UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A CARTESIAN PAINTER ROBOT FOR CONSTRUCTION INDUSTRY

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DEVELOPMENT OF A CARTESIAN PAINTER ROBOT FOR CONSTRUCTION INDUSTRY

By

A. K. M. PARVEZ IQBAL

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in the Fulfillment of the Requirements for the Degree of Master of Science

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TO MY DEAREST FATHER, MOTHER, SISTER AND BROTHER

Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science.

DEVELOPMENT OF A CARTESIAN PAINTER ROBOT FOR CONSTRUCTION INDUSTRY

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November 2002

Chairman: Dr. Ishak Bin Aris

Faculty: Institute of Advanced Technology

Nowadays robots are widely used in many applications such as in factories, the mining industries, the automobile industry etc. Currently, the application of robot is still not widely implemented in construction industry. In construction industry, robots are designed to increase speed and improve the accuracy of construction field operations. It can also be used to do hazardous and dangerous job in construction. For example, house painting is done manually. This process can be simplified using a special dedicated robot. It is very difficult and troublesome for human to work in an upright position especially for painting, cleaning and screwing in the ceiling for a long time. Painting in an upright position is also very dangerous for the eyes. To overcome this difficulty, a painter robot system is proposed and developed.

The main objective of this project is to develop a three-degree of freedom (DOF) painter robot and its intelligent system. In order to achieve the main objective, the following works are carried out:

Development of the mechanical structure of the robot. This includes the positioning module and end-effector module. The positioning module is divided into three parts

namely, X-axis module, Y-axis module and Z- axis module. Development of the electrical and electronic system of the robot. These include its power distribution system, sensor system, motor driver system, electro-pneumatic system and programmable logic controller and development of the controlling program of the robot.

The proposed painter robot has three degree of freedom (DOF). For X direction, a single-phase induction motor and a chain-sprocket mechanism are used. Two limit switches and two electronic sensors are used to limit the movement in X direction. Another sensor is used to position the robotic arm along the X direction. For Y direction, two limit switches are used to limit the movement in Y direction. Two sensors are used to protect the robotic arm along the Y direction. The single-phase motor with an inverter is utilized to control the speed of the robot in Y direction. For Z direction, a parallelogram structure and a ball-screw mechanism are used in this project. A single-phase brake motor and a photoelectric sensor are used to control the position in Z direction. Two limit switches are used to limit the movement in Z direction. The proposed robot is used to paint the ceiling of the houses. The paint is sprayed by the robot automatically using the pneumatic system.

The software part involves the design and development of the system control software. The system control software is created using FP WIN GR PLC programming software. This project implements the Matsushita NAIS FP0 programmable logic controller (PLC) to control the overall system of the machine.

From the tests conducted on the painter robot, it is observed that the robot is operating according to its original plan.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains.

PEMBINAAN ROBOT PENGECAT KARTESIAN UNTUK INDUSTRI PEMBINAAN

Oleh
A. K. M. PARVEZ IQBAL

November 2002

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Dalam era ini robot digunakan secara meluas dalam berbagai bidang seperti perkilangan, perlombongan dan sebagainya. Ketika ini penggunaan robot dalam industri pembinaan belum lagi digunakan secara meluas. Dalam industri pembinaan, robot direka untuk meningkatkan kepantasan dan memperbaiki ketepatan operasi. Ia juga boleh digunakan untuk melakukan kerja-kerja yang berbahaya dan berisiko tinggi dalam pembinaan. Sebagai contohnya, kerja-kerja mengecat rumah dilakukan secara manual. Proses ini boleh dipermudahkan dengan menggunakan suatu robot istimewa yang berdedikasi. Adalah sangat sukar bagi manusia untuk bekerja pada posisi yang tinggi terutamanya untuk mengecat, mencuci, mengetatkan skru pada siling dalam jangkamasa yang lama. Untuk mengatasi kesulitan ini, suatu robot pengecat telah dicadangkan dan dibina.

Objektif utama projek ini ialah untuk membina suatu robot pengecat yang mempunyai tiga darjah kebebasan (DOF) dan juga sistem pintar bagi robot tersebut. Untuk mencapai objektif ini, kerja-kerja berikut dilakukan, iaitu: Pembinaan struktur mekanikal robot. Ini termasuklah 'positioning module' dan 'end-effector module'. 'Positioning module' dibahagikan kepada tiga bahagian, iaitu modul paksi-X, modul

paksi-Y dan modul paksi-Z. Pembinaan sistem elektrik dan elektronik robot tersebut. Ini termasuklah sistem pembahagian kuasa, sistem penderia, sistem pemanduan bermotor, sistem elektro-pneumatik dan 'programmable logic controller' dan pembinaan program robot tersebut.

Robot pengecat yang dicadangkan mempunyai tiga darjah kebebasan (DOF). Bagi arah X, suatu motor 'induction' satu fasa dan mekanisma 'chain-sprocket' digunakan. Dua suis penghad dan dua penderia elektronik digunakan untuk menghadkan pergerakan dalam arah X. Satu penderia lain digunakan untuk meletakkan tangan robot di sepanjang arah X. Bagi arah Y, dua suis penghad digunakan untuk menghadkan pergerakan dalam arah Y. Dua penderia digunakan untuk melindungi tangan robot di sepanjang arah Y. Motor satu fasa dengan 'inverter' digunakan untuk mengawal kepantasan robot dalam arah Y. Bagi arah Z, suatu struktur 'parallelogram' dan mekanisma 'ball-screw' digunakan dalam projek ini. Motor brek satu fasa dan penderia fotoelektrik digunakan untuk mengawal posisi dalam arah Z. Dua suis penghad digunakan untuk menghadkan pergerakan dalam arah Z. Dua suis penghad digunakan untuk menghadkan pergerakan dalam arah Z. Robot tersebut digunakan untuk mengecat siling rumah kos rendah. Cat tersebut akan disembur secara automatik dengan menggunakan sistem pneumatik.

Bahagian perisian melibatkan penciptaan dan pembinaan perisian sistem pengawalan. Perisian sistem pengawalan dicipta dengan menggunakan program perisian FP WIN GR PLC. Projek ini menggunakan program 'logic controller' (PLC) Matsushita NAIS FPO untuk mengawal keseluruhan sistem mesin tersebut.

Daripada ujian yang dijalankan ke atas robot pengecat tersebut, didapati bahawa robot tersebut beroperasi mengikut pelan asal.

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I certify that an Examination Committee met on 14th November 2002 to conduct the final examination of A. K. M. Parvez Iqbal on his Master of Science thesis entitled "Development of a Cartesian Painter Robot for Construction Industry" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981.The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

A. K. M. Parvez Iqbal

A. K. M. PARVEZ IQBAL

Date: 26-11-2002

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LIST OF ABBREVIATIONS

AC	Alternative current
AML	A manufacturing language
CAD	Computer aided design
CCW	Counter clock wise
DC	Direct current
DOF	Degree of freedom
I/O	Input and output
MINT	Motion interpreter
PC	Personal computer
PLC	Programmable logic controller
RIA	Robotic industries association
RPP	Revolute, prismatic, prismatic
RRP	Revolute, revolute, prismatic

LIST OF SYMBOLS

K	Kinetic energy
T	Torque
J	Inertia
T	Time
ω	Angular velocity
g	Gravity constant
W_L	Weight of the load
W_S	Weight of the sprocket
W_C	Weight of the chain
F	Frictional Force
R	Radius of sprocket
V	Linear velocity
ρ	Density
R	Radius of shaft
L	Length
μ_s	Static coefficient of friction
d	Diameter of shaft
M	Maximum moment
δ_d	Design Stress
m	Mass
δ_u	Ultimate stress

δ_y	Yield stress
e	Efficiency of ball-screw
m	Meter
n	Newton
p	Pitch
mm	Millimeter
cm	Centimeter
L_n	Measured distance
M_1	Motion of parallelogram link
M_2	Motion of parallelogram link
V	Potential energy.