DESIGN AND FABRICATION OF AUTONOMOUS VEHICLE FOR LETTER/PARCEL DELIVERY

By

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FINAL PROJECT REPORT

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CERTIFICATION OF APPROVAL

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Approved:

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June or December 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.

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Nur Amalina Abdullah

ABSTRACT

In our everyday life, robots have been playing a big role in helping human with many kinds of works. Autonomous robots are being used in the industry, military, medical and also as a help in our everyday chores. In our everyday lives, sending parcels and letters around office can be a hectic work if the area of delivery is large. Distributing parcels and letters in an office area is a simple work yet carrying something from a place to another can be time consuming and also tiring. The objective of this project is basically to design an autonomous robot that can function as a delivery robot to help distribute parcel and letters to specific addresses assigned. The robot is able to navigate its movement in order to complete the task, which is to deliver parcel and letters to the assigned location using line tracking sensors. The robot is also equipped with a few mechanisms which are pulley system and chain mechanism and in order to ensure that the robot can execute its task, programming work is also needed. For this project, the autonomous mobile is equipped with two brushless dc motor and three line tracking sensors for the movement and also two power window motors for the pulley system and also three object sensors that will help the robot to transfer the parcels and deliver them to their rightful owners.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

The first commercial robot was developed in 1961 and used in the automotive industry by Ford. The robots were principally intended to replace humans in monotonous, heavy and hazardous processes [1]. In today's world, stimulated by economic reasons, robot has become a part of everyday life. They help human to build cars, clean homes and even perform surgery. The world of robotics develops from time to time and today, the robots are complex and capable of doing jobs that human cannot do or human do not want to. Even the basic type of robot can save a lot of time and money in the long run. Robots today can help human to do chores everyday in household or even do delivery in office environment. In this project, to be able to develop the mechanism of the robot, we first have to study the existing mechanisms, sensors, and controllers then compare the benefits and disadvantages.

1.2 Problem Statement

Sending parcel and letters around office can be a repetitive and boring work. It also can be a hectic work if the area of delivery is big. Distributing parcels and letters in an office area is a simple work and hiring a person to do the simple job is a loss to a company. Regardless of the simple task, carrying something from a place to another can be time consuming and also tiring. The challenge to complete the autonomous mobile robot for parcel delivery system is to make sure that the robot can store and carry the parcel safely and send it to the rightful owner and drop the parcel in such manner that will not damage any items in the parcel should there be any fragile objects.

1.3 Objectives of Study

The objectives of this project are;

- to design an autonomous robot that can function as a delivery robot to help distribute parcel and letters to specific addresses assigned. This includes designing the dynamics, mechanics, perception, sensor fusion, localization, path planning and navigation
- to construct a robot that can navigate its movement using line tracking sensors in order to complete the task, which is to deliver parcel and letters to the assigned location

1.4 Scope of Study

The scope of study mainly can be divided into a few sections such as literature review that begins with a research and reading on the history and the latest technology applied in robotics world. Besides that, understanding the mechanism that are used in robot to enable them to operate as per designed is very important. In addition, this project also requires deep understanding and a lot of programming work in the IFC(Interface Free Controller) board. Fabricating the robot requires knowledge on the selection material and also hands on work on the mechanical part.

1.5 Relevancy of the Project

In our everyday life, simple tasks like sweeping the floor or sending letters to an office mate that sits at the other end of the office is not a big task if only that task is needed to be done once. But in a busy environment, an autonomous mobile robot that can do delivery is a good solution and also gives profit in the long run. In an office, delivery can encompass a great many things. Large companies might need someone to carry interdepartmental mail throughout the building. Automating these deliveries can save many workers the time and will eventually money of the company. In addition, the mobile autonomous can work on its own without supervision from human. Thus, the autonomous mobile robot for parcel delivery system is a good help in everyday's life as a help and ease the distributing parcels and letters in an office surrounding.

1.6 Project Feasibility

Within two semester period of time, this project has to be done. For that kind of purpose, all activities need to be planned and scheduled systematically. This project is planned to be divided into two semester works where during the first semester, the objective is to finish the structure of the robot, and also finish the driving system for the robot. By the end of semester one, the robot should be able to move around. The full prototype which includes programming, sensors and other working mechanisms will be finished on the second semester.

CHAPTER2

LITERATURE REVIEW

2.1 Introduction

Robot can be defined as “A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks.” This definition is taken from Robot Institute of America 1979. While there is no standard definition of “robot”, the simplest way to define a robot could be “a mechanism which moves and reacts to its environment [1].

Not all the things that move or looks like a robot can be considered as robot. There are certain characteristics that a machine must obey before it can be counted as robot which are;

- sensing:

  A robot needs to be able to sense its surrounding. This can be done through light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears) and taste sensors (tongue).

- movement:

  A robot needs to be able to move around its environment and this can be done either by walking on legs or by rolling on wheels. To be counted as robot, the movement is either the whole robot moves or just parts of robot moves, for example, the arm.

- energy:

A robot needs to be able to power itself. There are many ways to power up a robot. It might be a solar powered, electrically powered, or battery powered. The way the robot gets its energy usually depends on what the task of the robot.

- intelligence:

A robot needs to be "smart". This can be done with programming. A programmer is the person to give the robot its "smart" and the robot will have to have some ways to receive the program and execute its tasks.

2.2 History

The word "robot" was first used by Karel Capek (1890-1938) he was a Czech playwright and the word robot comes from the word 'robota' which is a Czech word for worker or drone. This word is used in a play called "R.U.R" (Rossum's Universal Robot) written by Karl Capek circa 1990 [2].

Due to the development of automatons in the seventeenth and eighteenth centuries, robots have gotten bad reputations because of misconceptions. During the time, robots were given an appealing human shape because they are introduced to upper levels of society. For example, a robot chamber orchestra was introduced to the court of Marie Antoinette took form of a miniature replica of three musicians playing string instruments which are violins, cello and double bass [1].

One of the highest functioning types of automatons was the one created by Jacques Droz as seen in Figure 1 [3]. Droz's machine could play musical instrumental and draw phrases and artwork.

Figure [1]: From left the Droz Drawer, the Droz Musician and the Droz Writer

Because of the bad reputation and perception, thus came the three laws of Robotics (1942). This law stated that;

1. A robot may not injure a human being, or through inaction, allow a human being come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the first law.
3. A robot must protect its own existence as long as protection does not conflict with First and Second Laws.

2.3 Robot Applications

There are many applications of robot that we can see in our everyday life. Robots are being used to do dirty, dull and dangerous jobs. Robots have been applied into our daily life to ease the task in our daily lives since humans have limits and also need rest. The application of robots can be divided into several fields which are military, medical, space exploration and service as illustrated in Figure 2.

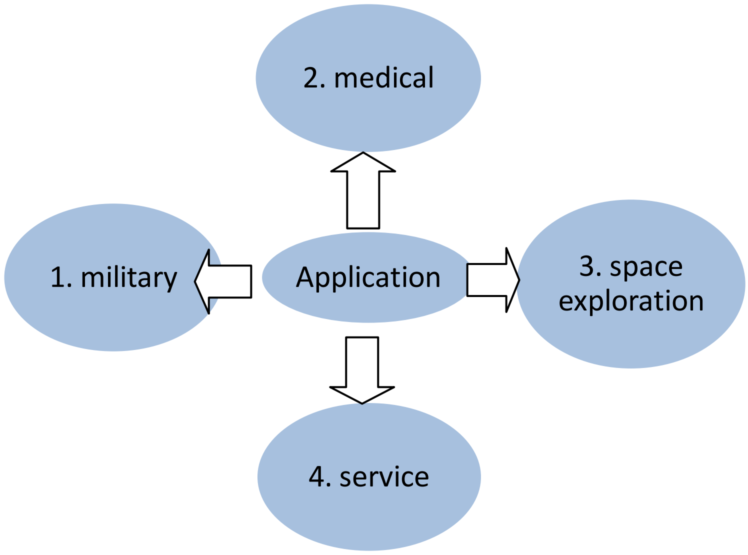


Figure [2]: Application of robots in various fields

- Military

The robot's applications in military have brought many advantages since the capabilities of the robots are better than human. For example the Predator drone as seen in Figure 3 [4] is capable to take surveillance photographs and also launch missiles at ground targets accurately without pilot.

Figure [3]: Predator Drone

Surveillance robots are also used in military to detect hostage and survivor rescue, illicit drug raids, and responses to nuclear, chemical or toxic waste contamination. Secret autonomous surveillance in tightly constrained space is also needed in many missions.

- Medical

In medical field, robots are critical where extreme precision and slim error margin is needed. In surgeries, robots are used to perform major operations by making small incisions. Robots are also able to perform heart surgery without opening patient's chest. Pregnant humanoid robots are used to test medical students and also to prepare students for various birth complications.

- Space exploration

Robots are playing a very important role for outer space exploration. The robotic unmanned spacecraft is the key of exploring the stars and other planets. For example the Twin Mars Rovers as seen in Figure 4 [5] which is used to examine the texture, colour, mineralogy and structure of the local terrain with a panoramic camera attached to it.

Figure [4]: Twin Mars Rovers

- Service

The most common application of robots is as a help to everyday chores. The examples of intelligent home applications are home security monitor and energy usage controller. Domestic or household robots include many different devices such as 'Roomba' as seen in Figure 5 [6] which is the robotic vacuum cleaner.

Figure [5]: ‘Roomba’ the autonomous robot vacuum cleaner

2.4 Autonomous Robot

Autonomous robot can be defined as robots that can move around to do desired tasks without continuous human guidance. A fully autonomous robot should have the ability to gain information about the environment, work for extended period without human intervention, move either all or part of itself throughout its operating environment without human assistance, avoid situations that are harmful to people, property or itself unless those are part of its design specifications and maintain its owns survival at the expense of the previous rules.

First electronic digital autonomous robot was created by William Grey Walter, as seen in Figure 6 [7]. He built one of the first robotic tortoises in 1940’s. Walter gave names to his robots. The first two robots were Elmer, as seen in Figure 7 [7] and the other one was named Elsie. These two robotic tortoises were later dissembled to create another 6 tortoise.

Figure [6]: Dr. William Grey Walter

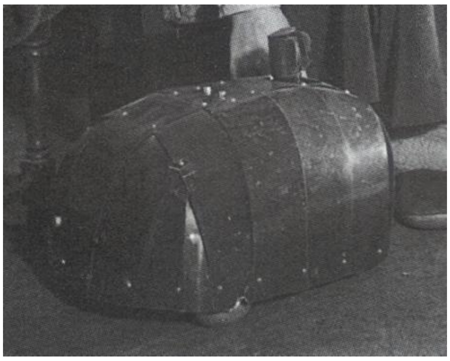


Figure [7]: ELMER (Electro- Mechanic Robot)

Autonomous mobile robot basically means robot that can move around and these robots can be classified by the environment which they travel:

1. Humanoid: Land or home robots which are most commonly wheeled but also include legged robots with two or more legs. For example, robot Honda ASIMO as seen in Figure 8 [8] and robot Nao as seen in Figure 9 [9] which is a robot created to compete in RoboCup soccer championship.

Figure [8]: Honda ASIMO

Figure [9]: Robot Nao

2. Unmanned aerial vehicles (UAVs): Aerial robots

UAV are aircraft that fly without human crew on board and will be reused for future use different from missile that is intended to be fired just once. It is used mainly for military. The example of UAVs is as seen in Figure 10 [10].

Figure [10]: Unmanned aerial aircraft (UAF)

3. Autonomous underwater vehicles (AUVs): Underwater robots

AUV range from small to extremely large and works extremely well when it comes to the duty they are created to fulfil which can be for commercial purpose in oil and gas exploration, for military purpose where is used to find out whether there are any booby-traps set in the ocean and also for research and exploring purpose. For example, Figure 11 [11] shows the Navy UAV Talisman.

Figure [11]: Navy UAV Talisman

2.5 Parts of Robot

For a machine to of any kinds and sizes to be considered as robot, it should have five parts of components that work together which are the controller, the manipulator (arm), an end effector, sensor and also a driving system.

1. Controller

"Every robot is connected to a computer, which keeps the pieces of the arm working together. The computer is known as the controller and function as brain of the robot. Controller also allows the robot to be networked to other systems, so that it may work together with other machines, process or robots.

Robots today have controllers that are run by programs. The controller is where the instructions were written. Almost all robots of today are entirely pre-programmed by people. They can do only what they are programmed to do at the time and nothing else. In the future, controller with artificial intelligence or AI could allow robot to think on their own, even program themselves. This could make robots more self-reliant and independent.” [12]

Controller is the part of robot that coordinates all movements of the mechanical system. The heart of a robot’s controller is a microprocessor linked to input/output and monitoring devices. The command given by the controller activate the motion control mechanism, consists of various controllers, amplifiers and actuators.

2. Manipulator (arm)

“ Robot arms come in all shapes and sizes. The arm is the part of the robot that positions the end effector and sensors to do their pre-programmed business.

Many but not all manipulators resemble human arms, and have shoulders, elbows, wrists, even fingers. This gives the robot a lot of ways to position itself in its environment. Each joint is said to give the robot one degree of freedom.

So, a simple robot with 3 degrees of freedom could move in 3 ways; up and down, left and right, forward and backward. Most working robots today have 6 degrees of freedom.” [13]. The Figure 12 is an example of robot’s arm or manipulator.

Figure [12]: Robot’s arm / manipulator

3. Driving System

"The drive is the engine that drives the link (the sections between the joints) into their desired position. Without a drive, a robot would just sit there, which is not often helpful. Most drives are power by air, water pressure or electricity." [14]

A robot requires a drive system to move their arm, wrist and body. The driving system determines the speed of the arm movement, the robot's strength and also dynamic performance. There are three types of driving system used for actuating robot joins which are electric drive system, hydraulic drive system and pneumatic drive system.

1. Electric drive system

Electric drive system is perfect for small robots and precise applications. It is also capable to move robots with high power or speed. The actuation of this type of robots can be done using either DC servo motors or DC stepping motors. This system has greater accuracy and repeatability and can be well-suited for rotational joints and linear joints. Electric drive system can be separated into a few types which are;

- motors

The principle of stepper motor is very similar to DC motor but it has many coils instead of just one, to operate s stepper motor, the different coils must be activated in particular patterns to generate motor rotation. The stepper motor needs to be sent patterned commands to rotate. These commands are sent over several lines as high and low logic and must be pulsed in a particular order and combination. Separated by a set step angle, steppers are often used for feedback control as seen in Figure 13 [15].

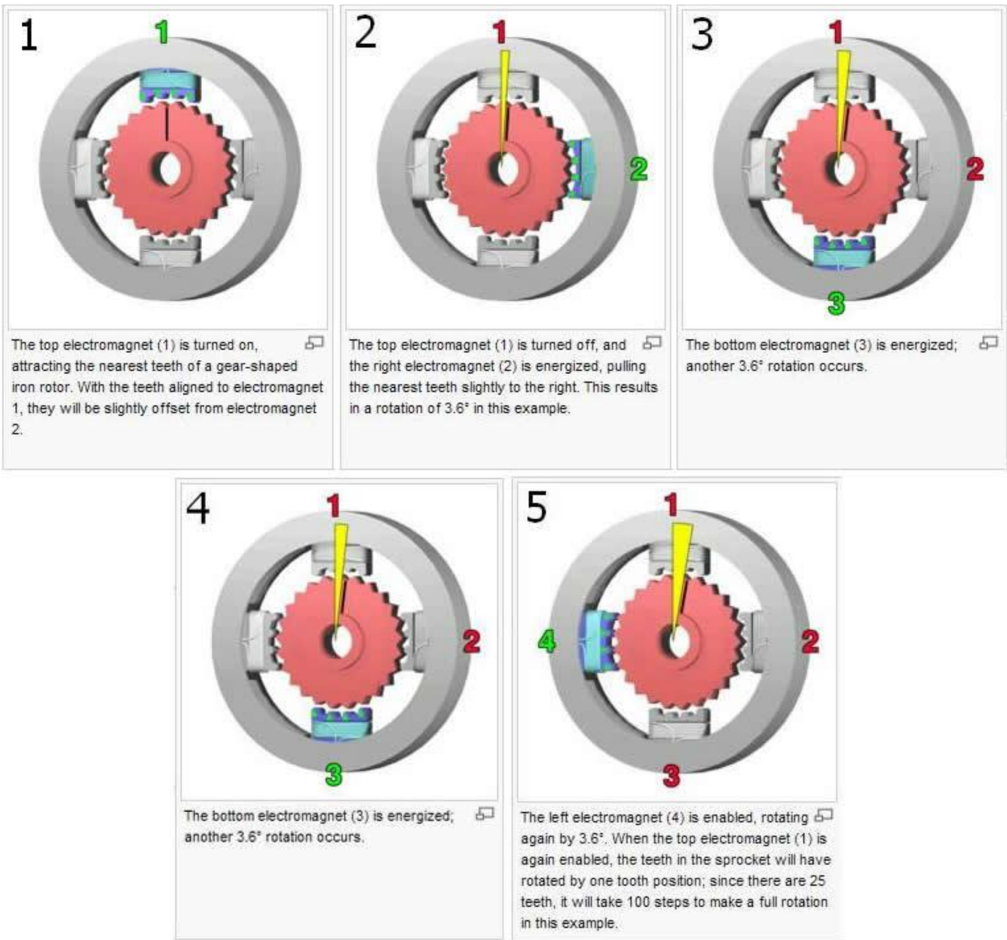


Figure [13]: Step by step operation of stepper motor

- servo motors.

a) Non-servo

Non servo robots are considered a non-intelligent robot, the simplest robots and often referred as “limited sequence,” “pick and place,” or “fixed stop” robots. It is an open loop system, where no feedback mechanism is used to compare programmed positions to actual.

b) Servo

Is a closed loop system because it allows feedback. Servo mechanism is a type of system that detects for errors and corrects it.

- RC servos

RC (remote control) servo motor is a small box designed for use in airplanes and cars. Inside this box is a complete servo system including motor, gearbox, feedback device (pot), servo control circuit and drive circuit as seen in Figure 14 [16] and Figure 15 [16] shows the block diagram for RC servo motor.

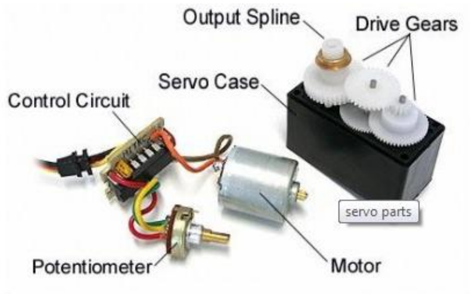


Figure [14]: RC servo motors

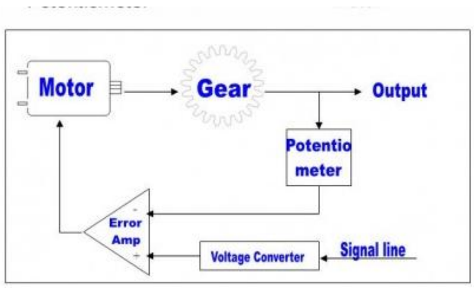


Figure [15]: Block diagram for RC servo motor

2. Hydraulic Drive System

This system is meant for large sized robot since it delivers high power or speed than electric drive system. It can be used for linear and rotational joints while the rotary motions are provided by the rotary vane actuator and the linear motions are produced by hydraulic pistons. The major disadvantage of this drive is the leakage of hydraulic oils.

3. Pneumatic Drive system

This system provides fine accuracy and speed and especially used for the small type of robots that have less than five degrees of freedom. This drive system produces rotary movements by actuating the rotary actuators. Operating the pistons will provide translational movements of sliding joints. Unfortunately, it is not good for faster operations.

4. End effector

"The end effector is the hand connected to the robot's arm. It is often different from human hand- it could be a tool such as a gripper, a vacuum pump, tweezers, scalpel, blowtorch- just about anything that helps its do its job. Some robots can change the end effectors, and be programmed for different set of tasks.

If the robot has more than one arm, there can be more than one end effector on the same robot, each suited for specific task."[17]. The Figure 16 below is the example of end effector for a robot which is a gripper and Figure 17 shows a tweezer.

Figure [16]: Gripper as end effector

Figure [17]: Tweezer as end effector

5. Sensor

"Most robots of today are nearly deaf and blind. Sensors can provide some limited feedback to the robot so it can do its job. Compared to the senses and abilities of even the simplest living things, robots have a very long way to go.

The sensor sends information, in the form of electronic signals back to the controller. Sensors also give the robot's controller information about its surroundings and let the robot knows the exact position of the arm, or the state of the world around it.

Sight, sound, touch, taste, and smell are the kinds of information we get from our world. Robots can be designed and programmed to get specific information that is beyond what our 5 senses can tell us. For instance, a robot sensor might "see" in the dark, detect tiny amounts of invisible radiation or measure movement that is too small or fast for the human eye to see." [18]

There are many types of sensors that can help robot to navigate its way. For example:

- Compasses and navigation sensors
- Ultrasonic range sensors
- IR sensors

The most popular for experimental robots and usually divided into two basic types which is the first is the passive type/ PIR that emits no IR radiation as shown in Figure 18 [17] and the other type is the active type which emits an IR beam that is again detected by reflection.

Figure [18]: IR sensors

- Positional encoders

These encoders can use electrical contacts, magnetic Hall-effect detectors, or the more popular optical path broken by rotating teeth or opaque and clear graphics etched on a wheel. Absolute encoders output a binary word for each incremental position and are complex and expensive. Incremental encoders provide a pulse for each increment of shaft movements. The use of two optical channels enable the determination of the direction of rotation as seen in Figure 19 [20].

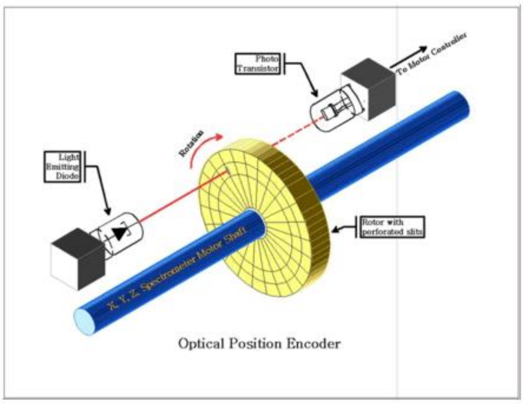


Figure [19]: Optical positional encoders

CHAPTER 3

METHODOLOGY

Chapter 3 is dedicated to explain the research methodology of this project. It is divided into three sections. Section 3.1 will elaborate on the research methodology and project activities, section 3.2 explains about tools and materials used in this project and section 3.3 shows the Gantt chart of this project for both semester one and semester two.

3.1 Research Methodology and Project Activities

The flow of the process is illustrated in the Figure 20

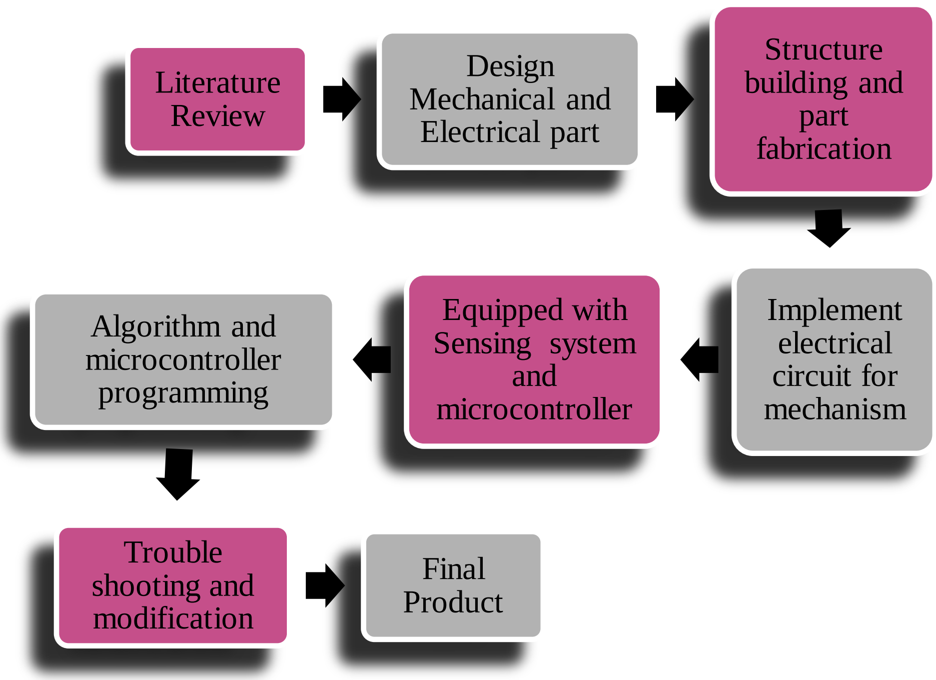


Figure [20]: Flowchart for the process during second semester

This project was conducted according to the flowchart to make sure that the objectives were achieved. The project was started with literature review about the topic. From the literature review, information were gained and used to decide on which mechanism and systems to be choose in building the prototype that can function as desired. After that, the mechanical and electrical parts of the robot that will help the robot to execute its task were designed. Then, the structure of the robot and mechanisms needed were fabricated first before the electrical circuit was implemented. Next, the robot was equipped with sensing system and microcontroller before programming can be done. Then, trouble shooting and modification was done until the final product that is fully working was achieved.

3.2 Tools and Equipments used.

The base of the robot was constructed using aluminium bars. The robot also needs three castor tyres which were installed at the front of the robot. These tyres help the robot to move around but they are not controlled by any motor. Figure 21 shows the aluminium bar and Figure 22 shows the castor tyre.

Figure [21]: Aluminium L-Bar Figure [22]: Castor tyre

Figure 23 shows the IFC boards that are used to connect sensors, driving the mechanism of the robot to the controller. Figure 24 shows two types of sensors needed for the robot which are the object sensor and line tracking sensor. Figure 25 shows three types of motors that are being use to help the robot execute its task.

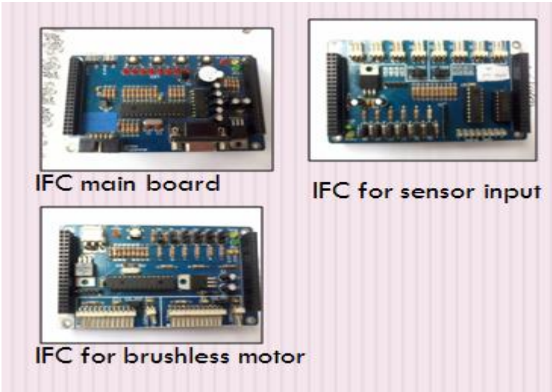
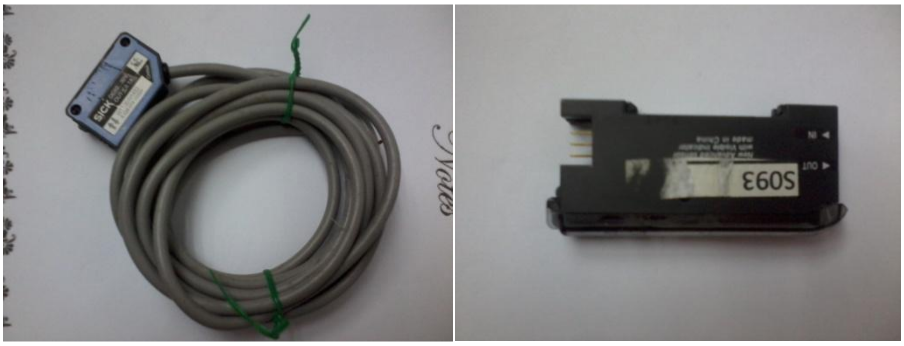


Figure [23]: Different types of IFC boards



Object sensor Line tracking sensor

Figure [24]: Example of several types of sensors

Brushless motor Power window motor

DC motor

Figure [25]: several types of motor used

In order for the mechanical parts and driving system of the robot to move as desired, the robot needs programming. The programme codes are written in MPLAB IDE and downloaded into the IFC board through PIC kit. Figure 26 shows the interface for MPLAB IDE and Figure 27 shows the interface for PIC kit.

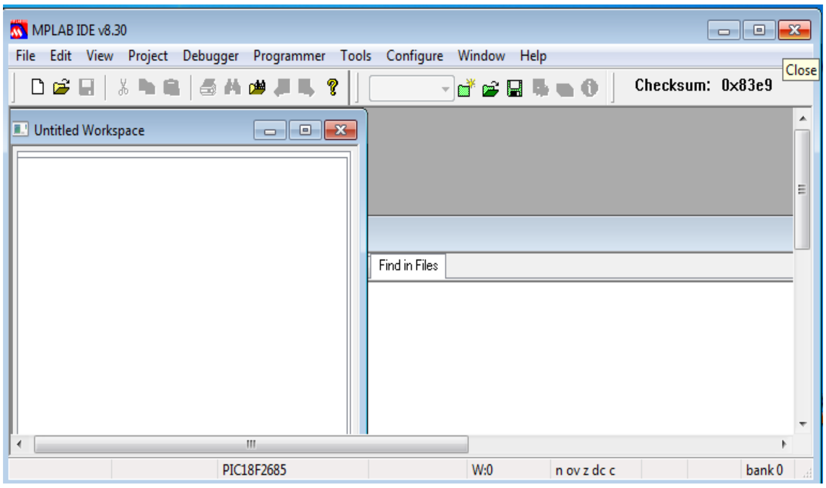


Figure [26]: Interface for software MPLAB IDE

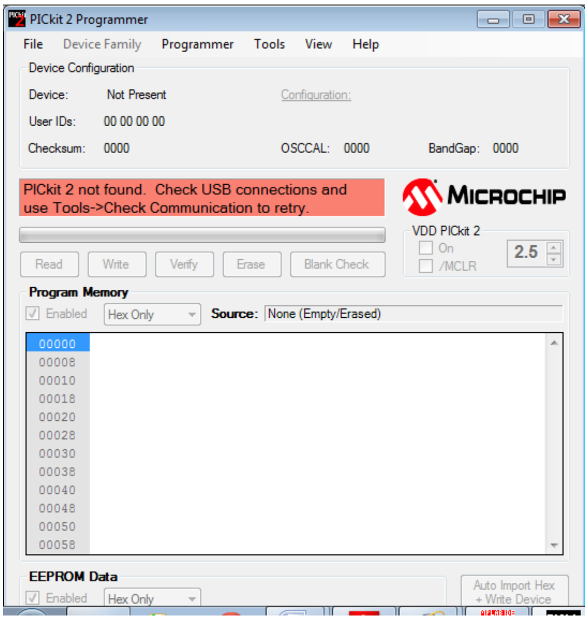


Figure [27]: Interface for PIC kit

3.3 Gantt Chart

The Gantt chart is a guideline for the project timeline. It can be changed from time to time depending on certain circumstances. Table 1 shows the work done during the first semester and Table 2 shows the activities done during the second semester.

Table 1 Gantt Chart for the first semester.

No	Detail/Week	1	2	3	4	5	6	7	Mid-semester Break	8	9	10	11	12	13	14
1	Selection of Project Topic: Design and Fabrication of Autonomous Robot For Security Monitoring	■	■													
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

Table 2 Gantt Chart for the second semester.

No.	Detail/ Week	1	2	3	4	5	6	7	Mid-Semester Break	8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■									
2	Submission of Progress Report									●							
3	Project Work Continues									■	■	■	■	■			
4	Pre-EDX												●				
5	Submission of Draft Report													●			
6	Submission of Dissertation (soft bound)														●		
7	Submission of Technical Paper														●		
8	Oral Presentation															●	
9	Submission of Project Dissertation (Hard Bound)																●

● Suggested milestone
■ Process

APF

CHAPTER 4

RESULTS AND DISCUSSION

This chapter elaborates the output of this project including the mechanical structure of the robot, the robot's mechanisms which are the pulley system and the chain mechanism, robot's driving system and sensors to help the robot to execute its task and also the movement plan of the robot to deliver the parcel/letter.

4.1 Mechanical Structure

In order to obtain a robot that can fulfil the requirements needed by the autonomous vehicle, the structure of the robot was designed as in Figure 28. The structure can store parcel and letters, carry the parcels and letters from the starting point to the desired locations, raise them to the table height and transfer them safely from the robot onto the table in a way that will not damage the content of the parcels. The structure of the robot is shown in Figure 28.

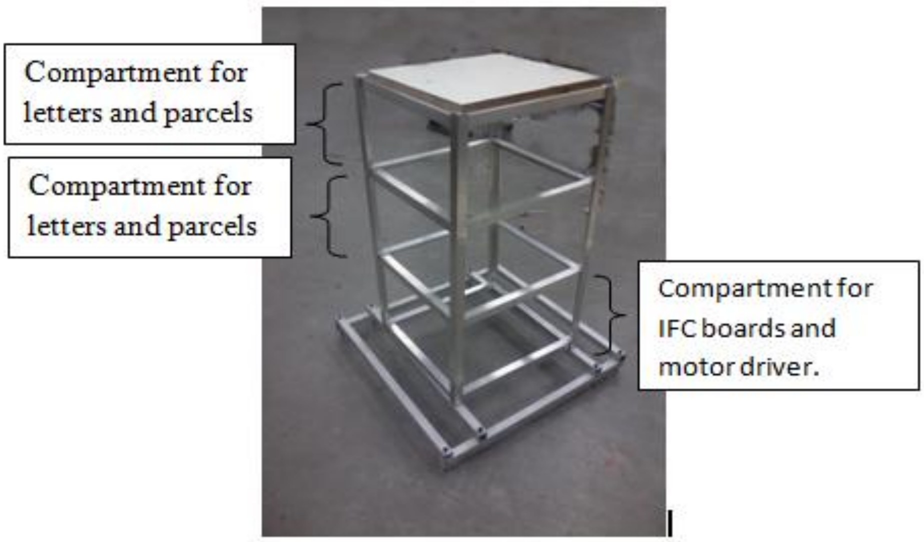


Figure [28]: The robot structure (without wheels)

This robot’s structure was constructed using aluminium bars and designed with three compartments. Two of the compartments are being used to store the parcels and letters and another one which situated at the lowest part of the structure is being used to store the IFC boards and motor driver needed to move the robot and its mechanisms.

The complete robot’s structure as shown in Figure 29 is equipped with two brushless DC motors, two power window motors, one brush DC motor, two wheels, three castors, three line tracking sensors, three object sensors, motor drivers and IFC boards.

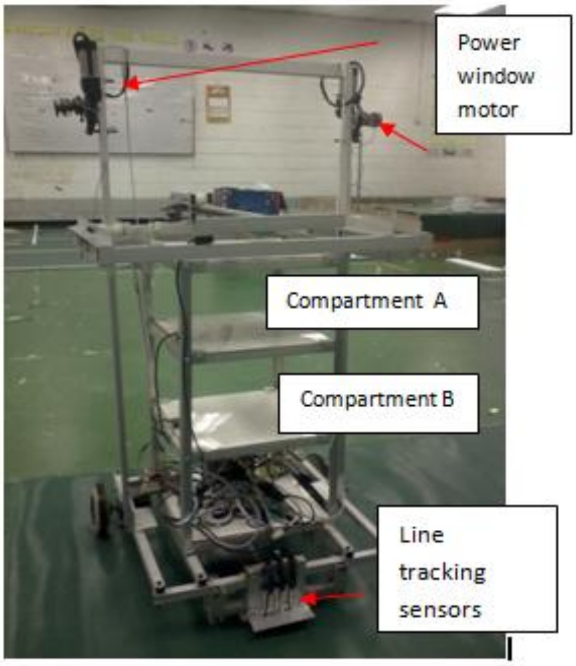


Figure [29]: The full robot structure

4.2. Robot Mechanisms.

4.2.1 Pulley System

This robot uses the pulley system as a mechanism to lift up a load. This system is using a fixed pulley. The load is another mechanism which is the chain mechanism. The pulley system is a system made with rope wrapped around a wheel to lift up a load. Then, the load is lifted up using power window motor. The motor is attached to the wheel. The same system is being used at two places at the robot. Figure 30 shows the picture of the power window motor and Figure 31 shows the pulley system.

Figure [30]: Power window motor

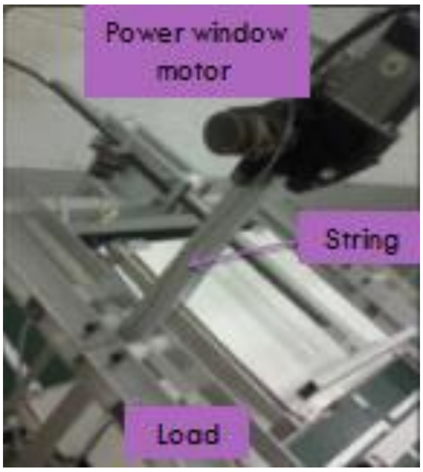


Figure [31]: Pulley system

The features of this motor are shown in Table 3.

Table 3 Features of Power window motor

Working voltage	12 V
No load current	< 3.5 A
No load speed	90 – 110 rpm
Current (3Nm)	< 11 A
Speed (3Nm)	55 rpm
Max. Torque	8 Nm
Block current	30 A

The pulley system is used to lift the load to three positions, which are:

1. To the level of compartment A to enable the chain mechanism to push out the parcel/letter to the receiving end.
2. To the level of compartment B to enable the chain mechanism to push out the parcel/letter to the receiving end.
3. To the level of table to enable the chain mechanism to push out the parcel/letter from the robot onto the table.

The load is lifted up by the pulley mechanism using different number of rotations at the power window motors at each level. The load, which in this case is the chain mechanism, was lifted to the level of compartment A, level of compartment B and level of table, are shown in the Figure 32.

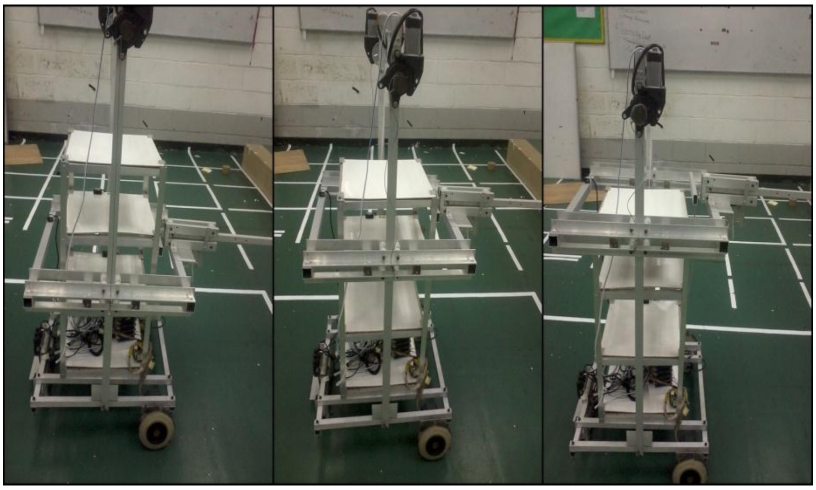


Figure [32]: Positions of the load

Before the robot executes its task according to the location of the parcel, the load was positioned at the lowest compartment and always at the same height since the load was lifted using the number of rotations of the power window motor. The number of rotations depends on the size of each compartment. Positioning the load at the wrong height will result to the load did not reach the desired level and the chain mechanism cannot work accordingly.

4.2.2 Chain Mechanism

Chain mechanism uses combination of chain and DC motor. Figure 33 shows the chain system and a DC motor used as the moving mechanism.

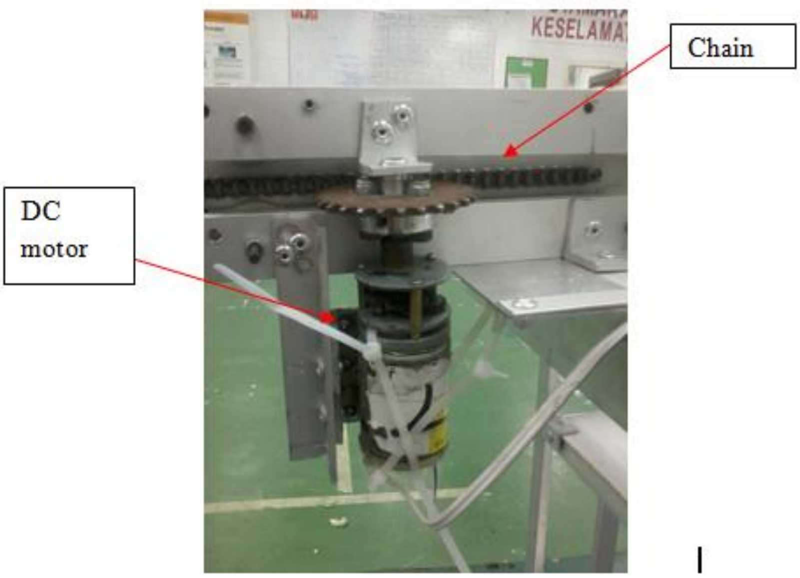


Figure [33]: Chain mechanism

This mechanism is lifted up to the level of compartment A, compartment B or to the height of the table by the pulley system. This robot uses the chain mechanism to do the following tasks:

1. Push the parcel/letter out of the compartment onto the receiving end.
2. Push the parcel/letter from the robot onto the table.

The number of rotations of the DC motor will determine how long the chain mechanism will extend and the length of the chain mechanism depends on the size of the compartment and the size of receiving end at the robot. Pushing the parcel/letter out of the compartment onto the receiving end, the chain mechanism will not be extended to the fullest, or else the parcel/letter will fall off from the robot. Pushing the parcel/letter from the robot onto the table, the chain mechanism will be extended to the maximum to ensure that the parcel/letter will be delivered successfully onto the table.

Figure 34 shows the chain mechanism when in state of pushing the parcel/letter out of the compartment onto the receiving end and Figure 35 shows the chain mechanism when in state of pushing the parcel/letter from the robot onto the table.

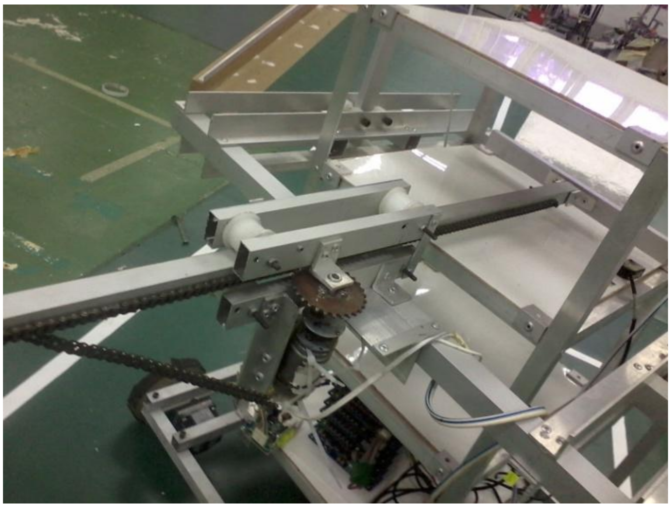


Figure [34]: Chain mechanism pushing the parcel/letter out of the compartment onto the receiving end

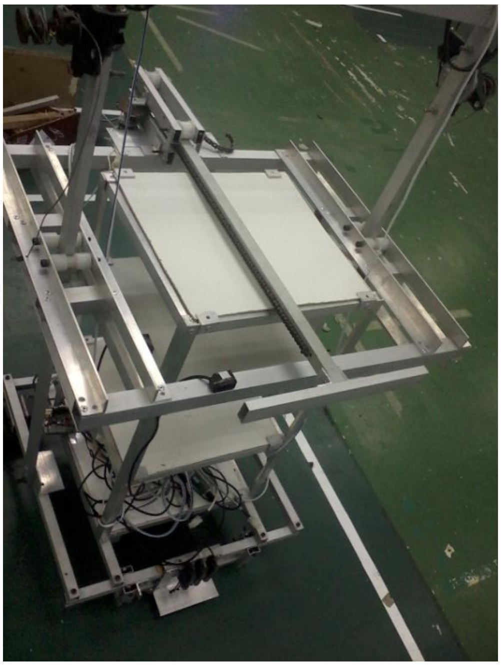


Figure [35]: Chain mechanism pushing the parcel/letter from the robot onto the table.

4.3 Driving System and Sensors

The robot is equipped with two tyres at the back of the robot. These tyres are controlled by 5 V brushless motor each and with three castors attached at the front of the robot that act as free tyres. Each of the tyres is connected to a motor driver before connected to the IFC board where the controlling of the motor's speed and rotation are uploaded. The motor driver and the IFC board are connected to a power supply with minimum voltage of 12 V in order for the driving system to work. The Figure 36 shows the motor driver, Figure 37 shows IFC boards and Figure 38 shows the power supply used for the robot.

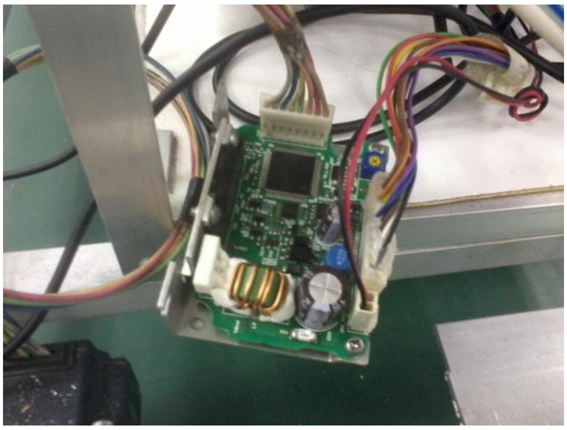


Figure [36]: The motor driver

Figure [37]: IFC boards for the sensors and motors used for the robot

Figure [38]: 12V Power Supply

This robot is equipped with two types of sensors which are the line tracking sensors and object sensors. The line tracking sensors are being used to control the movement of the robot. Since the robot is required to follow a predetermined path, the use of line tracking sensors is the most suitable for this project. The reason why this robot has a predetermined path is because the robot will be working in an office environment where the table for each worker are fixed and the robot does not have to avoid any obstacle. The Figure 39 shows the picture of the robot with the line tracking sensors.

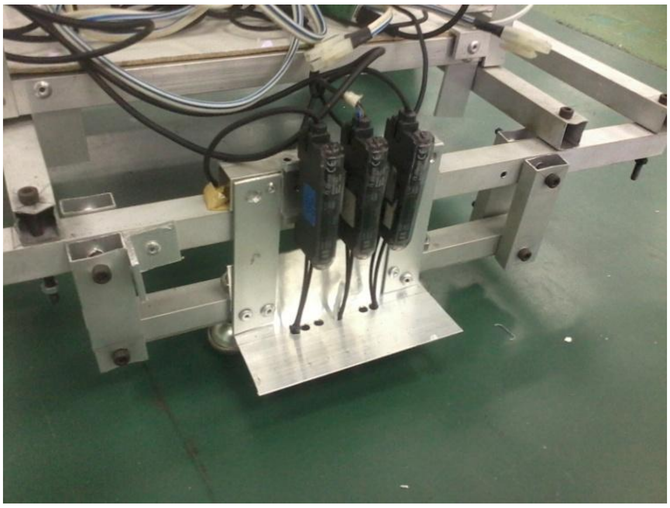
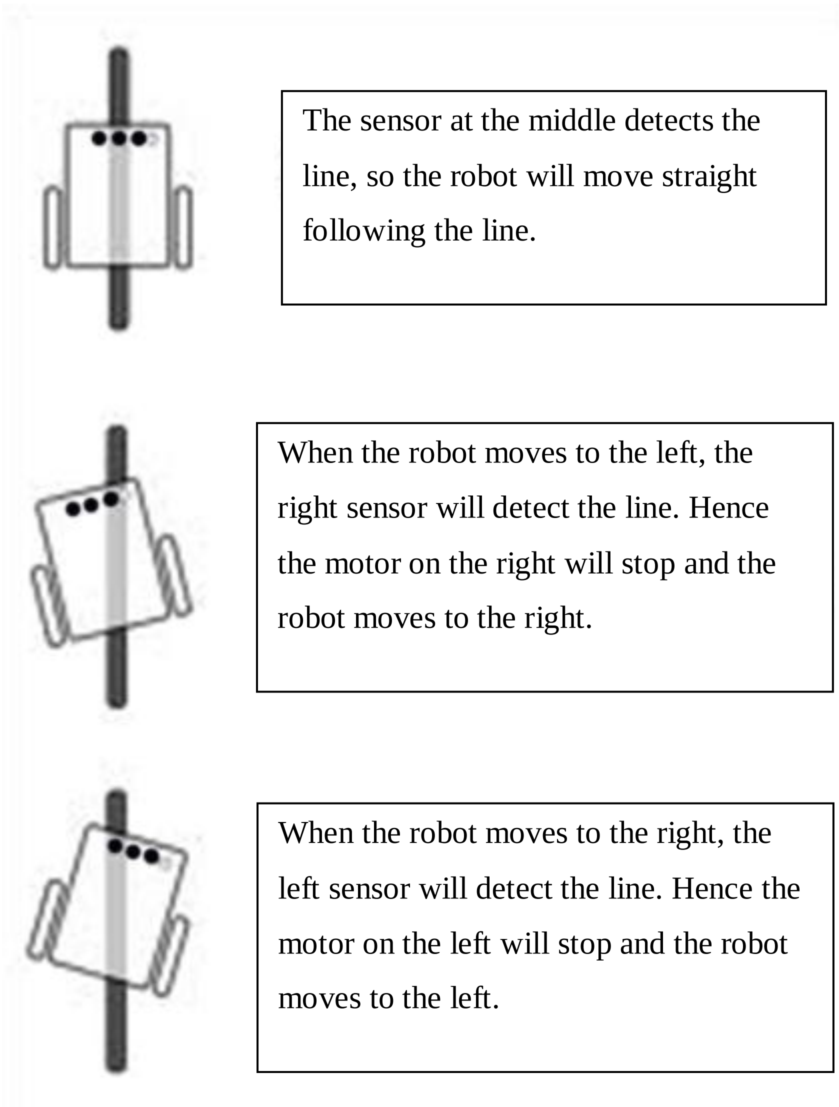


Figure [39]: The robot with the line tracking sensors

To ensure that the robot follow the path and move in a straight line, the robot uses three line tracking sensors to detect the position of the line. The line can be a black line on white background or white line on black background. The sensors will gather data and the microcontroller will analyze the data then the robot will move itself in appropriate direction to center the line under it. The Figure 40 shows how the line tracking sensors work.



Figure[40]: Line tracking sensor navigation

The line tracking sensor will determine the rotation of the brushless motor to keep the robot moving according to the line. Figure 41 shows where the brushless DC motors were mounted and the locations of three line tracking sensors and Table 4 shows the direction of both brushless motor to move and also correct the robot if it is not moving on the line.

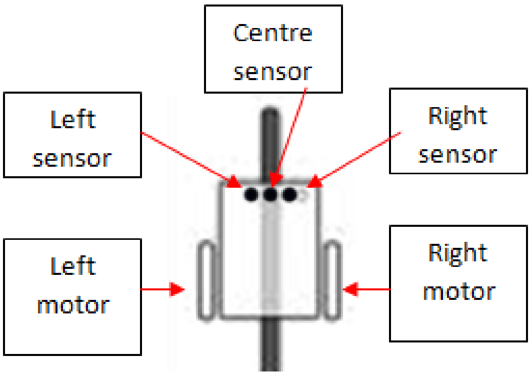


Figure [41]: Positions of Line tracking sensor and Brushless DC motor

Table 4 : Line tracking sensor navigation algorithm

Condition			Left Motor	Right Motor
Left	Centre	Right	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

The object sensors are being used to help the robot to execute its task. The robot is equipped with three object sensors. Two of the sensors are used to detect the presence of parcels and letters in each of the compartments and another one is being used to detect the presence of the table so that the robot can stop in front of the table and make the delivery safely to the intended recipient. The Figure 42 shows the location of the object sensors at the robot.

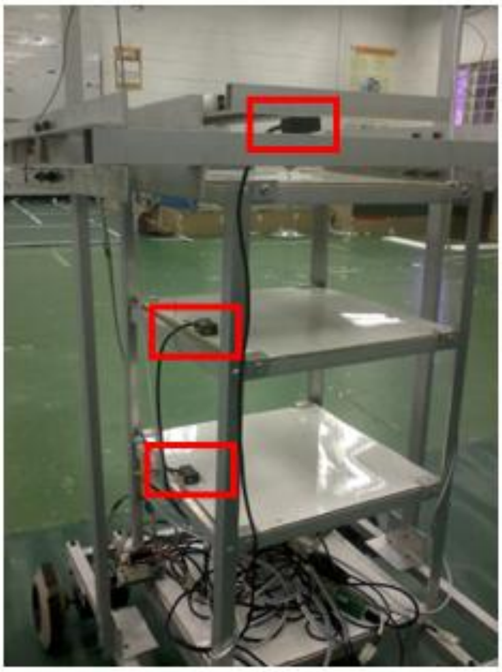


Figure [42]: Location of the object sensors at the robot

Two object sensors at both compartments were set to detect the presence of parcel/letter. The distance set was same with the size of the compartment which is 30cm and another object sensor was set to detect the presence of the table where the parcel/letter will be delivered. The distance of the table and the object sensor was set to 33 cm. The object sensors will send the data gathered to the IFC boards to be processed and the robot will move according to the presence of the parcels and letters in the compartments. The movement plan of the robot will be explained later.

4.4 Movement Plan

The robot movement depend on the location of the parcels and letters. Since the robot has two compartments that can store the parcels and letters and each compartment is assigned to a specific location, there are three different situations where the parcels and letters can be loaded. The location of the parcels and letters can either be:

Situation A: The parcels and letters are in compartment A only.

Situation B: The parcels and letters are in compartment B only.

Situation C: The parcels and letters are in both compartment A and B.

Figure 43 shows the route that the robot will take to deliver the parcel/letter. Location A and Location B represent the table for two different recipients. For each location, the robot will move and follow the steps below to avoid sending the parcels and letters to the wrong recipients. Table 3 summarizes the movement of the robot according the location of the parcels and letters.

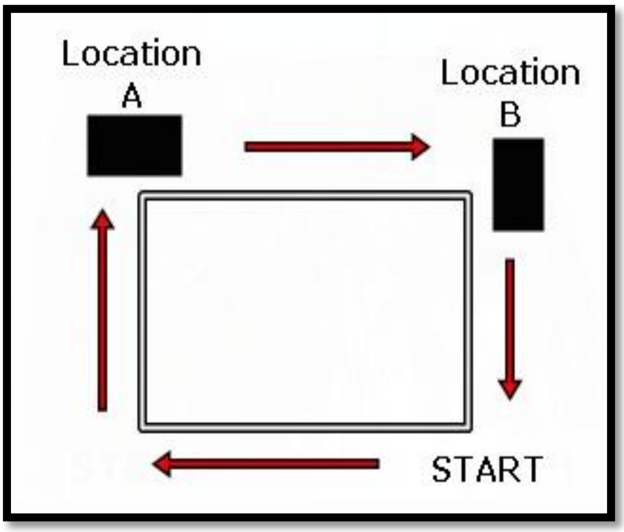


Figure [43]: Map of the route taken by the robot

Table 4 Movements of the robot

SITUATION	ROBOT'S MOVEMENT
Situation A	The robot will move from the starting point to location A and unload the parcels and letters at location A. Then the robot will continue to move back to the START point without stopping at location B.
Situation B	The robot will move from the starting point to location B without stopping at location A and unload the parcels and letters at location B. Then the robot will continue to move back to the START point.
Situation C	The robot will move from the starting point to location A and unload the parcels and letters at location A. Then the robot will continue to move to location B and unload the parcels and letters at location B then make its way back to the START point.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

As a conclusion, completing this project requires a lot of information and broad knowledge especially about the technologies and variety of mechanisms that are being used in robotic world. The objectives of this project have been met. The robot can function as a delivery robot in an office environment and able to deliver parcel/letter successfully to the intended recipients.

For future improvement, there are some recommendations:

- The pulley system can be constructed more smoothly since the pulley system now is having too much friction that makes lifting the load a bit hard and it also have difficulties to go down.
- The usage of chain mechanism can be switched into another mechanism because it will not be possible if the delivery area is limited since it requires more space at the back of the robot to operate.

For further development, the robot can be designed with more compartments to send the parcel/letter in a bigger office area with more recipients and the compartments that store parcel/letter should be covered to ensure that it will be delivered safely and to prevent them from falling off the robot.

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APPENDICES

Appendix A

C PROGRAMME CODES

```
if(!cps1)
        {
        while(1)
        {
                linetrack_a(20,20);
        }
        }

        if(!cps2)
        {
                if(!sen1&&sen2)                                 //target A
                {
                        led1=1;
                        while(sen3)                             //move till A
                        {
                                linetrack_a(20,20);
                        }
                        brake();
                        delay(50000);
                        ccw1;cw2;                               //reach table
                        pwm1(20);pwm2(20);
                        delay(600000);
                        brake();
                        delay(100000);
                        mecha();                                //mech
                        cw1;ccw2;                               //back to line
                        pwm1(20);pwm2(20);
                        delay(800000);
                        ccw1;ccw2;                              //turn avoid a
                        pwm1(20);pwm2(20);
                        delay(300000);
                        while(sen7)                               //move till line
                        {
                                linetrack_a(20,20);
                        }
                        brake();
                        delay(50000);
                        while(sen3)                             //move till end
                        {
                                linetrack_a(20,20);
                        }
                        brake();
                        delay(100000);
                        ccw1;ccw2;                              //turn avoid b
                        pwm1(20);pwm2(20);
                        delay(300000);
                        while(sen3)                             //move till finish
                        {
                                linetrack_a(20,20);
                        }
                        brake();
                }

                if(sen1&&!sen2)                                 //target B
                {
                        led2=1;
                        while(sen3)                             //move till A
                        {
                                linetrack_a(20,20);
                        }
                        brake();
                        delay(50000);
                        ccw1;cw2;                               //reach table
```

```
		pwm1(20);pwm2(20);
		delay(600000);
		brake();
		delay(100000);
		cw1;ccw2;					//back to line
		pwm1(20);pwm2(20);
		delay(800000);
		ccw1;ccw2;					//turn avoid a
		pwm1(20);pwm2(20);
		delay(300000);
		while(sen7)					//move till line
		{
			linetrack_a(20,20);
		}
		brake();
		delay(50000);
		while(sen3)					//move till end
		{
			linetrack_a(20,20);
		}
		brake();
		delay(100000);
		ccw1;cw2;					//reach table
		pwm1(20);pwm2(20);
		delay(600000);
		brake();
		delay(100000);
		mechb();
		cw1;ccw2;					//back to line
		pwm1(20);pwm2(20);
		delay(800000);
		ccw1;ccw2;					//turn avoid b
		pwm1(20);pwm2(20);
		delay(300000);
		while(sen3)					//move till finish
		{
			linetrack_a(20,20);
		}
		brake();
	}

	if(!sen1&&!sen2)					//target A+B
	{
		led3=1;
		while(sen3)					//move till A
		{
			linetrack_a(20,20);
		}
		brake();
		delay(50000);
		ccw1;cw2;					//reach table
		pwm1(20);pwm2(20);
		delay(800000);
		brake();
		delay(100000);
		mecha();
		cw1;ccw2;					//back to line
		pwm1(20);pwm2(20);
		delay(100000);
		ccw1;ccw2;					//turn avoid a
		pwm1(20);pwm2(20);
		delay(300000);
		while(sen7)			//move till line
		{
			linetrack_a(20,20);
		}
		brake();
		delay(50000);
		while(sen3)					//move till end
		{
			linetrack_a(20,20);
		}
		brake();
		delay(100000);
		ccw1;cw2;					//reach table
		pwm1(20);pwm2(20);
		delay(600000);
```

```
                        brake();
                        delay(100000);
                }
                brake();
                buzzer=1;

        }

        if(!cps3)
        {
                mechb();
        }

        if(!cps4)
        {
                mecha();
        }

        if(!sw1)
        {
                ccw3;ccw4;                                      //up, A=1800000,
B=700000
                pwm3(250);pwm4(250);
                delay(1300000);
                brake3;brake4;
        }

        if(!sw2)
        {
                cw3;cw4;                                        //down
                pwm3(250);pwm4(250);
                delay(300000);
                brake3;brake4;
        }

        if(!sw3)
        {
                ccw3;ccw4;                                      //btm to A
                pwm3(250);pwm4(250);
                delay(1300000);
                brake3;brake4;

                cw5;                                            //extend half
                pwm5(200);
                delay(200000);
                brake5;
                delay(100000);
                ccw5;
                pwm5(200);
                delay(220000);
                brake5;
                delay(100000);

                ccw3;ccw4;                                      //lift to top
                pwm3(250);pwm4(250);
                delay(900000);
                brake3;brake4;

                cw5;                                            //extend full
                pwm5(200);
                delay(300000);
                brake5;
                delay(100000);
                ccw5;
                pwm5(200);
                delay(320000);
                brake5;
                delay(100000);
        }

        }


}
```