AUTONOMOUS ROBOT FOR COLLECTING TENNIS BALL

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By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2010

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.

Jeffrey Law Han Ling

ABSTRACT

This report discusses the project done on Autonomous Robot for Collecting Tennis Ball. The objective of the project is to provide a means to save tennis players' energy and time in collecting tennis ball, which in this project is achieved by building an autonomous machine that collects tennis balls by sweeping around on the tennis court itself. This report starts with a brief introduction and the objective of the project is mentioned, followed by a literature review section, which tells different types of tennis ball collectors and different means of building a tennis ball collector prototype. Next, the methodology used for doing this project is explained. Generally, the methodology is divided into procedure identification, tools and equipment used, mechanical design, controller design and navigation systems. Lastly, the result and discussion section reports on the project outcome which is basically the mechanical systems, controller systems and the navigation systems of the robot. Conclusion and recommendation is made for the project.

ACKNOWLEDGEMENTS

It was a wonderful experience in carrying out this final year project. This project would not be completed without the help, supports and advices from a number of people. Thus, I would like to take the opportunity to express my gratitude to them.

First and foremost, I would like to thank my supervisor, Assoc. Prof. Dr. Irraivan Elamvazuthi for this guidance and moral supports throughout this project. Being under his supervision has been a great pleasure. Without the advice from him, this project would not have succeeded.

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Last but not least, my appreciation goes to my family for their love, moral support and financial support to complete this project.

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LIST OF ABBREVIATIONS

LED	Light Emitting Diode
NPN	Negative-Positive-Negative
CPU	Central Processing Unit
RAM	Random Access Memory
ROM	Read Only Memory
I/O	Input/output
PROM	Programmable Read Only Memory
EEPROM	Electrically Erasable PROM
IC	Integrated Circuit
PWM	Pulse Width Modulation
DC	Direct Current
ARFCTB	Autonomous Robot for Collecting Tennis Ball
PCB	Printed Circuit Board
RPM	Revolutions Per Minutes

CHAPTER 1
INTRODUCTION

1.1 Background of study

Tennis is one of the famous and high class sports in the world. As prize money are increasing in every Grand Slam tournament, International Tennis Federation tournament, ITF Davis Cup tournament, Association of Tennis Professionals tournament, Women's Tennis Association tournaments, more and more people tend to play tennis. New tennis players who take professional tennis as their life career are increasing year by year.

Grand slam is the most important and major tournament in tennis career. It is the ultimate dream goal of every tennis player. Therefore, tennis players would work hard to win grand slam titles. In order to win a grand slam title, a lot of trainings and scarifies needs to be done by each tennis player. Thus, coaching/training sessions are very important.

Tennis training academies get popular all over the world because coaching/trainings are available there. When tennis trainees are under coaching/trainings, one of the feedbacks made by a majority of tennis trainees is collecting tennis balls manually is tiresome. It is better to have an autonomous robot for collecting tennis balls during each coaching/training session.

The autonomous robot will not only help in collecting tennis balls on the court; it will also increase the efficiency of the tennis training and allow more resting time to tennis trainees.

1.2 Problem statement

- Plenty of time wasted in collecting the large amount of tennis balls.
- Insufficient resting time for tennis players.
- More energy exhaustion in collecting tennis balls for tennis players.
- Unsatisfactory performances of tennis players in coaching sessions.

1.2.1 Problem Identification

Tennis balls are not unlimited during coaching sessions. Tennis players need to collect balls after each round of practices. There are many ball-collecting devices in the market that are either human-powered or man-controlled which are designed by Playmate, Gamma, and others. However, there is almost no existing sport product that does not require the labor of a person. Therefore, in a generation where the number of athletes is growing, there is a bigger demand for machines that make athletes' lives simpler and effective.

1.2.2 Significance of the Project

This project will allow tennis coaching sessions to be more efficient and fruitful. Tennis trainees will get enough rest by using the time to collect tennis balls after each round of coaching for resting. With this project, tennis trainees can save twenty minutes a day for each two-hour long coaching/training. Thus, the twenty minutes saved can be used for resting or extra coaching/training. Besides, tennis trainees do not have to spend extra energy in collecting tennis ball at the end of each practice. This directly increases their performances in the training sessions. Another thing is this robot may be able to collect other balls of similar shape or weight such as golf balls or ping pong balls.

1.3 Objective and Scope of Study

The objectives of the robot are: -

i. To build a robot that can sweep around the tennis court to collect tennis balls autonomously (navigating by itself).
ii. Enhance tennis coaching/training quality.
iii. Save time and energy of tennis players.
iv. To provide a low-cost solution for collecting tennis balls.

The scope of study will cover details related in building the prototype. The details are listed below: -

i. Structure/mechanical design – The structure/mechanical design includes electronics hardware, wheels, motors, and sensors. This is important to determine which solution is the best for building the robot.

ii. Controller systems – The design of microcontroller board, motor driver board, L298 Motor driver board and sensors board need to be accomplished because microcontroller act as the brain of the robot to control the motor driver and sensor.

iii. Navigation systems – The flowchart is constructed in order to clarify the navigation of the robot.

CHAPTER 2
LITERATURE REVIEW

2.1 Background

The diameter and weight of a tennis ball is 6.67cm and 57.7grams respectively. The typical size of the tennis court is 29.80 meter long and 14.63 meter wide. Figure 1 shows the typical size of the tennis court.

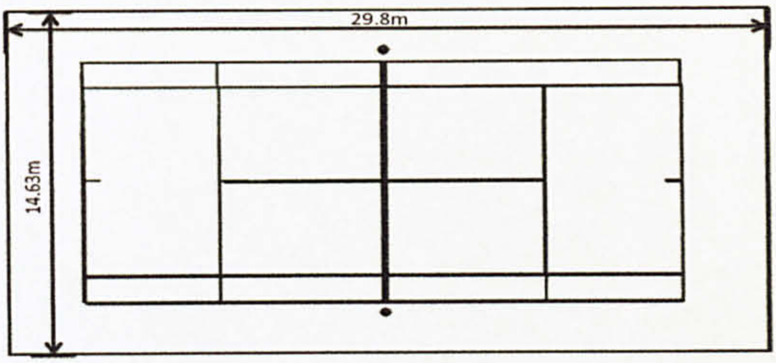
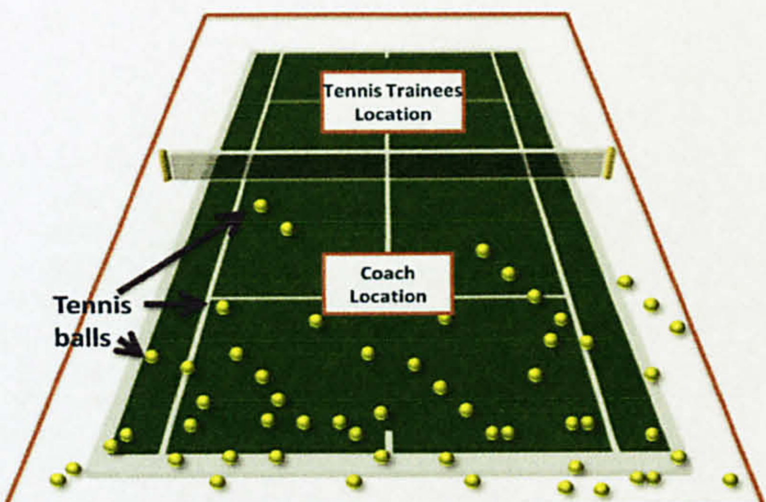


Figure 1: Size of the tennis court

In each training sessions, a coach will feed lots of tennis balls to tennis trainees, and hence there will be a lot of tennis balls scatter at the back of the court. Figure 2 illustrates tennis balls scattering on the court after each round of training.



Source: http://tenniscourtreviews.com/about-tennis-courts

Figure 2: Tennis ball on the court

2.2 Mechanical Systems

2.2.1 Human-controlled/manual Tennis Ball Retriever

The tennis ball retriever comprising a handle having a T-shaped grip on the end of it for users to push it, and a cylindrical collection drum attached in between of the handle so that it may rotate freely in either direction relative to the handle. The collection drum is mainly consisting of several circumferential tines axially spaced apart by a distance just less than the diameter of a tennis ball. The circumferential tines have an abrasive surface for engaging tennis balls and urging the tennis balls which are between a pair of circumferential tines and into the hollow interior of the collection drum. The abrasive surface is made of several grooves which are placed along the perimeter of the tine. The first and last tines are larger and without the grooves. However, there have tires attached to them to ease the movement of the tennis ball retriever. The collection drum has 2 end faces that block the balls from coming out. In order to take out the ball, the gate of the first end face can be opened. To retrieve the tennis ball, the tennis ball retriever is pushed towards the tennis ball. The collection drum will rotate and advance to a position in which the tennis ball is centered between pair of adjacent tines and gripped by the grooves. This will cause the tennis ball to be squeezed into the collection drum by further advancing the tennis ball retriever [2].

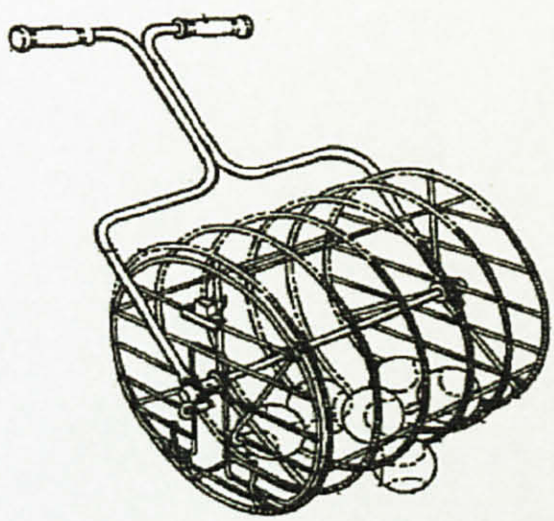
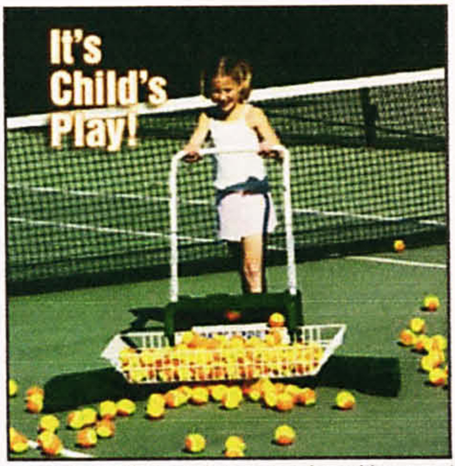


Figure 3: Tennis Ball Retriever [2]

2.2.2 Playmate Mower

Playmate mower has folding arms for ease of storage. It can collect the tennis balls on the entire court. Besides that, it is built from aluminum material and it has one year warranty. Figure 4 shows the picture of Playmate mower.



Source: Playmate Tennis, http://www.playmatetennismachines.com/mower.htm

Figure 4: Playmate Mower

2.2.3 Autonomous Tennis Ball Picker

This Autonomous Tennis Ball Picker has a ball storage basket which comprises of cardboard withheld by duct tape, but a wooden board is put below the basket to sustain the heavy weigh. It also serves as a platform for the attachment of servo motors on each side of the basket. The front of the basket contains a rectangular hole for balls to go in when they are swept up. The ball grabber comprises of 3 wooden blades attached around a wooden cylinder. A servo motor and a wheel connector are attached to this wooden cylinder so that all the torque of the motor is used for turning the cylinder. Two circular foam boards are attached on each side of the wooden cylinder and a tin sheet is positioned under the rotating blades as a ramp to receive the balls that are pushed in by the blades. The whole device is supported by plastic wheels that are attached to the wooden board, two on each side [1].

At the front of the rotary blades, there are 2 pairs of LED emitters and NPN Phototransistors which act as touch sensors to detect incoming walls or obstacles. 2 pairs of LED emitters and detectors are used in front of the rotary blades to detect if a ball has passed through and ready to be picked up. Another 3 pairs of LED emitters and detectors are placed just behind the front hole of the basket to detect if a ball has been successfully picked up and dumped into the basket. These sensors can tell us whether the ball is still in the rotary wheel, and hence reverse the direction of the blades to fix the jam. On the other hand, NPN Phototransistors will detect the LEDs for their corresponding voltage output to determine whether the sensor is to be activated [1].

For the software part, 2 state machines of this project: Front wheel and Rear wheel are given appropriate functions. Front wheel contains the function of FrontStop (stops and waits to pick up balls), FrontForward (moves forward to pick up the tennis ball), FrontBackward (moves backward when the ball gets stuck). Meanwhile, the rear wheel state machine has 7 functions which enable them to stop, moves forward, backward, left, right, moves to the left originally, but it moves to the right after it senses a wall, as well as moves to the right originally, but it moves to the left after it senses a wall [1].

The drawback of this invention is that the servo motors are unreliable, especially under long term usage. Besides, servo motor has lesser torque compared to DC motor. This makes the tennis ball picker does not able to have high speed and hence high efficiency of picking up most/all of the balls on the court [1].

Source: http://instruct1.cit.cornell.edu/courses/ee476/FinalProjects/s2009/peterfkung/BallPicker.htm#_top

Figure 5: Autonomous Tennis Ball Picker

2.2.4 Motors

Different types of motors can be used for autonomous robot (mobile robot). The most common types of motors are DC motors, stepper motors, and servomotors. DC motors are powered by direct current and inherently bidirectional rotations. The most popular of the stepper motor is the four-phase unipolar stepper. A unipolar stepper motor is relaying two motors sandwiched together [8]. Servomotors are designed for closed feedback systems. The output of the motor is coupled to control circuit [8].

2.2.5 Materials

There are many kinds of materials that are used in building robots. The most common types of materials can be used in building a robot are perspex, aluminum, pipe, steel, wood, plywood, form board, polystyrene, and etc [8].

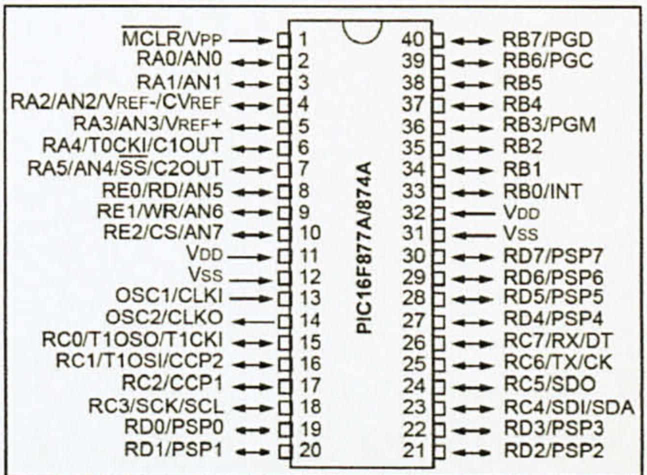
2.2.6 Circuit board

The circuit boards that can be used are printed circuit board and bread board. Printed circuit board simplifies the assembly of electronics components and wiring of the circuits. On the other hand, bread board is a temporary prototyping circuit platform which the holes are connected to adjacent ones by a spring-loaded connector [8].

2.3 Controller Systems

2.3.1 Microcontroller

A microcontroller is essentially an inexpensive single-chip computer. The microcontroller has features similar to those of a standard personal computer [7]. The microcontroller contains a CPU, RAM, ROM, I/O lines, serial and parallel ports, timers, and sometimes other built-in peripherals such as analog-to-digital and digital-to-analog converters. The key feature, however, is the microcontroller's capability of uploading, storing, and running a program [3].



Source: Datasheet of PIC16F877A

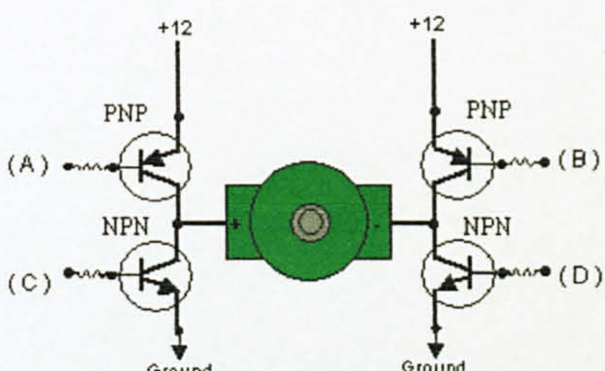
Figure 6: PIC16F877A

RAM is used to store the temporary data while the program is running. Higher amount of RAM means higher capability of the chip to process more data during operation. The data stored in RAM will be lost if the power goes off and it is therefore called as volatile memory [10]. ROM is the memory space for storing fixed and permanent data such as application software and this type of memory will not disappear even if the power supply is disconnect. When the microcontroller has CPU and sufficient and necessary memory spaces to operate, it needs something to trigger an expected event. In other meaning, it needs input to prompt the decision-making process and output corresponding event. Therefore, I/O pins are essential for microcontroller. Timer is equal peripheral device of the microcontroller which is either internally or externally. The timer is used to measure time period, obtain pulse width and the periodic time [4].

There are many microcontroller manufacturers in the current market such as Microchip, Motorola, Intel and etc [5]. The microcontroller (PIC16F) manufactured by Microchip was chosen. Besides that, UTP has the programmer of PIC which allows reprogramming of the microcontroller. On the other hand, PIC16F877A chip with the letter 'F' means flash which indicates this PIC16F877A has on-chip program ROM in the form of flash memory. Flash memory is an EEPROM where it can be reprogrammed easily in seconds and this is the reason PIC16F877A was chosen [4].

2.3.2 DC Motor Controller

DC motor controller uses the concept of the H-Bridge because it is able to control the direction of a motor such as forward or backward. This was achieved by managing current flow through circuit elements called transistors. The formation looks like an H and that's where it gets the name H-Bridge [6]. Figure 7 shows the H-Bridge operations:



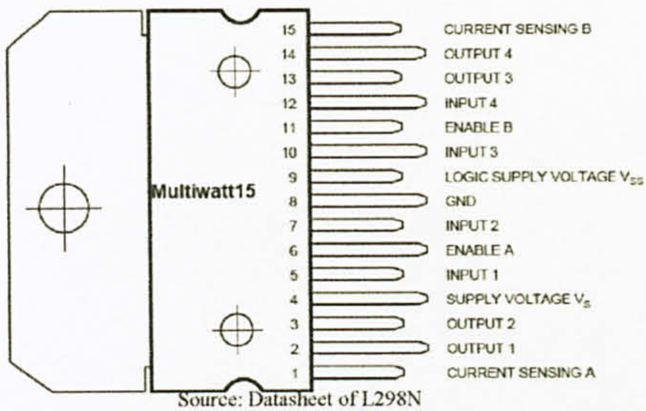
A	B	C	D	Function
1	0	0	1	Forward
0	1	1	0	Reverse
1	1	0	0	Brake
0	0	1	1	Brake

Source: http://www.pyroelectro.com/tutorials/l298_control/theory.html

Figure 7: H-Bridge concept

The two cases that interest us are when A & D are both 1 and when B & C are both 1. When A & D are 1 current from the battery will flow from point A through the motor to D's ground and the motor will turn clockwise. However for the case when B & C are both 1, current will flow in the opposite direction from B through the motor to C's ground and the motor will turn anticlockwise [6].

L298N IC has the same concept as H-Bridge. Therefore, L298N is used to drive a motor. The advantage that the L298N offers is that all the extra diodes typically necessary with a standard L298N circuit are already internally in the chip. It saves us an extra element for the motor control circuit. It can also vary DC Motor speed by using PWM input from Microcontroller. The frequency of the PWM is dependent upon the motor. For example, 1 KHz input frequency. This means the motor speed will be updates 1 thousand times a second. Thus, the duty cycle of the PWM will determine the speed & direction of the motor. Figure 8 shows the pin available on L298N IC [6].



Source: Datasheet of L298N

Figure 8: L298N IC

2.3.3 Sensors

A robot needs to be aware of what is happening in the world around it. That is why all our robots are equipped with several sensors linked to the controller [8]. Thus, there are many sensors available in the market that can be used for robotics. These sensors are: -

i. Ultrasonic Sensor
ii. Optical Sensor
iii. Photoelectric Sensor
iv. Proximity Sensor
v. Limit Switch
vi. Infrared Sensor

2.3.4 Power Supplies

The power supply needs to be obtained by all the circuits' board. Without it, all the circuit would not be functioning. The first stage in planning the supply is to list the devices and circuits in the system and what it will need. All systems will include one or more PICs so start with this. If everything can run at the same voltage it makes the circuit design much simpler. It is preferable to use low-voltage (3 V or 6 V) motors that can run on the same supply as the PIC. Sometimes a 12 V motor, solenoid or relay is the only suitable type and two supplies have to be set up. The power supply circuit, single or double, should also include an on-off switch and preferably an indicator LED to light when it is switched on. Some circuits for this are shown overleaf. If the drive motors have their own supply it is better to use separate switch [8].

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

The procedure identification starts from literature review, conceptual design, fabrication of prototype, testing of prototype, and ends with cost analysis. If the testing of prototype does not obtain the expected outcome, we need to go back to conceptual design. Conceptual design includes mechanical system, controller system, and navigation system.

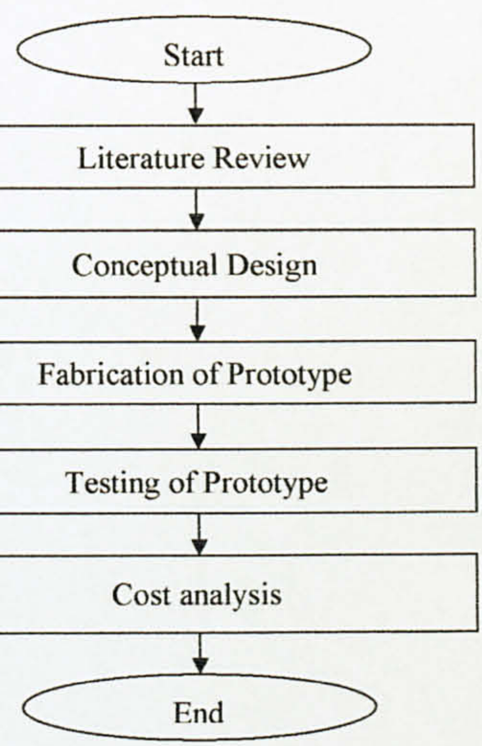


Figure 9: Project Methodology

3.1.1 Tools & Equipments

The tools used for this project are MPLAB, PIC C Compiler, Proteus 7.2, Eagle 4.13, UIC Programmer, Pro's Kit tools, and Workshop Tools such as cutting tools and drills. The equipments used are DC motor, Limit Switch, Power Window motor, electronics components, PIC, Milling Machine, and Laboratory DC Power Supply.

3.1.2 Cost

The total cost is RM638.10. Table 1 shows the breakdown cost of Mechanical Structure and electronics controller system.

Table 1: Cost of the robot

Material	Quantity	Cost per unit (RM)	Total cost (RM)
Aluminum Sheet	1x1m	4.00	4.00
Wheels	2	15.00	30.00
DC motors	2	80.00	160.00
DC power window motor	1	50.00	50.00
Coupler for DC motor and wheel	2	25.00	50.00
Limit Switch	3	1.00	3.00
12V Rechargeable Battery 4.5Ah	1	55.00	55.00
Steel Pipe (42cm)	1	11.60	11.60
PIC16F877A microcontroller	1	16.00	16.00
Microcontroller Board	1	50.00	50.00
Motor driver 10A	1	63.00	63.00
L298N motor driver for DC motor	1	30.00	30.00
Perspex (Acrylic sheet)	1	50.00	50.00
Perspex (Acrylic sheet) 42cmx9cmx0.5cm	3	3.00	9.00
Acrylic hinges 1'	3	1.00	3.00
Acrylic locks	1	3.50	3.50
Acrylic Ball 18mm	1	1.50	1.50
Spray paint	1	7.00	7.00
Sand Paper	1	0.50	0.50
Bearing 4.5cm	1	20.00	20.00
Bearing 3cm	1	2.00	2.00
Screw, nut, aluminum wrap, and washer	4	2.00	2.00
Bolt	2	2.00	4.00
Epoxy Gum	1	10.00	10.00
Castor	1	3.00	3.00
		TOTAL (RM)	638.10

3.1.3 Gantt chart and key milestone

The Gantt chart of the Final Year Project I & II is as shown in **Appendix A**

3.2 Design of the robot

3.2.1 Mechanical design

The front part of the robot consists of three limit switch, tennis ball fetcher, wheels, and power window motor. The limit switch is activated when it is triggered by obstacles. The tennis ball fetcher consists of 3 blades to sweep in the tennis balls into the storage. In the meantime, the DC power window motor is used to spin the tennis ball fetcher. Also, the wheels are used to navigate the robot around the tennis court. From the two side views of the prototype, we can see that the tennis ball storage is used to store the tennis balls that have been swept in by tennis ball fetcher. Electronics compartment is used to put all the controller system of the robot as well as battery. The castor is free to rotate according to the navigating of the wheels. The rear part of the robot consists of two DC motors which are used to control the robot's navigation directions. Top view shows the control panel of the robot.

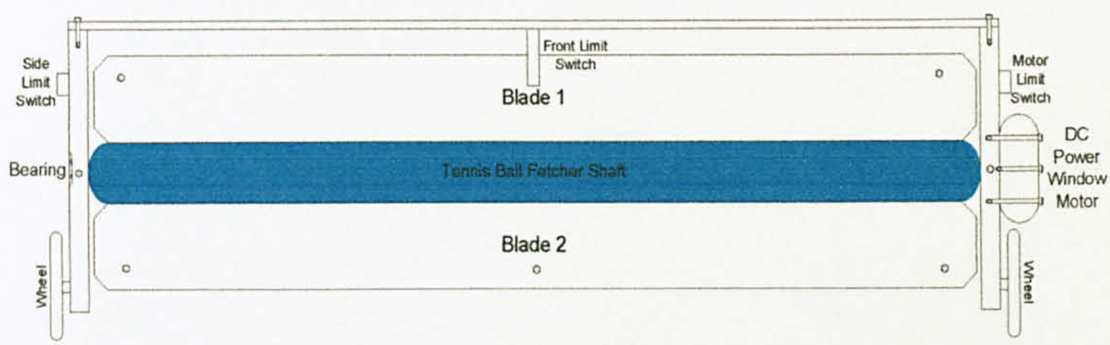


Figure 10: Front view of the prototype

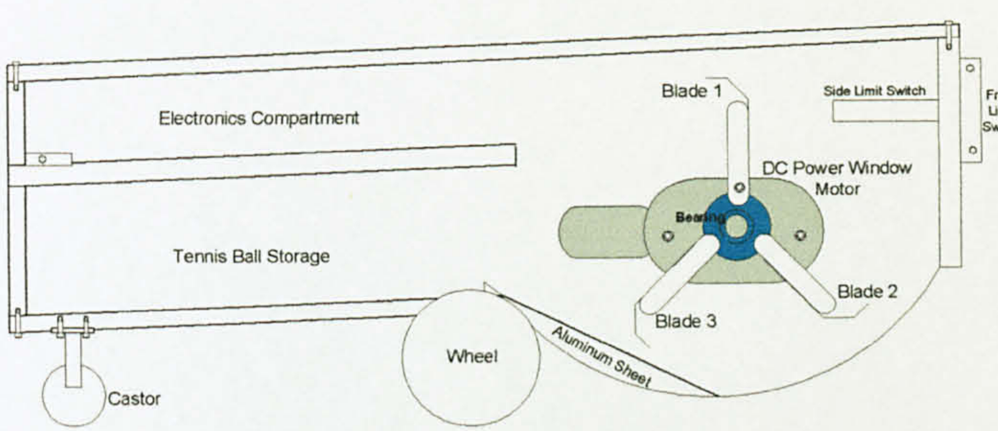


Figure 11: Right side view of the prototype

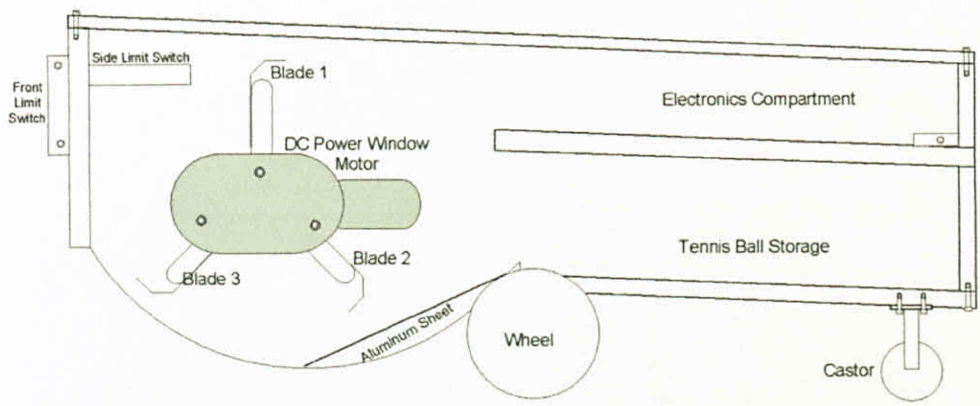


Figure 12: Left side view of the prototype

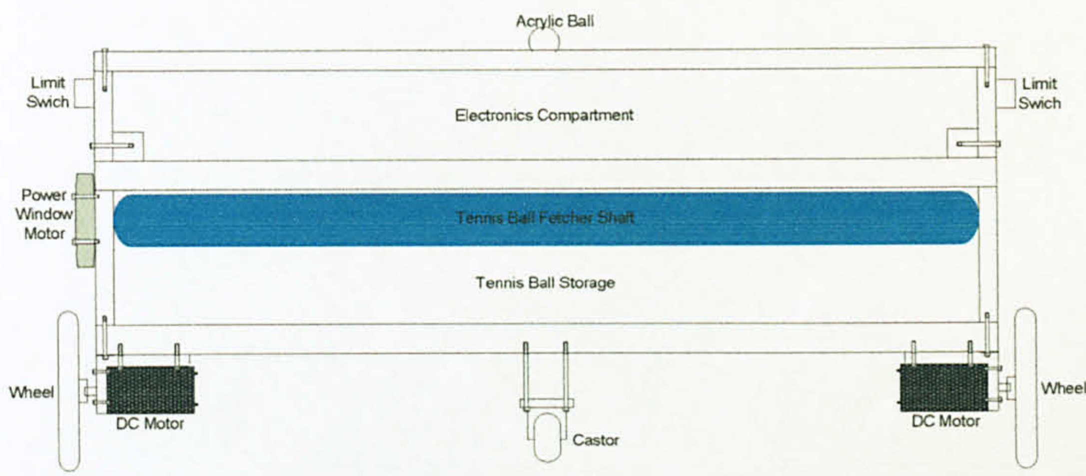


Figure 13: Rear view of the prototype

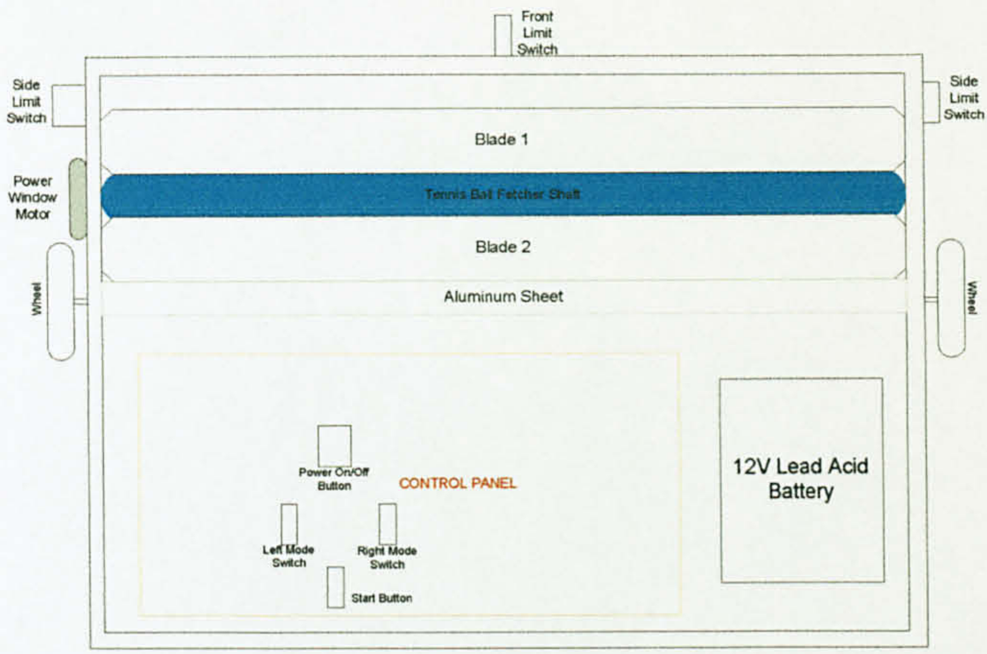


Figure 14: Top view of the robot

3.2.1.1 Tennis ball fetcher mechanism design

Tennis Ball Fetcher is made from a steel pipe, 10mm screw shaft, aluminum sheet and Perspex. The 3 slots at the steel pipe are made using milling machine. The purpose of the coupler is to join power window motor and 10mm screw shaft together. Besides that, the coupler is also used to join DC motor and wheel.

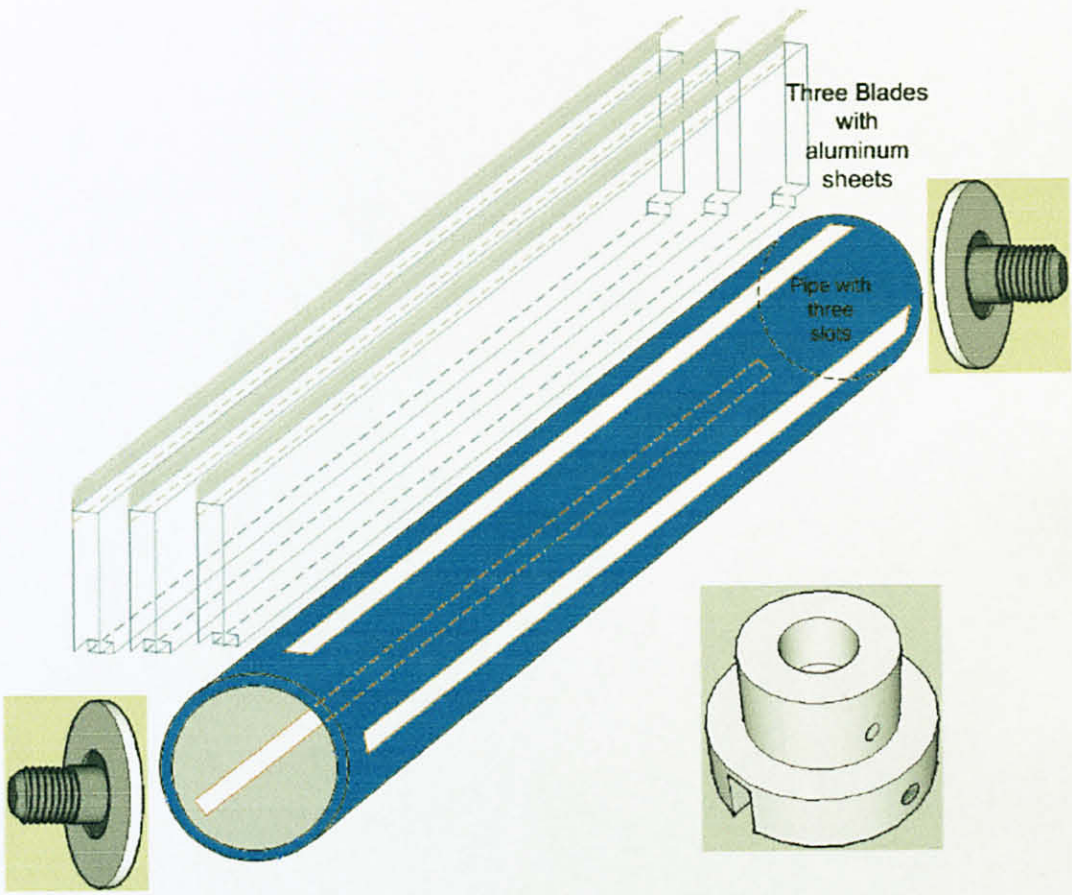


Figure 15: Design of Tennis ball fetcher

3.2.2 Controller design

The controller system consists of Front and Side limit switch boards, power window motor driver board, power supply board to regulate 9V to 5V, microcontroller board and L298N motor driver board. Figure 16 shows the arrangement of the controller systems.

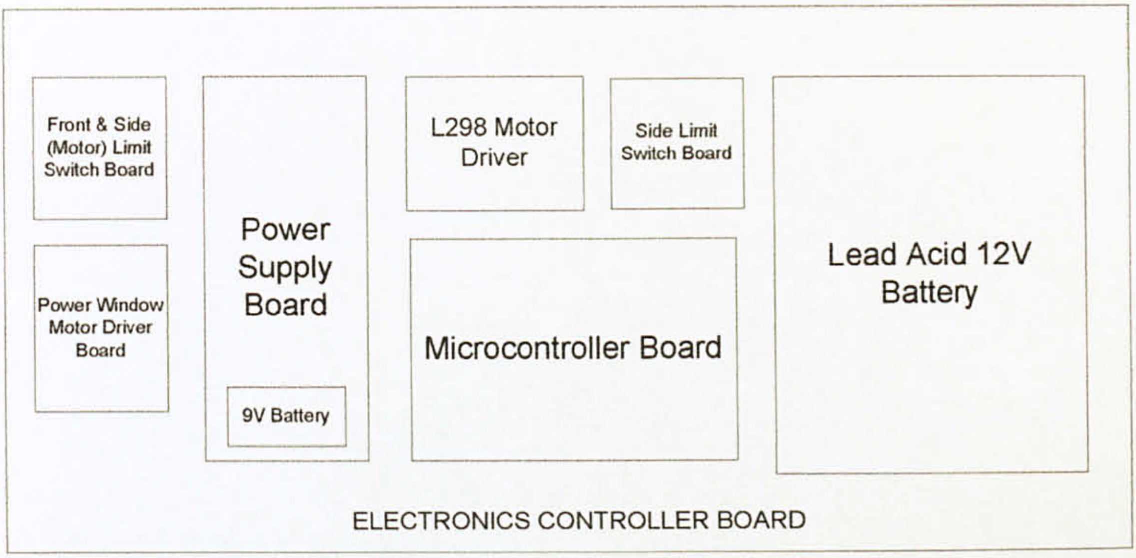


Figure 16: Robot Controller Systems

3.2.2.1 Schematics

The schematics of the Front & Side Limit Switch Board and power window motor driver are shown in figure 17 and 18.

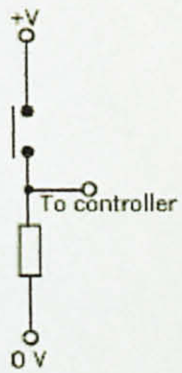


Figure 17: Active high configuration for the Limit switch board

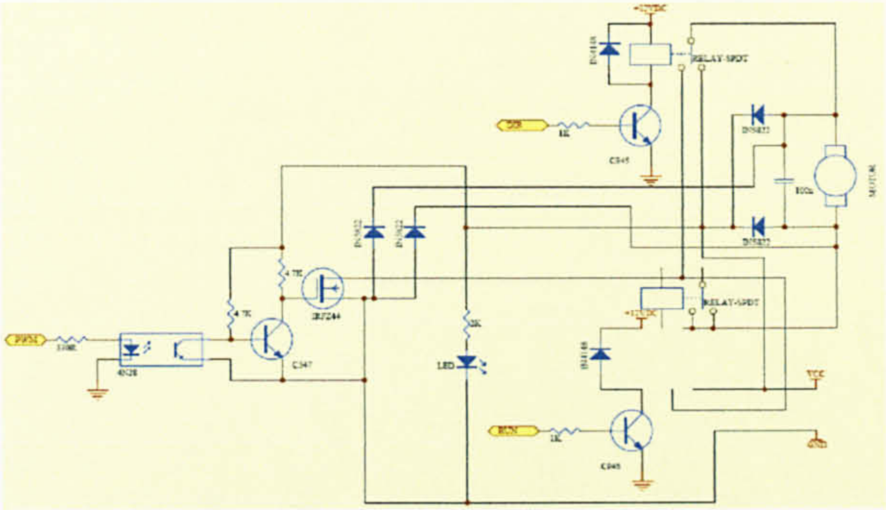


Figure 18: Schematics of power window motor driver

3.2.2.2 PCB Design

The PCB design of power window motor driver and L298N motor driver is shown below: -

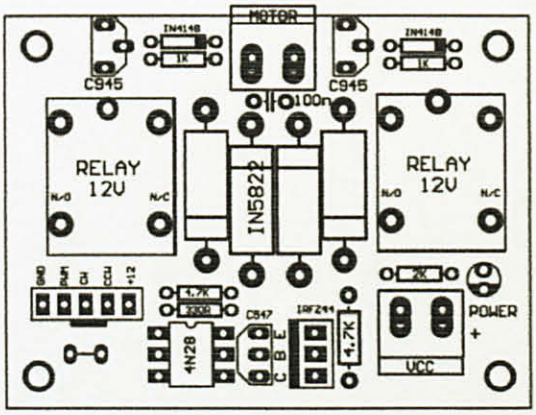


Figure 19: Components on PCB layout for Power window motor driver

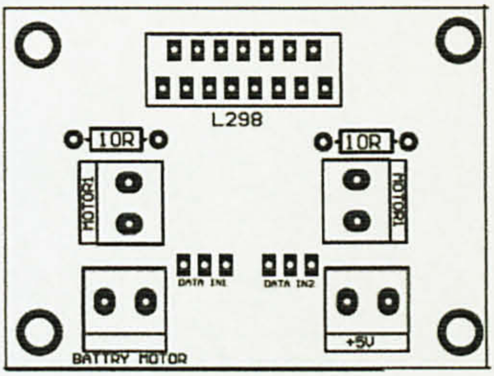


Figure 20: Components on PCB layout for L298N motor driver

3.3 Navigation & Software Systems

The navigation system of the robot can be explained through the robot's navigation/collecting area, navigation methods, flowchart, and programming of the robot. The flowchart has been constructed to fulfill the requirement of: -

i. Robot navigation/collecting area.
ii. Navigation methods.

Thus, the programming code can be obtained from the flowchart. Therefore, details of explanations are shown in the following subtopic: -

3.3.1 Robot Navigation/collecting Area

The navigating/collecting area of the robot is determined based on the literature review, where it mentioned most of the tennis balls will be distributed around the back of the court. Hence, this robot will sweep the court as shown in Figure 21.

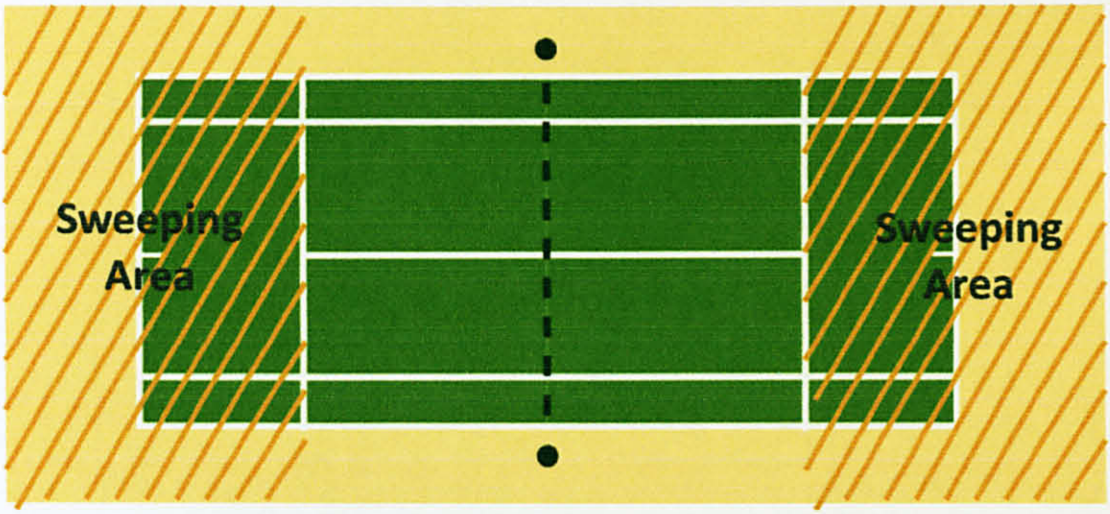


Figure 21: Collecting tennis ball area by robot

3.3.2 Navigating Methods

The navigating of the robot follows one method, which is left side navigation. This is shown in Figure 22.

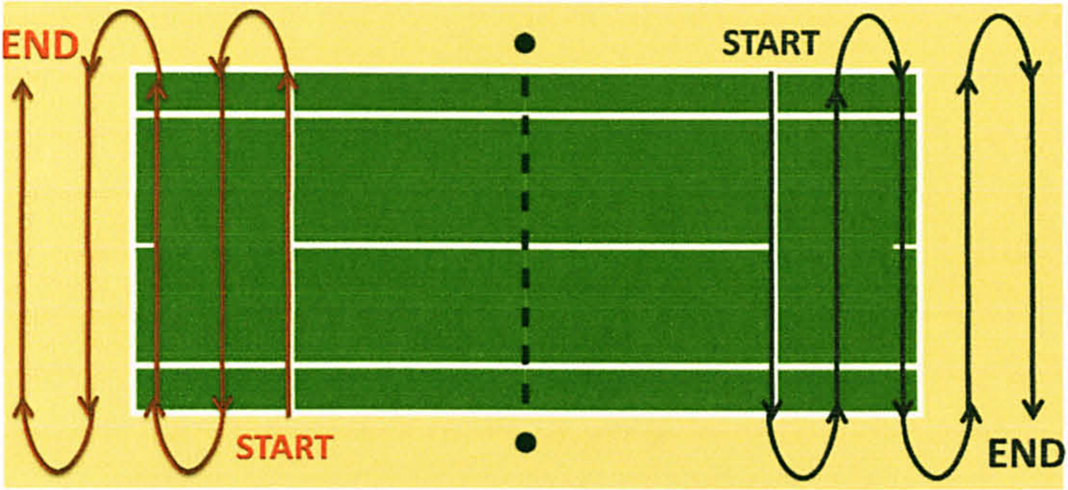


Figure 22: method of navigation

3.3.3 Flowchart

Firstly, user needs to switch on the power. In the case of the left button is being pressed, the robot will reverse and make a left U-turn if its front switch is triggered. Then it will continue to move forward. If the front switch is triggered for the 2nd time, the robot will reverse and make a right U-turn for this time. Then, it will continue to move forward again. The same step will repeat again whenever the front switch is triggered by making left and right U-turn alternately. Another condition is that, if the left/right switch and the front switch are both triggered, meaning it is detected that the robot has reached a corner and it will be stopped. The flowchart is shown in the figure 23.

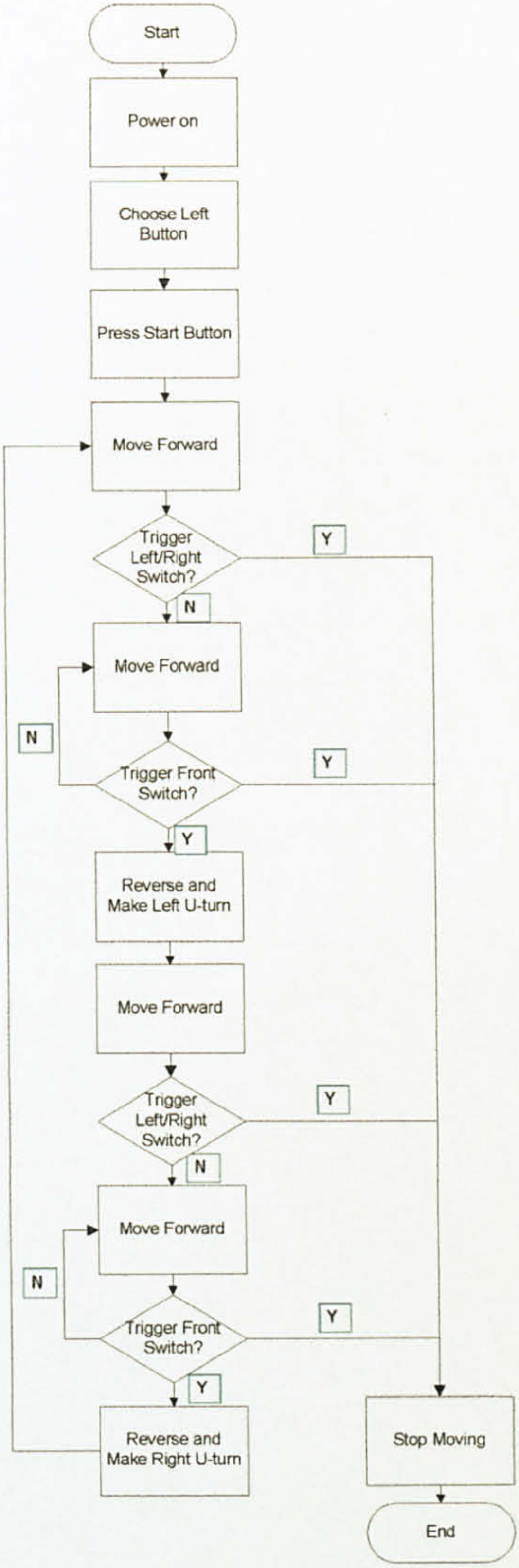


Figure 23: Flowchart of the navigation system

3.3.4 Software/programming

From the flowchart above, the programming code is obtained. Please refer to **Appendix C** for programming code.

3.3.5 Truth Table

The truth table of the robot's navigation systems are tabulated based on the information obtained in the flowchart.

Input

LB	= 0	when the button is not pressed at the control panel
	= 1	when the button is pressed at the control panel
FLS	= 0	when the Front Limit Switch is not triggered by obstacle
	= 1	when the Front Limit Switch is triggered by obstacle
LLS	= 0	when the Left Limit Switch is not triggered by obstacle
	= 1	when the Left Limit Switch is triggered by obstacle
RLS	= 0	when the Right Limit Switch is not triggered by obstacle
	= 1	when the Right Limit Switch is triggered by obstacle

Output

LMF = 1	Left motor forward
LMR= 1	Left motor reverse
RMF = 1	Right motor forward
RMR= 1	Right motor reverse

Table 2: Truth table of the robot before it navigates

Input				Output				Remarks of robot
LB	FLS	LLS	RLS	LMF	RMF	LMR	RMR	
0	0	0	0	0	0	0	0	Stop
0	0	0	0	1	1	0	0	Forward
1	0	0	0	1	1	0	0	Forward
1	0	0	0	0	0	0	0	Stop
0	1	0	0	0	0	0	0	Stop
0	0	1	0	0	0	0	0	Stop
0	0	0	1	0	0	0	0	Stop

Table 3: Truth table of the robot when it is navigating

Input				Output				Remarks of robot
LB	FLS	LLS	RLS	LMF	RMF	LMR	RMR	
0	0	0	0	0	0	0	0	Continue
1	0	0	0	0	0	0	0	Continue
1	0	0	0	0	0	0	0	Continue
0	1	0	0	0	0	1	1	Reverse + U-turn
0	0	1	0	0	0	0	0	Stop
0	0	0	1	0	0	0	0	Stop

CHAPTER 4
RESULT AND DISCUSSION

4.1 Physical Structure

4.1.1 Mechanical Design

The final outcome of the robot is obtained. The mechanical design can be shown from the front view, right and left side view, rear view and top view. The design of the robot is rugged and stable.

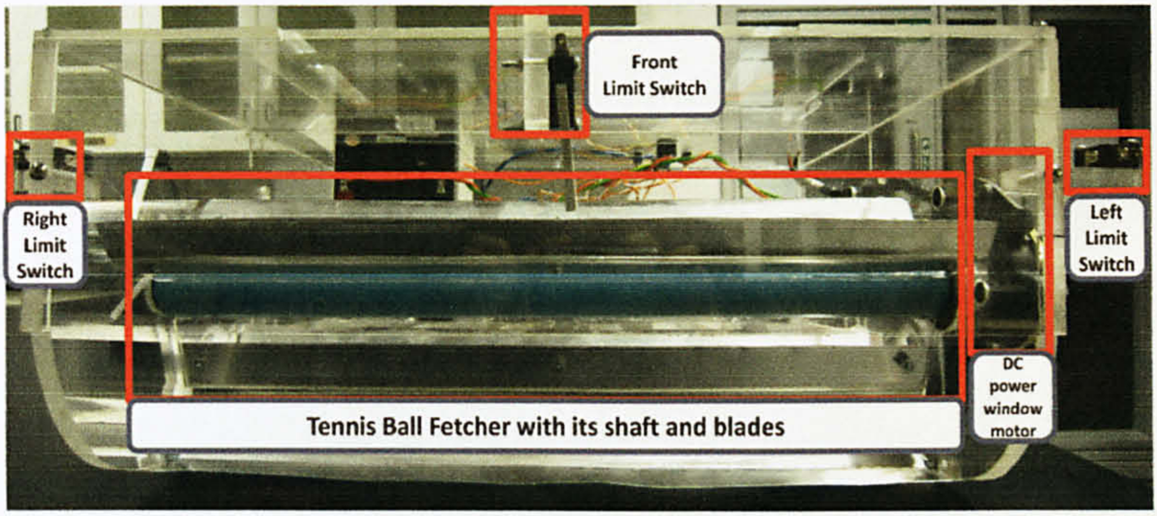


Figure 24: Front view of the robot

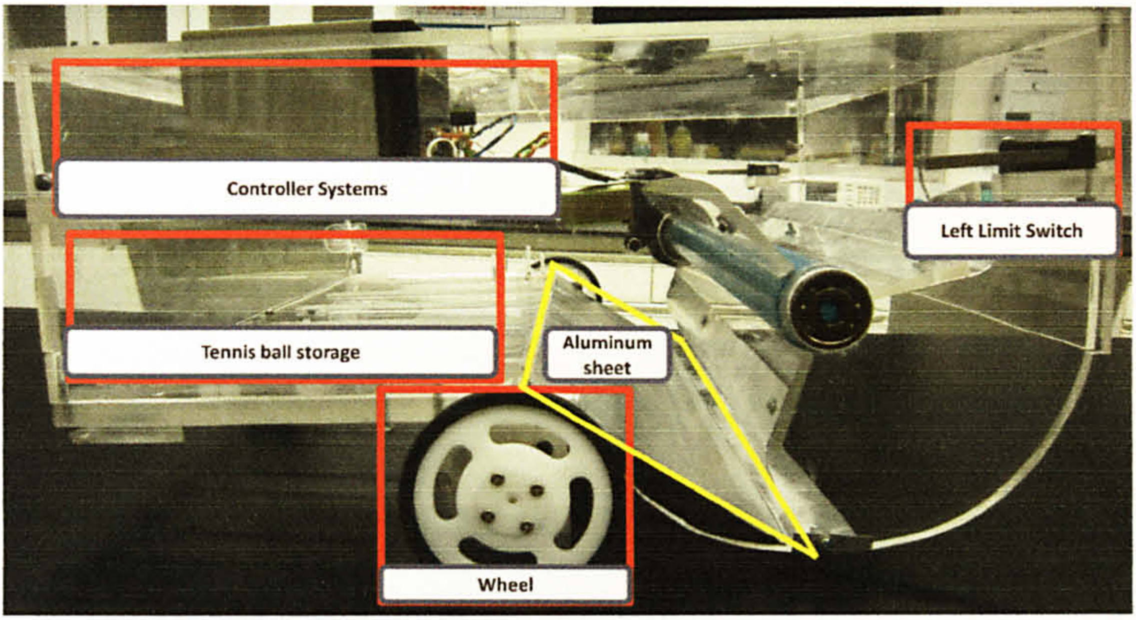


Figure 25: Right side view of the robot

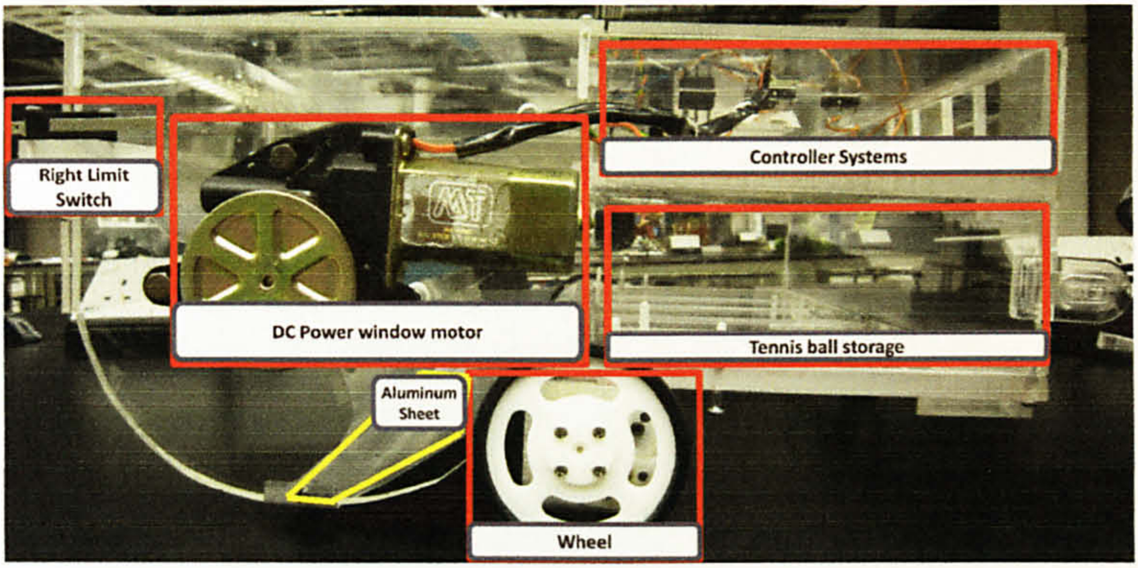


Figure 26: Left side view of the robot

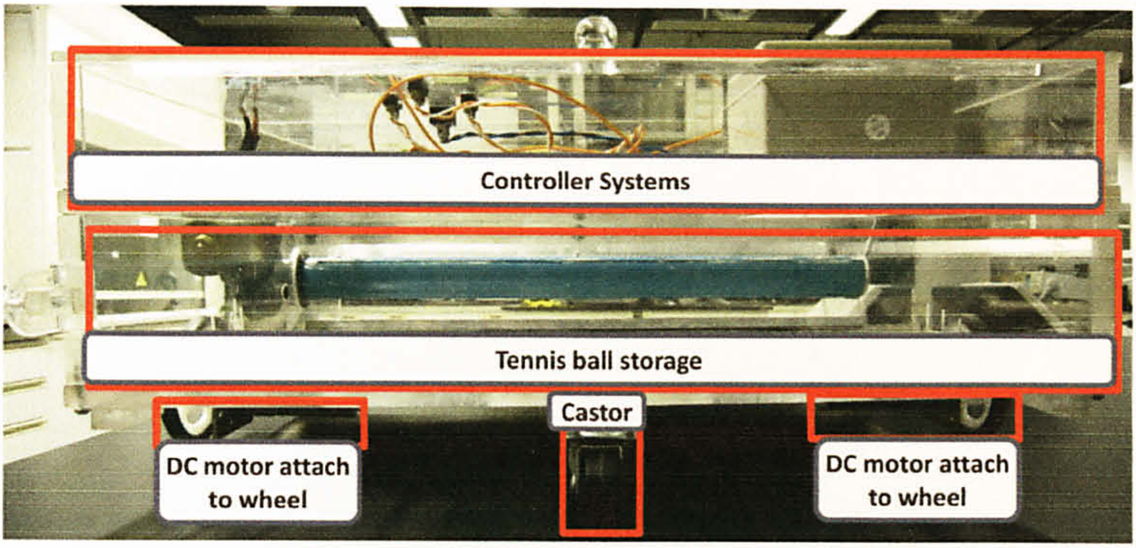


Figure 27: Rear view of the robot

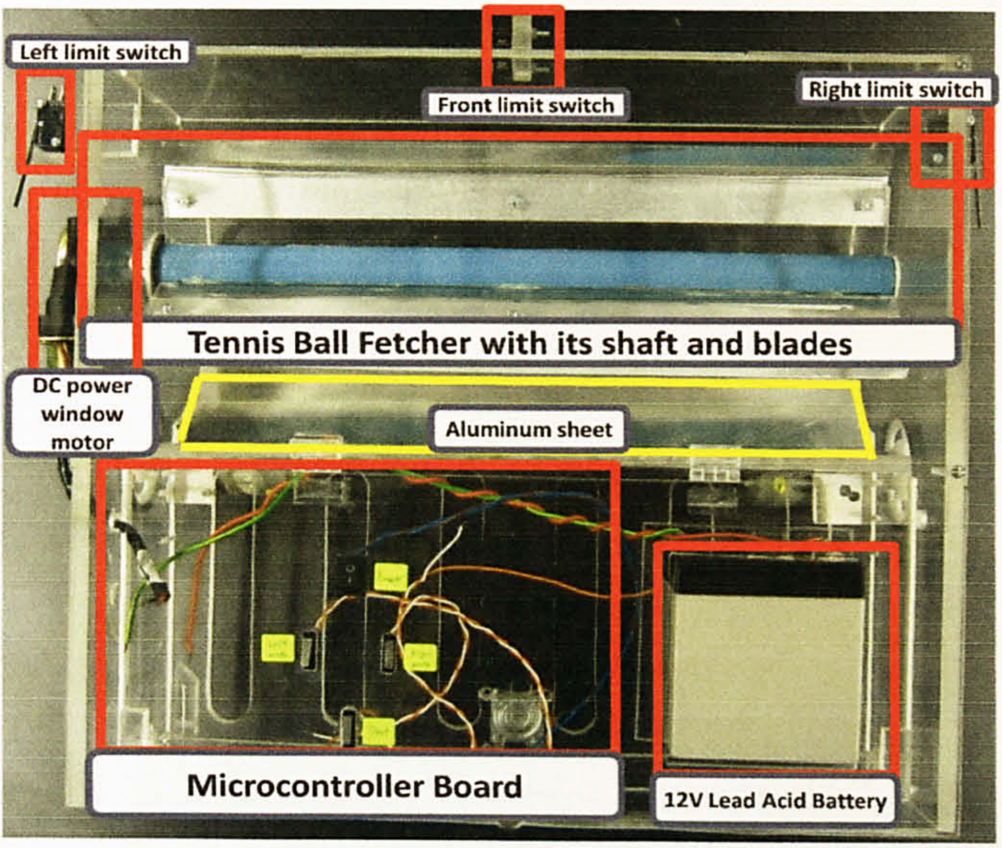


Figure 28: Top view of the robot

4.1.1.1 Mechanism

Tennis ball will be swept into the tennis ball storage by Tennis ball fetcher. The operation of the tennis ball fetcher is shown in figure 29.

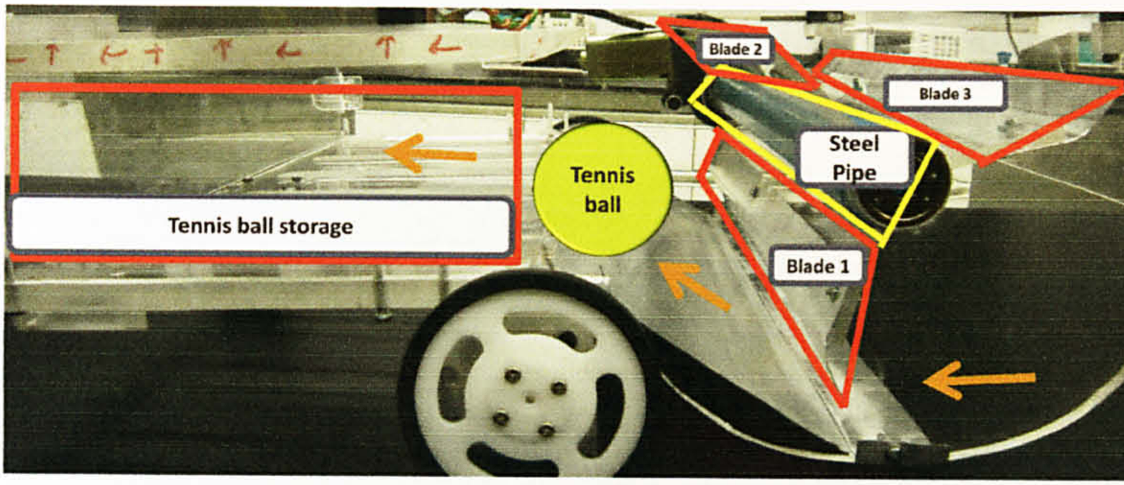


Figure 29: Tennis Ball Fetcher

4.1.2 Controller Design

The controller system consists of Front and side limit switch board, DC power window motor driver, Power supply board, L298N motor driver, side limit switch board, and microcontroller board. The overall controller system is shown in figure 30.

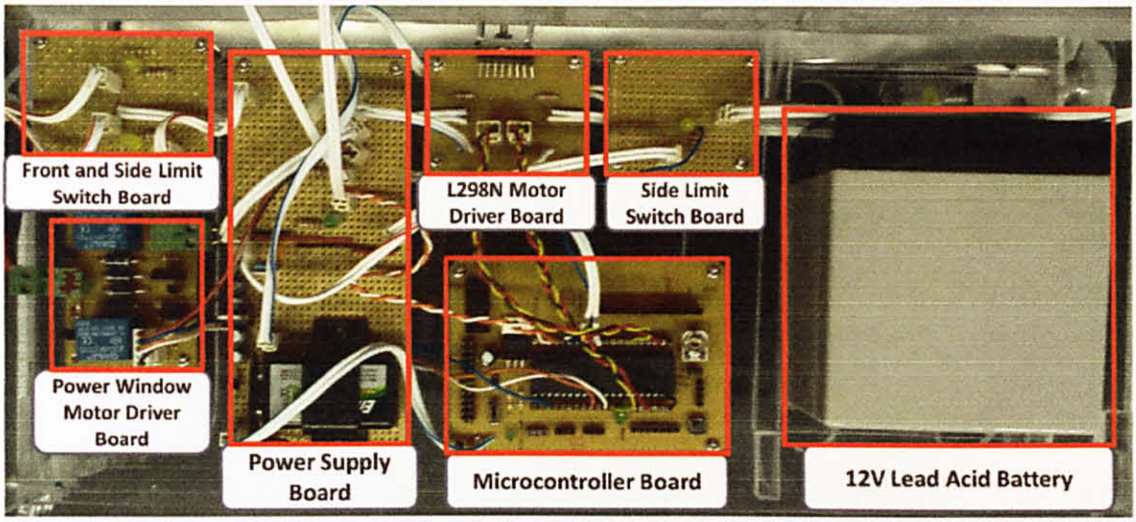


Figure 30: Controller systems

The outcome of the schematics design of DC power window motor drive and L298N motor driver is shown below:-

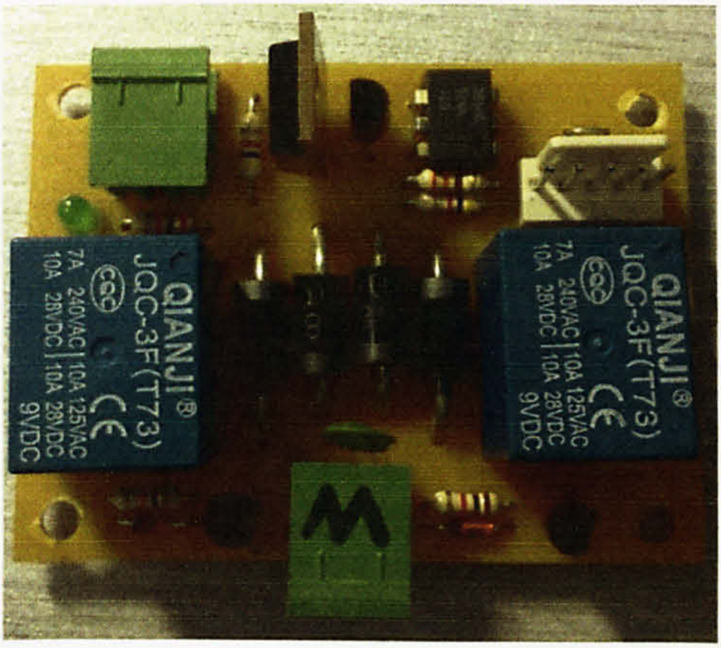


Figure 31: DC power window motor driver

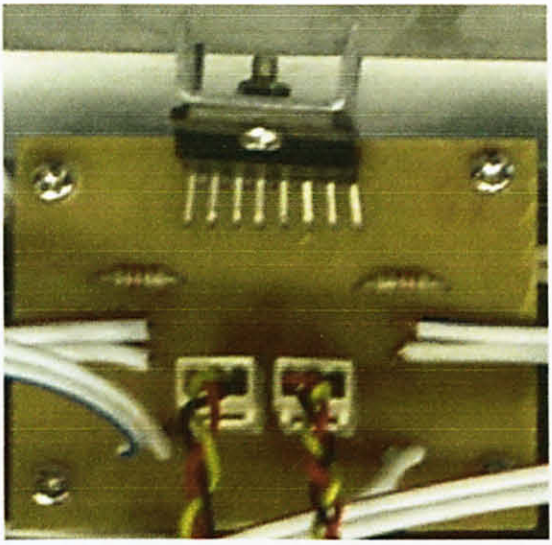


Figure 32: L298N motor driver

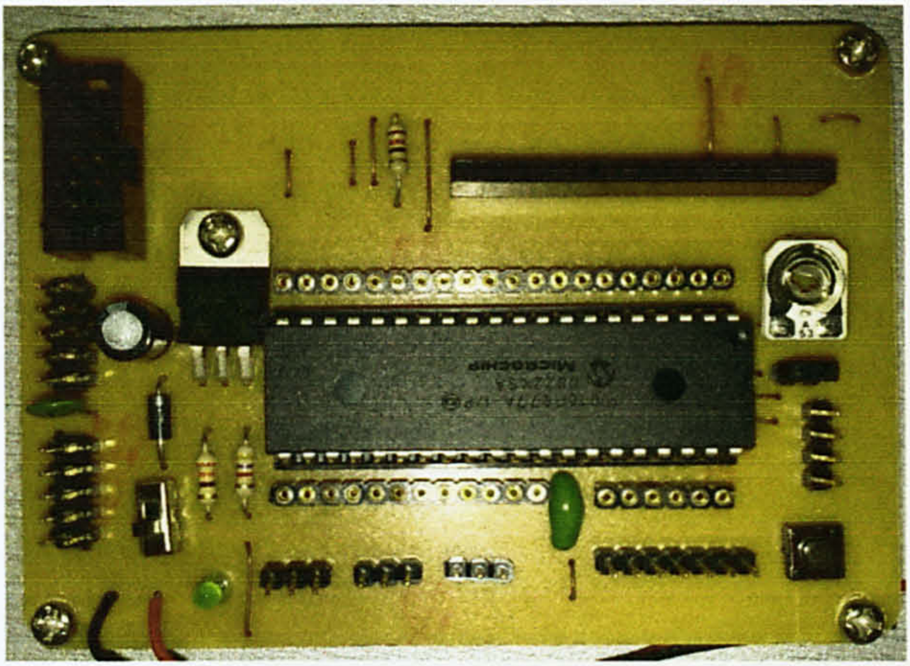


Figure 33: Microcontroller board

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The main objective of the project is achieved, which is to design a machine to collect tennis balls autonomously. Besides that, autonomous robot for collecting tennis balls consists of a mechanical structure, a controller system, and a navigation system. The mechanical structure is the physical appearance of the robot. Without the mechanical structure, the controller system cannot be integrated into the robot. The controller system consists of a microcontroller board, a motor driver board, a power supply board and a limit switch board. The navigation system consists of software programming and the navigating path of the robot.

The project is completed and it meets the minimum expectation. Modification need to be done in order to have a better result. Besides that, the forward direction of the robot is not straight. This is because DC motor is solely depending on current supply by the battery, alignment of the robot's wheel, and the delay which we programmed.

5.2 Recommendations

This project can be improved by adding new features such as solar powered and distance sensor in replacement of a limit switch. Besides that, the physical structure of the robot can be modified that the robot can carry water bottles on the top of the robot while tennis trainees can grab it when trainees get thirsty.

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APPENDIX A

GANTT CHART OF PROJECT

Final Year Project I

No.	Detail / Week	1	2	3	4	5	6	7	8	9		10	11	12	13	14
1	Submission of Project Topic										Mid-semester break					
2	Preliminary Research Work & Literature Review															
3	Submission of Preliminary Report															
4	Continue Research & Literature Review															
6	Submission of Progress Report															
7	Seminar															
8	Designing Prototype															
9	Submission of Interim Draft Report															
10	Submission of Interim Report															
11	Oral Presentation											After Final Exam				

Final Year Project II

No.	Detail / Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Continue research and understanding the project								Mid-semester break							
2	Designing New Prototype															
3	Purchasing of Material															
4	Submission of Progress Report I															
5	Building Prototype															
6	Submission of Progress Report II															
7	Designing Circuit															
8	Poster Presentation															
9	Circuit and Hardware connections															
10	Programming of the Robot															
11	Test run Prototype															
12	Submission of Final Draft															
13	Submission of Final Report & Technical Report															
14	Oral Presentation									After Final Exam						

APPENDIX B
GALLERY OF THE "ARFCTB"

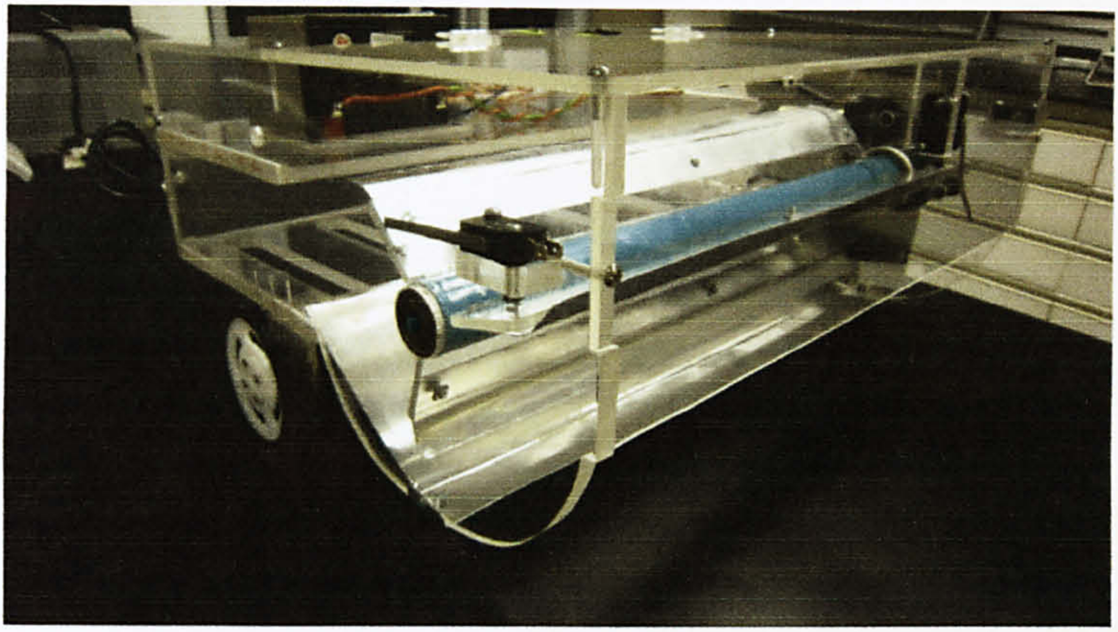

Figure 34: Snapshot of the robot

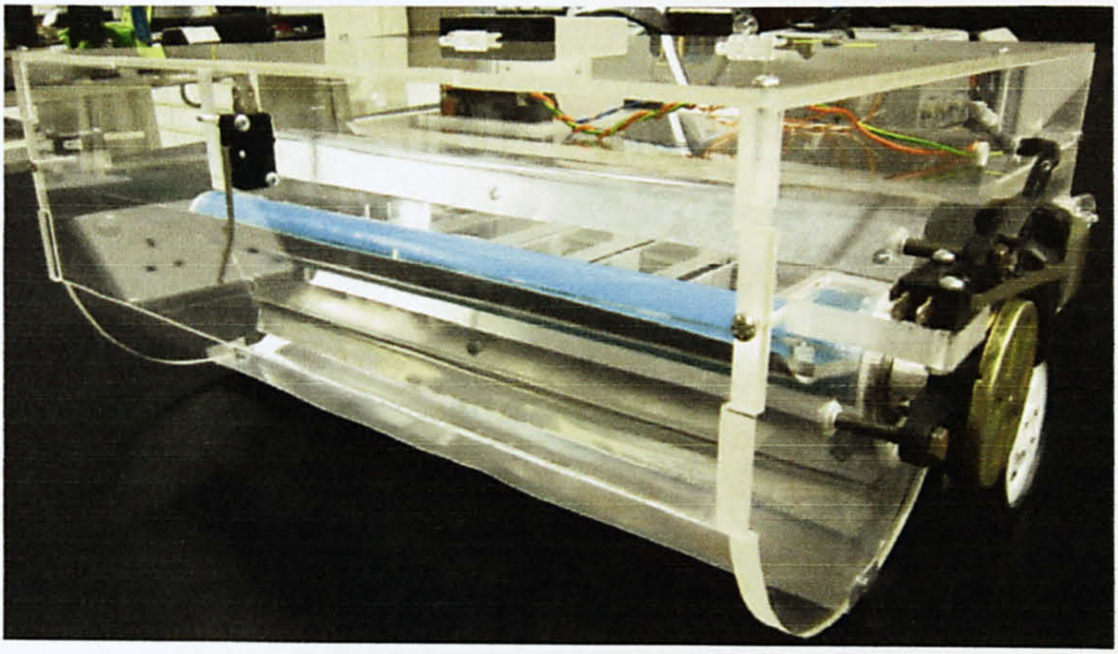

Figure 35: Snapshot 2 of the robot

APPENDIX C
PROGRAMMING CODE

```
#include <16f877a.h>
#USE DELAY(CLOCK=4000000) /* Using a 4 Mhz clock */

#FUSES XT,NOWDT,NOPROTECT,NOLVP
/* Use XT mode, No Watch Dog, No Code Protect, No Low Voltage Programming */

unsigned int8 x;

void forward()
{
    output_b(0xf1);  //xxxx0001
    output_c(0x00);
    CCP_1 = 100;
    delay_ms(500);
}

void reverse()
{
    output_b(0xf2);
    output_c(0x00);
    CCP_1 = 100;
    delay_ms(500);
}

void turn_right()
{
    output_c(0x01);
    output_b(0xf4);
//    CCP_2 = 100;
    delay_ms(10);
}

void turn_left()
{
    output_c(0x01);
    output_b(0xf8);
//    CCP_2 = 100;
    delay_ms(10);
}void forward_right()
{
    output_c(0x01);
    output_b(0xF5);
    CCP_1=100;
    delay_ms(300);
    output_c(0x00);
}
```

```
void forward_left()
{
    output_c(0x01);
    output_b(0xF9);
    CCP_1=100;
    delay_ms(400);
    output_c(0x00);
}
void Reverse_right()
{
    output_c(0x01);
    output_b(0xF6);
    CCP_1=100;
    delay_ms(300);
    output_c(0x00);
}
void Reverse_left()
{
    output_c(0x01);
    output_b(0xFA);
    CCP_1=100;
    delay_ms(400);
    output_c(0x00);
}

main()
{
    //setup_adc_ports( ALL_ANALOG );
    //setup_adc(ADC_CLOCK_INTERNAL);        // Use internal ADC clock.

    setup_timer_2(T2_DIV_BY_1,99,1); //enable Timer2, PR2=99, prescaler=1
    setup_ccp1(CCP_PWM); //enable PWM mode
    setup_ccp2(CCP_PWM); //enable PWM mode
    set_tris_b(0x00);//set all pins at portB as output
    //set_tris_c(0x00);//set all pins at portC as output
    set_tris_d(0xff);//set pin (7:4) at portD as input and pin (3:0) as output
    set_tris_c(0x00);

  while(1)
  {


    x=input_d();  //read PortD from receiver

    if(x == 0x10)  //forward
    {
    forward();
    }

    else if (x == 0x20)  //reverse
```

```
{
reverse();
}

else if (x == 0x40)  //turn
{
turn_right();
}

else if (x == 0x80)  //turn
{
turn_left();
}

else if (x == 0x50)  //turn
{
forward_right();
}
else if (x == 0x90)
{
Forward_left();
}
else if (x == 0x60)
{
Reverse_right();
}
else if (x == 0xA0)
{
Reverse_left();
}
else
CCP_1 = 0;
output_c(0x00);
 }
}
```

APPENDIX D
PCB LAYOUT

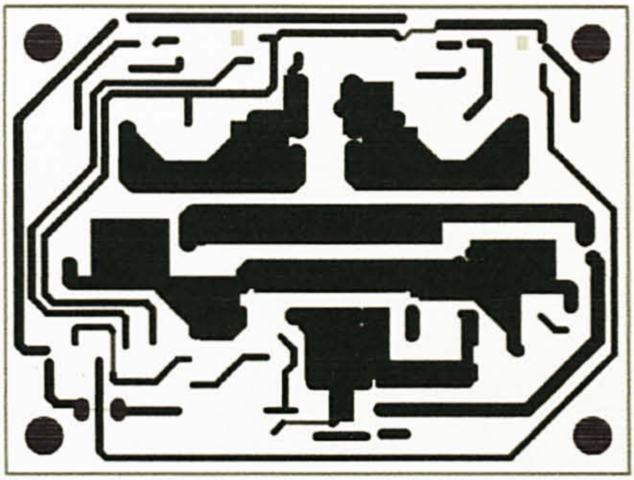

Figure 36: Power window motor driver connections

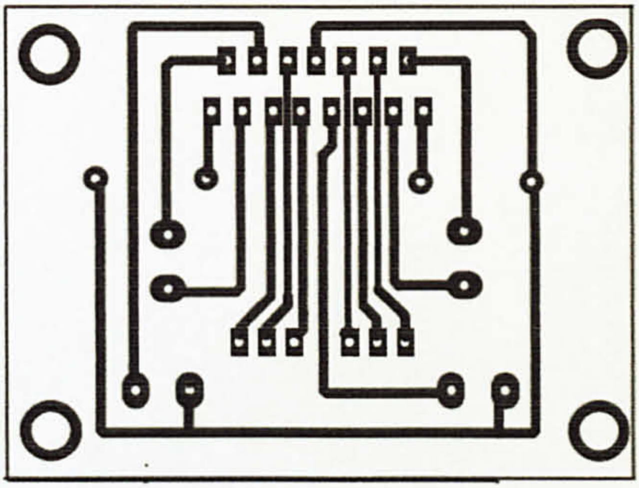

Figure 37: L298N motor driver connections

APPENDIX E

CIRCUITS DIAGRAM

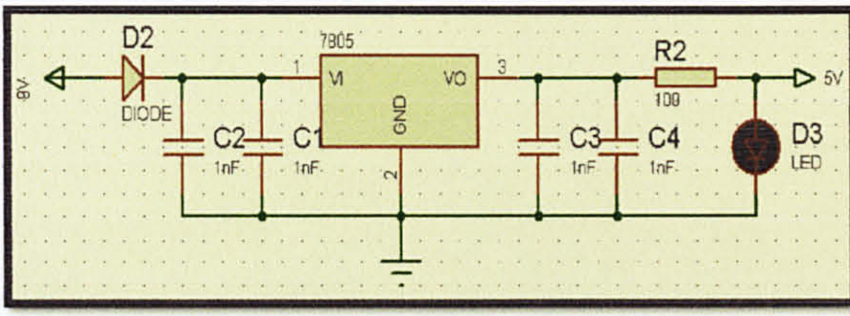

Figure 38: 5V voltage regulator

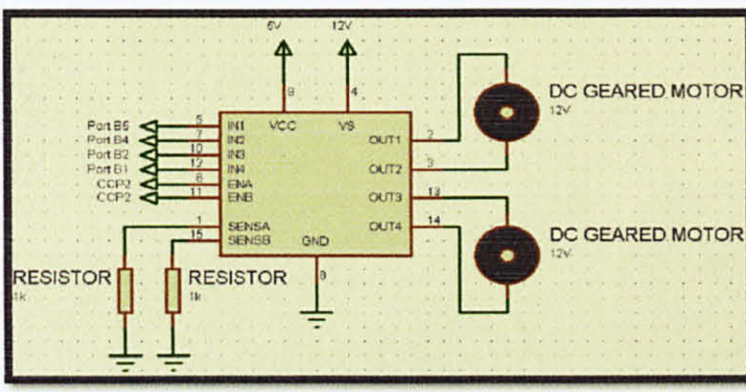

Figure 39: L298N motor driver for DC geared motor

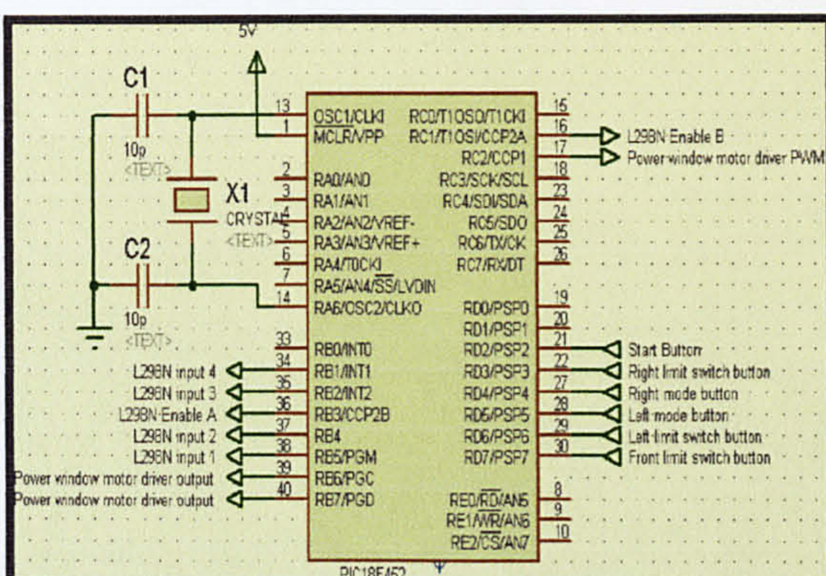

Figure 40: Microcontroller Cicuit board