UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A REMOTE CONTROL AUTONOMOUS MOBILE ROBOT

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By

YONG VOON SIEW

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

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DEDICATION

Dedicated to my beloved wife and family.

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 REMOTE CONTROL AUTONOMOUS ROBOT

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August 2003

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Faculty: Engineering

Current commercial edutainment robots are expensive, not widely available in the country, and most of the times they have limited features, programmability and functions. This thesis described the design and development of a remote control autonomous mobile robot that enables the studies of robotics controls and its behaviour, such as obstacle avoidance and phototropic behaviour. The proposed robot structure consists of both hardware and software. The hardware comprises of a mobile platform, microcontrollers, motors and sensors. Software provides the programmable brain of the robot to control its entire functions. The robot is designed to be open architecture so that more peripheral can be added. Each of the hardware and software are tested separately, combined as a whole system and test on a few robotic behaviour experiments. The test results meet the thesis objective and it is a successful project. The robot has been constructed, tested and demonstrated in a few public events and the latter proved to be a real crowd puller. In general the proposed robot can be used as a tool for the children to learn and to play.

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

PEMBANGUNAN SEBUAH AUTONOMOS ROBOT KAWALAN JAUH

Oleh

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Pada masa kini, robot sebagai alat pembelajaran dan permainan adalah mahal, sukar diperolehi di pasaran tempatan, dan selalunya mempunyai ciri-ciri, pemprograman dan fungsi yang terhad. Tesis ini membincangkan rekaan dan pembangunan sebuah robot kawalan jauh autonomos mobil robot, yang membolehkan pembelajaran kawalan dan sifat robot, seperti mengelak halangan dan sifat fototropik. Robot yang dicadangkan terdiri daripada perkakasan dan perisian. Perkakasan termasuklah sebuah pentas bergerak, pengawal mikro, motor dan sensor. Perisian merupai otak yang boleh diprogramkan untuk mengawal seluruh fungsi robot. Robot ini direkabentuk dalam akitektur yang terbuka agar penambahan perkakasan bantuan adalah tidak terbatas. Setiap perkakasan dan perisian diuji secara berasingan, kombinasi sistem dan mejalankan eksperimen sifat robot. Keputusan ujian mematuhi objektif tesis dan projeck ini telah berjaya dilaksanakan. Robot ini telah berjaya dibina, diuji dan didemonstrasi di hadapan khalayak ramai, dan sememangnya ia menpunyai daya tarikan yang kuat. Secara amnya, robot yang dicadangkan boleh digunakan sebagai alat pembelajaran dan permainan kanak-kanak.

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I would also like to thank my wife, Chen Huey Voon, my family and God for their help in various ways.

I certify that an Examination Committee met on 3rd June 2003 to conduct the final examination of Yong Voon Siew on his Master of Science thesis entitled "Development of a Remote Control Autonomous Mobile Robot" 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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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 of concurrently submitted for any degree at UPM or other institutions.

YONG VOON SIEW

Date: 18TH JULY 2003

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LIST OF SYMBOLS

A	Ampere
AH	Ampere per hour
cm	Centimeter
Hz	Hertz
k	Kilo
mA	Mili Ampere
$\mu\Phi$	Micro Farad
$\mu\sigma$	Micro second
ms^{-1}	Metre per second
nF	Nano Farad
π	3.142
S	Second
T	Time counter
V	Volt
VAC	Voltage of the Alternating Current
V_{ac}	AC voltage
V_{dc}	DC voltage
V_{peak}	Peak Voltage
Ω	Ohm
W	Watt

LIST OF ABBREVIATIONS

AC	Alternating Current
ADC	Analog to Digital Converter
ADCTL	Analog to Digital Control/Status Register
ADR1	Analog to Digital Converter Result Register 1
ADR2	Analog to Digital Converter Result Register 2
ASCII	American National Standard Code for Information
CD	Compact Disc
Cds	Cadmium Sulfide
CLI	Clear All Interrupts
COM	Communication
CPU	Central processing unit
CS OUT	Chip Select Out
CTS	Clear To Sent
DC	Direct Current
DOF	Degree of Freedom
EEPROM	Electrical Erasable Programmable Read Only Memory
EMF	Electro Magnetic Field
Gnd	Ground
HPRIO	Highest Priority Interrupt and Miscellaneous
I/O	Input/Output
IC	Integrated Circuit
ICSP	In Circuit Serial Programming Circuit
IDE11	Integrated Development Environment for 68HC11
IR	Infrared
IRQ	Interrupt Request
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LSB	Least Significant Bit
MAHPEN	Mahathir Pen Presenter
MOD	Operation Mode
MS DOS	Microsoft Disk Operating System
MSB	Most Significant Bit
N	No
NRZ	Asynchronous Nonreturn to Zero
OS	Operating System
PACNT	Pulse Accumulator Count Register
PACTL	Pulse Accumulator Control Register
PAI	Pulse Accumulator Input
PBx	Port B x pin

PCx	Port C x pin
PEx	Port E x pin
PVC	Polyvinyl Chloride
PWM	Pulse Wave Modulation
RAM	Random Access Memory
RAUBoT	Remote control AutonomoUs RoBOT
RC	Resistance and capacitance network
RLY	Relay
RTI	Real Time Interrupt
RxD	Receiver Data Input
SCCR1	Serial Communication Control Register 1
SCCR2	Serial Communication Control Register 2
SCDR	Serial Communication Data Register
SCI	Serial Communication Interface
SPI	Synchronous Serial Peripheral Interface
TTL	Transistor Transistor Logic
TV	Television
TxD	Transmitter Data Output
UART	Universal Asynchronous Receiver Transmitter
Vdd	Power supply
Y	Yes

CHAPTER ONE

INTRODUCTION

1.1 Introduction

In the past few years the technology of robotics, mechatronics, and artificial intelligence has exploded, leaving many with the desire but not the means to build and research their own projects. The fascination with the exciting field of robotics has led to development of a series of simple to complex robotic studies, which are designed to benefit both novice and experienced robotics researchers. The common components and technology featured in this robotic research are practical solutions that can be implemented easily without incorporating expensive, complicated technology and thus open up a wider society to benefit from this interesting field.

It is inevitable that in this high technological world, most industries are moving towards high end and sophisticated technology. More and more demand is put for the skilled and semi-skilled work force in technological background either directly or indirectly. Where does the country feed in the ever-hungry demand of high technology workers? School students especially the secondary schools play a very important nervous system in supplying the right amount of highly skilled fundamental workers in science and technology. But this does not happen as year-by-year, more and more secondary and university students opt for arts stream. The Higher Education Planning Committee set the ratio of 60% science students to 40% Arts students for Form Four level by the year 2010 in 1967 [1]. However more than three decades later, the ministry is no closer to meet the target. Statistics from the

Education Ministry shows that only 32.29% of Form Four students opted to take up science and technology subjects in 2000 [2]. One of the many means to get more students involve in science and technology is through early involvement in robotic which generates more likens in terms of human collaboration and interaction due to its' broad range of engineering.

1.2 How an Autonomous Robot Acts as an Educational Tool?

An autonomous robot is a self-contained robot with its own controller, hardware, and intelligence that able to carry out task with anticipated result that does not required human intelligence and intervention [3]. In reality, all robots have limitation of being fully autonomous since they require human interaction of some sort. Nevertheless, autonomous robots can possess many characteristics of a life being in nature. These robots have the ability to collect, process, and make decision based on data and perform task in order to render a desired result.

Robots can exist by executing sequences with or without human interaction at any given point in that sequence. What robots do not have is the ability to discover. Discovery does not mean finding a useful result that was not anticipated by the design. It does mean finding a result that is applied in such a way that it is useful possibly outside and beyond the scope of current goals. It is in turn, added to the design and expanding its own knowledge base. Artificial intelligence has made many significant steps in the area of autonomous learning. In the grand scheme of things, these are baby steps. So in designing a robot system, understanding the amount of intelligence and limitations is crucial to have robot that performs tasks or a research study project that could span in a wider aspect of engineering.

Autonomous robot design can be as simple or as complicated to make. Autonomous robot had enormous opportunities for learning. One amazing feature of robot design is the fact that it employs so many different disciplines. A robot is not purely electrical, mechanical nor algorithmic. It is all of the above, and moreover, all these systems that must function together harmoniously to define the robot. So not only does one get to work on what they like the most, they also get to learn about all of the other aspects and systems. This coupled with the experiment aspect of robot design, makes this particular hobby one of the most educational hobbies around. The robot presented in this thesis is a robotic mobile platform, which carries its hardware in wheels and can be controlled remotely or autonomously.

1.3 Objective

The objectives of this project are as follows:

- To develop a remote control mobile robot that able to perform autonomously. This robot is called RAUBoT, abbreviated from Remote control AutonomoUs RoBoT.
- To develop the locomotion, steering mechanism and electronic control, which are able to give mobility and hardware control of the robot.
- To develop a multiple microcontroller system that interface with actuators and sensors.

- To decode a commercial TV remote control and use it as a remote control for RAUBoT.
- To develop a portable power and charging system.
- To develop a Z-axis Cartesian gripper manipulator.
- To develop specific robotic behaviour and control programmes - obstacle avoidance, light seeker, object retrieval, interactive robot and speed control.

1.4 The General Structure of the Proposed Robot

This robot is intended as an edutainment kits in robotics. The use of commercial robots for robotics studies is too costly due to accuracy and some of the features might be over killed. Since edutainment robotics need not have to be so precise in engineering, small scale down robots meant for desktop or room exploration is more than sufficient. However, the use of commercial toy robots available in the market do not provides the expandability, durability and sufficient features that can be utilized. Some of the controls are either purely hardware logics or non-programmable firmware.

Most of the commercial mobile robots are using sequential processing from its single processor that only enable sequential and concurrent parallelism, which are still deemed as not in real time processing [4]. The robot design in this project will allow parallel processing in real time due to availability of multitude processors. Furthermore, most of commercially available mobile platforms do not have remote control capability for the use of executing uploaded programs in the robots. By adding remote control capability of the RAUBoT, total control of the robot functionality and movement can be monitored and studied.

This RAUBoT consists of several fundamental building blocks as shown in Figure 1.1, that encompasses several different engineering fields which included mechanical structure, motion control, feedback control, electrical and power, electronic, microcontroller, programming, sensory devices, speech/sound recording and processing and artificial intelligence. As thus, this robot project is a challenging feat to design and develop, and requires a wide field of engineering.

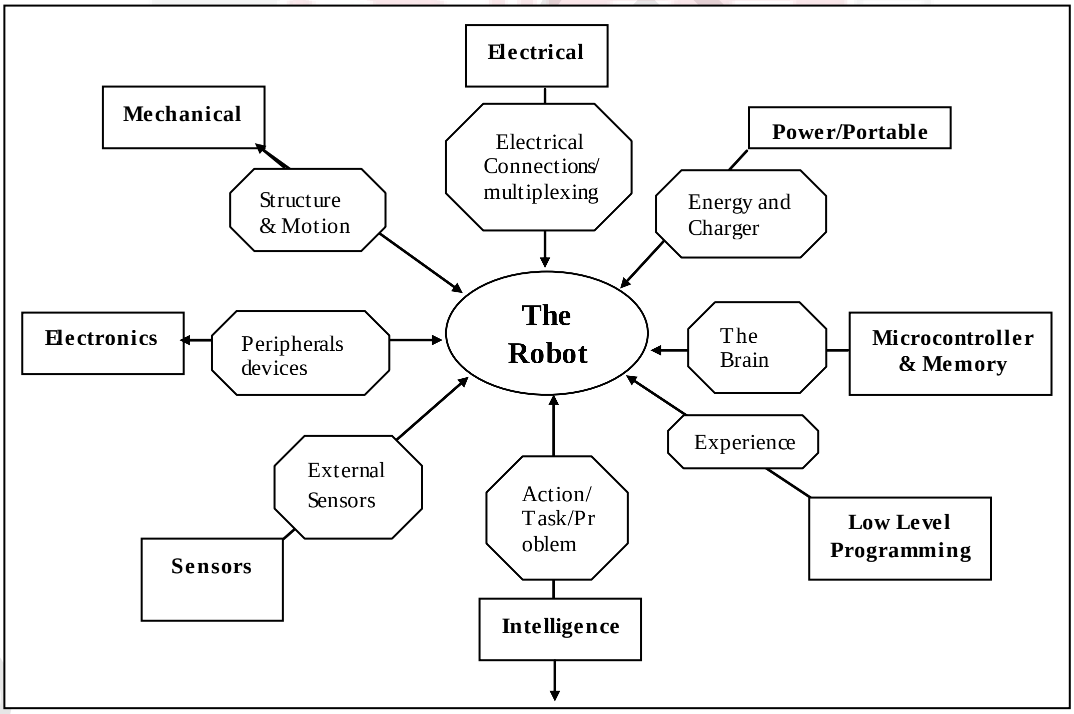

Figure 1.1: The Fundamental Building Blocks of the RAUBoT

RAUBoT will have these following features:

- One driving wheel and two idle wheels.
- Able to move in 270 degree in XY vectors with respective to one point.
- Pick and place small size object either instructively or planned.
- Auto detect object in the gripper manipulator.
- Programme memories are reprogrammable.
- Real time execution with parallel processing.
- Programmes selected using the IR remote control.
- Speed control, speed regulator, electric brake and position orientation steering.
- CdS sensor, infrared sensor receivers, optical encoders and position sensor.
- It can move with wire, wireless and autonomous control.
- In wire control, host terminal control is via serial cable.
- In wireless control, an infrared TV remote control gives the command.
- In autonomous mode, programme is executed and the robot behaves on its own.
- Low battery alarm warning, recovery delay and sleep mode for inactivity.
- Built in charging system, portable power and dual power system with auto charging and no interruption when connect to mains.
- In circuit serial programming capability.
- Hardware dual bumpers protection.
- Interactive dancing robot with music.
- Speech and sound synthesis accompaniment for tasks.

- Sound can be recorded via microphone or input jack and dedicated microcontroller allows sound synthesis programming.

1.5 The Specifications and Constraints of the RAUBoT

The RAUBoT is designed based on these specification and constraint:

- No mechanical accuracy and precision are taken into consideration since the objective is to have functionalities. The mechanical hardware is built and assembled from modified recycle material. The robot mechanical design, kinematics and dynamic studies are not taken into consideration since the overall system performance relies on electrical and software control.
- Only 2048 Bytes of programmed memories are used for each microcontroller. No added memories to maximize board space.
- Steering mechanism has a maximum of 270 degree of rotation at a given point. It is constrained by the end limit sensors and driving mechanic structures.
- The robot can traverse freely on smooth hard plane or floor. However, it cannot traverse properly in rug or carpet.
- Maximum payload of the hardware that can be supported by the platform driving force and steering torque is about 10 kg. The payload for the gripper manipulator is less than 50 g whereas the gripper clamp is less than 10 g.
- Its low infrared sensors count and blind spot area, limits the detection area of obstacle in avoidance mode. The infrared sensor does not detect black material and glass properly.

- Battery power running time is about 60 minutes. Delay recovery power system does not guarantee performance of the gripper manipulator.

1.6 Thesis Layout

The thesis consists of five chapters and its' layout can be summarized as follows:

a) Chapter 1 presents the discussion of the importance of robot for education. This chapter includes the aims, objectives and general overview of the project.

b) Chapter 2 presents the literature review. This chapter reviews the fundamental building blocks and design of the robot and also comparison with works on other robots. It also presents a study on the microcontroller and the programming environment setup. This chapter includes the basic requirements of other modules such as motor driver, IR obstacle detection system, IR remote control decoding and various complementing peripherals.

c) Chapter 3 presents the insight details of the material and methodology that used to develop the hardware and software. Hardware design sections will explain all the components and materials in constructing the robot and also all the underlying connections between the various modules. The software part will explain how the software works on various modules in detail block diagrams and the main operating system of the robot.

d) Chapter 4 presents the results and discussion of the robot. A few programmes with robot activities will be presented for discussions and comprehension. It also explains the final objective of the interlinking of the modules and the robot as a whole. Cost analysis of the project is presented at the end of this chapter.

e) Chapter 5 presents the conclusion, recommendations, and future improvement that can be introduced to enhance its functionality and usage.

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