THE 4-DOF PARALLEL ROBOT: CONTROL SYSTEM DEVELOPMENT

Thesis submitted in accordance with the requirements of the University Technical Malaysia Malacca (UTeM) for the Degree of Bachelor of Engineering (Honours) Manufacturing (Robotics & automation)

By

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**BORANG PENGESAHAN STATUS TESIS**

**JUDUL:** THE 4-DOF PARALLEL ROBOT: CONTROL SYSTEM DEVELOPMENT

**SESIF PENGAJIAN:** 2006/2007

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Co-Supervisor
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I hereby, declare this thesis entitled
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is the results of my own research except as cited in the reference.

Signature : 

Author’s Name : VINCENT A/L ARUN KENADZIR

Date : 09 May 2007
ABSTRACT

The project of control system development for four degree of freedom parallel robot is divided in two parts. First part of the project is about proposal and the second part is about project implementation. This report fully describes about the combination of both part, which contains six chapters starting from introduction, literature review methodology, results, discussion and conclusion respectively. The first chapter describes about scope and objective of the project and expected results. The main objective of the project is to develop control system for 4 DOF parallel robots. While the second chapter is discusses about literature review. The literature search is performed to study, analyses and design the robot control system for 4 DOF parallel robots. The next chapter is methodology. This chapter was describes about steps or procedures that is used to complete this project. In this project a serial interface circuit board is designed with PIC 16F84A and servo commander serial interface is developed using visual basic 6.0. The both tools are interfaced using serial port. Three pieces of servo motor are used to rotate the robot link in clock wise and counter clockwise direction. User can control the position and rotational speed of servos through servo commander. Therefore, some experimental results are obtained and described in chapter four. The following chapter is discusses about the result, problems and suggestion to overcome the problems. Finally, the overall project and its achievements are concludes in chapter six.
DEDICATION

for my beloved mum and dad.
ACKNOWLEDGEMENTS

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CHAPTER 1
INTRODUCTION

1.1 Background of the Problem

The four degree of freedom parallel robot was previously developed in a small scale and with improper finishing but without a controller. This task requires development of a control system for the 4-DOF parallel robot. The 4-DOF parallel robot has three freedoms of rotational and one translation movements. Each movement is conducted by three main links and joints. Three motors are fixed to the links for rotary motions in forward and backward direction.

The task is required to control the motions of the motor according to desired value. This is a user interfacing control system which a user can control the degree of motors rotation using a control mode from computer. For this purpose, software is developed and a command window was designed. Furthermore, it also requires the use of basic stamp for interfacing purpose. The basic stamp has various functions that can help to complete the control system development of parallel robot.
1.2 Scope

Parallel manipulators are classified as planar, spherical, or spatial manipulators in accordance to their motion characteristics. There are extensive applications of parallel manipulator. The early parallel manipulator is introduced by Stewart and later is known as Stewart-Gough Platform [2]. It is a spatial mechanism in which a moving platform is connected to a fixed base with six extensible limbs by spherical joints. In recent years Zlatonov and Gosselin see that there is an increasing interest in platforms with fewer than six degrees of freedom (DOF) [2]. They desire mechanisms that have less than 6-DOF, which can perform tasks normally achievable with 6-DOF platforms. It has three freedoms rotational and one translation. The design has an added feature to perform tasks that require one translation motion along with three rotations. This project; however is to develop a control system for the 4-DOF robot.

1.3 Problem Statement:

The 4-DOF parallel previously developed was of small scale and improper finishing but without a controller. However, there is a prospect of building an actual working robot. Thus it is necessary to develop a software and hardware that can control the 4-DOF robot according to the task required due to the gap in this type of robot development. The software is used for user interfacing which the robot can control by user using computer in which the dialog box or command window should display the parameters for control. Finally choose a proper interfacing method to interface between the software and hardware.
1.4 Objective

The aim of this study is to develop a control system and determine the mechanisms of 4 DOF parallel robot. Next, identify the electrical and electronics theories and concepts while expose to the electronic devices and circuit design. Besides, develop a proper software and hardware for robot controller. Finally, train student working independently to design, analysis, assemble, and test any form of system or experimental rig using available facilities including library, laboratory equipment, sensors, software and so on.

1.5 Expected Results

It is expected that, the product will be able to fulfill the task required. Firstly proper software is developed. The software is used for user interface with robot controller. In other words user can control the robot using this software. In this software a command window or a control mode is created. Thus, user can control the robot using control mode from a computer. Besides, a proper hardware is designed for robot controller. The hardware contains a microcontroller, motor control circuit and three motors. These three main components are connected together and interface with software. Then, the motors will rotate forward and backwards direction according to the program. The degree of rotation or position will be control by a user through the software developed earlier. Therefore a proper interfacing method is used to converting digital signal to analog signal. These signals are transferred between computer and hardware. Figure 1-1 shows a simple model for control system development of 4–DOF robot.
Figure 1-1: A simple model for control system development of 4-DOF robot.
1.6 Project Planning

Gantt Chart (PSM 1)

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Figure 1-2: Gantt Chart for PSM 1
Gantt Chart (PSM 2)

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**Figure 1-3: Gantt Chart for PSM 2**
CHAPTER 2

LITERATURE REVIEW

A literature search was performed to study, analyses and design the robot control system for 4DOF parallel robot. It also included the investigation of what others have done in this area. This study included the areas of electric and electronic and software development.

2.1 Background of the Project

2.1.1 Parallel Robot

A parallel robot is "a closed-loop mechanism of which the end-effectors is connected to the base by a multitude of independent kinematics chains." according to one of the leading researchers in the field, Dr. Jean-Pierre Merlet. [5]. The load is distributed in parallel mechanisms therefore it is naturally stronger than serial mechanisms. Also, for some architecture, the legs of a parallel robot are only subjected to axial loads. Parallel manipulators are also more precise since they are more rigid and since the errors in the legs are averaged instead of built up. Parallel robots are also faster because they have their motors mounted to the base. On the other hand, parallel-link robots have a more limited and complex-shaped workspace. The control and calibration of parallel mechanisms are complicated as the rotation and position capabilities are highly coupled. Last but not least, computing the resulting end-effectors pose for a given set of actuator inputs is a complex problem allowing as many as 40 solutions.
2.1.2 Critical review about robot control system

There are few researchers who have done any research on robot control system in various fields. Edward M. Sollbach [10] explains in detail how to control robot joints in real-time at high sample rates. This has been traditionally achieved by control loops embedded in customized hardware. Faster computers and lower price-performance ratios have made it possible to move control from specialized hardware to software running on general-purpose computers. Software controllers have a number of advantages over hardware; they are less expensive, more flexible, and allow the use of more complex control algorithms. The purpose of the reported work was to design and develop a universal robot control system (URCS) that would enable computation-intensive control algorithms to be implemented and modified.

Besides that Michael Predko [7] describes about the Universal Robot Control System (URCS). It was developed based on the University of Toronto Multiprocessor System (TUNIS) as the computing platform. One processor reads sensors, another calculates compensation signals and commands to the motors, a third is designated for operator requests, and the last is used for the operating system. An interface that allows the URCS to control the PUMA 560 Robot was also designed and built.

G.R. Meijer [12] in accordance illustrated an intelligent control system. An intelligent robot control system has been developed, which has the capability of exception handling. Meanwhile an intelligent sensor system with similar capability of detecting, diagnosing and recovering from errors has been studied. The hybrid model relies not only upon the robot model but also the sensory feedback. While developing the sensor system, the concept of logical sensor has played an essential role of germination, and its introduction leads up to a systematic method to process the sensory information.
Young Shin Kim [11] suggested a new architecture for the robot control system that is based on the CAN protocol. The CAN was used to connect modules in the PUMA robot in order to show the application possibility of field buses to the robot control system. The communication latency was caused when a network based robot control system is constructed based on the CAN protocol, was evaluated. It was shown that the effect of the communication latency on the control performance is negligible.

2.1.3 Mechanical Architectures

More than 100 different mechanical architectures of parallel robots have already been proposed and it is probable that not all of them have been discovered. Unfortunately there are not so many proposed architecture that have only 4 or 5 DOF while many applications require such number of DOF. Hence a recent trend is to propose parallel robots with less than 6 DOF [2]. This is clearly an interesting research area but many questions arise with this type of robots:

The proposed structures have in theory only the 4 or 5 DOF and they rely on geometrical constraints to obtain this reduced number of DOF. In practice however these constraints will never been perfectly fulfilled and hence these robots will exhibit parasitic motions. Open problems are to determine what will be the maximal amplitude of these parasitic motions being given manufacturing tolerances and the dual problem of determining the amplitude of the manufacturing tolerances so that the maximal amplitude of the parasitic motion will not exceed a given threshold. In my opinion some of the proposed architectures which may sound interesting in theory will be quite difficult to realize

Although having less actuators and sensors may sound economically interesting it is, unclear if more classical robot which is redundant with respect to the task may not be, on the whole, more appropriate. Indeed first all their kinematic chains are identical
(which is not the case for 4 and 5 DOF. robot) which will reduce the maintenance cost. Then by using the redundancy it is possible to optimize the performances of the robot for a given task: for example for machining operations which require only 5 DOF. it is possible to use the extra DOF. of a Gough platform[2] (the rotation of the platform around its own normal) so that the overall stiffness over a typical trajectory will be 5 to 25% larger than the stiffness of an identical robot in which the redundancy is not used.

Redundancy is also an interesting and open research area. In the field of parallel robot for machine-tools redundancy has been used to increase the workspace of the robot [10] (such as in the Eclipse parallel robot) and to deal with singularities. Another form of redundancy is the concept of modular robots in which additional actuators allow to adapt the geometry of the robot according to the task to be performed and the main unsolved problem for redundant parallel robot is to determine how to use the redundancy for an optimal use of the robot.

2.2 Basic Electrical Theory and Electronic Devices

2.2.1 Electrical Circuits and Switches

a) Electrical Circuit

Basically every electrical circuit has three parts to it. Electricity is provided by a power source and passes through conductors (wires) to the load [7]. The load converts the electrical energy into some other form and performs work with it. (Load might be light, microcontroller, electrical motor or combination of parts). Figure 2.2 below show the conventional circuit diagram.
b) Switches

Switch is a device that brings two wires together to allow electricity to pass from one to another. Figure 2-3, below shows a single pole double throw (SPDT) switch.

Connection: Connect the middle (common terminal) pins to one of the outside pins.

2.2.2 Breadboard