



**UNIVERSITI PUTRA MALAYSIA**

**DESIGN AND FABRICATION OF AUTONOMOUS  
ENTERTAINMENT MOBILE ROBOT**

**ASNOR JURAIZA BINTI DATO' HJ. ISHAK**

**FK 2003 41**

**DESIGN AND FABRICATION OF AUTONOMOUS ENTERTAINMENT  
MOBILE ROBOT**

**By**

**ASNOR JURAIZA BINTI DATO' HJ. ISHAK**

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

**September 2003**



*Dedicated to my parents,  
Dato' Hj. Ishak Idris and Datin Hjh. Asmah Md Rashid,*

*my husband and daughter,  
Aziz Kamal and Anis Amalina Aziz,*

*and  
my dearest brothers and sister.....*

*.....With Love.....*

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

**DESIGN AND FABRICATION OF AUTONOMOUS ENTERTAINMENT  
MOBILE ROBOT**

**By**

**ASNOR JURAIZA BINTI DATO' HJ. ISHAK**

**September 2003**

**Chairman : Associate Professor Ishak bin Aris, PhD.**

**Faculty : Engineering**

Mobile robots are already widely used for surveillance, inspection and transportation tasks. An emerging technology with enormous potential is the entertainment mobile robot. Sony Corporation has developed a Sony dog known as Sony's Aibo that cannot speak but can chase a ball, lie down, sit and wag its tail. The robot must operate in a safe and friendly manner, avoiding obstacles and posing no risk to human in its vicinity. The scenario in Malaysia is that not many entertainment mobile robot has been developed because generally, Malaysians are content with their role as a user rather than a developer.. In order to achieve the objectives of the "Vision 2020", Malaysia should produce more scientists and developers in various areas. The best and most effective way of learning and stimulating interest in entertainment robot is through contests. Therefore, Sirim Berhad and the Ministry of Education have organized the Robot Games Festival or Robofest 2002 to encourage researchers, lecturers and students to design and develop robotic systems.

The main objective of this project is to design and develop an entertainment mobile robot that can place as many beach balls as possible into the cylinder tubes within 3

minutes. In the festival, the robot can be manual and/or automatic. The manual robot must not touch Kinabalu Zone (Appendix B1) and starts only at 'Start Zone A'. Meanwhile, the automatic robot can touch and enter the entire area of the game field and starts at 'Start Zone B' in the Kinabalu Zone.

The development of the entertainment mobile robot consists of hardware and software development. The hardware development is divided into two parts namely, mechanical design and electrical design. The mechanical design involves a platform module, a storage module and an arm manipulator module. While, electrical design includes a power supply module, a sensing system, a control panel, a DC motor driver and a programming logic controller. The software development is required to develop the programming of this robot and the software used is FPWIN GR PLC.

The design of the proposed robot is based on the Cylindrical coordinate concept known as Y-Z- $\theta$  coordinate. In the contest, two strategies plan of motion are applied that are the I motion and the L motion. Therefore, the strategy should be selected before the match starts. The I motion only involves Y-axis motion or straight motion while L motion requires Y-axis, Z-axis (turn left or right) and  $\theta$ -axis motion (rotation).

Based on the result testing and the contest that took place, the entertainment mobile robot is found to be operating according to its contest motion plan.

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

## **REKABENTUK DAN FABRIKASI ROBOT HIBURAN**

**Oleh**

**ASNOR JURAIZA BINTI DATO' HJ. ISHAK**

**September 2003**

**Pengerusi : Profesor Madya Ishak bin Aris, PhD.**

**Fakulti : Kejuruteraan**

Robot hiburan secara meluasnya telah digunakan dalam bidang pengawasan, pemeriksaan dan pengangkutan. Robot hiburan mempunyai pontensi yang tinggi dalam bidang teknologi. Syarikat Sony telah membina sebuah robot anjing Sony yang dikenali sebagai Sony Aibo dimana robot ini tidak boleh bercakap tetapi mempunyai keupayaan memegang bola, baring dan duduk serta menggerakkan ekornya. Robot harus dikendalikan secara selamat dan berkeadaan baik bagi mengelakkan halangan dan risiko pada persekitaran manusia. Senario di Malaysia secara umumnya memperlihatkan bahawa tidak banyak pembinaan robot hiburan kerana dasar dan peraturan kerajaan yang hanya bertindak sebagai pengguna daripada bertindak sebagai pengusaha. Sebagai panduan untuk mencapai sasaran “Wawasan 2020”, Malaysia seharusnya melahirkan lebih ramai saintis dan pengusaha dalam pelbagai bidang. Jalan terbaik dan berkesan untuk mempelajari dan menaruh minat dalam bidang robot hiburan adalah melalui pertandingan. Untuk yang demikian, Sirim Berhad dan Kementerian Pendidikan telah menganjurkan satu kejohanan Pesta Pertandingan Robot 2002 untuk menggalakkan penyelidik, pensyarah dan pelajar merebentuk dan membina sistem robotik.

Objektif utama projek ini ialah untuk merekabentuk dan membina sebuah robot hiburan yang membolehkan ianya memasukkan bola pantai sebanyak mungkin ke dalam tiub silinder dalam masa 3 minit. Dalam pertandingan ini, robot ini boleh dikawal samada secara manual ataupun automatik. Robot manual tidak boleh memasuki dan menyentuh Zon Kinabalu (Apendik B1) dan perlu bermula di 'Zon Permulaan A'. Manakala, robot yang dikawal secara automatik dibolehkan memasuki dan menyentuh kawasan pertandingan dan bermula di 'Zon Permulaan B' dalam kawasan Zon Kinabalu.

Pembinaan robot hiburan ini melibatkan pembinaan perkakasan dan perisian. Pembinaan perkakasan dibahagikan kepada dua kategori iaitu rekabentuk mekanikal dan rekabentuk elektrik. Rekabentuk mekanikal melibatkan rekabentuk modul planta, modul simpanan dan modul lengan robot. Manakala rekabentuk elektrik merangkumi modul bekalan kuasa, sistem pegasan, panel kawalan, motor arus terus dan kawalan pengaturcara logik. Pembinaan perisian dalam robot ini diperlukan dengan membina satu sistem pengaturcara menggunakan perisian FPWIN GR PLC.

Rekabentuk robot yang diperlukan ini adalah berdasarkan kepada konsep kordinat berbentuk silinder yang dikenali sebagai kordinat Y-Z- $\theta$ . Dalam pertandingan ini, dua rancangan strategi pergerakan diaplikasikan iaitu pergerakan I dan pergerakan L. Walaubagaimanapun, strategi harus ditentukan sebelum pertandingan bermula. Pergerakan I hanya melibatkan pergerakan paksi Y atau pergerakan lurus manakala pergerakan L melibatkan paksi Y, paksi Z (pusing kekiri dan kekanan) dan paksi  $\theta$  (putaran).

Berdasarkan kepada keputusan ujian dan keputusan ketika pertandingan, robot hiburan ini dapat beroperasi seperti keperluan dalam pertandingan tersebut.



## ACKNOWLEDGEMENTS

I could not have accomplished this project without the help of Allah S.W.T. Thanks to Allah S.W.T that I can complete my project successfully.

First and foremost, I would like to express my gratitude to my project supervisor, Associate Professor Dr. Ishak Aris for his valuable advice, guidance and willingness to share his expertise knowledge.

I would also like to thanks my project co-supervisor, Dr. Samsul Bahari Mohd Noor and Associate Professor Dr. Napsiah Ismail for their valuable opinions and guidance and checking the accuracy of my entire project.

I have also indebted to the help of Hj. Noorfaizal Dato' Hj. Yidris and Mr. Danny Lim of Intellogic Technology Sdn Bhd for their various ideas, suggestions and valuable aid to carry out this project.

Special thanks to my loves ones, Dato' Hj. Ishak Idris and Datin Hjh. Asmah Md Rashid, my beloved husband and daughter, Aziz Kamal and Anis Amalina Aziz, my dearest brothers and sister, my dearest friends, Mashida Sakrani, Huda Rameli, Izadora Mustafa, Siti Fatimah Sadikon and anyone for their patience, encouragement and continuous support.

# TABLE OF CONTENTS

	<b>Page</b>
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL SHEETS	ix
DECLARATION	xi
LIST OF TABLES	xv
LIST OF FIGURES	xvi
LIST OF ABBREVIATIONS	xx
LIST OF SYMBOLS	xxi
<b>CHAPTER</b>	
<b>1 INTRODUCTION</b>	
1.1 Introduction	1.1
1.2 Objectives	1.2
1.3 Project Overview	1.3
1.4 Features of the Entertainment Mobile Robot	1.9
1.5 Organization	1.10
<b>2 LITERATURE REVIEW</b>	
2.1 Introduction of Robot Festival Contest (ROBOCON)	2.1
2.2 Research on Mobile Robot	2.3
2.3 Selected Components used for the Propose Robot	2.8
2.3.1 Photoelectric Sensors	2.8
2.3.2 Inductive Proximity Sensor	2.10
2.3.3 Incremental Rotary Encoders	2.10
2.3.4 Solenoid	2.11
2.3.5 Relays	2.12
2.3.6 Direct Current (DC) Motor	2.13
2.3.7 Stepper Motors	2.15
2.3.8 Spur Gear and Worm Gear	2.16
2.3.9 Springs	2.19
2.3.10 Robot Controller and Programming Software	2.20
2.3.8.1 Programmable Logic Controller (PLC)	2.21
2.3.8.2 Basic Structure of PLC	2.21
2.3.8.3 Types of Inputs and Outputs	2.23
2.3.8.4 Advantages and disadvantages of PLC	2.24
2.4 PLC Programming	2.25
2.5 Summary of Literature Review	2.26



3	METHODOLOGY	
3.1	Overview	3.1
3.2	Mechanical Design	3.2
3.2.1	Platform Module	3.5
3.2.1.1	Design of the Y-axis motion	3.8
3.2.1.2	Design of the Z-axis motion	3.11
3.2.1.3	Design of the $\theta$ -axis motion	3.16
3.2.2	Storage Module	3.21
3.2.3	Arm Manipulator Module	3.23
3.3	Electrical Design and Development	3.32
3.3.1	Power supply module management	3.33
3.3.2	Permanent –magnet DC Motor	3.35
3.3.3	Sensing System	3.38
3.3.4	Control Panel	3.40
3.3.5	Circuit Protection	3.43
3.3.6	Programmable Logic Control	3.44
3.4	Software Development	3.46
3.4.1	Flow chart and ladder diagram design	3.47
3.4.2	NAIS PLC Programming Development Software	3.61
3.4.3	Creating and Editing the Program	3.62
3.4.4	Checking and Compiling the Program	3.63
3.4.5	The Input and Output Port Indication	3.64
3.5	System Integration	3.65
4	RESULT AND DISCUSSION	
4.1	Introduction	4.1
4.2	Platform Module	4.1
4.2.1	Y-axis Motion	4.2
4.2.1.1	Test Conducted to the Y-axis motion	4.4
4.2.1.1.1	Y-axis direction accuracy test	4.4
4.2.1.1.2	Timing accuracy test for Y-axis	4.6
4.2.2	Z-axis Motion	4.7
4.2.2.1	Test Conducted to the Z-axis motion	4.9
4.2.2.1.1	Sensor detection test for Z-axis	4.9
4.2.3	$\theta$ -axis Motion	4.11
4.2.3.1	Test Conducted to the $\theta$ -axis Motion	4.12
4.2.3.1.1	Repeated positioning test for $\theta$ -axis Motion	4.13
4.3	Storage Module	4.14
4.3.1	Test Conducted to the storage module	4.16
4.3.1.1	Divider positioning test	4.16
4.3.1.2	Cylinders positioning test	4.16
4.4	Arm Manipulator	4.17
4.4.1	Test Conducted to the Arm Manipulator Module	4.20
4.4.1.1	Solenoids Test	4.20
4.4.1.2	Adjustment of the level barrier	4.22
4.5	Permanent Magnet DC Motor Drivers	4.23
4.6	System Control Software	4.25

5	CONCLUSION	
5.1	System Integration	5.1
	5.1.1 Cost of the Project	5.3
5.2	The Real Game	5.3
5.3	Conclusion	5.5
5.4	Recommendation	5.6
	REFERENCES	R.1
	APPENDIXES	
	Appendix A: Mechanical Drawing of the proposed robot	A.1
	Appendix B: Game field layout	A.2
	Appendix C: Programmable Logic Controller (PLC) programming	A.4
	Appendix D: Design chart	A.8
	Appendix E: Electrical components	A.13
	BIODATA OF THE AUTHOR	B.1



## LIST OF TABLES

	<b>Page</b>
Table 3.1: Inputs and outputs mapping of the system	3.64
Table 4.1: The range measured for each repeated movement	4.5
Table 4.2: The testing duration of the trial game	4.7
Table 4.3: Test the sensor functioning based on setting distance	4.10
Table 4.4: The testing result of the motor positioning in $\theta$ -axis	4.13
Table 4.5: The amount of the discharge balls based on cylinder rotation	4.17
Table 4.6: The operation status of the hooks and plunger solenoids	4.22
Table 4.7: Accuracy of the barrier level	4.7
Table 4.8: The testing result of the motor driver	4.25
Table 4.9: Type and function of relays	4.25
Table 4.10: The I/O mapping of the FPO	4.26
Table 5.1: Robot specification	5.2
Table 5.2: Cost of the project	5.3

## LIST OF FIGURES

	<b>Page</b>
Figure 1.1: Development Process of the Proposed Robot	1.3
Figure 1.2: Design Process of the Proposed Robot	1.6
Figure 1.3: Mechanical Design of the Entertainment Mobile Robot	1.7
Figure 1.4: Electrical Design of the Mobile Robot	1.8
Figure 1.5: Software Development of the Robot	1.8
Figure 2.1: Robot Soccer	2.5
Figure 2.2: Three Type of Reflective Surface for Photoelectric Systems	2.9
Figure 2.3: Internal Operation of Incremental Encoder	2.10
Figure 2.4: A Solenoid	2.12
Figure 2.5(a) and (b): Normally Open and Normally Closed Relay	2.13
Figure 2.6: Basic Components of a Simple DC Motor	2.14
Figure 2.7: Spur Gears	2.17
Figure 2.8: Worm Wheel Attach to Worm Gear	2.18
Figure 2.9: Spring	2.20
Figure 2.10: Structure of Programmable Logic Controller	2.22
Figure 2.11: Type of Input and Output Signal	2.23
Figure 2.12: Signal from Switch or Sensors	2.23
Figure 3.1: Project Activities of the Proposed Robot	3.3
Figure 3.2: The I Motion and L Motion	3.4
Figure 3.3: The Front Wheels of Vehicle Frame	3.5
Figure 3.4: Technical Drawing of the Platform Module	3.7
Figure 3.5: The Driver Motor for Y-axis Movement	3.8
Figure 3.6: The 2D View of the Proposed Robot	3.9

Figure 3.7: The Jack Stand Couples with the Spur and Worm Gear	3.12
Figure 3.8: The motor, gears, shaft and encoder arrangement of the $\theta$ -axis motion	3.17
Figure 3.9: Storage Module	3.21
Figure 3.10: The Three Modules of the Mechanical Design	3.22
Figure 3.11: Technical Drawing of the Storage Module	3.28
Figure 3.12: Technical Drawing of the Arm Manipulator	3.31
Figure 3.13: The Arm Manipulator Module	3.32
Figure 3.14: Distribution of Power Supply	3.33
Figure 3.15: Power Supply Management	3.34
Figure 3.16: Wiring diagram of relay and DC motor for the connection to PLC	3.36
Figure 3.17: The Schematic Diagram of the DC Motors and Relays	3.37
Figure 3.18: Wiring Diagram of Switches to the PLC	3.39
Figure 3.19: Typical Wiring Diagram of Photoelectric Sensor to the PLC	3.40
Figure 3.20: Technical Drawing of the Control Panel Box	3.41
Figure 3.21: Wiring Connection of the Robot to the PLC	3.42
Figure 3.22: Layout of the Electronic Devices Inside Control Panel	3.43
Figure 3.23: Inputs and Outputs Devices are Connected to the PLC Com ports	3.46
Figure 3.24: The Flow Chart of the Software Development	3.55
Figure 3.25: The FPWIN GR Programming Edit Window	3.61
Figure 3.26: Select the PLC Type	3.62
Figure 3.27: The Checking Result of the Program	3.64
Figure 4.1: The Driver Motor is Coupled with an Encoder	4.3
Figure 4.2: The Two Wheel is Fixed with Steel Bar	4.3
Figure 4.3: The Testing Field for Y-axis Direction	4.5
Figure 4.4: The Jack Stand and Marker	4.8

Figure 4.5: The Photoelectric Sensor	4.9
Figure 4.6: The Correlation of the Output Voltage Sensor and Setting Distance	4.11
Figure 4.7: The Start Zone B Position	4.12
Figure 4.8: The Storage Module	4.15
Figure 4.9: The View of Arms in Home Position	4.18
Figure 4.10: The View of Arms After the Hooks are Released	4.19
Figure 4.11: A pair of Shock Absorber	4.19
Figure 4.12: The Solenoid in Released Position	4.20
Figure 4.13: The Hook and Plunger Solenoid (upper position) in Home Position	4.21
Figure 4.14: The Testing of Plunger Positioning	4.21
Figure 4.15: The Level of Barrier in Various Angel	4.23
Figure 4.16: The Testing of Z-axis and $\theta$ -axis Motor	4.24
Figure 4.17: Stop and Reset Function	4.26
Figure 4.18: Manual Mode Function	4.26
Figure 4.19: Automatic Mode Function	4.27
Figure 4.20: Y-axis Motion when Switch left/right Off Function	4.27
Figure 4.21: Whole Robot Rotate 90 Function	4.27
Figure 4.22: Y-axis Motion when Switch left/right On Function	4.27
Figure 4.23: Whole Robot Rotate 270 Function	4.27
Figure 4.24: Stop and Reset Function	4.28
Figure 4.25: I Motion Function	4.28
Figure 4.26: Cylinders Rotation Function	4.28
Figure 4.27: Combination of I Motion and Cylinders Rotation	4.29
Figure 4.28: Y-axis Forward Mode Function	4.30
Figure 4.29: Z-axis Forward Mode Function	4.30



Figure 4.30: Z-axis Reverse Mode Function	4.30
Figure 4.31: Arms Module Mode Function	4.30
Figure 4.32: $\theta$ -axis Forward Mode Function	4.30
Figure 4.33: Storage Module Mode Function	4.31
Figure 5.1: The Mechanical Structure of the Entertainment Mobile Robot	5.1

## LIST OF ABBREVIATIONS

AC	Alternative current
BISMARC	Biologically Inspired System for Map-based Autonomous Rover Control
CARL	Construction Automation and Robotics Laboratory
CPU	Centre processing unit
DC	Direct current
EEROM	Erasable programmable read-only memory
I/O	Input and output
LED	Light-emitting diode
MCSM	Mobile Camera Space Manipulation
NCSU	North Carolina State University
PLC	Programmable Logic Controller
RBMS	Robotic Bridge Maintenance System
ROBOCON	Robot Festival Contest
SIRIM	Standards and Industrial Research Institute of Malaysia
TISOFT	Texas Instruments software
VA	Volt amperes

## LIST OF SYMBOLS

$T$	Torque
$J$	Inertia
$t$	Time
$\omega$	Angular velocity
$g$	Gravity constant
$W_L$	Weight of the load
$W_G$	Weight of the gear
$R_L$	Radius of load wheel
$R_G$	Radius of gear
$N_G$	Number of teeth gear
$r$	Radius of gear
rpm	Revolutions per minute
$d$	Diameter of gear
$m$	Meter

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Robots are very useful in the manufacturing industry to perform tasks like welding, grinding and part assembly. Nowadays, mobile robots have begun to achieve the dreams of researchers. Mobile robots make our life easier and safer in many ways such as sea exploration, planet discovery, dangerous military and police missions, as well as being a new type of entertainment (Jones, et al., 1999).

In Malaysia, many industrial companies are not interested to participate in the research and development of robots. Lack of financial support and involvement by researchers and students worsen the situation. However, the recent success by Honda's Asimo and Sony's Aibo has changed people's perception. They make use of the development of robots in the world of entertainment.

Sirim Berhad believes that the best and most effective way of learning and stimulating interest in robotics is through contests. The proposed project was designed and fabricated to participate in the first Malaysia Robot Games Festival or Robofest 2002. It is an annual event to promote robotic and artificial intelligent fields and hold activities such as robot contests, exhibitions, demonstration, forum and seminar.

The contest (Robofest 2002) was held on 5th of May 2002 with SIRIM Berhad as the organizer. In the contest, only two types of machines were allowed; the automatic and manual machines. The participants were among university and polytechnic students. Each team had 4 members that were made up of 3 students and 1 instructor or lecturer. The layout of the game field is attached in Appendix B1.

## **1.2 Objectives**

The main objective of this project is to develop an entertainment mobile robot that can place as many beach balls as possible into the cylinder tubes within 3 minutes.

In order to achieve the main objective, the following works must be carried out. They involve the development of:

- the platform module
- the storage module
- the robot arm manipulator module
- the DC motor driver
- the sensing system
- the power supply module
- the controller
- the programming design.

### 1.3 Project Overview

The development process of the proposed robot is based on the block diagram as shown in Figure 1.1. The first step of the development process is discussed in detail in the game rules and a strategy is done based on the rules.

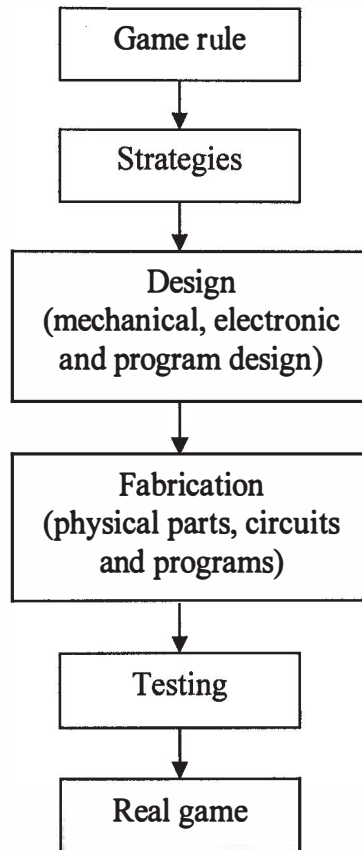


Figure 1.1: Development Process of the Proposed Robot

In the contest, each team can construct either or both the manual machines or the automatic machines, or both. There is no restriction on the number of machines. The machines must mount beach balls at the start of the game, and the number of balls is not restricted. The total weight of all machines must be less than 40 kg.