an object, moves to a second prescribed location, and release the object

(see Figure 1.1). ABB robots are being actively applied in foundry industry for the needs of flexibility, capability, and precision in handling both delicate and heavy parts. One of the reasons robots used in foundry industry is to reduce the hazards (heat, noise, fumes, and dust) exposure to the workers. When using robots for foundry environment, some protections have to be made including anti-rust coat on all unpainted parts; all bearings, joints and cable-contacts are sealed; anti-dust strip above the controller cabinets' door.

1.2.2 Welding

Welding is a process that joints metals by fusing them. Spot welding and arc welding are two major welding techniques that robots have been successfully used. There are over 20,000 ABB robots installed in the body shops of the world's leading car manufacturers.

1. **Spot welding** - Spot welding is a process in which two sheet metal parts are fused together at localised points by passing a large electric current through the parts where the weld is to be made. The electric current results in sufficient heat in the contact area to fuse the two metal parts, hence producing the weld. ABB robot – IRB 6400 has been specially design for spot welding applications (see Figure 1.2). IRB 6400 robots have several advanced capabilities including:
    - Reweld and process-error routines.
    - Multi-tasking functionality.
    - High load offset capability.

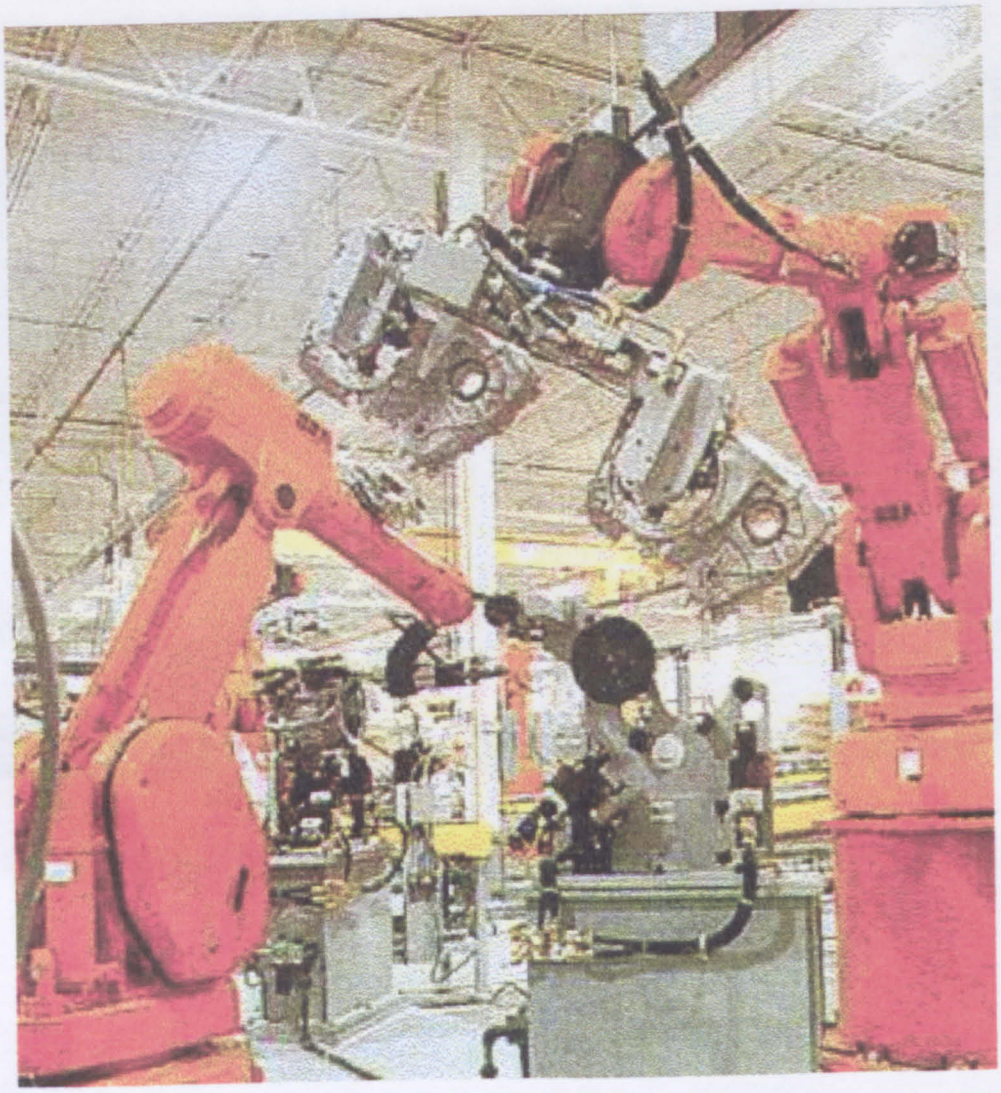

Figure 1.1 ABB robot in material handling task. ***(Source: ABB Flexible Automation.)***

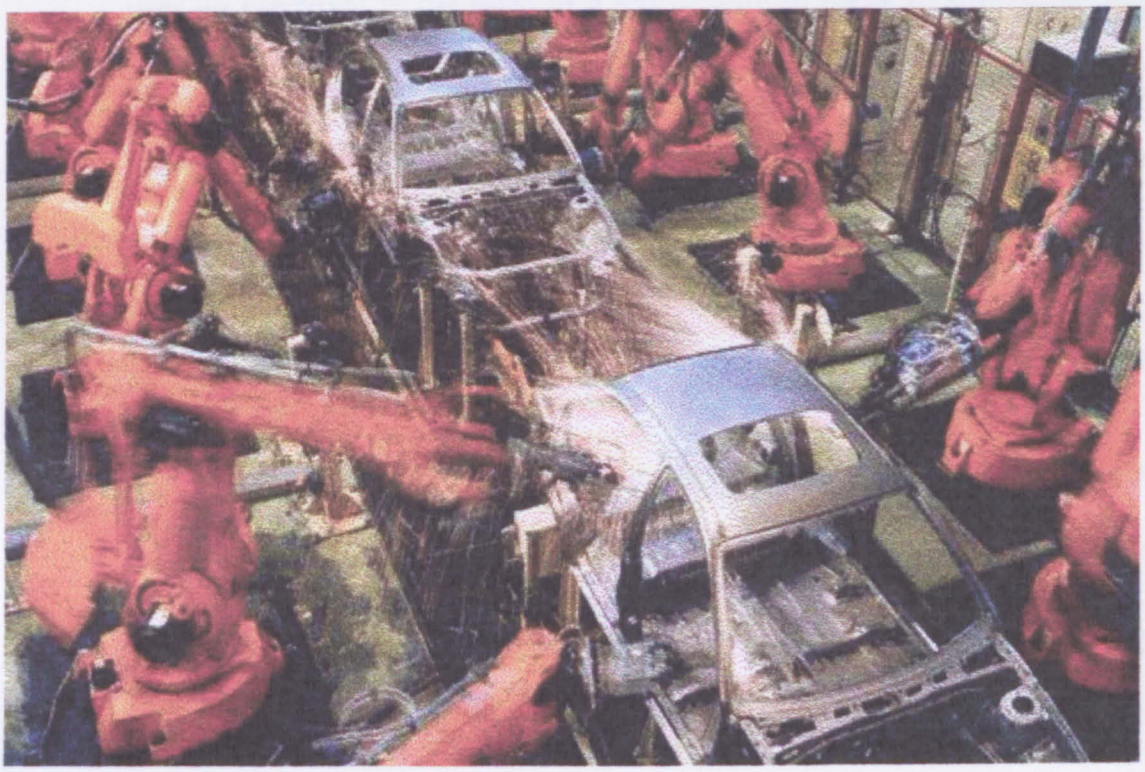

Figure 1.2 Spot welding. ***(Source: ABB Flexible Automation.)***

2. **Arc welding** - Arc welding is a continuous welding process. The process uses an electrode in the form of a rod or wire of metal to supply the high electric current (100 to 300 A) needed for establishing the arc. The arc between the welding rod and the metal parts to be joined produces temperatures that are sufficiently high to form a pool of molten metal to fuse the two pieces together.

One of the advanced functions for ABB robots in arc welding is Master-Slave application (see Figure 1.3). Master-slave means two ABB robots can weld on the same workpiece while it is moving in a positioner. One robot is the master, and the second robot, the slave, moves and welds in time with the master robot. Besides, one robot can be used as a six-axis positioner, holding and moving the workpiece while a second robot welds the workpiece. The positioner robot can pick-up and unloads workpieces.

1.2.3 Spray Painting/Coating

Because of the health hazards such as fumes and mist in the air, noise from nozzle, fire hazards and potential cancer hazards to human, the use of industrial robots has developed as an alternative means of performing spray painting/coating operations. ABB robot - TR 5002 has been specially design for painting operation (see Figure 1.4). TR 5002 is able to perform enhanced path accuracy and uniform speed through corners, which give an even film, build on the painted surface.

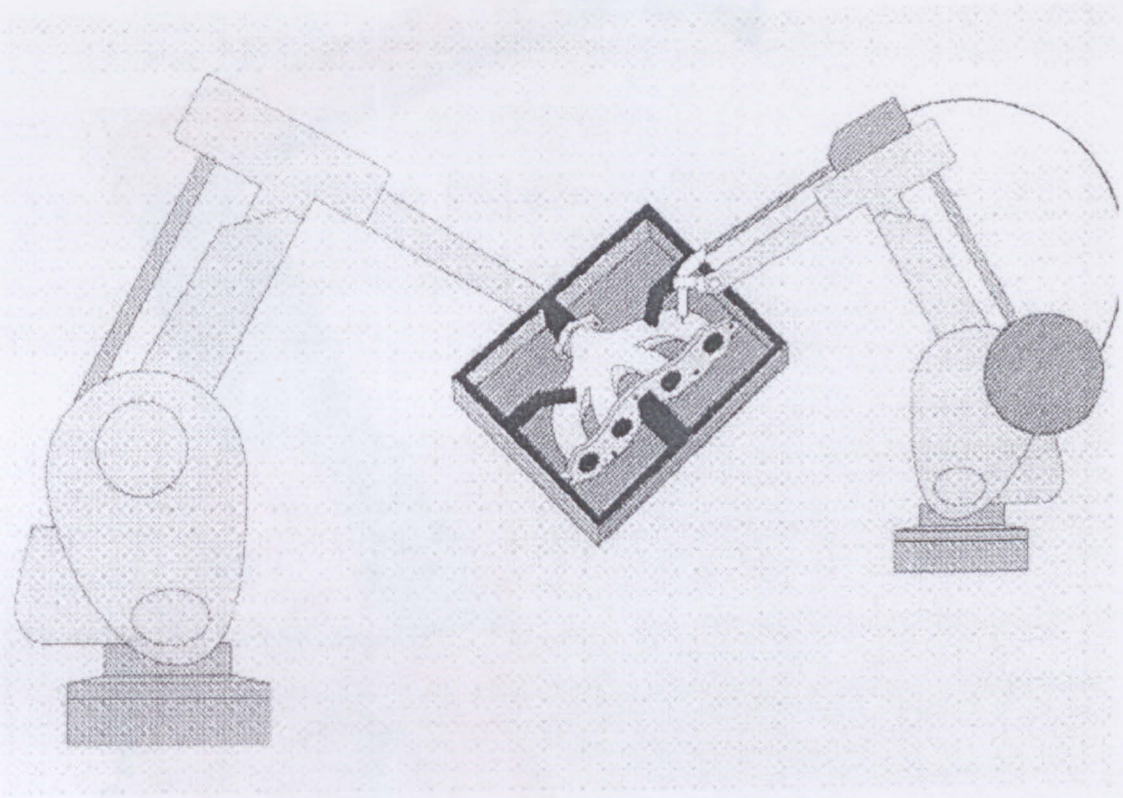

Figure 1.3 Master-slave arc welding. ***(Source: ABB Flexible Automation.)***

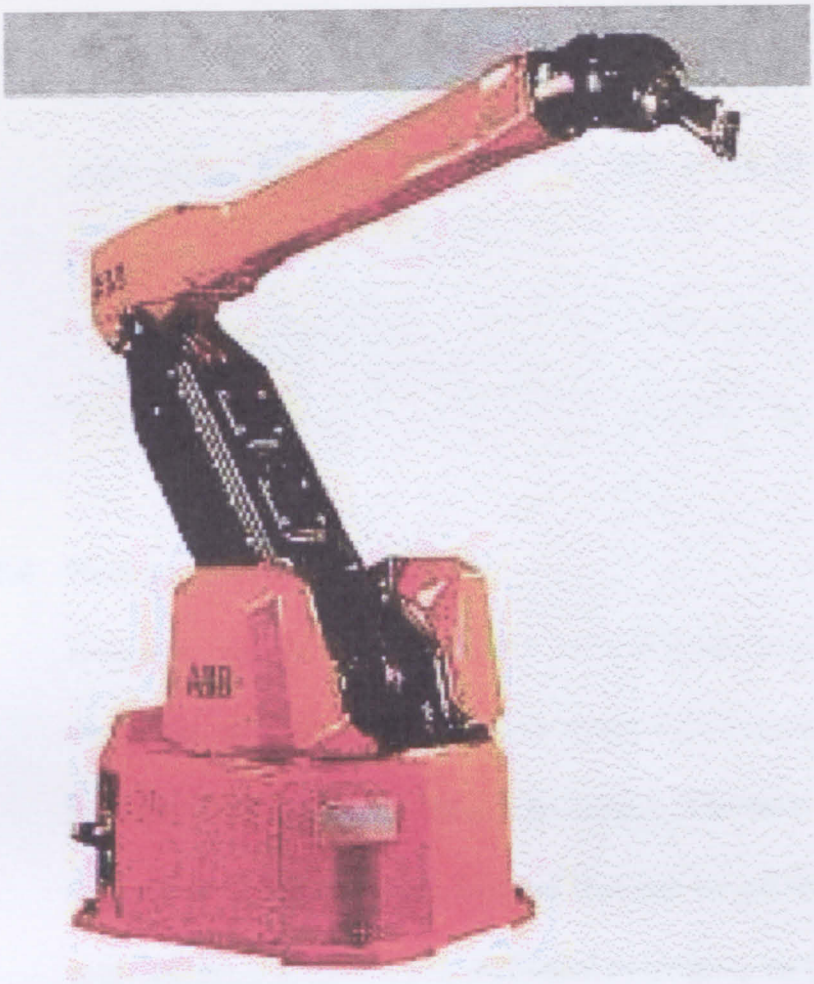

Figure 1.4 TR 5002. ***(Source: ABB Flexible Automation.)***

Besides, TR 5002 has a large working envelope shown in Figure 1.5.

ABB robot - IRB 4400L10 has been specially developed for sealing application illustrated in Figure 1.6. IRB 4400L10 able to perform several sealing processes involved:

1. Stone-ship coating.
2. Sealing.
3. Body-side coating.
4. Air blasting.

1.2.4 Packaging and Palletising

Frequent changes in packaging style and shape have become a key factor in marketing consumer goods. A robot-based packaging line gives the flexibility and reliability to meet these challenges. Operator safety, space and cost savings are some principal features that can be gained in robotised packaging applications, compared with dedicated packaging systems.

ABB robot – IRB 640 has been design specially to suit the palletising operations. It is able to carry a payload up to 160 kg and having a high productivity up to 1,200 cycles per hour. Bellow is some palletising operations that can be done by IRB 640:

1. End-of-the-line palletising.
2. Middle-of-the-line palletising.
3. Complex-end-of-the-line palletising.
4. Palletising/depalletising station.