DESIGN & FABRICATION OF AUTONOMOUS ROBOT FOR SECURITY MONITORING

By

NIK NURSHAHIRAH BT MUHAMAD NASIR

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

DESIGN & FABRICATION OF AUTONOMOUS ROBOT FOR SECURITY MONITORING

by

Nik Nurshahirah bt Muhamad Nasir

A project dissertation submitted to the
Department of Electrical & Electronic Engineering
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved:

____

Dr. Mohd Haris Md Khir
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

Nik Nurshahirah bt Muhamad Nasir

ABSTRACT

Nowadays, autonomous robots are widely used for various applications area from sciences and industries to military and security monitoring. Generally, the autonomous robot is capable to navigate on its own in a known environment. This can be implemented when robot can do its own decision making with having the movement mechanism and the environmental sensors to analyze the surrounding to perform the task with respect to requirement. This project focuses on designing and fabricating the autonomous robot for 24 hours security monitoring with less human intervention. This robot is equipped with microprocessor, sensing systems, and wireless camera for security monitoring. When the autonomous robot detects any safety related issues, the alarm on the robot will be triggered and at the same time the situation will be send to wireless camera for human monitoring to take any sufficient respond afterwards. 24 hours security monitoring robot is found to be a practical solution to be implemented for security purposed in order to make sure any safety issues is in controlled.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my greatest gratitude to God Almighty for His blessings and grant me health and life to be able to complete this project. Special thanks to Electrical & Electronic Engineering Department of Universiti Teknologi PETRONAS for giving opportunity to me to do this project and Dr. Mohd Haris Md Khir, my supervisor for his endless guidance, patience and idea while doing this robot's project. Being very supportive throughout the project, he patiently guided me from the beginning, while giving me the direction whenever I get stuck in any related problems towards the completion of the project.

Huge thanks to UTP Robocon team for their constant advises and for helping me out to build the robot and conducting experiments. Working with them, they have shared with me not only the engineering related knowledge but also their valuable experiences, which help me to successfully complete my final year project.

My deepest gratitude is also goes to my mother, Nik Norizan bt Ghazali who always gives me all the moral supports, concerns and motivation while doing this project.

Last but not least, I would like to thank all my friends and colleagues for their precious time to give support and assistance to me in any form.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Background

When societies first began developing, nearly all production and effort were the result of human labors. With technological advances becoming more complex, machines were slowly developed. For the last decades, many researches had been done to develop the autonomous robot in order to perform the dangerous, risky and continued task and hence replace human in certain job. Throughout the time, the autonomous robot has been developed according to the progress in different ability such as self-maintenance, task performance, sensing the environment, outdoor autonomous position-sensing and navigation, and indoor position sensing and navigation. Today, the security monitoring job is required and important for the most of place due to safety issues. The monitoring job generally needs to be done in 24 hours time to ensure that any unwanted incident will not happen and because of that, the autonomous robot is needed to be design so that it can replaced the human work which is currently doing the security monitoring manually by checking around the area continuously.

1.2 Problem Statement

This project involves the requirement for security monitoring in 24 hours time due to safety issues. The security monitoring system that exists today is whether by human monitoring (security guard) or CCTV (closed circuit television). For security guard, by checking the area manually and continuously they are tend to feel tired and possible to be drowsy, then did not alert if something wrong happened in that particular area. Meanwhile for CCTV, it has the blind spot and just monitor for the certain angles only.

1.3 Objectives and Scope of Study

The objective of this project is mainly to study and develop the system for security monitoring in 24 hours time continuously. The objectives of the project are defined as below:

1. Construct a stable wheel-based basic structure.
2. Design an autonomous robot which is being able to navigate according to a predetermined path for the security monitoring purposed.
3. Design a robot which has the capability to go to a pre-determined location, monitor the particular area, and give the signal through the camera to human when something wrong is happen. This could be seen as an extra feature added to the robot.

The scope of this project is divided into two parts which are for two semesters and the targets that needs to be achieved are as followed:

1. 1stsemester: Design and structure fabrication of basic part of robot.
2. 2nd semester: Mount the wheels and drive circuit ready so that the robot can performed basic movement. Then, develop the sensing system together with the microcontroller equipped to the robot. With the artificial intelligence embedded, the robot is able to operate autonomously and monitor the surrounding for the security monitoring purposed.

The relevancies of this project are:

- Autonomous robot development and improvement will make the security job become easier and more efficient since it is no longer need 24 hours manually human monitoring.
- Demand for security monitoring is high since it will be necessary in many places due to safety issues.

The feasibilities of this project are:

- UTP Robocon Lab is equipped with necessary tools and equipment needed such as driller, hammer, screwdrivers, wrenches, metal saw, and vernier calipers
- Common electronics stuff like sensors, motor, and microprocessor also available in this UTP Robocon Lab
- Use UTP intelligence to be applied for this project such as for software that will be used which is MPLab and complete in time since there are 2 semesters are given

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 Robotic History

A robot is a mechanical or virtual intelligent agent that can perform tasks automatically or with guidance, typically by remote control [1]. In practice, a robot is usually is an electro-mechanical machine which combine sciences of electromagnetism, electrical engineering, and mechanics. It is guided by computer and electronic programming. The branch of technology that deals with robots is robotics. Robots can be autonomous, semi-autonomous or remotely controlled. Autonomous robots are robots that can perform desired tasks in unstructured environments without continuous human guidance and explicit human control. It is able to adapt itself to changes during the task execution without any kind of human assistance [2 - 3].

The history of robots begins since 1495. Leonardo Da Vinci for an example through to Jacques de Vaucanson in 1739, as well as rediscovering the Greek engineering methods, have made plans for and built robots leading to books of designs such as the Japanese KarakuriZui (Illustrated Machinery) in 1796 [4]. Makoto Nishimura who is the biologist, in 1929 has created Gakutensoku as shown in Figure 1, which cried and changed its facial expressions [5].

Figure 1: Gakutensoku and Makoto Nishimura

2.2 Autonomous Robot

General-purpose autonomous robots can perform a variety of functions independently. Autonomous robots typically can navigate independently in known spaces, handle their own re-charging needs, interface with electronic doors and elevators and perform other basic tasks. It can link with networks, software and accessories that increase their usefulness and act like computers. They may recognize people or objects, talk, provide companionship, monitor environmental quality, respond to alarms, pick up supplies and perform other useful tasks. General-purpose robots may perform a variety of functions simultaneously or they may take on different roles at different times of day. Some such robots try to mimic human beings and may even resemble people in appearance; this type of robot is called a humanoid robot. Humanoid robots are still in a very limited stage and can actually navigate around a room that it has never been in. Thus, humanoid robots are really quite limited, despite their intelligent behaviors in their well-known environments. Some of the characteristic of ability and benefits that exist on fully autonomous robot are:

- Work for an extended period without human intervention
- Gain information about the environment
- Avoid situations that are harmful to people, property, or itself unless those are part of its design specifications
- Move either all or part of itself throughout its operating environment without human assistance

There are some of the examples for the progress towards commercial autonomous robots which are self-maintenance, task performance, sensing the environment, outdoor autonomous position-sensing and navigation, and indoor position sensing and navigation.

2.2.1 Self-maintenance

First and foremost, the ability for a robot to take care of itself is the first requirement for complete physical autonomy. Nowadays in the market, there are many of the battery powered robots and connect to a charging station that can be found. Self-maintenance is based on "proprioception", or sensing one's own internal status. For this case, the robot can tell proprioceptively that its batteries are low and it then seeks the charger for the battery charging example. Sony's Aibo as shown in Figure 2 is one of the examples for some toys that are capable of self-docking when it is time to charge their batteries [6].

Figure 2: The AIBO ERS-7

The named AIBO was originated from **A**rtificial **I**ntelligence ro**BO**t. Sony was the one who designed and manufactured it and this was one of several types of robotic pets. Since May 11, 1999 there have been several types of different models and even though, this AIBO was discontinued in 2006. Based on external stimuli from their owner, their environment and from other AIBOs, they have the ability to learned and matured. Because of that, AIBO robotic pets can be considered to be autonomous robots. AIBO is also have the ability to walk and look around in its surrounding of environment through the camera, and even can recognize spoken commands in Spanish and English. Artist Hajime Sorayama who is a Japanese illustrator, created the initial designs for the AIBO. Another common proprioceptive sensor is for heat monitoring. Increased proprioception will be required for robots to work autonomously near people and in harsh environments. The other proprioceptive sensors in common are thermal, hall effect, optical, and contact.

2.2.2 *Task Performance*

To actually perform a physical task is the next step in autonomous behaviour. With a flood of small vacuuming robots starting in 2002 with Electrolux as shown in Figure 3 and iRobot, a new area showing commercial promise is domestic robots.

Figure 3: The Lux vacuum is the first product Electrolux sold, 1919

Through out of the time while the level of intelligence is not high in these systems, the navigation to direct and guide over wide areas and pilot in tight situations around homes using contact and non-contact sensors was exist. Both of these robots use proprietary algorithms to increase coverage over simple random bounce. For the next level, the security robots can respond in a particular way depending on where the intruder is and to do that, they have first needed to have the programmed to detect intruders then, because the requirement for robot is to perform conditional tasks for this autonomous task performance for instance.

2.2.3 *Sensing the Environment*

To be considered as autonomous robots it must have a range of environmental sensors to perform their task and stay out of trouble. Exteroception is sensing things about the environment and the common exteroceptive sensors are electromagnetic spectrum, attitude (inclination), sound, touch, range to thing in the environment, chemical sensors (smell, odour), and temperature. For the example, to sense how much dirt is being picked up, some vacuum cleaning robots have the dirt detectors and it will used this information to tell them to stay in one area longer. Whereas, by detecting the speed in which grass grows as needed, some robotic lawn mowers will adapt their programming to maintain a perfect cut lawn.

2.2.4 Outdoor Autonomous Position-sensing and Navigation

Cruise missiles are rather dangerous highly autonomous robots because it carries an explosive payload and is propelled which is designed to deliver a large warhead over long distances with high accuracy. Outdoor autonomy is most easily achieved in the air and usually for reconnaissance, pilotless drone aircraft are being used. Due to great disparities in surface density, weather exigencies, dimensional terrain, and instability of the sensed environment, outdoor autonomy is the most difficult for ground vehicles. Some drone aircraft are capable of a safe, automatic landing, but some of these unmanned aerial vehicles (UAVs) are capable of flying their entire mission without any human interaction at all except possibly for the landing where a person intervenes using radio remote control. Around 1990s in the US, the MDARS project as shown in Figure 4, this defined and built a prototype outdoor surveillance robot, was moving into production and has been implemented in 2006 [11].

Figure 4: The Seekur and MDARS robots

The General Dynamics MDARS robot can navigate semi-autonomously and detect intruders, using the MRHA software architecture planned for all unmanned military vehicles. The Seekur robot was the first commercially available robot to demonstrate MDARS-like capabilities for general use by airports, utility plants, corrections facilities and Homeland Security for security efforts to protect states against terrorist activity.

2.2.5 Indoor Position Sensing and Navigation

By sensing natural features, currently commercial robots autonomously navigate based on it. In 1970s, this kind of navigation began with wire-guidance and in early 2000s, it has been progressed to beacon-based triangulation, where instead of measuring the distance to the point directly, this is the process by measuring angles to determine the location of a point from known points to it at either end of a fixed baseline [7]. With one known side and two known angles, the point can then be fixed as the third point of a triangle. In 1980s, Pyxis' Help Mate hospital robot as shown in Figure 5 and the Cyber Motion guard robot as shown in Figure 6 were both designed by robotics pioneers and these were the first commercial robots to achieve this because of the usage of manually created CAD floor plans, sonar sensing, and wall-following variations to navigate buildings [8]. The Pyxis Help Mate robotic courier navigates autonomously throughout medical facilities, transporting pharmaceuticals, laboratory specimens, equipment, supplies, meals, medical records, and radiology films between support departments and nursing floors [9].

Figure 5: Pyxis Help Mate

Figure 6: Cybermotion SR2 robot in museum

Moving throughout the time, planar sensors such as laser range-finders was the only based that can be used for autonomous navigation which only sense at one level, but after that the use of information from various sensor for both localization (position) and navigation is exist in the most advanced system. For this, different sensors in different areas can be rely on depending on the most reliable data at the time in system and also can re-map a building autonomously [10].

2.3 Application in Robotics

2.3.1 Medical Robots

Because of highly precision machines, robots are used in medicine. Even the first generation of surgical robots as shown in Figure 7 are not true autonomous robots that can perform surgical tasks on their own, but to surgeons they are assisting them by lending a mechanical helping hand to them. The part like input instructions for ordering is still required and the human surgeon is still needed for this machine. Remote control and voice activation are the methods by which these surgical robots are controlled. They have been used in the field of robotic surgery to perform closed-chest, beating-heart surgery by tooling with surgical instruments [12]. Robotic surgery which is the technological developments that use robotic systems to aid in surgical procedures was developed to overcome both the limitations of minimally invasive surgery or to enhance the capabilities of surgeons performing open surgery. The first robotic surgery took place at The Ohio State University Medical Center in Columbus, Ohio under the direction of Dr. Robert E. Michler, Professor and Chief, Cardiothoracic Surgery [13].

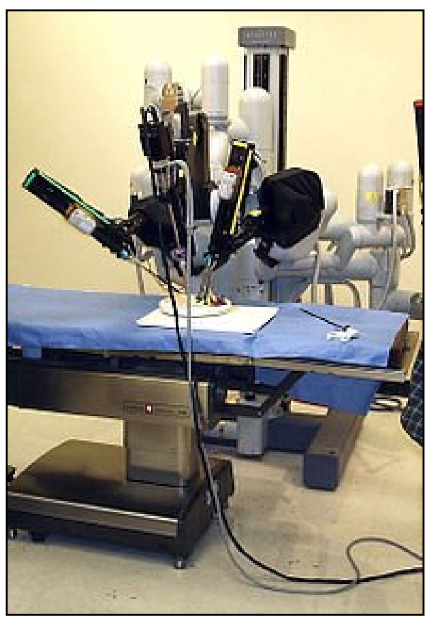


Figure 7: A robotically assisted surgical system

2.3.2 Military Robots

In an attempt to camouflage or to deceive the enemy, military robots may look like vehicles, airplanes, insects or animals or other objects. Military robots as shown in Figure 8 are capable of replacing humans to perform many, if not most combat functions on the battlefield. The presence of autonomous robots, networked and integrated, on the battlefield will take human out of the loop as early as 2025 and it was suggested by the U.S. Joint Forces Command. The capability of taking surveillance photographs and launching missiles accurately at ground target without a pilot is the success of unmanned vehicle like the Predator drone. They have been put or acted like mine sweeper and for bomb disposal when on the ground.

Figure 8: Military robots can handle tasks like clearing explosives and hauling cargo

To perform the duty, being a soldier required to do the job like walking through minefield and deactivating unexploded bombs or clearing out hostile building. These are definitely the more dangerous task than others and because of that, it is better if they send robot to finish the jobs instead of humans [14]. The loss of human cannot be replaced if compared to loss of robot if there is something went wrong because the loss in robots means the loss in money and it is possible to rebuild the robot instead of losing human life which is irreplaceable.

2.3.3 Surveillance Using Robotic

2.3.3.1 Aquatic Weed Surveillance Using Robotic Aircraft

The proposed of this project is to build a robotic aircraft and surveillance system to detect aquatic weeds in inaccessible habitats as shown in Figure 9. One major limitation in controlling aquatic weeds is the difficulty of conducting detailed surveillance over vast areas such as irrigation schemes, or over inaccessible aquatic habitats. Satellite remote sensing has been used in the past to overcome this limitation, but is not cost effective and cannot detect small infestations, especially where overhanging foliage or environmental sensor clutter and backscattering can affect surveillance performance. The prototype used is aerial robot houses sensors and spray systems. The sensors take imagery of the environment the robot flies over, classify the imagery so as to detect where the weeds are (if any), and geo-reference the location of those weeds. The robot can then be tasked to go back to those weed locations and spray them with an appropriate herbicide, or be tasked to spray them at the same time that they are detected [15].

Figure 9: Several Species in Waterways

For the robotic platform, it used a modified model helicopter as the platform as shown in Figure 10. Using a helicopter gave full maneuverability, including ability to hover, making it possible to traverse large distances, move in tight situations, and hold position to take imagery or to spray herbicide. This involved development and tuning of flight control and navigation algorithms and spray mechanisms. The final system can fly for approximately two hours and carry approximately 500 ml of herbicide (water was used in the project for demonstration).

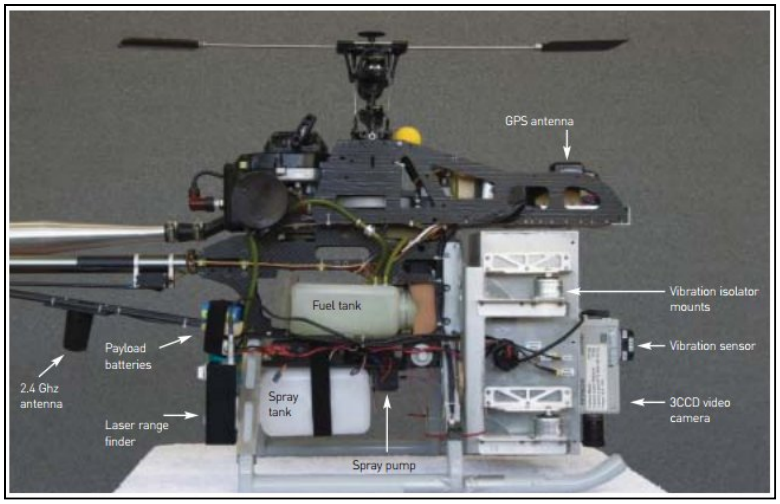


Figure 10: Complex Internal Structured of Robotic Aircraft

In this project, in order to classify weeds in near real-time, it needed a means of learning the particular attributes of a weed so that an algorithmic model describing the weed could be developed and used on the platform. The algorithmic model can help to settle down the mechanism for this case. Several aquatic weeds are aggressive invaders of waterways in Australia. Species such as alligator weed, cabomba and salvinia, which have been declared Weeds of National Significance, can cover entire water surfaces. Flows are prevented, channels blocked and flood patterns altered. Weed mats reduce available oxygen in waterways, resulting in increased fish kills and loss of native plant species, and adversely affecting water quality. Unchecked, aquatic weed invasions cause millions of dollars of damage to agriculture, fisheries and the environment. The future looks very exciting for this intelligent little machine. The project may be continued with a specific focus on aquatic weeds, and to broaden its capabilities into other ecology management arenas, such as woody weeds and biomass measurements.

2.4 General Parts in Autonomous Robot

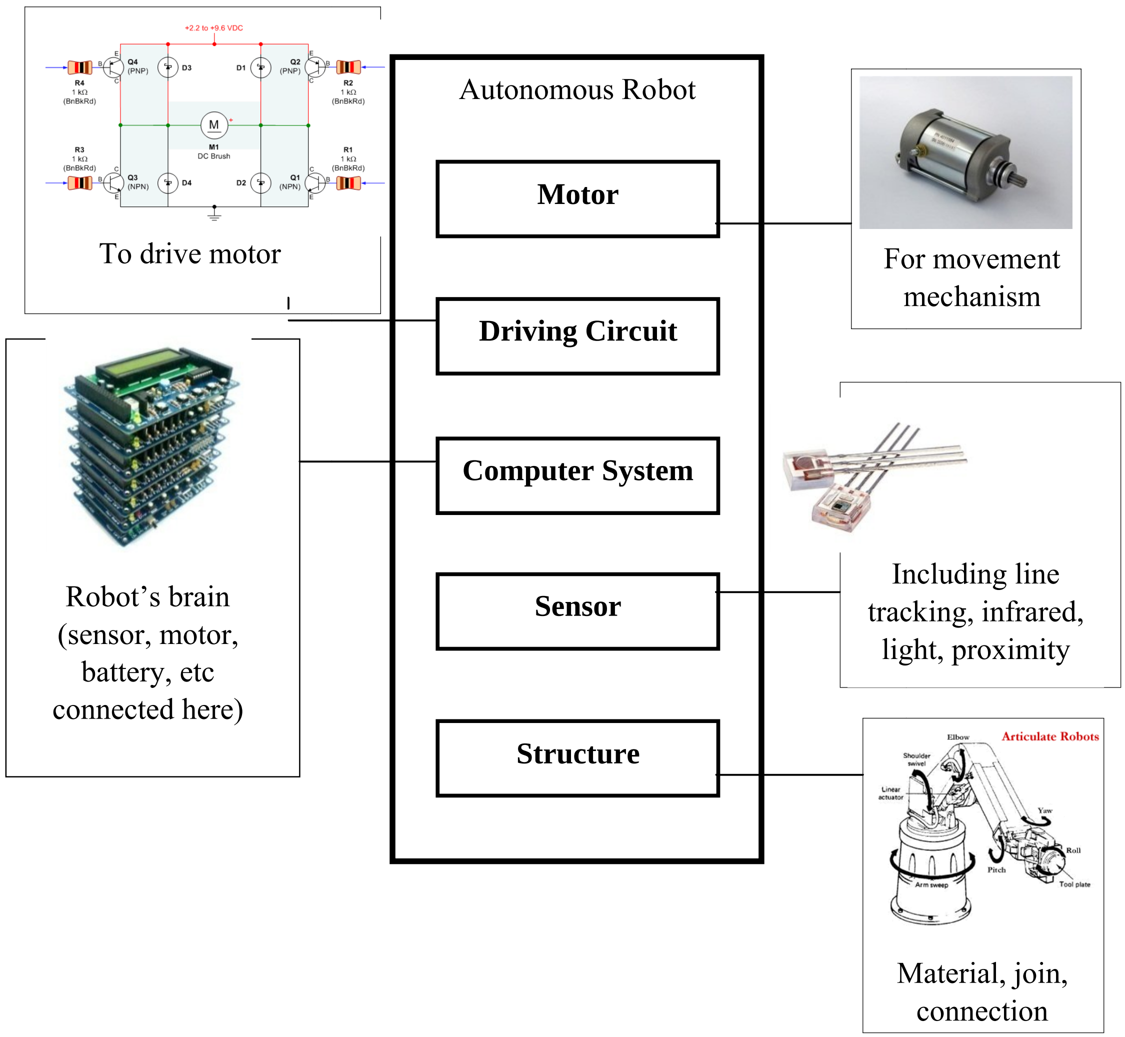


Figure 11: Block Diagram for Autonomous Robot's General Part

Figure 11 shows the general most important part in autonomous robot structure. They are contains of motor, driving circuit, computer system, sensor and structure. The details of every part will be explained in the next section.

2.4.1 Motor

There are several types of motor that usually used for robot mechanism such as DC motor, stepper motor, and servo motor. The details for every each of these motors are explained above.

2.4.1.1 DC Motor

With DC motor, the speed can be controlled smoothly until zero and after that without switching of power circuit, it is followed by acceleration but in the other opposite direction. In terms of braking, it has two kind which are regenerative braking and dynamic braking. Dynamic braking is when the dc motor generated energy is given to a resistor grid. Meanwhile, regenerative braking is when the dc motor-generated energy is given back into the dc motor supply. This kind of dc motor also respond faster for inertia even for changing in control signal from high ratio of torque of dc motor. Because of the speed and torque relationship can be different in such many ways and in either direction of rotation, for industrial applications, it will usually use dc motor. Here, application of power causes the shaft to rotate continuously and obviously it will only stop when the power is being off or removed, or also when it cannot drive the load anymore [16]. By far the most common DC motor types are the brushed and brushless types, which use internal and external commutation respectively to reverse the current in the windings in synchronism with rotation. The brushed DC electric motor as shown in Figure 12 generates torque directly from DC power supplied to the motor by using internal commutation, stationary magnets (permanent or electromagnets), and rotating electrical magnets. Like all electric motors or generators, torque is produced by the principle of Lorentz force, which states that any current-carrying conductor placed within an external magnetic field experiences a torque or force known as Lorentz force. Advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses. Maintenance involves regularly replacing the brushes and springs which carry the electric current, cleaning or replacing the commutator [20].

DC motors have AC in a wound rotor also called an armature, with a split ring commutator, and either a wound or permanent magnet stator. The commutator and brushes is a long-life rotary switch. The rotor consists of one or more coils of wire wound around a laminated "soft" ferromagnetic core on a shaft; an electrical power source feeds the rotor windings through the commutator and its brushes, temporarily magnetizing the rotor core in a specific direction. The commutator switches power to the coils as the rotor turns, keeping the magnetic poles of the rotor from ever fully aligning with the magnetic poles of the stator field, so that the rotor never stops (like a compass needle does), but rather keeps rotating as long as power is applied.

Brushless DC motors as shown in Figure 13 use a rotating permanent magnet or soft magnetic core in the rotor, and stationary electrical magnets on the motor housing. This design is simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor. Advantages of brushless motors include long life span, little or no maintenance, and high efficiency. Disadvantages include high initial cost, and more complicated motor speed controllers. Some such brushless motors are sometimes referred to as "synchronous motors" although they have no external power supply to be synchronized with, as would be the case with normal AC synchronous motors. Some of the problems of the brushed DC motor are eliminated in the brushless design. In this motor, the mechanical "rotating switch" or commutator/brushgear assembly is replaced by an external electronic switch synchronised to the rotor's position [21].

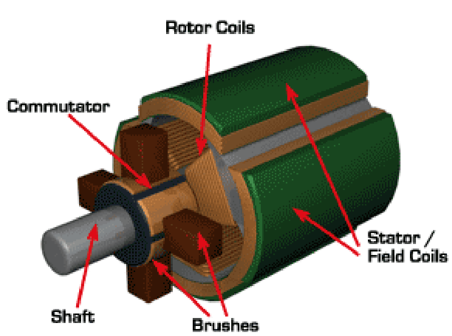


Figure 12: Brushed DC Motor

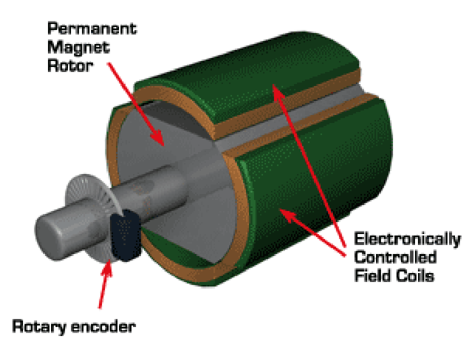


Figure 13: Brushless DC Motor

2.4.1.2 *Stepper motor*

Other than that, for stepper motor, it is also powered by electrical which will make the rotation for the motor from the electrical current driven. This kind of motor can be in large size physically but make sure it is small enough to be driven by current which is usually in range of milliampere. What differentiate stepper motor from dc motor is dc motor has continuous rotation unlike stepper. Even though, the stepper motor can also be in near to continuous rotation but it required more skills in input waveform. Figure 14 below shows the basic difference between DC motor and stepper in rotation basic principle.

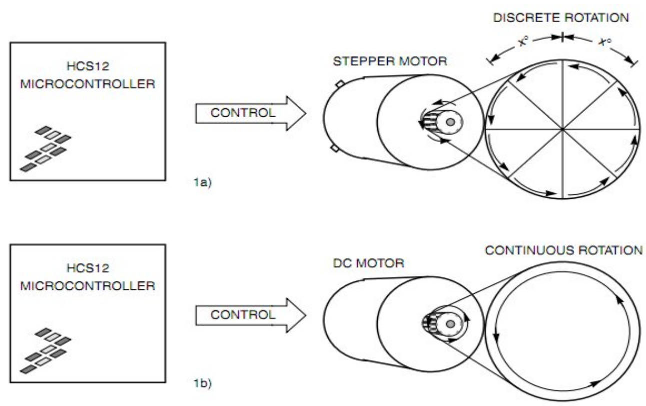


Figure 14: General Differences between DC Motor and Stepper Motor

They can be divided into two groups which are permanent-magnet (PM) stepper motor and variable-reluctance (VR) stepper motor. PM stepper motor basic working principle is the forces between an electromagnet and permanent magnet which is created by electrical current will cause the motor itself to do the rotation. This means that when there is no power, the motor still can be turned by the produced magnetic resistance. But, for the VR stepper motor, it rotation is definitely depend on electromagnetic forces and does not have permanent-magnet, so that when there is no power, the magnetic resistance does not produced to turn the motor itself. As can be inferred from the name, a rotor in stepper motors moves itself in a step-by-step way. Although this accuracy is sufficient for some applications, there are other drawbacks of stepping motors which are lack of smooth motion, particularly obvious at slow speeds, significant loss of torque at high speeds, and further positioning errors in the presence of static friction or external torque.

2.4.1.3 Servo motor

Servos are extremely popular with robot, which it can rotate about 90 to 180 degrees. And some of them can go to 360 degrees for rotation or more. Servo is DC motors with built in gearing and feedback control loop circuitry. This motor can be used when precise of angular control is required or for continuous rotation. It requires modification for in case to be used for continuous rotation and this motor needs the driving circuit to operate. There are three types of servo motor according to it requirement of usage. Dc servo motors which are based on dc motor designs, ac servo motors which are based on induction motor designs and ac brushless servo motor which are based on synchronous motor designs. Servo motor work is the control variable and there are used in closed loop control systems. To drive the servo motor, operation of the servo motor is being direct by digital servo motor controller by sending velocity command signals to the amplifier. Then, devices such as encoder and tachometer, or an integral feedback device as known as resolver will be combined within the servo motor or mounted itself, on the load itself. By this, the velocity signal can be altered when controller compares to programmed motion files when there are velocity feedback and servo motor's position are provided. This controller can define servo motor operation for the time, velocity, and position also. The differences between the motion profile and feedback signals are fully depends on type of controls and servo motors are being used. Servo motors are characterized by their ability to any position (limited only by the sensitivity of the sensors). It uses several stator phases to arbitrarily set magnetic flux [22]. Figure 15 and Figure 16 below show the stepper motor and servo motor simplified diagram.

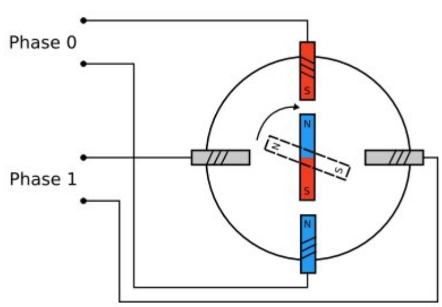


Figure 15: Stepper motor

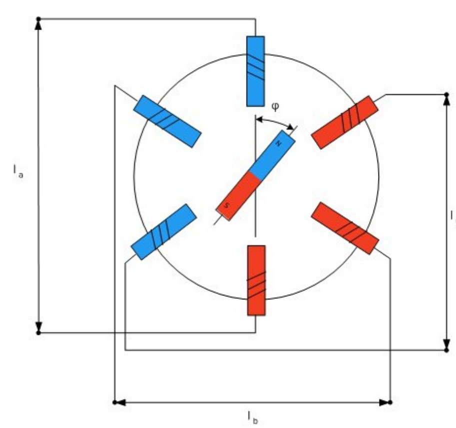


Figure 16: Servo-motor

2.4.2 Sensor

Kop (2009) has discussed about for the robot line tracking as shown in Figure 17, the sensor will be used such as line sensor. A line sensor in its simplest form is a sensor capable of detecting a contrast between adjacent surfaces, such as difference in colour, roughness, or magnetic properties, for example. The simplest would be detecting a difference in colour, for example black and white surfaces. Using simple optoelectronics, such as infrared photo-transistors, colour contrast can easily be detected and also easy to interface to a microcontroller.

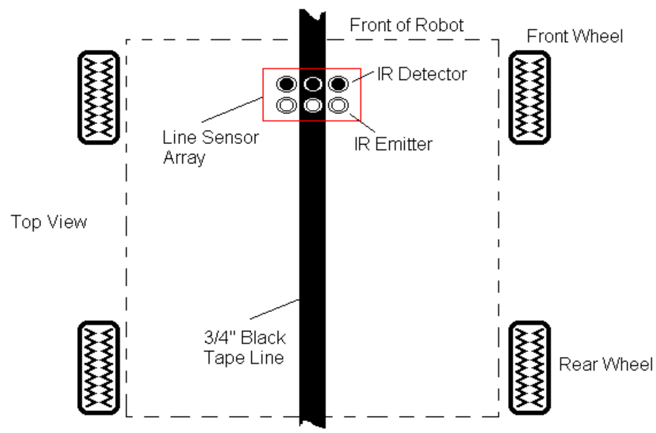


Figure 17: Line Tracking

2.4.3 Structure (Material)

For robot mobility, it can used wheels to achieve motion in order to allow the robot move forward or backward. Wheels are the most popular because it can be in any size and practically, small robot will have small wheels less than two or three inches in diameter and usually will be balanced by a pair of them on either side. Material choosing for robot structure is also important to be chosen for the suitability of the job. For example, materials such as a cheap piece of old woods cannot be used if the robot body is going to be free from shed or far away from the shed. For the plastic material, sometimes this is going to be easier and being the material of choices because it can be readily moulded to shape, but it also exists in raw shape such as sheet, bar, and rod that can be cut into the desired form.

2.4.4 Driving Circuit

Driving circuit is used to regulate current flowing through a circuit or used to control the other factors such as other components and some devices in circuit [17].Without the use of a computer system to mechanically operate the robot, the circuit uses a plurality of relays, timers and sensors. A driving control circuit controls a robot in grasping a desired product positioned within an injection mould, safely moving the desired product to a predetermined place, and then returning the robot to its initial position. In electronics, an electrical circuit or other electronic component controlled another circuit or other component such as high-power transistor and that is what being called as a driver. The driving control circuit allows the robot to function using a general motor without the use of an expensive stepping motor standard in robotics. The elimination of the stepping motor reduces the manufacturing cost, thereby, improving industrial automation [18].Usually, for driving circuit, H-bridge circuit as shown in Figure 18 is used. An H-bridge is an arrangement of transistors that allows a circuit full control over a standard electric DC motor. That is, with an H-bridge a microcontroller, logic chip, or remote control can electronically command the motor to go forward, reverse, brake, and coast [23].

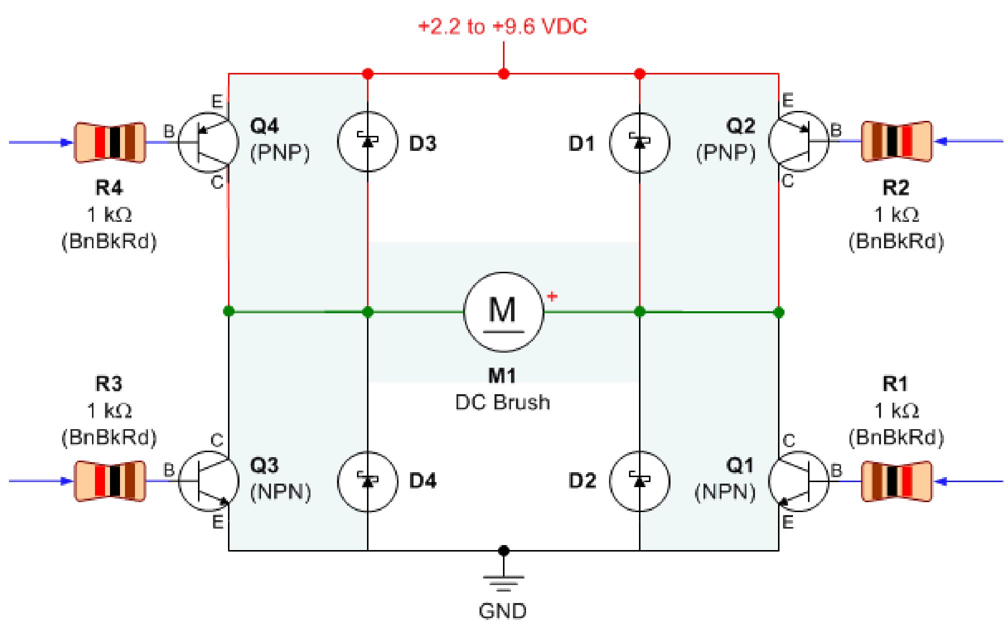


Figure 18: Schematic of a bipolar transistor H-bridge circuit

2.4.5 Computer System

One of the computer systems that can be used is IFC as shown in Figure 19. IFC is Interface Free Controller that can be used to develop microcontroller embedded system and robotics system as well. There is no need to determine hardware interface and configuring peripheral in software if IFC is being used [19].

Figure 19: IFC Board

With functions based software library, software development can be done only concentrating on algorithm development instead of scrolling the datasheets. IFC used interfacing card concept and it may make easier because it offered as many as 64 cards to be stack in microcontroller system development. IFC come with a brain card or main controller where the main program is loaded. Several cards for robotics development which are like control panel, 15A brush motor driver, brushless motor controller, counter and digital input, output card and power card are available here. In IFC, Power card and Main Board is the minimum card required and the other several cards are stacked to get a complete embedded system. The capability of IFC with serial communication perception is the possibilities to develop the embedded system creatively and easily.

CHAPTER 3
METHODOLOGY & PROJECT WORKS

Chapter 3 discusses the detail steps or methodology implemented to complete this project. It begins with Section 3.1 which elaborates the project methodology followed by the components list that used to complete the project.

3.1 Methodology

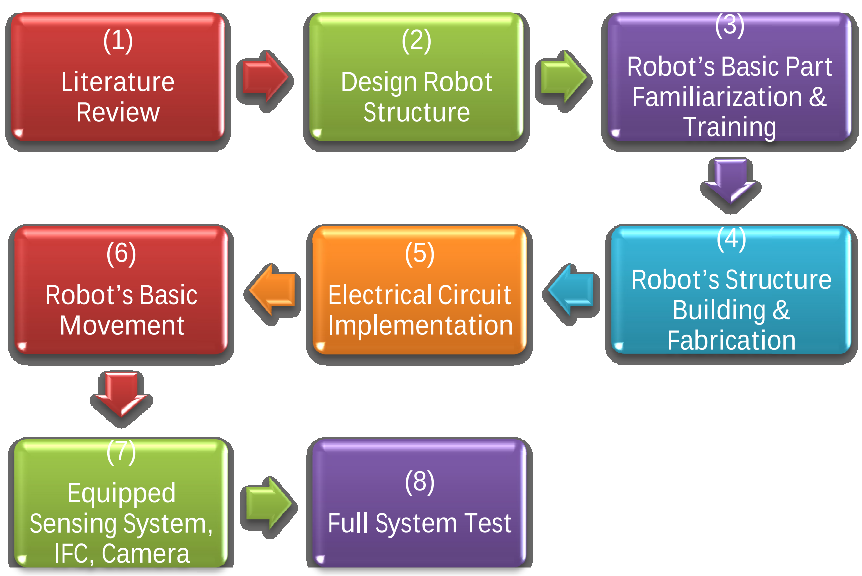


Figure 20: Project Methodology

Referring to Figure 20, the project starts with intensive literature review on the available autonomous security robot. This include information gathering from the internet, books, and conference papers. Next, the robot structure is designed and it is including for the wheel design, the size estimation of the robot, and determined all the important part of the robot that is put inside the body.

Then, the robot basic's part familiarization and also training is conducted to be able to fully understand how does they work and know how to construct them together to do perform the task that required. After has this basic, the robot structure is built and fabricated based on the earlier design.

Next, when finished with the robot structure, electrical circuit implementation is started and involves the things like driving circuit and motor implementation. The next step is doing the robot's basic movement such as forward and reversed. Then, the sensing system and IFC board is equipped to make the robot able to do the task as per required. The final product is tested and from the result, the conclusion is being analyzed for further implementation and improvement.

3.2 Basic Components

To complete the construction of the security robot, several items need to be used such as the aluminum material for structure and mechanism. The details of these components are listed as follows:

- Wheels (2)
- Aluminium alloy
- Brushless DC motor (2)
- DC motor
- IFC board
- Motor driver (2)
- Sensor (infrared, ultrasonic, thermal)
- Battery pack 12V (2)

3.3 Activities/Gantt Chart and Milestones

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic: Design and Fabrication of Autonomous Robot For Security Monitoring								Mid-semester Break							
2	Preliminary Research Work: Research on literatures related to the topic															
3	Submission of Extended Proposal															
4	Proposal Defense															
5	Robot basic part familiarization															
6	Submission of Interim Draft Report															
10	Submission of Interim Report															

Suggested milestone

Process

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Robot Structure Design and Movement Mechanism	■	■	■	■	■	■	■	Mid-semester Break								
2	Submission of Progress Report									●							
3	Electrical Circuit Implementation									■	■	■	■	■	■		
4	Pre-EDX												●				
5	Submission of Draft Report													●			
6	Submission of Dissertation														●		
7	Submission of Technical Paper														●		
8	Oral Presentation															●	
9	Submission of Project Dissertation																●

● Suggested milestone

■ Process

CHAPTER 4
RESULT AND DISCUSSION

Chapter 4 discusses on the results and discussions of this project. It can be divided into six sections. Section 4.1 elaborates the structural of the robot. In section 4.2 and 4.3, the explanation on how does motor, motor driver and IFC board functions is discussed here. Meanwhile, for section 4.4 is about all details of the sensors that have been equipped at robot. For section 4.5, the camera rotating mechanism is being explained here and the robot's working principle is in section 4.6.

4.1 Basic Structure

For the robot structure, aluminum materials are selected due to its strength and fabrication ability to build the basic parts of the robot. A stable structure is required to make sure that it can support the other important parts that will be attached to robot's body such as motor, IFC board, wheels, and sensors. The main structure of the robot is shown in Figure 21, Figure 22, and Figure 23. Figure 21 shows the 3D drawing of the robot. The overall dimension of the robot's structure is 30cm x 30cm x 30cm.

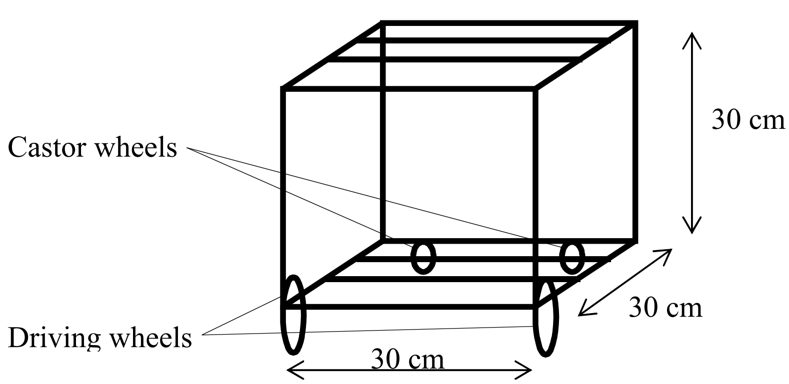


Figure 21: Robot's Base Structure Dimension

Figure 22 shows the robot base in implementation followed by Figure 23 shows the castor wheels that have been equipped at the back side of robot. This complete robot's structure in Figure 24 contains of 2 brushless DC motors, 2 wheels, 2 castors, line tracking sensors, LDR sensor, objects sensors, smoke detector, motor drivers, IFC boards, DC motor, and wireless camera.

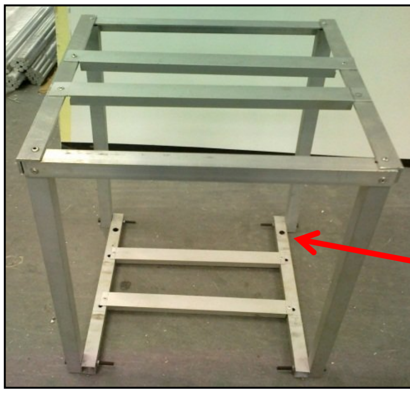


Figure 22: Robot's base in implementation

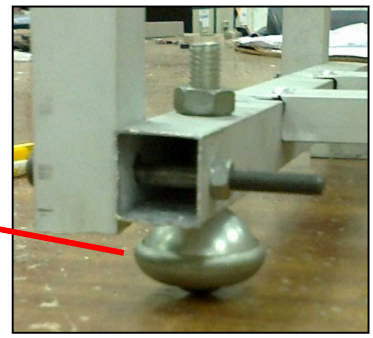


Figure 23: Castor wheel

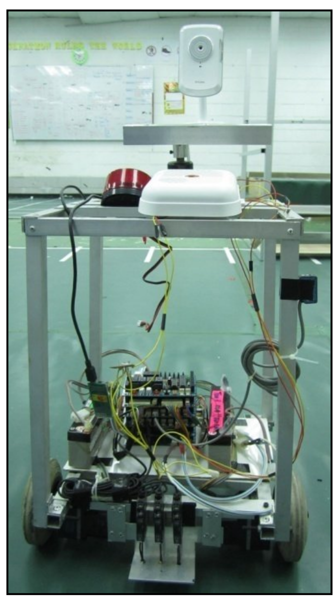


Figure 24: Complete robot's structure

4.2 Motor

Section 4.2 explains the driving mechanism which utilizes two DC motors equipped with driving wheels.

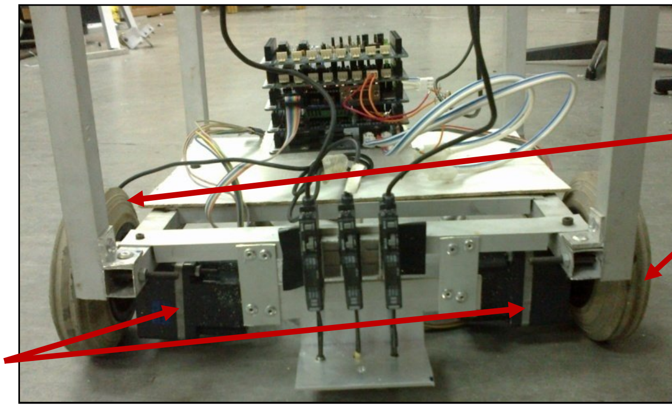


Figure 25: Motor with wheels structure

As shown in Figure 25, two wheels in front of the robot are controlled by 12 V brushless DC motor which are used for changing the direction of the robot, while the other two castor wheels are being installed at the back to make the robot easier to pivot. This design offers the stable structure of robot since it will make the robot's rotation easier.

4.3 Motor Driver & IFC Board

For robot movement, motor driver as shown in Figure 26 is installed for 12 V brushless DC motor and Figure 27 shows the IFC board. All the programming and sensors are being loaded into IFC board. The instructions to robot are being executed from IFC board to control the function as required. All of the basic parts for the robot functions are shown with functional blocks diagram in Figure 28.

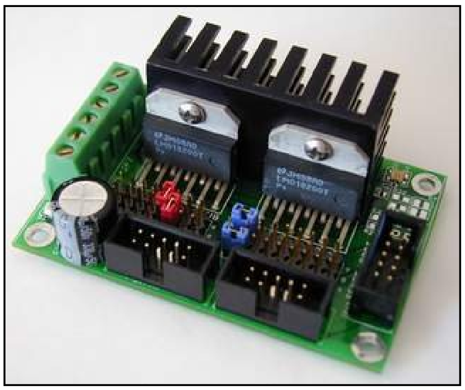


Figure 26: Motor Driver

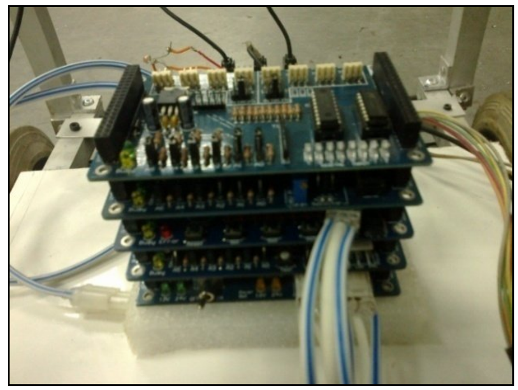


Figure 27: IFC Board

4.4

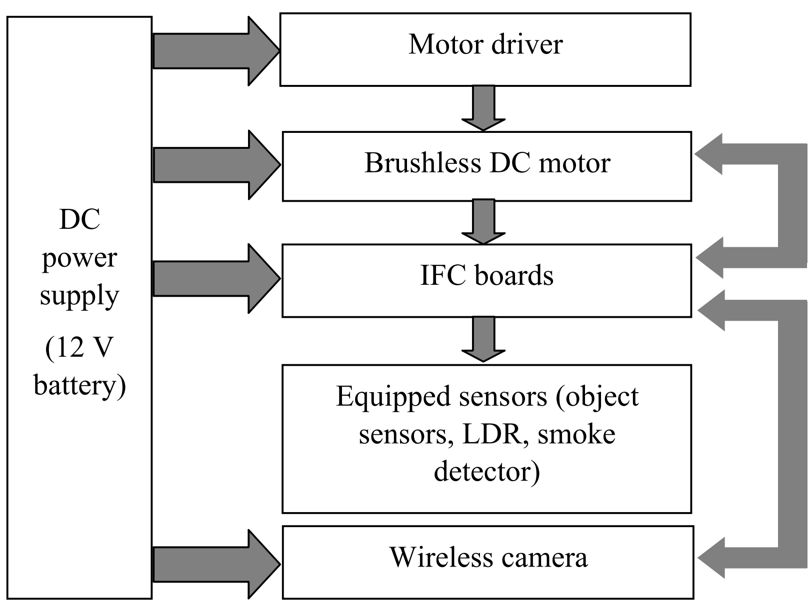


Figure 28: Functional blocks on basic parts of robot functions

4.4 Sensors

For this robot, there are four different sensors being used with the different functions which are line tracking sensors, LDR sensor, objects sensor, and smoke detector. Another additional feature which is wireless camera also included here and all the details about every single part are being explained in section 4.4.1, 4.4.2, 4.4.3, and 4.4.4.

4.4.1 Line tracking sensor

A common task for a robot is to follow a predetermined path. The path is marked with a high contrast line, such as light colour tape on a dark colour surface. Figure 29 shows the line tracking sensor at robot's body and Figure 30 shows the navigation of them.

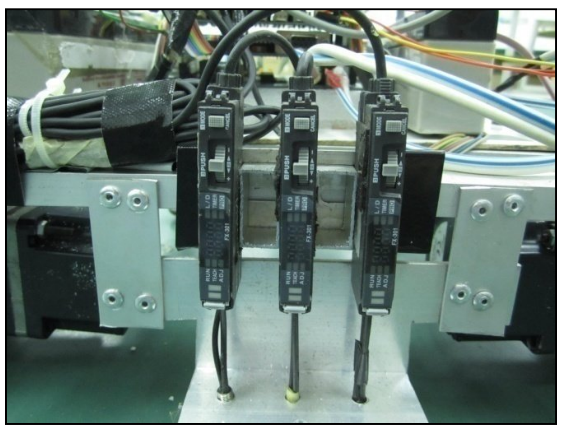


Figure 29: Line tracking sensor

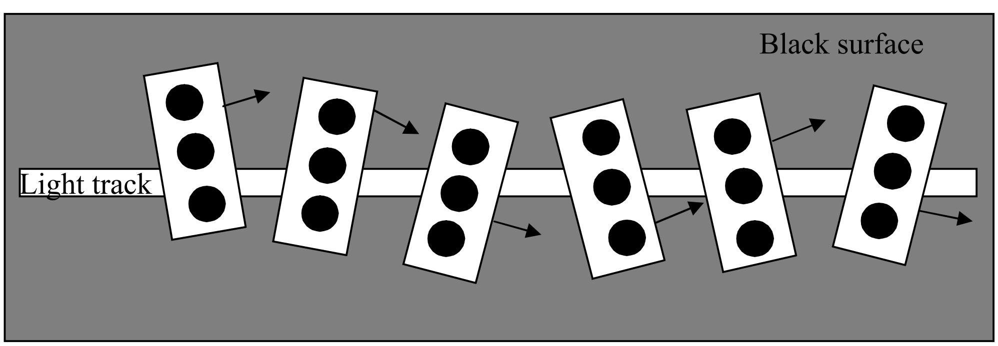


Figure 30: Example of line tracking navigation

To calibrate this line sensor, the programming language will be applied in order to determine the way on how the line sensor itself will do the correction on the line if it gets the track lost. The edges are more clearly define and the contrast between on-track and off-track are greatest with the sensor close to the track. Another thing to be considered is the number of line sensors that will be used for line tracking. For this robot, three line sensors are used to increase the accuracy of the sensor itself in order for the robot to move along by following the line at predetermined path. Its position and navigation algorithm are shown in Figure 31 and Table 1.

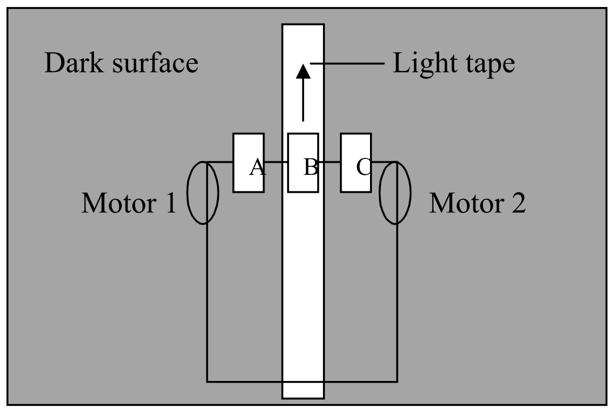


Figure 31: Line sensors position

Table 1: Line sensor navigation algorithm

Condition			Motor 1	Motor 2
A	B	C	Rotating mode	Rotating mode
0	1	0	CCW	CW
1	1	0	CCW	CW
1	0	0	CW	CW
0	1	1	CCW	CW
0	0	1	CCW	CCW
1	1	1	CCW	CW
0	0	0	-	-

* 1 : Line tracking sensor detects light tape
* 2 : Line tracking sensor detects dark surface

4.4.2 Light Dependent Resistor (LDR) sensor

First sensor that is used is LDR sensor. The additional circuit is needed to connect this LDR sensor to make it works as per required. Figure 32 shows the schematics of additional circuit LDR sensor (voltage divider) which is equipped at the robot's structure. Before constructing this circuit, the resistance of LDR sensor itself is measured to get a most possible value of resistor that will be used. For this sensor, it measured as 130 kΩ resistance. In theory, the voltage divider is most sensitive when the resistance of the fixed resistor is almost equal to the resistance of the LDR. It matters what value of fixed resistor that used in a voltage divider. Thus, the 100 kΩ resistor has been used for this voltage divider since the optimum value of fixed resistor gives the biggest changes in V_{out}.

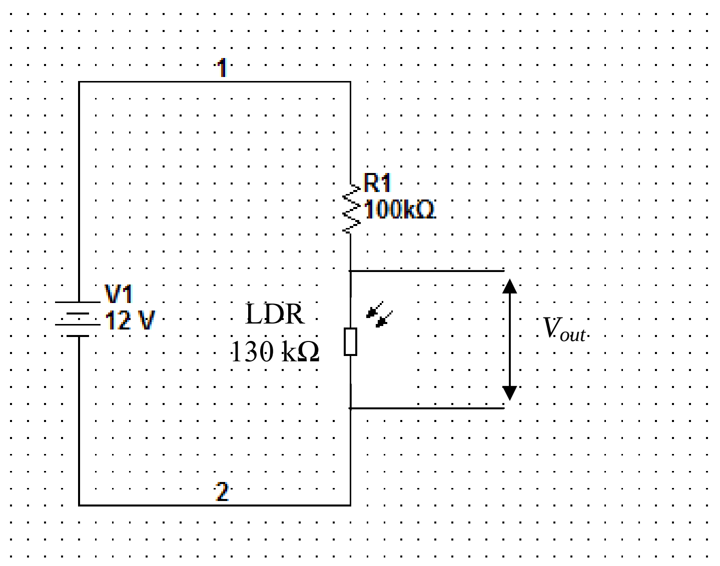


Figure 32: Voltage divider circuit diagram

The testing that has been done for LDR sensor is by placing the robot at different kind of places with different brightness. In this case, the resistance of the LDR sensor will vary. Since LDR sensor is an analogue sensor, V_{out} should be measured by multimeter at LDR sensor itself.

Control panel card is one of the cards from IFC board and acts as Human Machine Interface platform. It can be used to display the analogue value of LDR resistance instead of measuring with a multimeter. Referring to the Table 2, the control panel display value is the value where it displays in 0 – 255 range. For LDR sensor testing, the higher value means that the darker the place will be and vice versa.

Table 2: LDR testing data

Condition	Control Panel Display Value
Without Room Light (Night)	88
Without Room Light (Daylight)	49
Single Room Light	7
Double Room Light	6

From this value, the calculation can be made to solve for the voltage (V) that is measured at the LDR sensor itself. General Equation (1) to measure voltage at LDR sensor is as shown below:

$$V_{out} = \frac{R_{LDR}}{R_{LDR} + R_{resistor}} \text{ x } V_{in} \quad (1)$$

Since we used control panel and it displays the analogue value which is in range 0 – 255, another formula as shown below (2) is applied by calculating the value ratio:

$$V_{out} = \frac{x}{255} \text{ x } 5\,V \quad (2)$$

1. Without room light (night):

$$V_{out} = \frac{88}{255} \text{ x } 5\,V \quad (3)$$
$$= 1.725\,V$$

2. Without room light (daylight):

$$V_{out} = \frac{49}{255} \text{ x } 5\,V \quad (4)$$
$$= 0.961\,V$$

3. Single room light:

$$V_{out} = \frac{7}{255} \text{ x } 5V \quad (5)$$
$$= 0.137\ V$$

4. Double room light:

$$V_{out} = \frac{6}{255} \text{ x } 5V \quad (6)$$
$$= 0.118\ V$$

From the testing result, it can be concluded that, when the brightness of particular area is decrease, the resistance of LDR is increase, while V_{out} is also increase. Figure 33 below shows the graph of V_{out} vs LDR Resistance based on the LDR testing data.

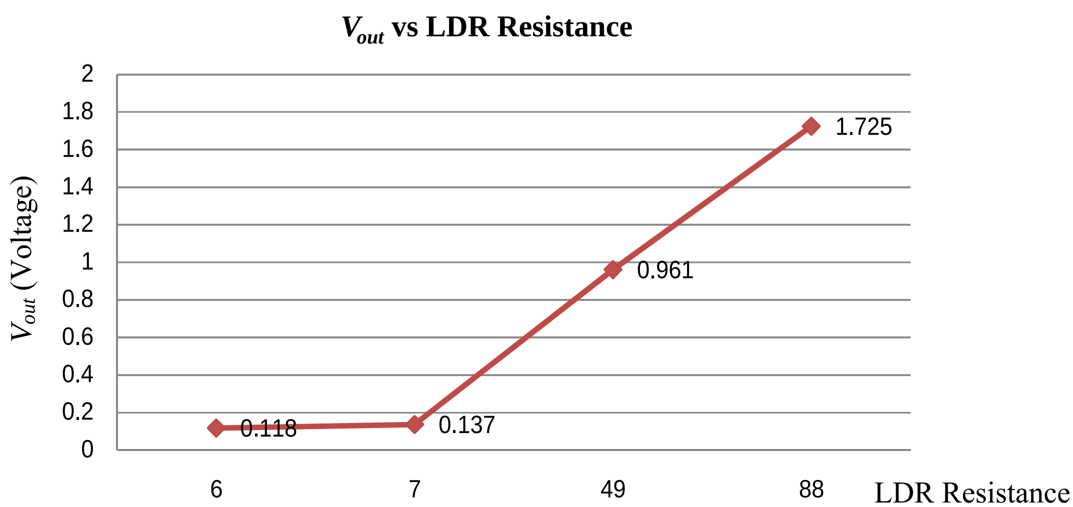


Figure 33: V_{out} vs LDR Resistance

From the graph, when the robot is placed in room without light at night, the value of LDR resistance is the highest and V_{out} is 1.725 V. Meanwhile, when it is placed in room with light, the value of LDR resistance is the lowest and V_{out} is 0.118 V.

4.4.3 Object Sensor

The second sensor that is equipped to this robot is object sensor to detect the presence of nearby objects without any physical contact. There are two object sensors that have been equipped to this robot. Object Sensor I function is to detect the wall or room door in certain range of distance. The different distance testing data for Object Sensor I is shown in Table 3.

Table 3: Object sensor testing data

Sensing Distance (cm)	Detectable	Motor Condition
20	Yes	Rotating
40	Yes	Rotating
60	Yes	Rotating
80	Yes	Rotating
100	No	Stop
120	No	Stop

Testing data shows that the maximum distance of Object Sensor I is 80 cm. If the wall is exceeding this distance range, sensor cannot detect the presence of that wall. This concept is applied for the door opened detection. Object Sensor I will detect the door opened since it cannot detect the presence of the door wall nearby if the door is opened. For Object Sensor II that has been equipped to detect poles at three different zones that located at testing area, the principles are:

1. If it detects the first pole at robot testing zone, it will indicate that the robot is now at Zone 1 and Object Sensor I will be activated in order to detect the door at that particular area.
2. If it detects the second pole at robot testing zone, it will indicate that the robot is now at Zone 2 and LDR sensor will be activated in order to detect the room light at that particular area.
3. If it detects the third pole at robot testing area, it will indicate that the robot is now at Zone 3 and smoke detector will be activated in order to detect the smoke at that particular area.

4.4.4 Smoke Detector

The third sensor that has been equipped for this robot is smoke detector. Smoke detector is used to detect if there is any smoke at that particular area. Usually, the smoke sensor triggered alarm and buzzer on when it detects smoke, but for this robot, it needs to send the signal into the IFC board and then the motor has to respond according to instruction from IFC board afterwards. This smoke sensor needs to be modified since the output that measured at the buzzer is only 0.3 V which is not enough to supply to the motor. The additional circuit which is called amplifier is constructed and the circuit diagram is being shown in Figure 34.

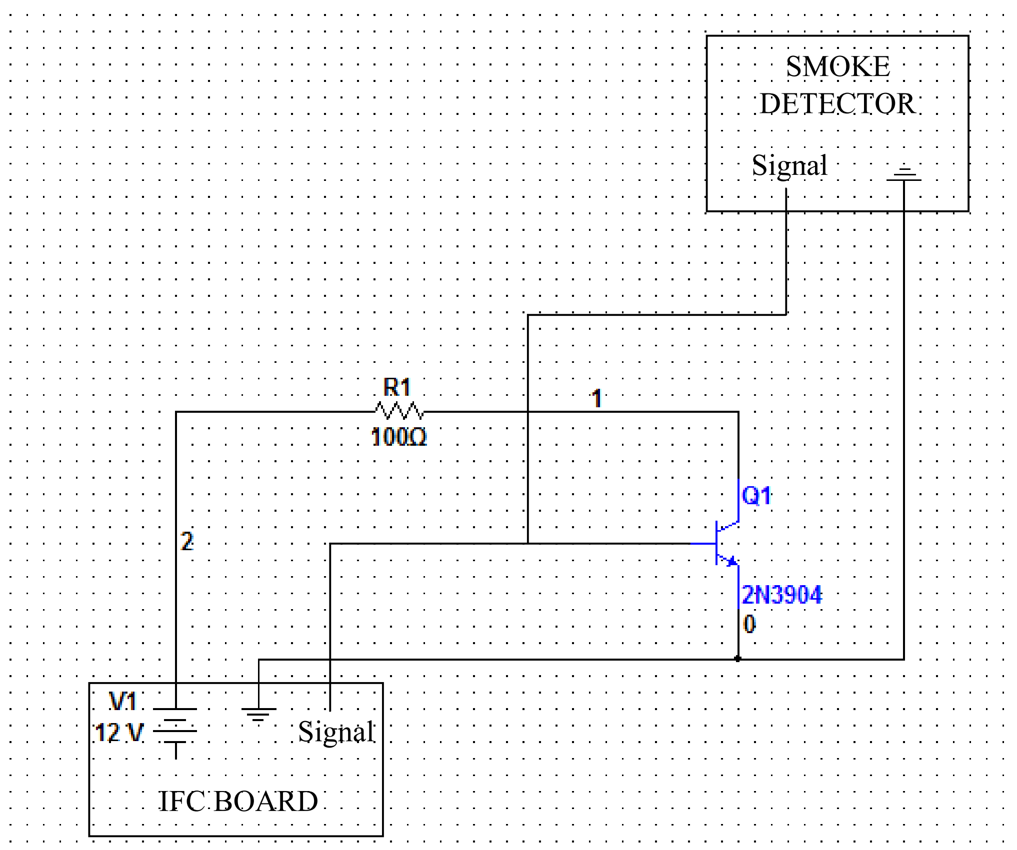


Figure 34: Smoke detector amplifier circuit diagram

After modification, V_{out} is measured and only then the output would be in 5 V. The signal from buzzer has been sent to the IFC board and from here, it gives the instruction to the motor. Apparently, the motor will keep on rotating when there is no smoke detected and stop when there is smoke at particular area.

4.5 Wireless Camera with Rotating Mechanism

One last additional feature to this robot is the wireless camera that is used by human to monitor the particular area from certain distance. This wireless camera is equipped with the rotating mechanism on the robot itself so that, when any of these three sensors (object sensor, LDR sensor, and smoke detector) detect something dangerous at that particular place, the camera will rotate in order to get the wider vision to get the information for the human to take the action afterwards. The wireless camera and its rotating mechanism are being shown in the Figure 35 and Figure 36.

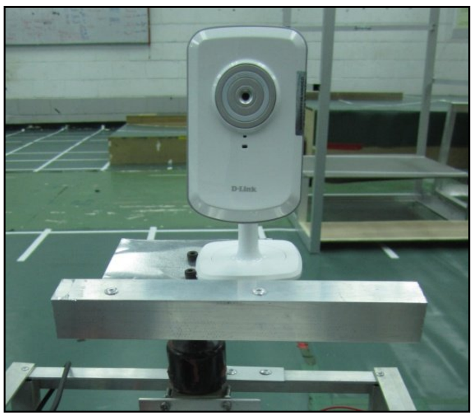


Figure 35: Wireless camera

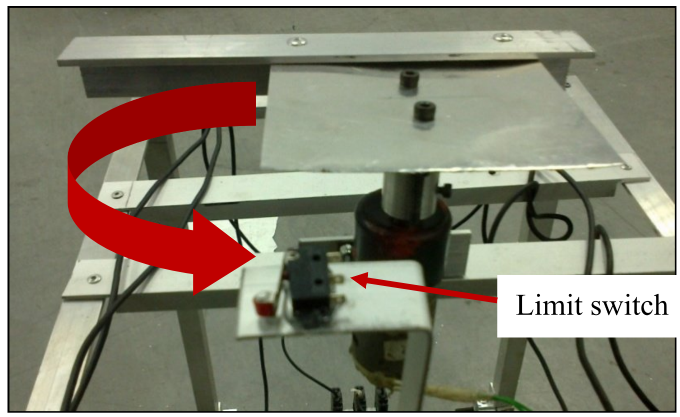


Figure 36: Rotating mechanism

The camera can be controlled by using a DC motor and is placed on the top of robot's body on the small aluminum plate. The purpose of locating the wireless camera on the top of robot is to make sure that people can monitor the particular area from far in certain range. The advantage of the rotating mechanism on robot is it can provide a wider vision of monitoring because it will make the camera rotated 180^o instead of static. After rotating for 180^o counter clockwise, the limit switch is used to stop the motor from rotating in clockwise direction. Then, the motor will change it direction to rotate for 180^o clockwise. The testing for this camera has been conducted in order to test the maximum distance between wireless camera and laptop. The table from this testing is shown in Table 4.

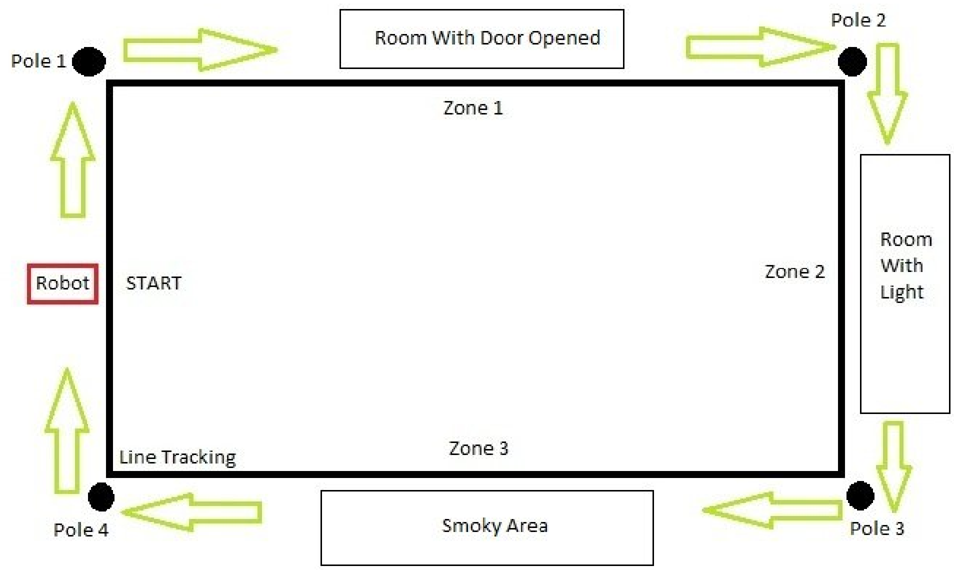
Table 4: Testing distance between wireless camera and laptop

Distance (m)	Image Availability	Internet signal
2	Available	Strong
4	Available	Strong
6	Available	Strong
8	Available	Strong
10	Not available	Weak

From Table 4, it can be concluded that, to access this wireless camera, the internet connection signal must be strong enough to let the laptop received the image from wireless camera. The requirement for full vision monitoring using this method is a stable network connection.

4.6 Robot's Working Principle

To do the full system test, this robot has been placed and testing at the robot test zone area as shown in Figure 37. Robot's working principle is being described respected to this figure.



*All Poles are detected by Object Sensor II

Figure 37: Robot test zone

1. Robot moves from the start zone approaching towards Pole 1
   - Object sensor I is activated and detected room with door opened
   - Robot stopped and camera started rotating to send image through laptop
   - Continue to move after the door are being closed
2. Robot moves approaching Pole 2
   - LDR sensor is activated and detected room with light
   - Robot stopped and camera started rotating to send image through laptop
   - Continue to move after the light are being switched off
3. Robot moves approaching Pole 3
   - Smoke detector is activated and detected the smoky area
   - Robot stopped and camera started rotating to send image through laptop
   - Continue to move after the light are being switched off
4. Robot moves approaching Poles 4 and stopped

The objective of flowchart in Figure 38 is to explain about the robot navigation and its outcome when there are different possibilities that occur when the full testing is run.

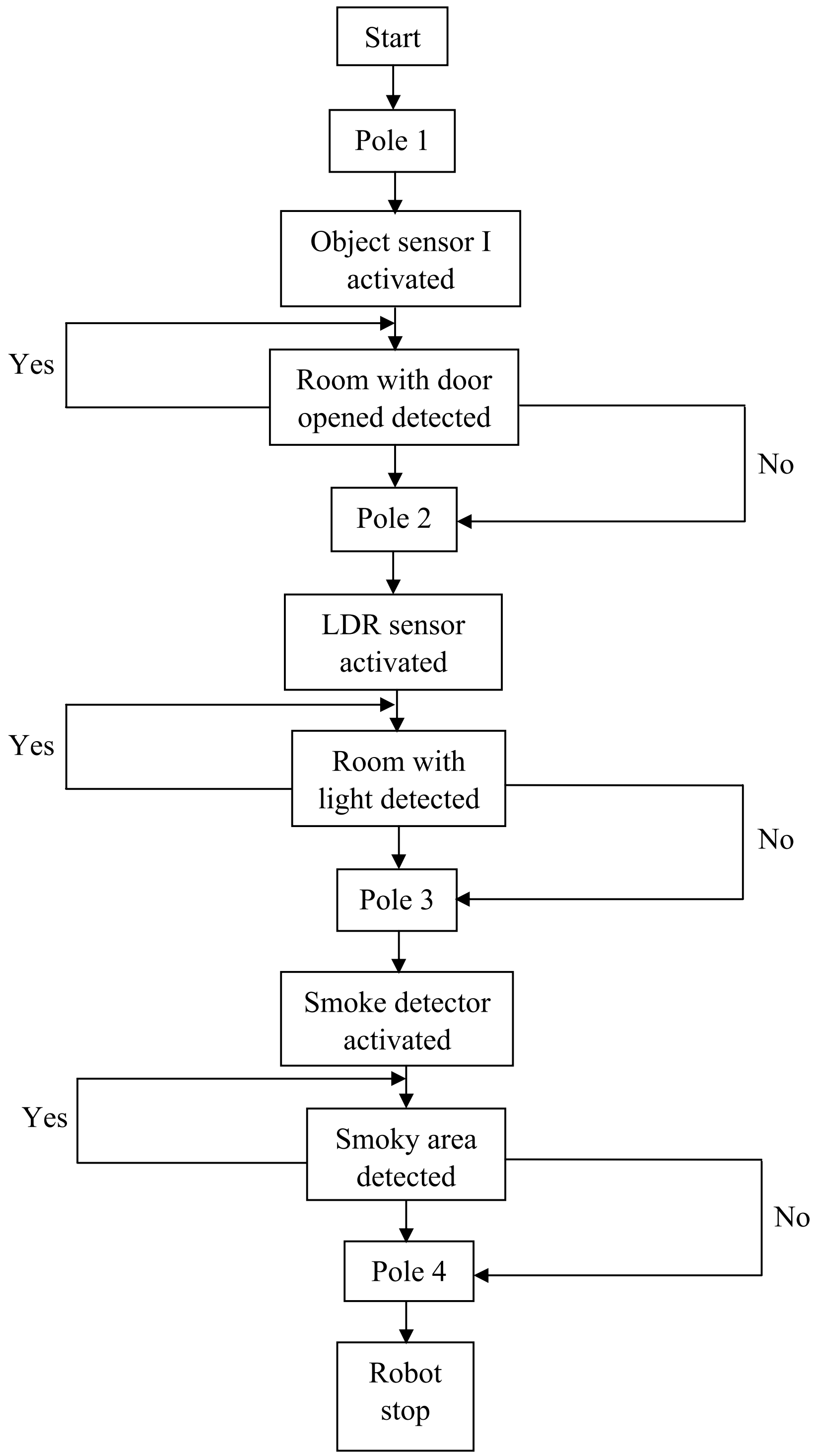


Figure 38: Robot navigation functional block diagram

CHAPTER 5
CONCLUSION

This project involves in designing and fabricating the autonomous security monitoring robot. The new system will improve the existing method of security monitoring system by incorporating certain intelligent into the robot such as anti theft system, room light detection, and smoke detector. It is not only able to move according to a predetermined plan while doing security monitoring, but also able to give vision through the wireless camera to the security guards to have the information about which area is robot in and what kind of situation is it having there.

The smart robot can be divided into several sections such as the main structure, driving mechanism, sensors, and computer system. In order to evaluate or determine the overall performance of the robot, each section is characterized separately. For the structural part, the characterization involve in building the basic structure part of the robot. Next for driving mechanism, this project utilizes two DC motors equipped with driving wheels. For the sensors, this project has equipped with object sensor, LDR sensor, and smoke detector. One of the additional features is wireless camera that used for vision monitoring. Lastly for computer system, this project uses IFC board as a robot’s brain to execute any instructions that required through programming.

For future development of similar system, the current security robot can be further improved which can be summarized as follows:

- The robot should have its own user interface in order for people to use this robot manually.
- To ensure this robot will operate smoothly during monitoring, the programming need to be improved so that there will be more specific instructions included.
- The sensors that have been equipped at the robot can be upgraded in term of performance and sensitivity to ensure the robot can response faster according to requirement.
- It is suggested that UTP can provide the complete structure of robot and then only proceed with electrical related part to save some time and decrease the mechanical defects on the robot compared with the robot that is totally build by student.

REFERENCES

[1] Autonomous Robot, 13 July 2012, <http://en.wikipedia.org/wiki/Autonomous_robot>

[2] Autonomy, 19 July 2012, <http://en.wikipedia.org/wiki/Autonomy>

[3] Electromechanics, 19 July 2012, <http://en.wikipedia.org/wiki/Electromechanics>

[4] Robotics, 20 July 2012, <http://en.wikipedia.org/wiki/Robotics>

[5] Robot, 23 July 2012, <http://en.wikipedia.org/wiki/Robot>

[6] Aibo, 30 July 2012, <http://en.wikipedia.org/wiki/Aibo>

[7] Triangulation, 30 July 2012, <http://en.wikipedia.org/wiki/Triangulation>

[8] A Robot to Help Make the Rounds, 1 August 2012, <http://www.sti.nasa.gov/tto/spinoff2003/hm_4.html>

[9] A.Buonanno, M. D'Urso, M. Mattei, E. F. Meliado, and V. Scordamaglia, "Robotic Sensor Networks for Security", Napoli, Italy.

[10] Cruise Missile, 2 August 2012, <http://en.wikipedia.org/wiki/Cruise_missile>

[11] Homeland Security, 2 August 2012, <http://en.wikipedia.org/wiki/Homeland_Security>

[12] Robot Application By Industries, 5 August 2012, <http://www.robotmatrix.org/RobotApplicationByIndustrial.htm>

[13] Robotic Surgery, 5 August 2012, <http://en.wikipedia.org/wiki/Robotic_surgery>

[14] How Military Robots Work, 9 August 2012, <http://science.howstuffworks.com/military-robot.htm>

[15] Salah Sukkarieh. 2009, "Aquatic Weed Surveillance Using Robotic Aircraft", The University of Sydney, Australia, <http://fedpub.ris.environment.gov.au>

[16] Jung-Moo Seo, Se-Hyun Rhyu, Joo-Han Kim, Jun-Hyuk Choi, In Soung Jung, Senior Member, "Design of Axial Flux Permanent Magnet Brushless DC Motor for Robot Joint Module", *International Power Electronics Conference*, 2010.

[17] Ching-Chih Tsai, Shu-Min Shish, Hsu-Chih Huang, Min-Yu Wang, Chih Chung Lee, "Autonomous Navigation of an Indoor Tour Guide Robot", *IEEE International Conference on Advanced Robotics and its Social Impacts,* 2008.

[18] Utkarsh, 3 August 2010, <http://www.aishack.in/2010/08/simple-motor-driver-circuit/>

[19] Robot Shop, 10 August 2012, <http://www.robotshop.com/world/content/PDF/users-manual-ifc-eb02.pdf>

[20] Rafael Falcon, Xu Li, and AmiyaNayak, "Carrier-Based Focused Coverage Formation in Wireless Sensor and Robot Networks", *IEEE Transactions on Automatic Control*, vol. 56, 2011.

[21] JordiPalacin, Jose Antonio Salse, IgnasiValganon, and XaviClua, "Building a Mobile Robot for a Floor-Cleaning Operation in Domestic Environments", *IEEE Transactions on Instrumentation and Measurement,* vol. 53, no. 5, page 5, 2004.

[22] R. C. Luo, Jian-Xian Li, Cheng-T Chen, "Indoor Localization Using Line Based Map for Autonomous Mobile Robot", *IEEE International Conference on Advanced Robotics and its Social Impacts,* 2008.

[23] H-Bridge Motor Using Bipolar Transistors, 13 August 2012, <http://www.robotroom.com/BipolarHBridge.html>

}

APPENDICES

C PROGRAM CODE

```
if(!cps1)
{
while(1)
{
        cp1_goto(0,0);

        cp1_dec(an2,3);
}
}

if(!cps2)
{
pole=0;
while(1)
{

while(pole==0)                          //no sensor
{
cp1_goto(0,0);

cp1_dec(pole,3);
linetrack_a(20,20);
}

while(pole==1)                          //wall sensor
{
        cp1_goto(0,0);

        cp1_dec(pole,3);
        if(sen5)                //no wall
        {
        brake1;brake2;
        ccw3;pwm3(100);
        room();
        scan();
        }
```

```
        else
        {
        linetrack_a(20,20);
        stop3;
        room();
        }
}

while(pole==2)                              //light sensor
{
        cp1_goto(0,0);

        cp1_dec(pole,3);
        if(an2<10)                          //light on
        {
        brake1;brake2;
        ccw3;pwm3(100);
        room();
        scan();
        }
        else                                //light off
        {
        linetrack_a(20,20);
        stop3;
        room();
        }
}

while(pole==3)                              //smoke sensor
{
        cp1_goto(0,0);

        cp1_dec(pole,3);
        if(an3<40)                          //smoke
        {
        brake1;brake2;
        ccw3;pwm3(100);
        room();
        scan();
```

```
		}
		else						//no smoke
		{
		linetrack_a(20,20);
		stop3;
		room();
		}
	}

	if(pole==4)					//end
	{break;}


	}
	brake1;brake2;
	}

	if(!cps3)
	{
		scan();
	}

	if(!cps4)
	{
	while(1)
	{
		cp1_goto(0,0);

		cp1_dec(an2,3);
		cp1_goto(0,7);

		cp1_dec(an3,3);
	}
	}



	}


}
```

```
void room(void)
{
        if(pole==0)
        {
        led=0;
        }
        if(pole==1)
        {
        led1=1;
        }
        if(pole==2)
        {
        led2=1;
        }
        if(pole==3)
        {
        led3=1;
        }
        if(pole==4)
        {
        led4=1;
        }
}

void scan(void)
{
        while(sen4)
        {
                ccw4;pwm4(18);
        }
        brake4;
        cw4;pwm4(18);
        delay(450000);
        brake4;
}


void juncount (void)
```

```
{
	int check;
	int valid=0;

	for(check=0;check<5;check++)
	{
		delay(100);
		if(!sen1&&!sen2&&!sen3&&!sen4&&!sen5)
		{
			valid++;
		}
	}
	if(valid>3)
	{
		while(1)
		{
			if(sen1||sen5)
			{
				buzzer=1;
		delay(100000);
		buzzer=0;
				delay(10000);
				junc++;
				break;
			}
		}
	}
}
void last_action (int c, int d)
{
	cw1; ccw2;

	if(last_act==0)
	{
		pwm1(c); pwm2(d);
	}
	if(last_act==2)
	{
```

```
			pwm1(c+20); pwm2(d-35);
		}
		if(last_act==1)
		{
			pwm1(c-35); pwm2(d+20);
		}
}
void junclinetrack_c(int p, int q, int r)
{
		while(junc<p)
		{
		while(p<3)
		linetrack_a(q*p,r*p);
		while(p<5)
		linetrack_a(q,r);
		linetrack_a(q,r);
		}
		junc=0;
		brake1;brake2;

}



void junclinetrack_b(int p, int q, int r)
{
		while(junc<p)
		linetrack_a(q,r);
		buzzer=1;
  delay(300000);
  buzzer=0;
		brake1;brake2;
		delay(10000);
		clr1;
		while(enc1<800)
		linetrack_a(30,0);
		while(1)
		linetrack_a(q,r);
		junc=0;
```

```
		brake1;brake2;
}
void junclinetrack_a(int p, int q, int r)
{
		while(q<230)
		{
		while(enc1<300)
		linetrack_a(q,r);
		buzzer=1;
   delay(100000);
   buzzer=0;
		q=q+20;r=r+20;
		clr1;
		}
		while(junc<p)
		{
		linetrack_a(q,r);
		if(enc1>300)
		{
		q=q-15;r=r-15;
		clr1;
		}
		}
		junc=0;
		brake1;brake2;

}
void linetrack_a (int c, int d)// speed not more than 225
{
		if(sen6&&!sen7&&sen8)				//010
		{
			ccw1;cw2;
			pwm1(c);pwm2(d);
		}
		if(!sen6&&!sen7&&sen8)				//110
		{
			ccw1;cw2;
			pwm1(c);pwm2(d+6);
```

```
}

if(!sen6&&sen7&&sen8)                    //100
{
        cw1;cw2;
        pwm1(c);pwm2(d);
}

if(sen6&&!sen7&&!sen8)                   //011
{
        ccw1;cw2;
        pwm1(c+6);pwm2(d);
}

if(sen6&&sen7&&!sen8)                    //001
{
        ccw1;ccw2;
        pwm1(c);pwm2(d);
}

if(!sen6&&!sen7&&!sen8)                  //111
{
        ccw1;cw2;
        pwm1(c);pwm2(d);
}

if(sen6&&sen7&&sen8)
{
while(1)
{
        ccw1;ccw2;
        pwm1(c);pwm2(d);
                if(!sen6)
                {
                        break;
                }
}
brake1;brake2;
```

```
		delay(50000);
		}

		if(!sen1)
		{
			while(1)
			{
				if(sen1)
				{
					pole++;
					break;
				}
			}
		}

	}
```