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DEVELOPMENT OF SCARA ROBOTIC ARM AND CONTROL SYSTEM FOR LABORATORY AUTOMATION

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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July 2002

Chairman: **Dr. Ishak Bin Aris**

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Recent developments in robotic system usage for material handlings, examine the various benefits of its applications in the chemical industry environment. In order to avoid the risk factor in chemical handling, various steps can be taken. One of the prominent methods is by substituting the human hands with the robotic arm in handling dangerous and erosive chemicals. It is with these reasons that this study was conducted with the primary objective to develop a system that would contribute towards encouraging a safety way of chemical testing and processing. This thesis provides an early analysis of robotic developments in the area.

The objective of this project is to develop a SCARA robotic arm and the intelligent control system. The design and development of this project involves three major sections. First section concerns about software programming, while the second section involves hardware construction and the final section deals with the graphic user interfacing (GUI).

The hardware design can mainly be categorised into electrical design and mechanical design. Electrical design involves proper electrical wiring of input and output devices, power distributions, safety devices, interfacing devices and control components. The mechanical design is referred to the construction of the robot arm structures. These comprise mechanical drawings, mechanical simulations, mathematical calculations, as well as parts fabrication. On the other hand, the design of software will consist of input and output assignments, program flow charts, robot-learning method and MINT programming. Design of GUI will involve Visual Basic (Professional Edition) programming.

Basically, this project comprises several subsystems, namely: a sensor system, which is used to obtain data about the state of the mechanism and the environment, a controller and drivers, to guide the mechanism and the sensors in a desired manner, a planning and control system that decides on the actions and also consists of a power distributions system. The specified function of the robotic system is accomplished by intelligent interpretation of sensor information and mechanical actuations in term of plan, task and model.

The entire robotic system was carefully and meticulously designed, constructed and tested. From the experimental results, it is proven that the proposed robotic system was successfully developed. This robotic arm can handle hazardous tasks in lab experiment specifically regarding chemical processing. Thus, reducing the risk on human.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN LENGAN ROBOT SCARA DAN SISTEM KAWALAN UNTUK AUTOMASI MAKMAL

Oleh

JOHNNY KOH SIAW PAW

Julai 2002

Pengerusi: **Dr. Ishak Bin Aris**

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Baru-baru ini, pembangunan dalam penggunaan sistem robotik untuk menguruskan bahan membuktikan pelbagai kebaikannya dalam industri bahan kimia. Demi untuk mengelak dari risiko pengendalian bahan kimia, pelbagai langkah boleh diambil. Salah saru langkah penting ialah dengan menggantikan tangan manusia dengan tangan robot untuk mengendalikan bahan-bahan kimia berbahaya dan menghakis. Untuk tujuan inilah, kajian ini dijalankan dengan matlamat utama untuk menghasilkan sebuah sistem yang dapat menyumbang kepada keselamatan pemprosesan dan pengujian bahan kimia. Tesis ini menyediakan analisis awal dalam pembangunan robot dalam bidang berkenaan.

Objektif projek adalah untuk menghasilkan sebuah robot jenis SCARA dengan sistem kawalannya. Rekabentuk dan pembangunan projek akan melibatkan tiga bahagian penting. Bahagian pertama menitikberatkan bidang perisian manakala bahagian kedua meliputi pembinaan perkakasan, dan disusuli dengan antaramuka pengguna secara grafik.

Rekabentuk perkakasan bolehlah dikategorikan kepada rekabentuk elektrikal dan rekabentuk mekanikal. Rekabentuk elektrikal merangkumi pendawaian alatan masukan dan keluaran, pengagihan kuasa, peranti keselamatan dan komponen kawalan. Rekabentuk mekanikal meliputi pembinaan struktur robot. Ini termasuk lukisan dan simulasi mekanikal, turut melibatkan pengiraan dan fabrikasi bahagian-bahagian robot. Rekabentuk perisian pula akan melibatkan penugasan masukan dan keluaran, carta-carta aliran program, teknik robot-belajar dan pengaturcaraan MINT. Sementara, antaramuka grafik akan meliputi pengaturcaraan Visual Basic.

Secara asasnya, projek ini membabitkan beberapa sub-sistem iaitu sistem penderia yang digunakan untuk mendapatkan maklumat keadaan mekanisme dan persekitaran, pengawal dan pemacu untuk mengawal mekanisme dan penderia, sistem kawalan dan juga sistem pengagihan kuasa. Fungsi khas sistem robotik dicapai dengan penterjemahan maklumat-maklumat penderia dan pemacuan mekanikal.

Keseluruhan sistem robotik ini telah direkabentuk, dibina dan diuji secara teliti. Daripada keputusan ujikaji, ternyata sistem robot yang dicadangkan telah berjaya dihasilkan. Tangan robot ini berupaya untuk mengendalikan kerja-kerja berbahaya dalam ujikaji makmal terutamanya pemprosesan bahan kimia. Pada masa yang sama, ini turut mengurangkan risiko kepada manusia.

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It is my hope that this report will contribute to the organisations in furthering their research.

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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LIST OF ABBREVIATIONS

AC	Alternative Current
ARR	Array
CW	Clockwise
CCW	Counter Clockwise
CFG	Configuration
CTRL	Control
DC	Direct Current
EEPROM	Electrical Erasable Programmable Read Only Memory
ELCB	Earth Leakage Circuit Breaker
GND	Ground
GUI	Graphic User Interface
IN	Input
I/O	Input and Output
LED	Light Emitting Diode
MCB	Miniature Circuit Breaker
MINT	Motion Interpreter
MPU	Main Processor Unit
OUT	Output
PC	Personal Computer
PLC	Programmable Logic Controller
PWM	Pulse Width Modulation
REM	Remark
SCARA	Selective Compliance Assembly Robotic Arm

LIST OF SYMBOLS

a	Link length vector, acceleration (mm/s^2)
A	Ampere
α	Link twist angle vector
c	Coefficient of friction
COM	Common
d	Joint distance vector, deceleration (mm/s^2)
e	Leadscrew efficiency
f	Frequency (Hz)
F	Force (kg)
g	Gravity constant
Hz	Hertz
I	Current (A)
J	Inertia ($kg\text{-}cm^2$)
L	Length (mm), distance (mm)
M	Reduction ratio
n	Number of contacting surfaces
N	Number of gear teeth
p	Pitch (revs/mm)
PPS	Pulse per second
ρ	Density (kg/mm^3)
q	Joint variable vector
r	Angular rotation
R	Resistance, radius

rpm	Revolution per minute
s	Second, safety factor
S	Step angle (°), sensing distance (mm)
T	Torque (Nm), transformation
t	Time (sec), temperature (°C)
μ_s	Coefficient of static friction
V	Voltage (volt)
v	Velocity (mm/sec)
W	Weight (kg)
ω	Angular velocity (rad/sec)
X	Linear translation
Ω	Ohm

CHAPTER 1

INTRODUCTION

1.1 Introduction

Science and technology play a major role in Malaysia's dynamic industrialisation. In the spirit of 'Malaysia incorporated' promulgated by the Prime Minister Dr. Mahathir Mohammad since 1983, the public and private sectors have been very supportive of science and technology developments in Malaysia. National awareness and interest in science and technology must be enhanced, as this constitutes a prerequisite for an inventive society. Inventing is a suitable approach to help make science and technology more interesting and relevant to the industries and economy. The spirit of inventiveness should be inculcated among Malaysians.

There are various types of inventions ranging from simple to complex base on its functionality and needs by the various industries. One of the quite prominent types is robotic invention. In an industrialisation era, robotics have certainly played a very important role not only in minimising and easing work burden but also to the extend of increasing productivity and not compromising on products quality. This has certainly brought prosperity to many countries such as Japan and Korea. In order to "mimic" this significant achievement, our Prime Minister had launched