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**DESIGN AND DEVELOP ROBOT TRACKED
VEHICLE PLATFORM FOR NAVIGATION AND RESCUE
APPLICATION**

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Bachelor of Mechatronics Engineering

2015

“ I hereby declare that I have read through this report entitle “Design and Develop Robot Tracked Vehicle Platform for Navigation and Rescue Application” and found that it has comply the partial fulfillment for awarding the Bachelor of Mechatronics Engineering with Honours. ”

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**DESIGN AND DEVELOP ROBOT TRACKED VEHICLE PLATFORM FOR
NAVIGATION AND RESCUE APPLICATION**

MUHAMMAD HASIF BIN MOHD AZIRI



**A report submitted in partial fulfillment of the requirements for the
Bachelor of Mechatronics Engineering with Honours**

**Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

2015

I declare that this report entitle “Design and Develop Robot Tracked Vehicle Platform for Navigation and Rescue Application” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

This project proposes designing and developing a Robot Tracked Vehicle Platform (RTVP) for navigation and rescue application by using a parallel mechanism based on the track structure from the viewpoint of the tracked locomotion design. Recently, robot platform is used as a control robot for research and development in the area of technologies especially for search and rescue task as well as for domestic purposes. This robot in this project is a robot tracked platform that consist of four nine-inch wheels size and driven by 24V DC brush motor with 350W power and 2600RPM at maximum speed. The motor function of the RTVP is driven by 30A DC Motor Driver with current capability up to 80A and 40A continuously. The body of RTVP is made of aluminium hollow, steel and sheathing plywood which is combined with a modified off road motorcycle tire as a track structure. Besides, the right size of the wheel and the design of the chassis must be in an accordance for stable movement in order to always maintain a parallel state of the robot mechanism. The RTVP capable to move from the left side and the right side as well maneuver in straight line, turn back and rotate 360 degree. The RTVP is controlled by Romeo-All In One Controller (Arduino Compatible Atmega 328) powered by four(4) 12V/7.0Ah lead acid battery that can be controlled via a wireless connection by using the APC220 RF module. Overall, the RTVP is designed for a wider range of applications which is able adapt to the complex terrain environment such as climbing the obstacle and off road use with low cost of manufacturing.

ABSTRAK

Projek ini adalah cadangan untuk merekabentuk dan membangunkan sebuah robot trek platform bagi tujuan navigasi dan menyelamatkan dengan menggunakan mekanisma selari berdasarkan struktur trek dari sudut pandangan rekabentuk pergerakan trek. Pada masa kini, robot trek platform digunakan untuk tujuan penyelidikan dan pembangunan dalam bidang teknologi dan ianya juga turut digunakan secara meluas untuk tugas mencari dan menyelamatkan serta bagi tujuan domestik. Robot ini adalah robot trek platform yang terdiri daripada empat roda bersaiz 9 inci dan dipacu dengan 24V motor arus terus berkuasa tinggi iaitu 350W dengan kelajuan 2600 RPM dalam keadaan tanpa beban. Motor yang digunakan untuk robot ini dipacu oleh “30A DC Motor Driver” yang mampu untuk mengawal nilai voltan dan arus yang tinggi mengikut keupayaan semasa dari 40A hingga 80A secara berterusan. Robot ini diperbuat daripada aluminium hollow, besi dan papan lapis serta menggunakan tayar motorsikal lasak yang telah diubahsuai untuk dijadikan sebagai struktur trek. Di samping itu, saiz roda dan rekabentuk casis yang betul amat penting untuk mengekalkan kestabilan pergerakan robot trek melalui kaedah konfigurasi secara keadaan selari. Robot ini mempunyai kebolehan untuk berpusing ke kiri dan kanan, ke hadapan dan belakang dalam keadaan lurus dan berpusing 360 darjah. Robot ini menggunakan pengawal “Romeo-All In One Controller (Arduino Compatible Atmega 328)” dan empat(4) 12V/7.0Ah bateri asid plumbum serta radio frekuensi APC220 digunakan sebagai alat kawalan tanpa wayar bagi keseluruhan operasi robot trek. Secara keseluruhan, robot trek platform ini direka untuk pelbagai aplikasi yang dapat beroperasi dalam persekitaran yang lasak dan ekstrim dengan kos yang rendah.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	ii
	ABSTRACT	iii
	TABLE OF CONTENTS	v
	LIST OF TABLES	ix
	LIST OF FIGURES	x
	LIST OF SYMBOLS	xiv
	LIST OF APPENDICES	xv
1	INTRODUCTION	1
	1.1 Motivation	2
	1.2 Problem Statement	2
	1.3 Objectives	3
	1.4 Scope of the Project	3
	1.5 Summary	4
2	LITERATURE REVIEW	5
	2.1 Introduction	5
	2.2 The Existing Mobile Robot with Tracked Locomotion Mode	5
	2.2.1 MOBIL, A Small Wheel -Track- Leg Mobile Robot	5
	2.2.2 Obstacle Negotiation for the Rescue Robot with Variable Single-tracked Mechanism	6
	2.2.3 Wheel & Track Hybrid Robot Platform for Optimal Navigation in an Urban Environment	7

CHAPTER	TITLE	PAGE
	2.2.4 Transformable Wheel-Track Robot with Self-adaptive Mobile Mechanism	8
	2.2.5 Joint Double-Track Robot	9
2.3	System Design with Locomotion Modes	9
	2.3.1 System Design with Locomotion Modes of the MOBIL, A Small Wheel -Track- Leg Mobile Robot	10
	2.3.2 System Design with Locomotion Modes of Obstacle Negotiation for the Rescue Robot with Variable Single-tracked Mechanism	12
	2.3.3 System Design with Locomotion Modes of the Wheel & Track Hybrid Robot Platform for Optimal Navigation in an Urban Environment	13
	2.3.4 System Design with Locomotion Modes of the Transformable Wheel-Track Robot with Self-adaptive Mobile Mechanism	15
	2.3.5 System Design with Locomotion Modes of the Joint Double-Track Robot	17
	2.4 Summary	19
3	METHODOLOGY	25
	3.1 Introduction	25
	3.2 Project Methodology	25
	3.3 Milestone and Project Planning	28
	3.4 Robot Tracked Vehicle Platform Design Ideas	28
	3.5 System Block Diagram	30
	3.5.1 Block Diagram of RF Transmitter	30
	3.5.2 Block Diagram of RF Receiver	31
	3.6 Component and Material Selection	32
	3.7 Hardware and Software Development	37
	3.7.1 Hardware Development	37

CHAPTER	TITLE	PAGE
	3.7.1.1 Development of Body Structure	38
	3.7.1.2 Gear Configuration	39
	3.7.1.3 Gear Ratio Calculation	40
	3.7.1.4 Chain Length Calculation	43
	3.7.1.5 Electrical Circuit Simulation	46
	3.7.2 Software Development	49
	3.7.2.1 Flowchart for Programming of Robot Controller	50
	3.7.2.2 Communication Between PC and Arduino Board Wirelessly	51
	3.7.2.3 Graphic User Interface (GUI) Controller	55
	3.8 Experiment and Project Set Up	56
	3.8.1 Experiment 1:	56
	Simulation for the chassis of Robot Track Vehicle Platform by using SolidWorks Simulation Xpress software	54
	3.8.2 Experiment 2:	57
	Forward and backward movement on the road test	
	3.8.3 Experiment 3:	58
	Right and left turn on the road test	
	3.8.4 Experiment 4:	59
	Obstacle test on difference heights of ladder	
	3.8.5 Experiment 5:	60
	Different condition of the surfaces test	
	3.9 Summary	61
4	RESULT AND DISSCUSSION	62
	4.1 Introduction	62
	4.2 Project Design	62

CHAPTER	TITLE	PAGE
	4.2.1 Design Characteristic of the Robot Tracked Vehicle Platform	62
	4.2.2 3D Drawing with Tolerance	65
	4.2.3 Completed Mechanical Construction	67
	4.3 Analysis of the Chassis Body	69
	4.3.1 Assumptions	70
	4.3.2 Material Properties	70
	4.3.3 Load and Fixtures	71
	4.3.4 Mesh Information	72
	4.3.5 Study Result	73
	4.4 Field Test of Robot Tracked Vehicle Platform	75
	4.4.1 Experiment 2: Forward and backward movement on the road test	75
	4.4.2 Experiment 3: Right and left turn on the road test	81
	4.4.3 Experiment 4: Obstacle test on difference heights of ladder	87
	4.4.4 Experiment 5: Different condition of the surfaces test	91
	4.5 Summary	96
5	CONCLUSION	97
	5.1 Introduction	97
	5.2 Conclusion	97
	5.3 Recommendations	98
	REFERENCES	99
	APPENDICES	102

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Summary about system design and locomotion mode of the existing robot tracked platform	20
3.1	Planning activities	28
3.2	Components and materials for mechanical parts	32
3.3	Components and materials for electrical parts	35
3.4	The pin definitons of APC220	51
3.5	Setting parameter of APC220 RF module	54
4.1	The specification of the Robot Tracked Vehicle Platform	63
4.2	Mass properties of the design by using SolidWorks software	64
4.3	The mass properties for chassis of the RTVP	69
4.4	Solid Bodies	70
4.5	Material Properties	70
4.6	Fixtures	71
4.7	Load	71
4.8	Details of mesh information	72
4.9	Result for Stress	73
4.10	Result for Displacement	73
4.11	Result for Deformation	74
4.12	Result for Factor of Safety	74
4.13	Result Test of Foward Movement	75
4.14	Result Test of Reverse Movement	78
4.15	The result test for the right turning movement	81
4.16	The result test for the left turning movement	82
4.17	The result for obstacle test on difference heights of ladder	88
4.18	The surfaces test on the stone	91
4.19	The surfaces test on the grass	93

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Search and Rescue Robot	2
2.1	MOBIT robot	6
2.2	Mode Transformation of VSTR	6
2.3	Wheel & Track Hybrid Robot Platform	7
2.4	NEZA-I prototype	8
2.5	Joint Double-Tracked Robot	9
2.6	The design of MOBIT robot	10
2.7	The locomotion modes of MOBIT robot	11
2.8	The design parameter of the the Rescue Robot with variable single-tracked Mechanism	12
2.9	The driving mode and the locomotion modes for overcoming the obstacles	13
2.10	The conceptual design of the robot platform	13
2.11	Locomotion modes of the Wheel & Track Hybrid Robot Platform	14
2.12	The design mechanism of the Transformable Wheel-Track Robot	15
2.13	The mechanism of Transformable Wheel-Track Robot	16
2.14	The locomotion of wheel mode	16
2.15	The locomotion of track mode	16
2.16	The locomotion of transforming configuration mode	17
2.17	System design of the Joint Double-Tracked Robot	17
2.18	The distribution of $G(Lx)$	18

FIGURE	TITLE	PAGE
2.19	The distribution of $G(Ly)$	16
2.20	The locomotion modes of the Joint Double-Track Robot	19
3.1	The overall methodology of the project	26
3.2	The whole process flowchart for FYP 1 and FYP 2	27
3.3	The RTVP design ideas	28
3.4	The K-Chart of the project design	29
3.5	Overall system block diagram	30
3.6	The block diagram of RF Transmitter module	31
3.7	The block diagram of RF Receiver module	31
3.8	The system overview of the body structure	37
3.9	The body structure of the RTVP	38
3.10	Gear Configuration	39
3.11	The drive ratio for RTVP	42
3.12	Chain length dimension	43
3.13	The interface of Proteus 7.9 software	46
3.14	The electrical wiring on Proteus 7.9 software	47
3.15	The electrical part for this project	48
3.16	The environment of arduino 1.6.6 software	49
3.17	Programming flow chart for robot controller	50
3.18	APC220 Radio Data Module	51
3.19	The connection of APC220 to PC via RS232-TTL converter	52
3.20	The connection of APC220 to MCU	52
3.21	The connection from PC to MCU via APC220	53

FIGURE	TITLE	PAGE
3.22	The connection from PC to PC via APC220	53
3.23	The attachment of APC220 module into PC/laptop	54
3.24	The attachment of APC220 module into Arduino board	54
3.25	The interface of Processing software	55
3.26	The interface of GUI for RTVP controller	55
4.1	The full design characteristics of the RTVP	63
4.2	The mass properties of the design	64
4.3	3D drawing of the RTVP	65
4.4	Side view of the RTVP	65
4.5	Top view of the RTVP	66
4.6	Front view of the RTVP	66
4.7	Mechanical construction from 3D view	67
4.8	Mechanical construction from front view	68
4.9	Mechanical construction from side view	68
4.10	Mechanical construction from top view	68
4.11	The graph for the forward movement on the road test	77
4.12	The forward and backward movement on the road test	79
4.13	The graph for the reverse movement on the road test	80
4.14	Right and left turn on the road test of 90°	83
4.15	Right and left turn on the road test of 180°	84
4.16	Right and left turn on the road test of 270°	84
4.17	Right and left turn on the road test of 360°	84
4.18	The graph for the right turning movement on road test	85
4.19	The graph for the left turning movement on road test	85

FIGURE	TITLE	PAGE
4.20	The average(s) vs degree of turning($^{\circ}$) for the turn right and left test	86
4.21	The angular velocity(rad/s) vs degree of turning($^{\circ}$) for the turn right and left test	86
4.22	The time(s) vs heights of ladder(m) for the obstacle test	89
4.23	The average(s) vs heights of ladder(m) for the obstacle test	89
4.24	Obstacle test on difference heights of ladder	90
4.25	The different condition of the surfaces test	94
4.26	The average(m) vs time(s) on the stone and grass test	95
4.27	The velocity(m) vs time(s) on the stone and grass test	95
4.28	The velocity(m) vs time(s) on the stone and grass test	95



LIST OF SYMBOLS

Ah	-	Ampere per hour
D,d	-	Diameter
DC	-	Direct current
F	-	Force
FEA	-	Finite element analysis
FYP	-	Final year project
g	-	Gravity = 9.81 m/s
l	-	Lenght
m	-	Mass
P	-	Pressure
PWM	-	Pulse width modulation
r	-	Radius
SW	-	Switch
θ	-	Angle
t	-	Time
h	-	Height
V	-	Volt
RTVP	-	Robot Tracked Vehicle Platform

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Gannt Chart for FYP 1 and FYP 2	102
B	DFRduino Romeo V1.1 layout	103
C	350W Electric Scooter Motor Datasheet	104
D	GUI (Graphical User Interface) Coding	105
E	Controller (Arduino Board) Coding	107



CHAPTER 1

INTRODUCTION

This project proposes designing and developing a Robot Tracked Vehicle Platform (RTVP) by using the parallel mechanism based on the track structure from the viewpoint of the tracked locomotion design. The RTVP capable to move from the left side and the right side as well maneuver in straight line, turn back and rotate 360 degree. On top of that, the RTVP is a robot tracked platform that consist of four nine-inch wheels size and driven by 24V DC brush motor with 350W power and 2600RPM at maximum speed. The motor function of the RTVP is driven by 30A DC Motor Driver with current capability up to 80A and 40A continuously. The body of RTVP is made of aluminium hollow, steel and sheathing plywood which is combined with a modified off road motorcycle tire as a track structure. In addition, this robot is controlled by Romeo-All In One Controller (Arduino Compatible Atmega 328) and powered by a by four(4) 12V/7.0Ah lead acid battery that can be controlled via a wireless connection by using the APC220 RF module. The RTVP is controlled by Romeo-All In One Controller (Arduino Compatible Atmega 328) powered by four(4) 12V/7.0Ah lead acid battery that can be controlled via a wireless connection by using the APC220 RF module. Overall, the RTVP is designed for a wider range of applications which is able adapt to the complex terrain environment such as climbing the obstacle and off road use with low cost of manufacturing.

1.1 Motivation

Recently, robotics are used for many genuine application in real world. Two essential that firmly connected ranges of use are robotic exploration, search and rescue includes investigation of areas that are dangerous and out of reach to people. There are several situation without putting human responders at danger such as in mine fields, polluted zone, different planets, submerged situations or underwater environments. The uses of rescue robot is highlited during rescue the breakdown of the Word Trade Center in New York in 2001, which is required for groups of robots to give broad help with inquiry and salvage undertakings. So, it is additionally important to create a controlled robot that ca be used for extremely facisnating fields of exploration such as navigation, mapping, casualty detection, correspondence and improvement of a practical human-robot interface.



Figure 1.1: Search and Rescue Robot [1][12]

This work and research of this project is conducted at the Universiti Teknikal Malaysia Melaka (UTeM). The main reason to conduct this project is to design and develop the RTVP can provide excellent stability, traction and low ground bearing pressure in order to achieve and perform for any hostile working conditions. Moreover, the size of the robot is 762mm x 635mm x 254mm which is very expensive to buy it from the market. The price on the market for large scale size of the robot is around RM 12,000 - RM 25,000 but the total cost for this project is only RM 2300. So, this project will produce large scale of RTVP with low cost of manufacturing. Therefore, the project needs to be successful and able to implement it perfectly.

1.2 Problem Statement

Recently, robot platform is used as a control robot for research and development in the area of technologies, especially for search and rescue task as well as for domestic purpose. However, the robot platform needs a perfect locomotion mechanism to move in smooth and stable throughout its environment. But, the selection for robot platform design has a large variety of possible ways for the selection of a robot's approach such as wheeled, tracked and legged locomotion system. The key issues for tracked locomotion mechanism is the compliment of manipulation which is sharing the same core issues of contact characteristic, stability and environmental type such as:

1. **Characteristic of Contact** : Path size, contact point, angle of contact, friction and shape.
2. **Stability** : Center of gravity, geometry of contact points, inclination of terrain, static and dynamic stability.
3. **Environmental Type** : Structure and medium (e.g. Obstacle or uneven surface and hard ground).

Based on the issues of the tracked locomotion mechanism, the perfect features are necessary in order to provide heavy-duty and excellent stability of robot platform that can perform admirably in any hostile working conditions.

1.3 Objectives

The objectives of this project are:

- i. To design and develop Robot Tracked Vehicle Platform by using SolidWorks premium 2013 by identify the size and the parts functionality of the robot.
- ii. To develop a communication system between Robot Tracked Vehicle Platform with PC by using the APC220 RF module.
- iii. To analyze the movement of the Robot Tracked Vehicle Platform that can go over the obstacles and move in an uneven surface.

1.4 Scope of the Project

The scopes of this project are:

- i. Design a Robot Tracked Vehicle Platform by using Romeo-All in one Controller (Arduino Compatible Atmega 328). The weight of the robot is 35kg and the size is 48 inch x 36 inch x 9 inch.
- ii. The Robot Tracked Vehicle Platform that can move in an uneven surface and over obstacles by using a 24V DC brush motor with 350W power which is driven by 30A DC Motor Drivers.
- iii. The communication system of the Robot Tracked Vehicles Platform using the APC220 RF module is linked with the Arduino Romeo-All In One that is programmed in Matlab environment to control the behavior of the robot.
- iv. Provide excellent stability, traction and low ground bearing pressure in order to achieve and perform for any hostile working conditions.

1.5 Summary

This chapter covers about motivation, problem statement, objectives and scopes for this project. Motivation part describes about the main reason to design and develop Robot Tracked Vehicle Platform and for problem part is about statement issues of the tracked locomotion mechanism. Lastly, the objectives and scopes of this project is to develop and design hardware with communication system by using RF modules and analyze the behavior of robot platform.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The system design and locomotion modes as well as analysis and experimental works of existing projects will be focused for this chapter. This chapter also will review and discuss about existing robot tracked in term of difference and the similarity of the previous project. The main sources for review this project are from journals and reference books.

2.2 The Existing Mobile Robot with Tracked Locomotion Mode

The research about robot for this part is about the existing mobile robot that using a tracked locomotion mode. There are many number of commercial robot that available for any field of applications. Most of these robots are designed from research academic institutions such as fire fighting, chemical and radioactive installations, reconnaissance operations, anti terrorism activities, etc [1]. The most common of these mobile robot with tracked locomotion mode will explain details in this topic.

2.2.1 MOBIT, A Small Wheel -Track- Leg Mobile Robot [2][3]

MOBIT was designed by Xingguang Duan, Qiang Huang and Nasir Rahman had different locomotion modes for outdoor and indoor environments [2]. It was small robotic platform that were combinations of legs, tracks and wheels which makes the robot high capability and good adaptability to move with different locomotion modes. This robot was confirmed by experiments such as traversing step, posture recovering, tipped over and as climbing stairs[3]. Figure 2.1 shows the physical figure of MOBIT robot.



Figure 2.1: MOBIT robot [2][3]

2.2.2 Obstacle Negotiation for the Rescue Robot with Variable Single-tracked Mechanism [4]

According to [4], the robot was developed to provide a practical introduction for a rescue operations. This robot able to overcome obstacles such as stairs because it had a variable single-tracked mechanism for the driving part. It had two driving mode such as the robot estimate whether or not any obstacles are there and the robot recognizes the forward environment once. The robot was tested in reflecting the proposed algorithm and opposition to several obstacles ultimately. Figure 2.2 shows the mode transformation of VSTR.



Mode 1



Mode 2

Figure 2.2 : Mode Transformation of VSTR [4]

2.2.3 Wheel & Track Hybrid Robot Platform for Optimal Navigation in an Urban Environment [5][6]

Various robot platforms were used for public safety in an urban environments and for task in a variety of disaster fields. This robot platform had transformable track structure which were can navigate the flat floor and climb the stairs rapidly. It also could transfer the power of actuators in three mode from rear, side and front that change between stair climbing and floor navigation as mention in [5] The four wheels were exposed to the outside when tracks on its right and left side are kept up and down folded posture during the robot navigates on a flatlane. The experimental result in [5] showed the robot platform has maximum sloop to climbing in angle of 45 degrees and the maximum speed on flatland is 7.2 km/h. Overall, this robot platform has goon performance in navigating flatland and climbing stair with two tracks. Figure 2.3 shows the wheel & track hybrid robot platform for optimal navigation in an urban environment.



Figure 2.3: Wheel & Track Hybrid Robot Platform [5]

2.2.4 Transformable Wheel-Track Robot with Self-adaptive Mobile Mechanism [7][8][9]

A novel robot (NEZA-I) could perform for the dangerous missions such as rescue, reconnaissance, planetary exploration, anti-terrorism, and so on. This robot able to move at even and uneven surface, soft and hard ground where might be an unpredictable environment [7]. It consists two symmetric transformable wheel-track (TWT) of a control system units. Each TWT unit was efficiently move over rough terrain by transforming the track configuration and changing the locomotion mode that driven only by one servo motor [8]. So, the design concept and mechanism of NEZA-I had self-adaptability to the irregular environment and also presented the drive system and structure of self-adaptive principle to the rough terrains [9]. Figure 2.4 shows the NEZA-I prototype of transformable wheel-track robot with self-adaptive mobile mechanism.

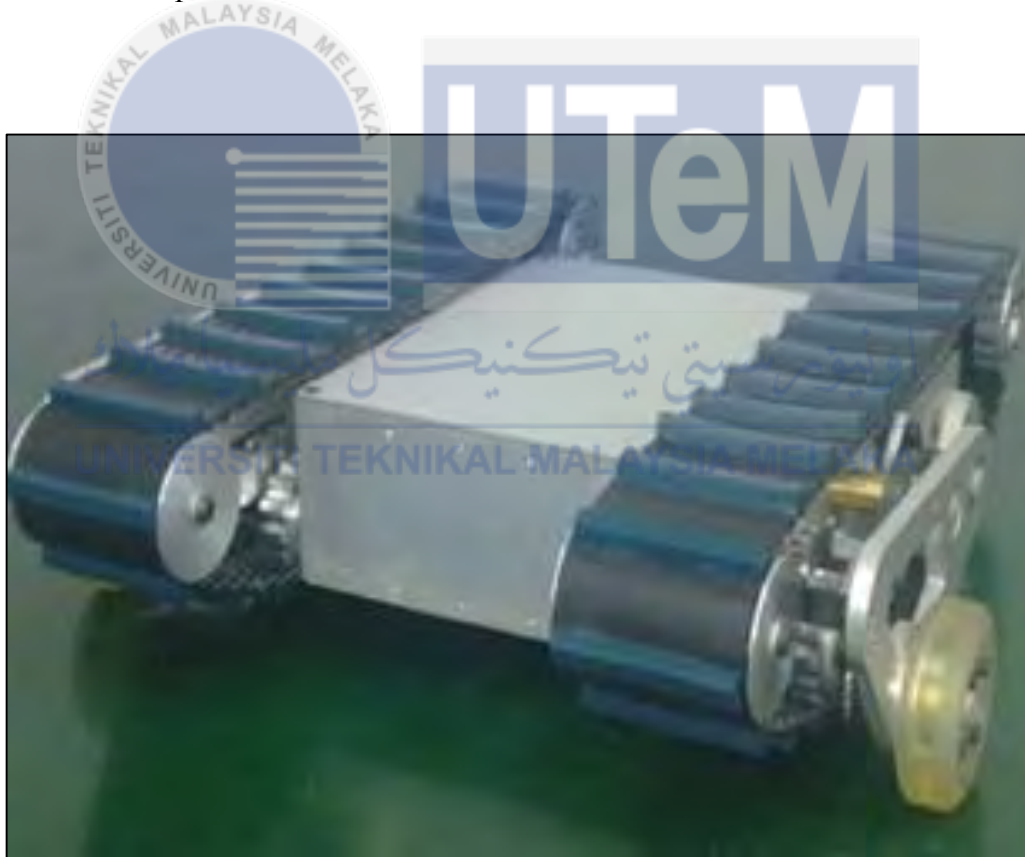


Figure 2.4: NEZA-I prototype [8]

2.2.5 Joint Double-Tracked Robot [10][11]

The design by [10], this robot was presented a double tracks of a joint that connected between two segments. It moves on many terrains because the robot can work like a four-tracked robot. According to [11], the geometry of the robot can be change when it meets stairs, obstacle or a pit. The performaces of the robot is same between double-tracked and four-tracked when the robot adapt to the rough terrains. Figure 2.5 shows a Joint Double-Tracked Robot which composed of two segments that connected between a joint.



Figure 2.5: Joint Double-Tracked Robot [10]

2.3 System Design with Locomotion Modes

As elaborated by [12], system design is about the application and process of defining the components, interfaces, architecture and data to satisfy specific requirements such as the diciplines of system architecture, system engineering and system analysis. As in [13], locomotion modes of robots was about the methods use from place to place for number of reasons such as moving, interacting and traversing rough terrain in human enviroments. The examples for locomotion modes of robots were wheeled, walking, running, rolling, swimming and tracked. However, the system design with tracked locomotion mode will explain details in this topic [14][15].

2.3.1 System Design with Locomotion Modes of the MOBIT, A Small Wheel -Track-Leg Mobile Robot [2][3]

The design objective by [2][3] was created a robotic platform that could performed a wide variety in 3-D environments with basic characteristics such as light weight, small size, compact, transportable, high capability and mobility of negotiating obstacles. The symmetrical layout designed with four articulated units in both left and right, at front and rear of the vehicle body. The tracks rotated at Y axis around the legs and it could rotated 360° for each articulations. The design is shown on Figure 2.6 that composed the rectangle frame with four independent of articulated parts.

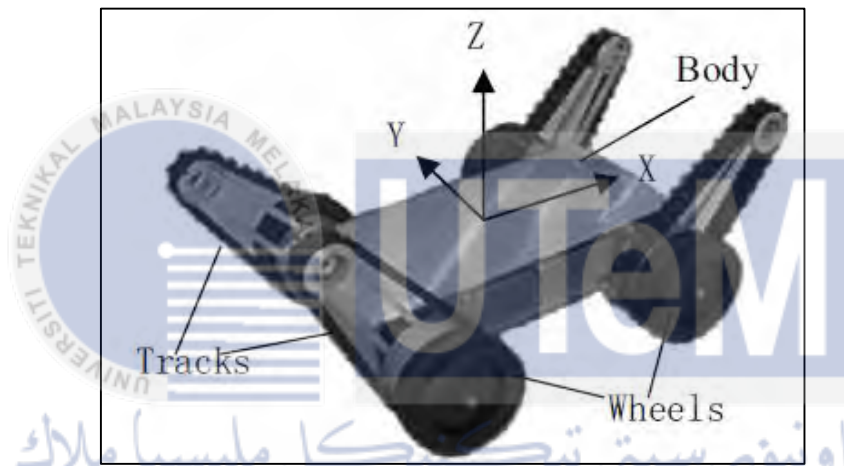


Figure 2.6: The design of MOBIT robot [3]

Figure 2.7(a) shows that the robot could move the four wheels to touch the ground when the arms of the robot rotates up. The tracks will rotate around the legs when the articulations were making the four tracks parallel to the ground and stretched as shown in figure 2.7(b) and figure 2.7(c). Figure 2.7(d) shows the step edge for climbing that allow the robot to start posture of hits when climb over obstacles. These methods also the other modes for climbing slopes of high angle in stable region that shown as in Figure 2.7(e) and Figure 2.7(f).

The MOBIT capable to performed in an another useful locomotion mode which was lifting it self up by controlling down its articulations of the legged mode as shown in Figure 2.7(g). Furthermore, the robot will encounter the 3-D uneven surface terrains when it traveled on the outdoor environment by using the legged mode that independently actuated

from stable bodywork posture and internal degree of freedom. Since each arm is independent as shown in Figure 2.7(h), (i) and (j), the robot had much more sophisticated locomotion modes such as could lift the body with higher step for climbing in the desired directions and gave great versatility and flexibility by offering 8 degrees of freedom in its motion capabilities [2][3]. Figure 2.7 below shows the all locomotion modes of MOBIT robot with a small wheel-track-leg mobile robot.

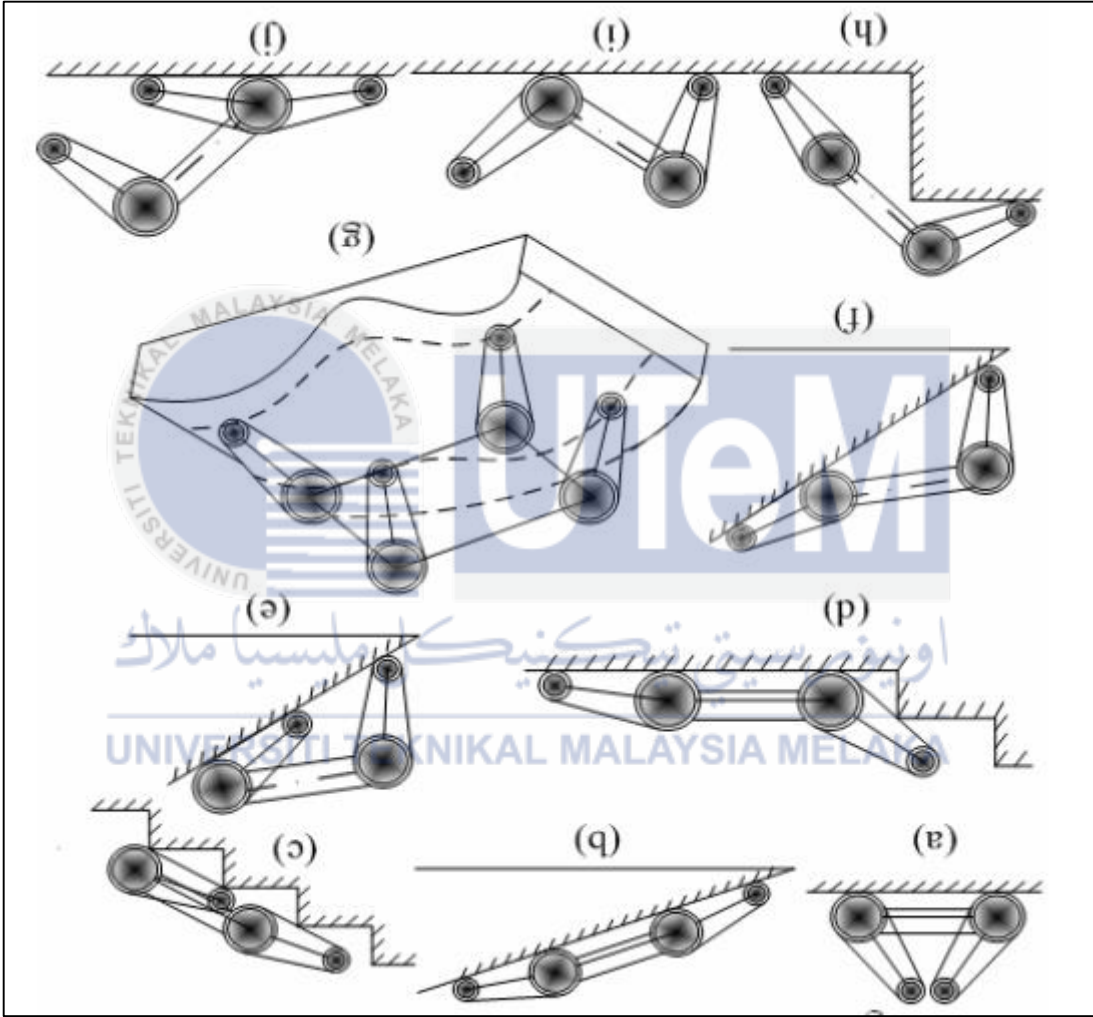


Figure 2.7: The locomotion modes of MOBIT robot [2]

2.3.2 System Design with Locomotion Modes of Obstacle Negotiation for the Rescue Robot with Variable Single-tracked Mechanism [4]

There are two modes of design parameters of the system which were 'Mode 1' and 'Mode 2'. The 'Mode 1' refers for the driving mode of the maximum climbing height with the driving radius. The 'Mode 2' refers to driving mode of maximum climbing height with H as shown in Figure 2.8. So, the thresholds of the height was estimated by maximum climbing height to achieve the design parameters and dimensions of the system.

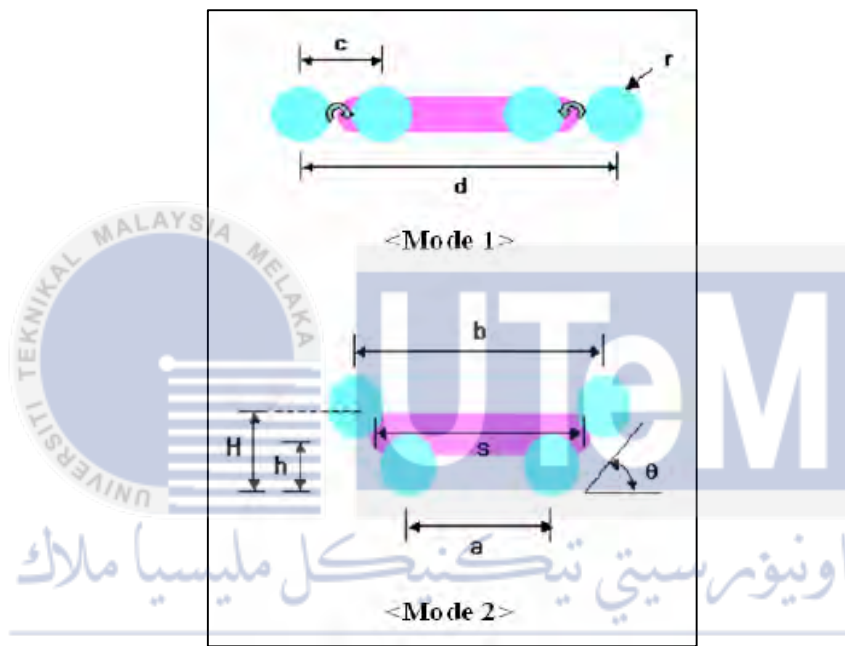


Figure 2.8: The design parameter of the the Rescue Robot with variable single-tracked Mechanism [4]

There are three driving mode and four phase of the locomotion modes for overcoming the obstacles as shown in Figure 2.9. The robot climb the first step for an angle of 45° in 'Mode 2' and then it will climb the second step in 'Mode 1' which was continuously for postural stability of the locomotion mode. Finally, it ascends the remaining steps. The driving mode of the robot was determined by the maximum height (ψ_{h1}, ψ_{h2}) and the angle (ψ_a) in Mode 1, 2 and 3 respectively. The tresholds value of driving modes was classified as in:

- $\gamma < \psi_a$ and $\psi_{h1} < \psi_{h2}$: **Mode transformation is not necessary. [Mode 1]**
 - Overcoming obstacles with Mode 1
 - Gentle slope or easy bump

- $\gamma < \psi_a$ and $\psi_{h1} \leq h < \psi_{h2}$: **Mode transformation is necessary. [Mode 2]**
 - Difficult to overcome obstacles without track variation
- $\gamma \geq \psi_a$ and $h \geq \psi_{h2}$: **Emergency stop [Mode 3]**
 - Not able to overcome obstacles

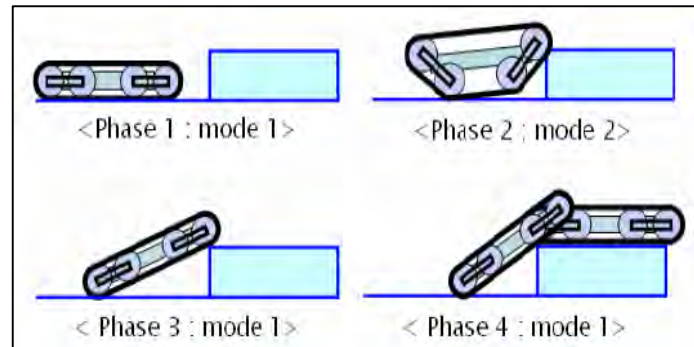
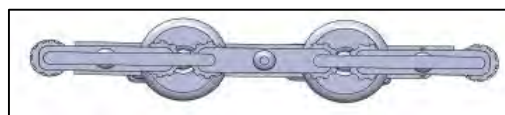


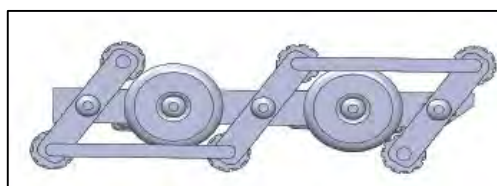
Figure 2.9: The driving mode and the locomotion modes for overcoming the obstacles [4]

2.3.3 System Design with Locomotion Modes of the Wheel & Track Hybrid Robot Platform for Optimal Navigation in an Urban Environment [5][6]

The conceptual design of the robot platform was achieved by transformable track design that has flexibility on flatland and stairs. There are two types of track posture mode in different environment to drive the robot platform. Figure 2.10(a) and Figure 2.10(b) show the 3D modelling of wheel and track drive mode which is folded with tracks on the left and right side of the robot with four wheels that could drove the flat floor rapidly without friction between the floor and tracks.



(a) Wheel drive mode



(b) Track drive mode

Figure 2.10: The conceptual design of the robot platform [6]

There are three types of locomotion modes for the robot which are flatland navigation mode, ascending and descending mode. Figure 2.11(a) shows the wheel driving on the flatland with the geometry of track for mobile platform. In this case, the robot can drive respectively without considerable the friction between the ground and tracks. This mode used four wheels and each tracks on the right and left side during wheeled navigation which were tracks and wheels always contacted on the ground.

Figure 2.11(b) and Figure 2.11(c) show that the attitude of tracks for ascending and descending the stairs respectively. From the figures, there were only two tracks that contacted with the ground and unfolded by keeping four wheels of the robot. Therefore, the four wheels of the robot are not being contacted with the ground. In this case, the two tracks of the robot are able to up and down the stairs, steep ramps stably and crawl over piles of rubble.

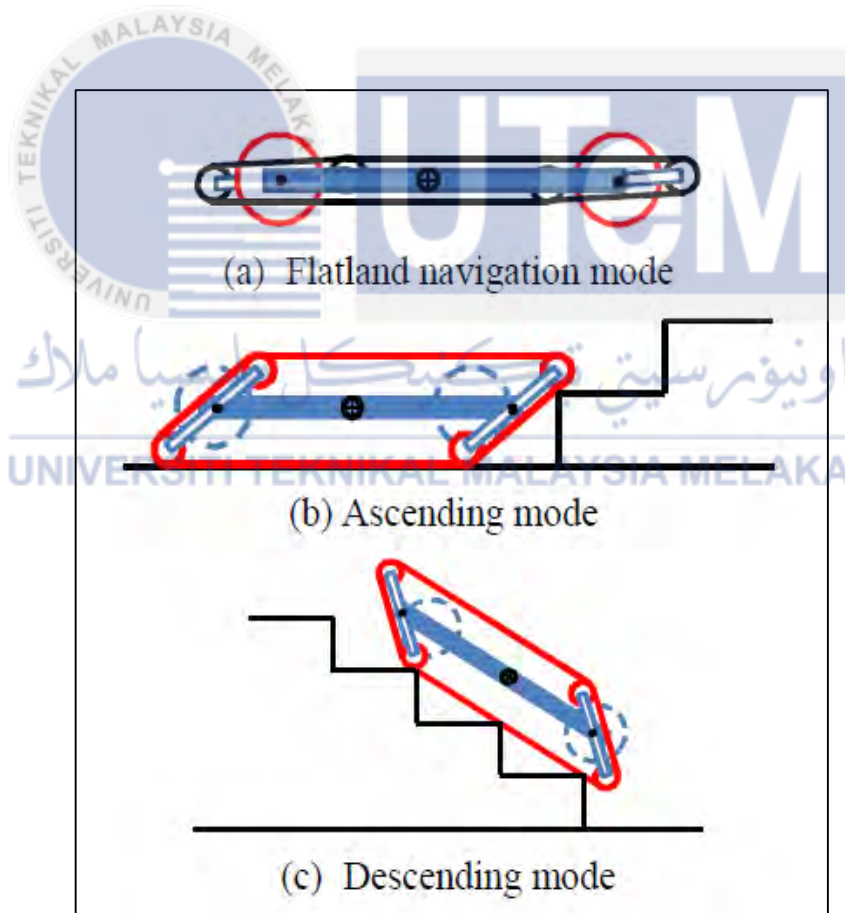
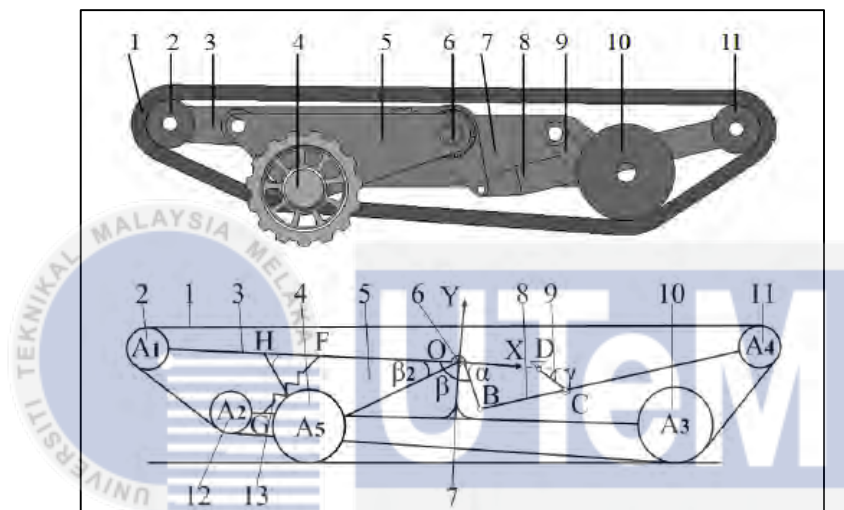


Figure 2.11: Locomotion modes of the Wheel & Track Hybrid Robot Platform [6]

2.3.4 System Design with Locomotion Modes of the Transformable Wheel-Track Robot with Self-adaptive Mobile Mechanism [7][8][9]

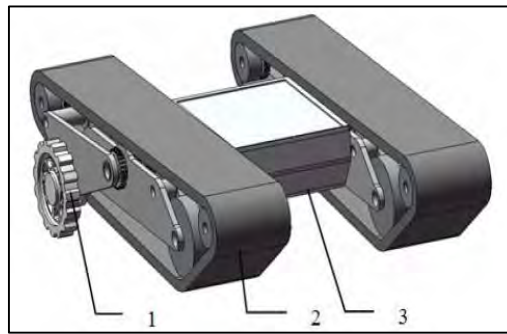
The design mechanism of the robot had the abilities to overcoming obstacles and turning the robot by using drive wheel and transformable track mechanism. Figure 2.12 shows the mechanism of the wheel-track unit that consist of the sprocket A_1 , the pulley A_2 , A_3 , A_4 , and four-bar of linkage. The front, rear and short adjusting link with the chasis were composed with four-bar linkage.



- | | | |
|-------------------------|-------------------------|------------------|
| 1. Track | 6. Basic shaft | 11. Pulley A_4 |
| 2. Sprocket A_1 | 7. Chassis | 12. Pulley A_2 |
| 3. Front adjusting link | 8. Rear adjusting link | 13. Spring |
| 4. Drive wheel A_5 | 9. Short adjusting link | |
| 5. Wheel supporter | 10. Pulley A_3 | |

Figure 2.12: The design mechanism of the Transformable Wheel-Track Robot [9]

Figure 2.13 shows the transformable wheel-track robot mechanism that consists of two symmetric transformable wheel-tracks and a control system unit. There were two types of the drive mechanism which were transformable track mechanism and drive wheel mechanism. This drive mechanism will provide different form of two outputs by using one servo motor or enable the wheel-tracks to transform the configuration of the track whether by using track or wheel. So, there are only two motors that can be controlled and the development of the control algorithm might be very simple.



1. Drive wheel mechanism 3. Control system unit
2. Track mechanism

Figure 2.13: The mechanism of Transformable Wheel-Track Robot [9]

The main mobility features of locomotion modes for this robot are as follows:

1. **Wheel mode:** Figure 2.14 shows the movement of the wheel and tracks on the flat ground. The tracks are tangent to the ground because the wheel locomotion mode has less energy consumption and the abilities of turning flexibility.

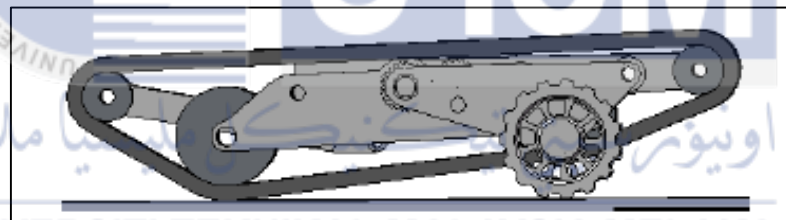


Figure 2.14: The locomotion of wheel mode [9]

2. **Track mode:** Figure 2.15 shows the movement of the track modes to overcome the obstacles. The wheel-track units can be adjusted to improve the stability of the robot when the tracks contact with the ground.

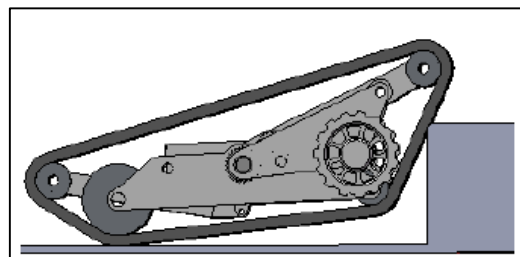


Figure 2.15: The locomotion of track mode [9]

3. **Transforming configuration mode:** Figure 2.16 shows the configuration of tracks to overcome the higher obstacles. The configuration of tracks can be transform in order to improve the performance of the robot when its overcome the higher obstacles.

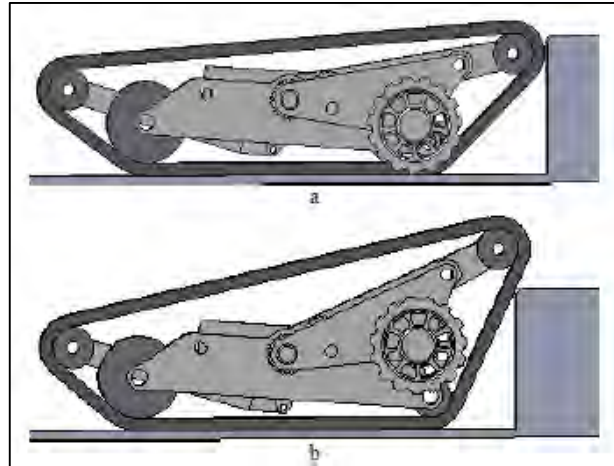


Figure 2.16: The locomotion of transforming configuration mode [9]

2.3.5 System Design with Locomotion Modes of the Joint Double-Track Robot [10][11]

The system design of this robot was for worked on the common rugged terrain which was the front segment of the robot will downward and raised upward to travel over the pits or obstacles. Figure 2.17 shows that the mass center of the segment for the coordinate system XCY and D was fixed which were D was the mass center of the front segment and C was the mass center of the main segment. This design can be assumed its Z coordinate to zero that also identical namely as $L_z \equiv 0$. The mass center location of the whole robot can be expressed as $G(L_x, L_y)$ that are shown in Figure 2.18 and Figure 2.19.

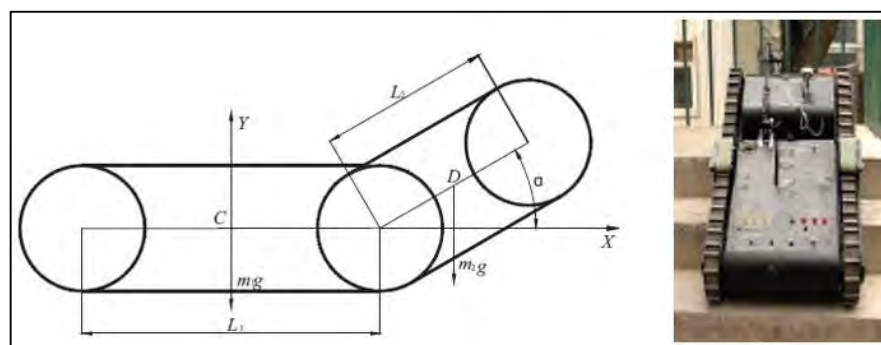


Figure 2.17: System design of the Joint Double-Track Robot [11]

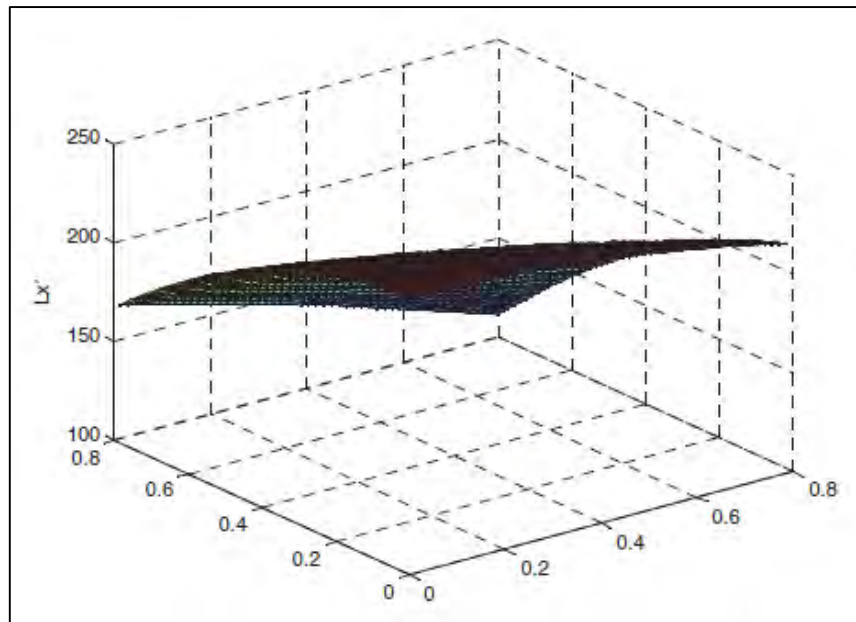


Figure 2.18: The distribution of $G(Lx)$ [11]

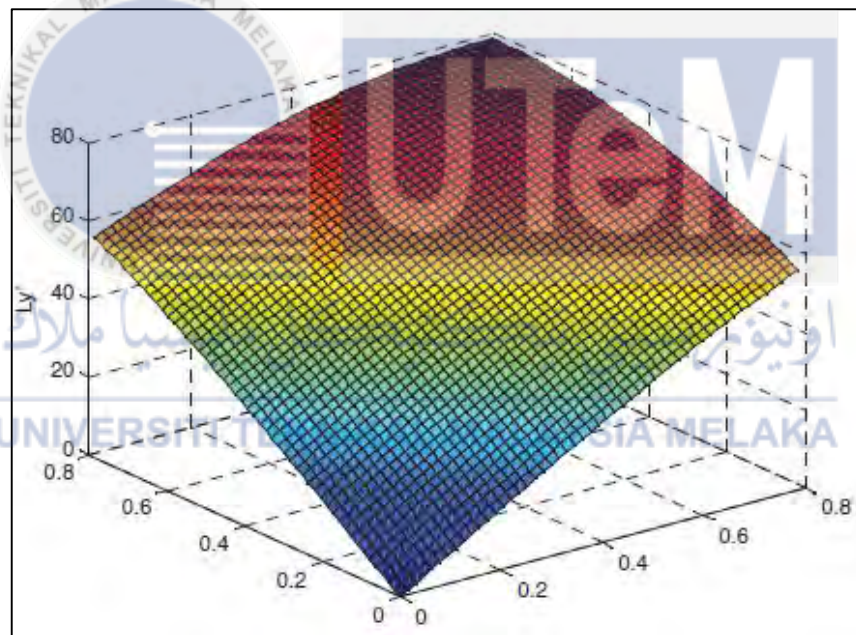


Figure 2.19: The distribution of $G(Ly)$ [11]

The locomotion mode of this robot platform had an extra part (front part) and main part (rear part) that is made up with two tracks. The robot had the ability to travelling over the obstacles and also climb the stairs as shown in Figure 2.20(a) and Figure 2.20(b) which was needed an elevation angle in order to maintain the moving posture of robot transformations. The robot must keep the body in parallel to obtain sticking force and sufficient friction when the robot platform on the stairs as shown in Figure 2.20(c).

Figure 2.20(d) shows at the top stairs which is the front part of the robot turned downward and touch the ground. So, the sticking and friction force will be increase and balance when the robot climbing up at the top of the stairs. Figure 2.20(e) shows the robot climbs over the stairs and the overall locomotion modes of this robot are shown in Figure 2.20.

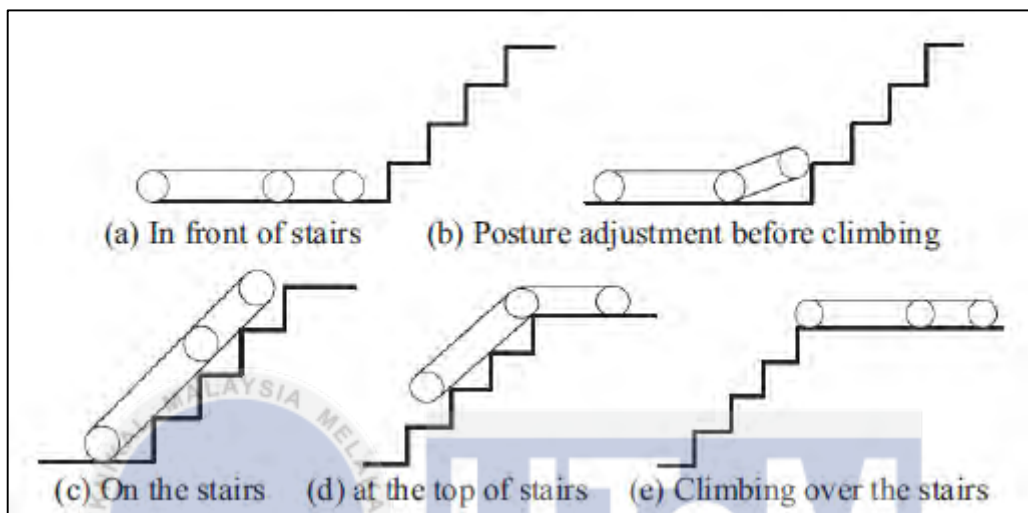


Figure 2.20: The locomotion modes of the Joint Double-Track Robot [11]

2.4 Summary

Based on the summary Table 2.1, the system design of the Rescue Robot with Variable Single-Track Mechanism is the best compare with other design because this robot transform in three mode which are mode one represents a flat shape mode, mode two represents an attack angle mode and mode three represent an emergency stop. The locomotion mode of all existing robot tracked platform on this research are good and the best one is the Rescue Robot with Variable Single-Track Mechanism. This robot has a variable single-tracked mechanism and this mechanism offers many symmetrical configurations such as a rectangle, trapezoids, inverse trapezoids and can generate various attack angles from 0° to 90° . So, based on the research in five different journals of existing robot tracked platform, the system design and locomotion mode of the Rescue Robot with Variable Single-Track Mechanism is the best design compare with others. The others design also have good features in system design, but all of them not well matched of the target for rescue operation and realize for navigation.

Table 2.1: Summary about system design and locomotion mode of the existing robot tracked platform.

The existing robot tracked platform	System design	Locomotion mode
1. MOBIT, A Small Wheel -Track- Leg Mobile Robot [2][3] <i>Prepared by Xingguang Duan, Qiang Huang, Nasir Rahman, Junchen Li and Jingtao Li</i>	The design objective is to create a robotic platform that can performing a wide variety in 3-D environments with basic characteristics such as: - Light weight - Small size - Compact - Transportable - High capability - Mobility of negotiating obstacles	There are 3-type of structure composed with four arms, four wheels, and robot body which are each locomotion unit consists of a track leg body, a driving wheel body and four track legs are configured inside of the wheel tracks. The locomotion modes of MOBIT can simply divide into four types: - Wheeled mode - Tracked mode - Legged mode - Obstacle negotiating mode

The existing robot tracked platform	System design	Locomotion mode
2. The Rescue Robot with Variable Single-tracked Mechanism [4] <i>Prepared by Keun Ha Choi, Hae Kwan Jeong, Kyung Hak Hyun, Hyun Do Choi and Yoon Keun Kwak</i>	The system design of this robot is given the capacity of obstacle negotiation as a hardware attachment in order to well matched of target for rescue operation and realize for autonomous navigation. There are three mode of system design for this robot such as: - 'Mode 1' represents a flat shape mode - 'Mode 2' represents an attack angle mode - 'Mode 3' represents an emergency stop	In particular, this robot has a variable single-tracked mechanism. This mechanism offers many symmetrical configurations such as: - A rectangle - Trapezoids - Inverse trapezoids - Can generate various attack angles from 0° to 90°

The existing robot tracked platform	System design	Locomotion mode
3. Wheel & Track Hybrid Robot Platform for Optimal Navigation in an Urban Environment [5][6] <i>Prepared by Jinwook Kim, Yoon-Gu Kim, Jeong-Hwan Kwak, Dae-Han Hong and Jinung An</i>	The system design of this robot has capability to navigate through a flatland and various hazardous environments. This robot is a hybrid robot platform because the design was combined with two types of driving modes which are: - Wheel drive mode - Track drive mode	The configuration of transformable tracks and wheel will be enhance for adaptability and flexibility on various terrain condition such as unpaved road, flatland and stairs. So, there are three kinds of locomotion modes and tracks geometry transformation for this robot in order to drive in different environment such as: - Flatland navigation mode - Ascending mode - Descending mode

The existing robot tracked platform	System design	Locomotion mode
4. Transformable Wheel-Track Robot with Self-adaptive Mobile Mechanism [7][8][9] <i>Prepared by Zhiqing Li, Shugen Ma, Bin Li, Minghui Wang and Yuechao Wang</i>	The design mechanism of the robot has the abilities to overcoming obstacles and turning the robot by using drive wheel and transformable track mechanism. So, there is only two motors that can be controlled and the development of the control algorithm might be very simple. In addition, there are three importances mechanism of the transformable wheel-track robot sauch as: - Drive wheel mechanism - Track mechanism - Control system unit	The main mobility features of locomotion modes for this robot are as follows: - Wheel mode: The tracks are tangent to the ground because the wheel locomotion mode has less energy consumption and the abilities of turning flexibility. - Track mode: The wheel-track units can be adjusted to improve the stability of the robot when the tracks contact with the ground. - Transforming configuration mode: The configuration of tracks can be transform in order to improve the performance of the robot when its overcome the higher obstacles.

The existing robot tracked platform	System design	Locomotion mode
5. Joint Double-Tracked Robot [10][11] <i>Prepared by Chengguo Zong, Shigong Jiang, Wenzeng Guo, Fuquan Dai and Xueshan Gao</i>	The system design of this robot presents with double tracks of a joint that connected between two segments. It moves on many terrains because the robot can work like a four-tracked robot. The geometry of the robot can be change when it meets stairs, obstacle or a pit. The design mode of this robot platform is made up with two tracks that were called as: - An extra part (front part) of the robot. - A main part (rear part) of the robot.	The locomotion modes of the Joint Double-Tracked Robot has the ability to travelling over the obstacles and also climb the stairs. There are five descriptions of posture for locomotion modes during robot climbing the stairs such as: - In front of stairs - Posture adjustment before climbing - On the stairs - At the top of stairs - Climbing over the stairs

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will discuss about the progress of the whole project. The system overview of this project can be described in details by using block diagram and flowchart with clear explanations. It will cover all about operational system, methodology flowchart, component selection and the development of hardware and software to complete the whole project perfectly.

3.2 Project Methodology

Firstly, suitable and an appropriate topic will be chosen by looking for undergraduate project. After the topic is decided, a short discussion with the supervisor will be made to discuss further about the topic. Then, deep research about the topic is needed by exploring through internet, books, previous thesis and journals. It is important to study and analyze all about the topic is covered for this project to make sure that the topic can be well explained. After that, mechanical parts need to design by using SolidWorks software, electrical part by using Proteus 7.9 software and programming part by using Arduino 1.6.6 software.

The next step is discussing about the final design of mechanical and electrical parts with supervisor about pro and contra of the design. After finishing with design concept, material and component used for mechanical and electrical parts need to survey about availability and prices for each component and material. The mechanical structure needs to redesign if some of the component or material parts are unavailable. For the next step is to build and develop the robot for mechanical parts. After mechanical parts are done, it follows by installing the electrical part and finally proceeds with programming part. Figure 3.1 shows the overall methodology of the project and Figure 3.2 shows the whole process flowchart for FYP 1 and FYP 2.

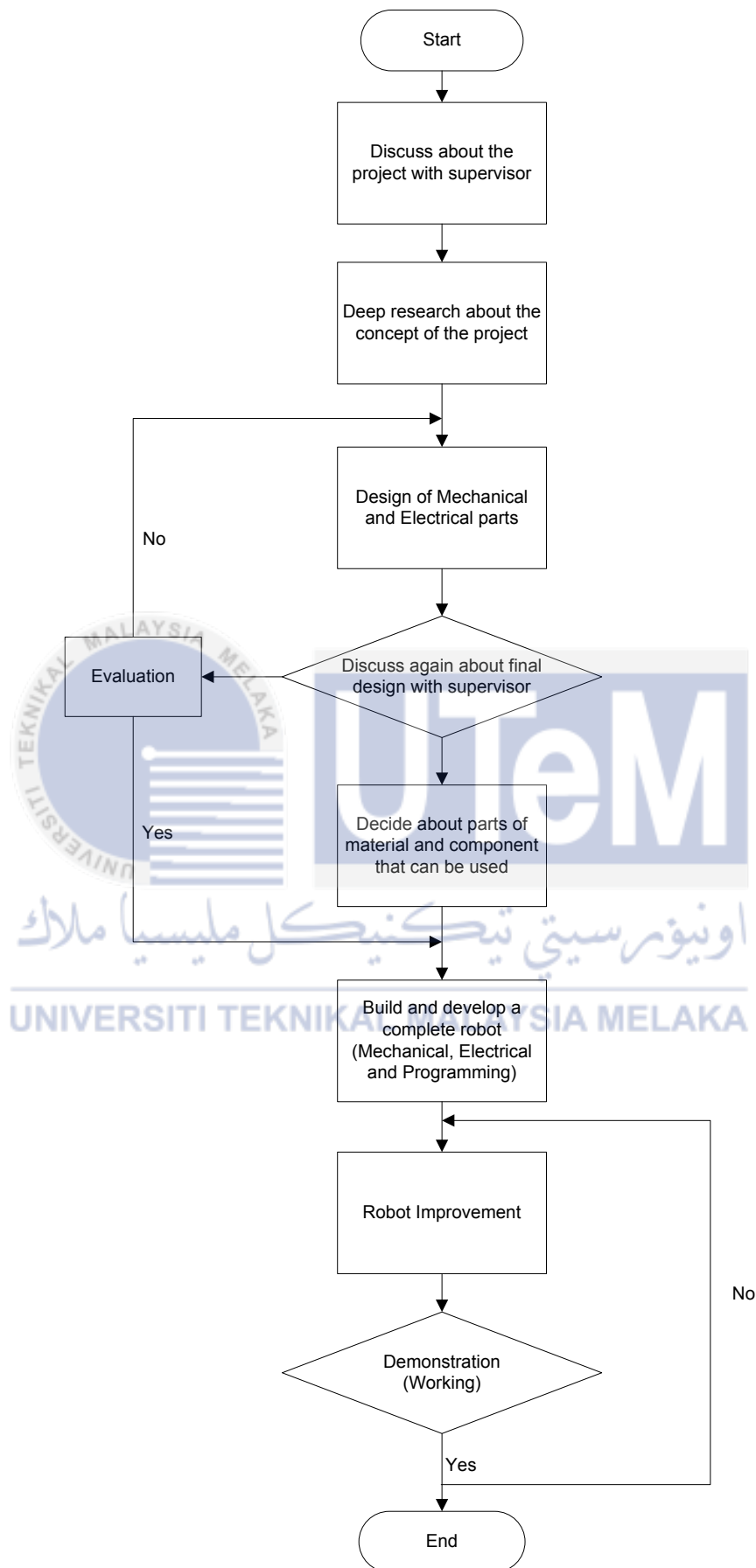


Figure 3.1: The overall methodology of the project

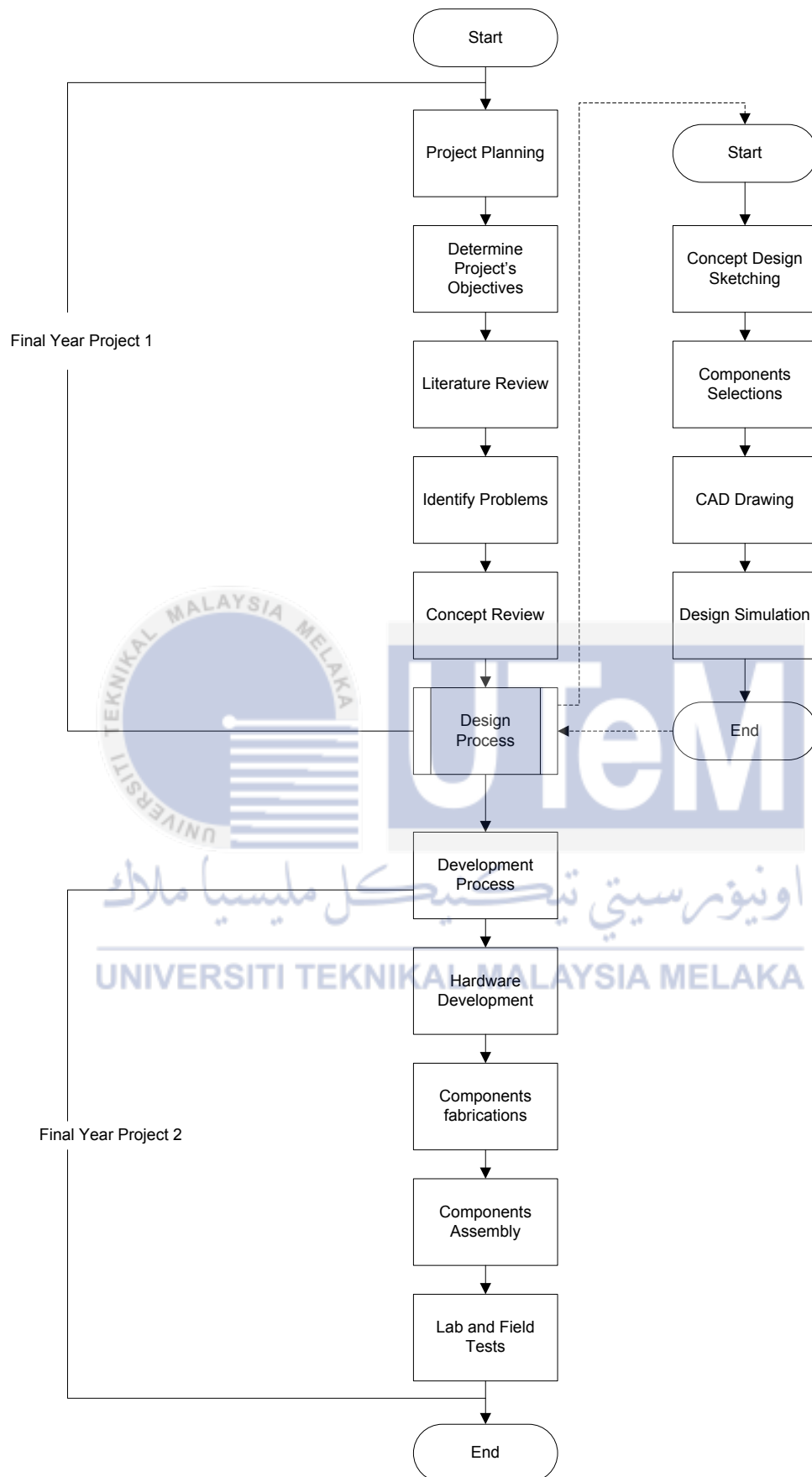


Figure 3.2: The whole process flowchart for FYP 1 and FYP 2

3.3 Milestone and Project Planning.

Table 3.1: Planning activities

No.	Activities	Date
1.	Project studies	September – November 2014
	1.1 Theoretical studies	
	2.1 Hardware design	
2.	Data collections and literature review	September – October 2014
3.	Designing hardware	October – November 2014
4.	Design simulations	October – November 2014
5.	Hardware implementations	November 2014 until January 2015
6.	System implementation	December 2014 until February 2015
7.	Test guidelines	February 2015
8.	Experiments and data collections	October 2015 until December 2015
9.	Hardware analysis	August 2015 until December 2015

3.4 Robot Tracked Vehicle Platform Design Ideas

The design of RTVP is divided into two parts which are hardware and software. The hardware part includes the electronics design by using Proteus software and mechanical design by using SolidWork 2013 software. The software part is about the programming of Arduino micro-controller by using Arduino 6.1.1 software. Figure 3.3 shows the Robot Tracked Vehicle Platform design ideas and Figure 3.4 shows the K-Chart of the project design.

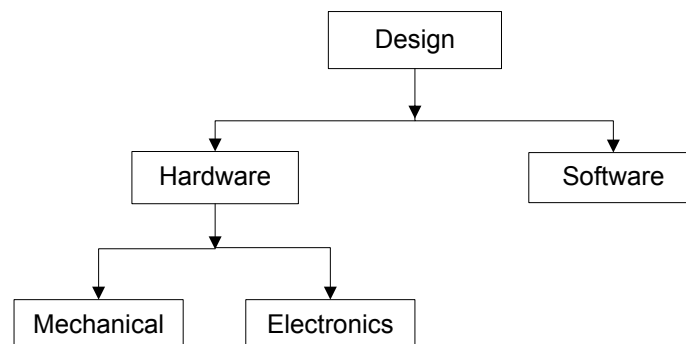


Figure 3.3: The RTVP design ideas

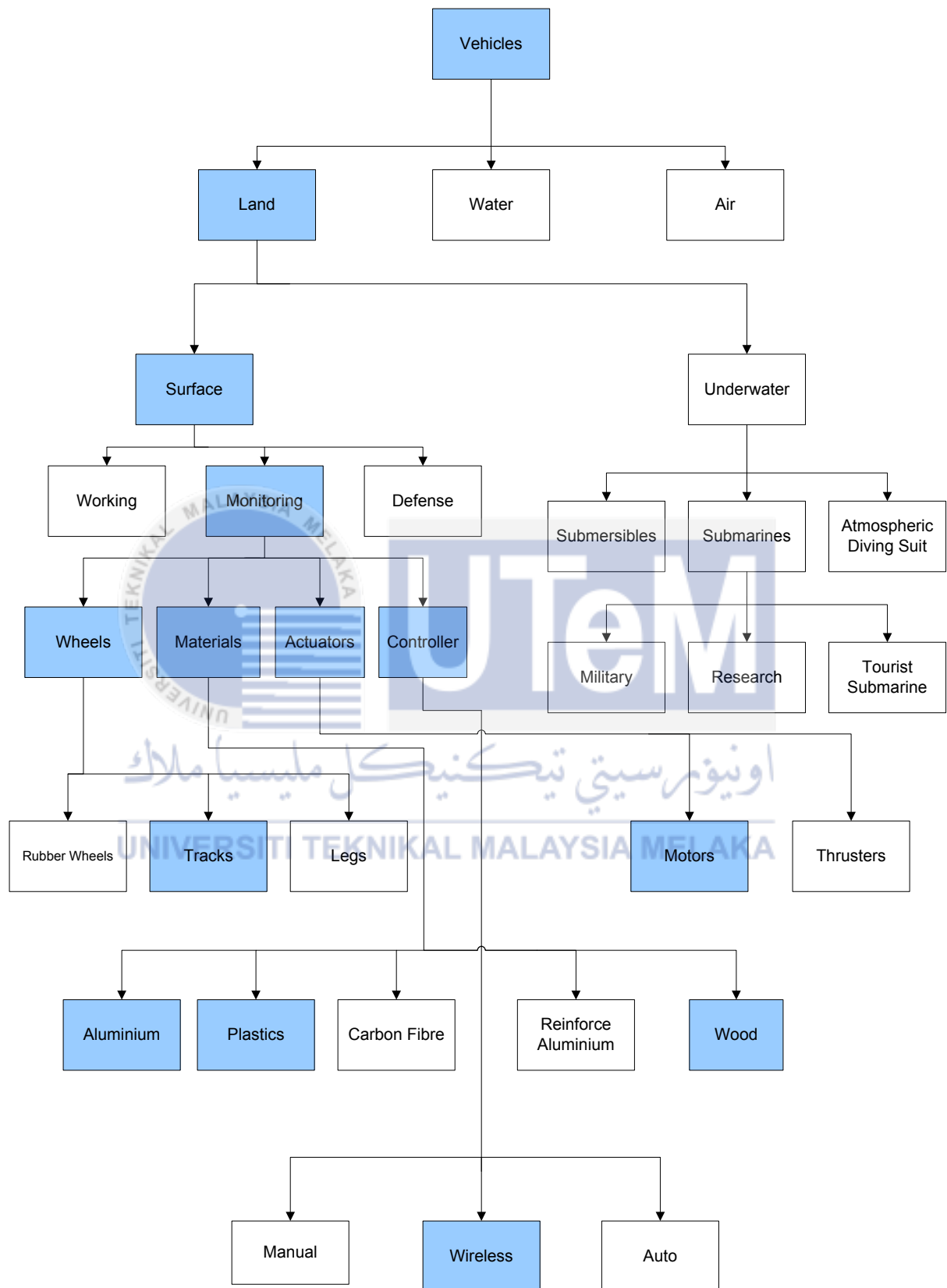


Figure 3.4: The K-Chart of the project design

3.5 System Block Diagram

The overall system block diagram of this project is illustrated in Figure 3.5 which is the combination of the the block diagram of RF Transmitter and the block diagram of RF Receiver.

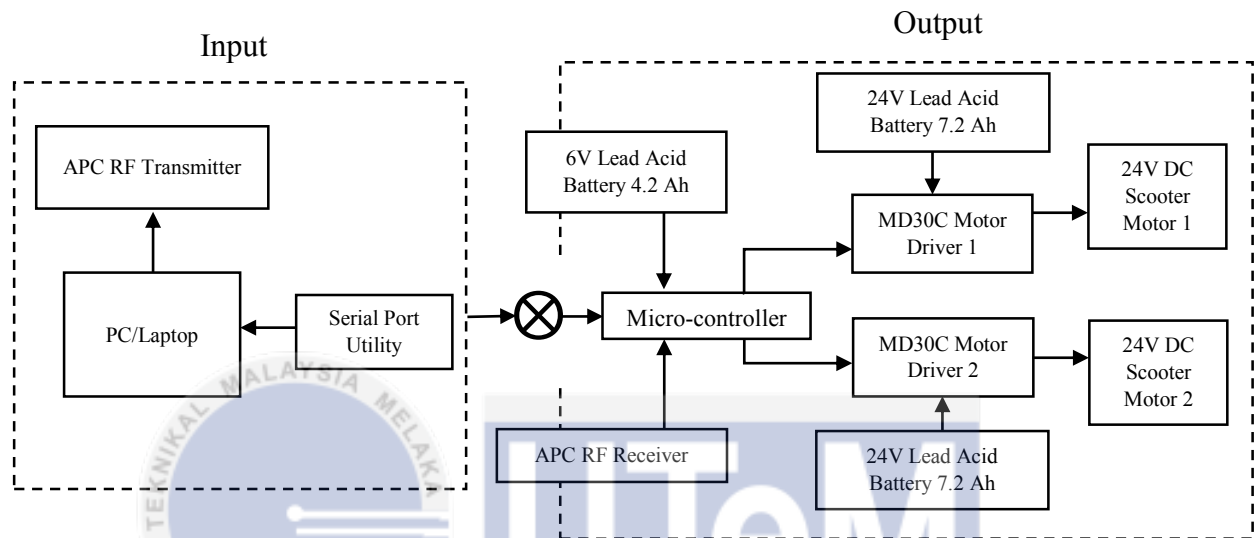


Figure 3.5: Overall system block diagram

System block diagram for this project is divided by two which are the block diagram of RF Transmitter and the block diagram of RF Receiver. The block diagram of RF transmitter module consist of APC 220 Transmitter module, PC/laptop and Serial Port Utility program while the block diagram of RF Receiver consist of Romeo-All In One Controller (Arduino compatible Atmega 328), batteries 6V and 24V, motor driver, 24V DC scooter motor and APC 220 Receiver module.

3.5.1 Block Diagram of RF Transmitter

The block diagram of RF transmitter consist of APC220 RF module that connected to the PC/laptop which is act as a RF tramitter. The Romeo-All in one Controller (Arduino compatible Atmega 328) will receive the data from the RF transmitter through RF Receiver. All the data from RF transmitter are obtain from the PC/laptop by using Serial Port Utility program. The figure 3.6 shows the block diagram of the RF Transmitter module.

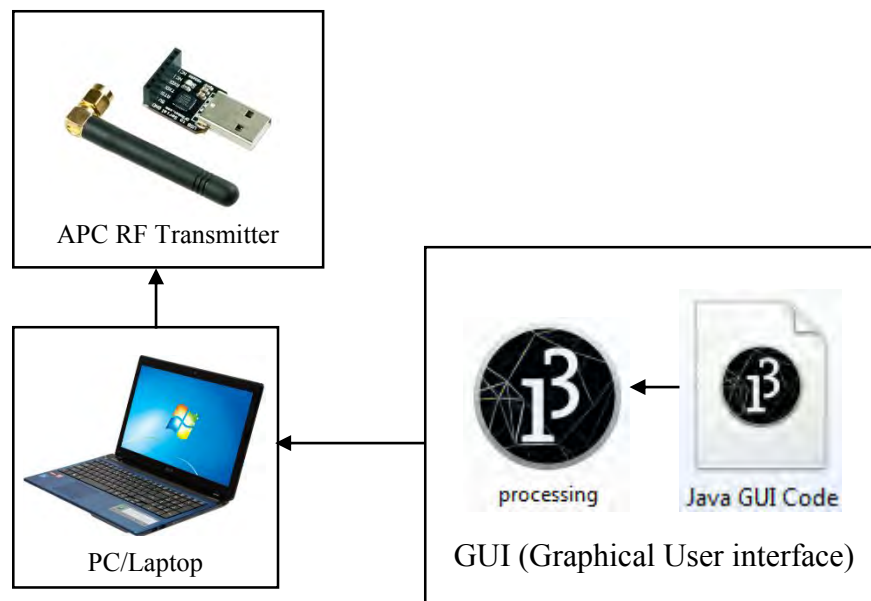


Figure 3.6: The block diagram of RF Transmitter module

3.5.2 Block Diagram of RF Receiver

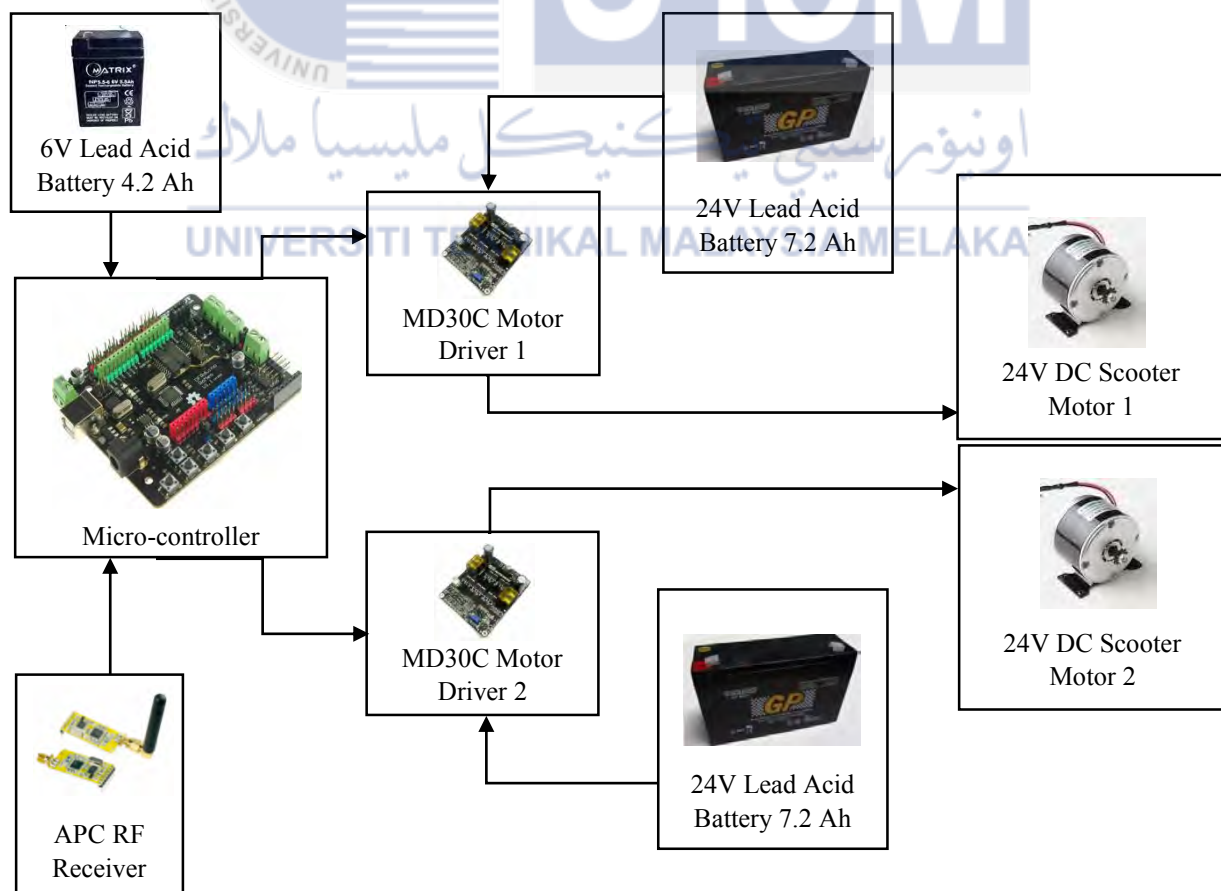


Figure 3.7: The block diagram of RF Receiver module

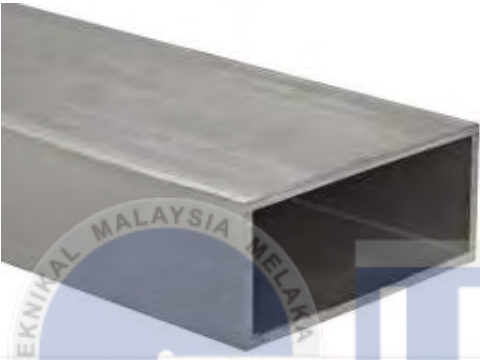
The block diagram of RF receiver consists of APC220 RF module that connected to the Romeo-All in one Controller (Arduino compatible Atmega 328) which acted as a RF receiver. The Romeo-All in one Controller (Arduino compatible Atmega 328) will receive the data from the RF transmitter through RF Receiver and the data from micro-controller will be sent to the MD30C motor driver. This motor driver used 24V lead acid battery to drive the DC Scooter motor. Figure 3.7 shows the block diagram of the RF Receiver module.

3.6 Components and Materials Selection

This part will explain about the components and materials use for this project. There are two parts that needs to do the selection of material and component which are for Mechanical parts and Electrical parts. Table 3.2 shows the components and materials for mechanical parts and Table 3.3 shows the components and materials for electrical parts.

Table 3.2: Components and materials for mechanical parts

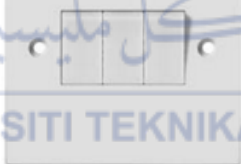
No.	Component/Material	Quantity	Price
1.		4 pcs	RM 80 per unit RM 80 × 4 pcs
	9inch Aluminium Pulleys		Total: RM 320
2.		6 pcs	RM 15 per unit RM 15 × 6 pcs
	19mm Steel Shaft		Total: RM 90

No.	Component/Material	Quantity	Price
3.	 Mounted Bearing	10 pcs	RM 17 per unit $\text{RM } 17 \times 10$ Total: RM 170
4.	 2 inch $\times$ 1 inch Aluminium Hollow	8 meter	RM 7 per meter $\text{RM } 7 \times 8$ Total: RM 56
5.	 Fixed Caster	4 pcs	RM 2.50 per unit $\text{RM } 2.50 \times 4$ Total: RM 10
6.	 30 Teeth Motorcycle Sprocket	2 pcs	RM 22 per unit $\text{RM } 22 \times 2$ Total: RM 44

No.	Component/Material	Quantity	Price
7.	 10 Teeth Sprocket	2 pcs	RM 30 per unit $\text{RM } 30 \times 2$
		Total: RM 60	
8.	 Motorcycle Roller Chains	2 pcs	RM 25 per unit $\text{RM } 25 \times 2$
		Total: RM 50	
9.	 Off Road Motorcycle Tires	2 pcs	RM 65 per unit $\text{RM } 65 \times 2$
		Total: RM 130	
10.	 10mm Sheathing Plywood	5 meter	RM 7 per meter $\text{RM } 7 \times 5$
		Total: RM 35	
Total prices of components and materials for mechanical parts			RM 555

Table 3.3: Components and materials for electrical parts

No.	Component/Material	Quantity	Price
1.	 Romeo-All in one Controller (Arduino compatible Atmega 328)	1 pcs	RM 157 per unit
			Total: RM 157
2.	 30A DC Motor Driver	2 pcs	RM 133 per unit $RM 133 \times 2$
			Total: RM 266
3.	 24V DC Electric Scooter Motor 350W	2 pcs	RM 296 per unit $RM 296 \times 2$
			Total: RM 592

No.	Component/Material	Quantity	Price
4.		4 pcs	RM 55 per unit RM 55 × 4
	12V/7.0Ah Lead Acid Battery		Total: RM 220
5.		1 pcs	RM 24 per unit
	12V/7.0Ah Lead Acid Battery		Total: RM 24
6.		1 pcs	RM 5 per unit
	3 Gang Switches		Total: RM 5
7.		1pcs	RM 155 per unit
	APC 220 RF Module		Total: RM 155
Total prices of components and materials for electrical parts			RM 1419

3.7 Hardware and Software Development

In designing and developing of RTVP, there are two parts which is hardware and software. The design structure of the robot is started by using SolidWorks 2013 software. Once the complete design is fully completed, the hardware development of Robot Tracked Vehicle Platform is assembled. Besides that, the robot movement is fully control wirelessly from PC/laptop by using APC220 RF module. The software configuration is firstly design by using Proteus 7.9 software before the whole electronic components is attached to the robot. In addition, the software development for this robot must be meet the specifications which are able to move the robot to the left, right, rotates 360°, forward and backward that can be fully control wirelessly from PC/laptop.

3.7.1 Hardware Development

The first stage of implementing the robot structure is designing the mechanical structure by using SolidWorks 2013 software. This software allows the user to draw easily in 2D and 3D. Besides that, this software can be used to measure the length and material strength for every part of the body frame of RTVP. It also can be used for finding the center of gravity for the design which is easier for building the hardware before start fabricate and assemble the hardware. Figure 3.8 shows the system overview of the body structure and

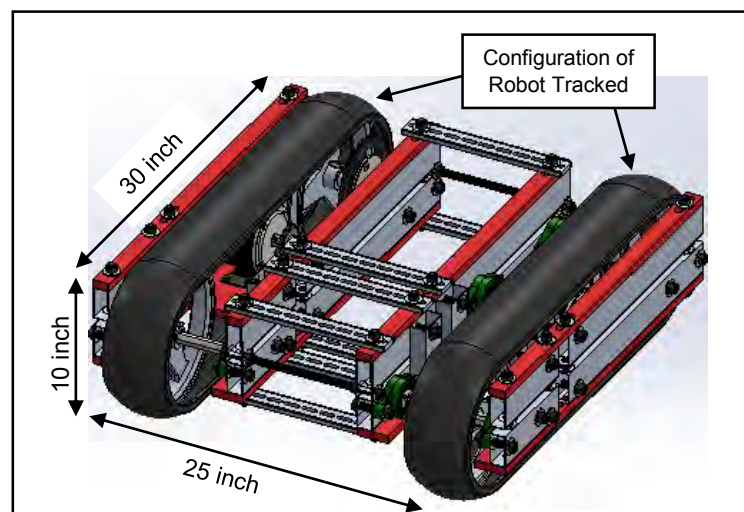


Figure 3.8: The system overview of the body structure

3.7.1.1 Development of the Body Structure

The development of the body structure are fabricate and assemble in Mechatronic FKE lab. The material that will be used to develop the body structure is 10mm thickness of sheathing plywood and 2 inch × 1 inch aluminium hollow. This material are selected because its easy to handle and have a lightweight characteristic. In order to maintain the durability of the material, the body structure is coated by using paint spray with the selected color. In this project, two driven wheels with four 9 inch aluminium pulley are being used because of the wide surface of contact area of the tracked system. Due to its wide surface which is having the diameter of 9 inch and width of 4 inch, the tracked system of the robot is able to maintain its stability without flipping over while run on rough surface. According to the pressure formula $P = \frac{F}{A}$, where P is the pressure, F is the force and A is the surface area. This shows that when the surface area of object is high then the pressure will be low. It is prove that the wide of surface area of the tracked to contribute the stability of the robot. Another performance using tracked system are can climb over a bump and aso can run on uneven surface smoothly. Figure 3.9 shows the body structure of RTVP.

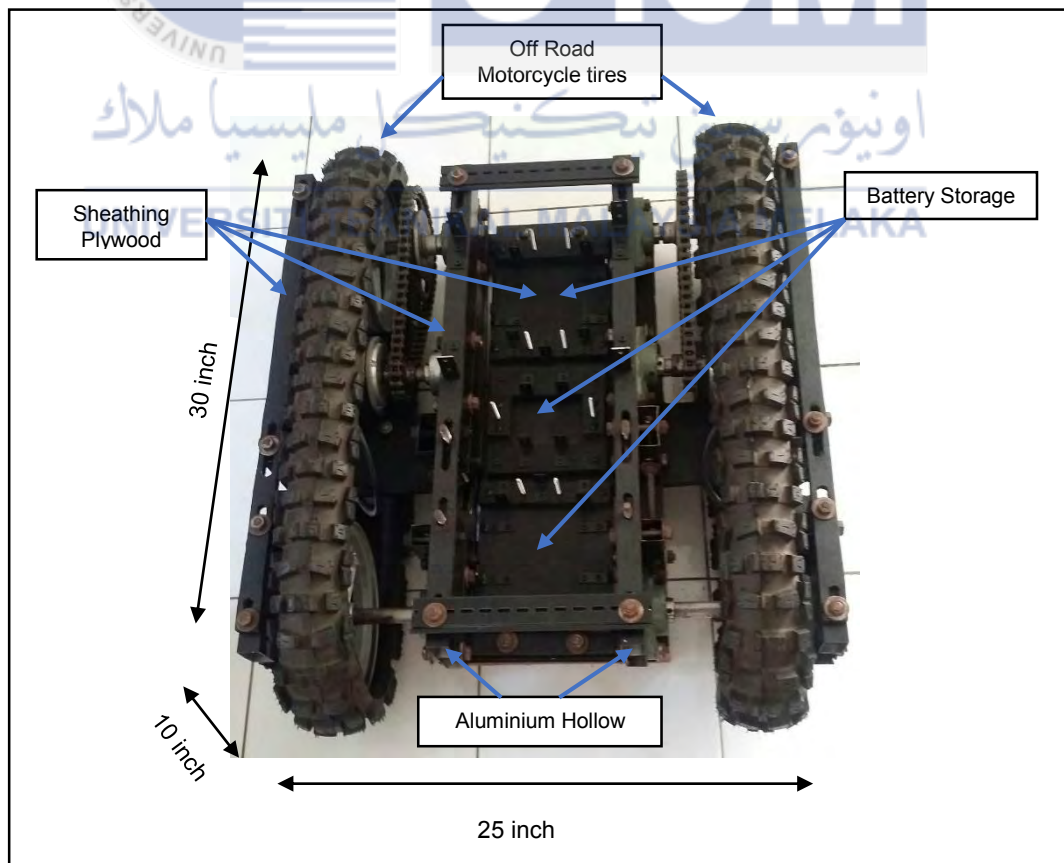


Figure 3.9: The body structure of the RTVP

3.7.1.2 Gear Configuration

The configuration for sprocket and chain ratio can be determined from the calculation of gear ratio and configuration. The basic rules and idea for both mechanical power transmitter is the same since both have a number of teeth, diameter and mechanism of their function. The input gear is rotating counter clockwise with an angular velocity, ω_{in} and the output gear rotating clockwise with an angular velocity, ω_{out} . An input torque, τ_{in} , is applied by the motor onto the input gear, and an opposing output torque, τ_{out} , onto the output gear which is applied by the system configuration. The radius of the gear is taken at the pitch circle of the gear which contact occurs between two gears. The development and optimizing the gear shape will help to reduce friction loss, reduce noise and even make a smooth power transfer. By including a gear ratio in the design, it will help to increase the output speed or torque of the power transmission. Figure 3.10 shows that the input gear is rotating counter clockwise with an angular velocity, ω_{in} and the output gear rotating clockwise with an angular velocity, ω_{out} .

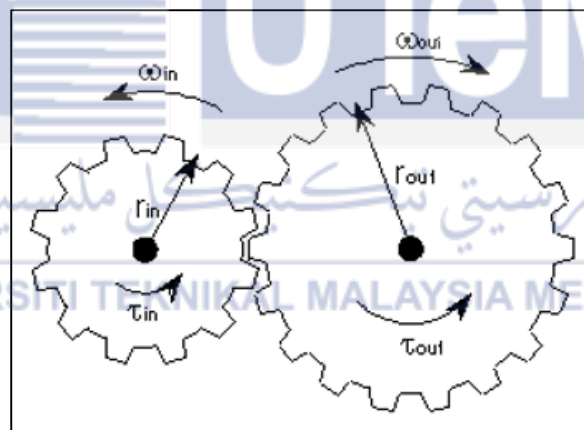


Figure 3.10: Gear Configuration

Where:

- ω_{in} : Input Angular Velocity
- r_{in} : Input Gear Radius
- τ_{in} : Input Torque
- ω_{out} : Output Angular Velocity
- τ_{out} : Output Torque
- r_{out} : Output Gear Radius

3.7.1.3 Gear Ratio Calculation

Gear Pair Equation: The relationship between number of teeth and torque.

$$\frac{n_{out}}{n_{in}} = \frac{\tau_{out}}{\tau_{in}} \quad (3.1)$$

Where:

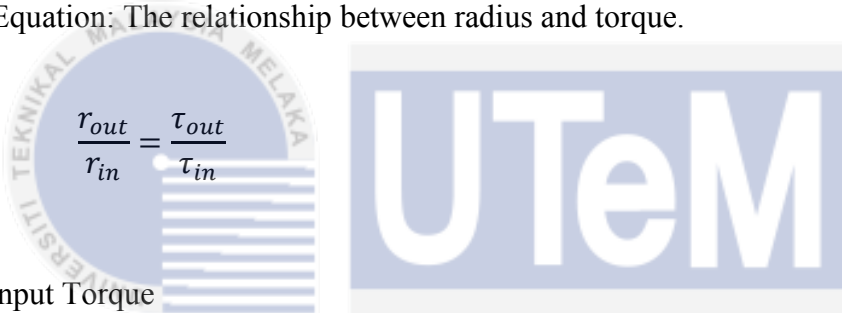
n_{in} : Number of Input Teeth

n_{out} : Number of Output Teeth

τ_{in} : Input Torque

τ_{out} : Output Torque

Gear Pair Equation: The relationship between radius and torque.



$$\frac{r_{out}}{r_{in}} = \frac{\tau_{out}}{\tau_{in}} \quad (3.2)$$

Where:

τ_{in} : Input Torque

τ_{out} : Output Torque

τ_{in} : Input Torque

τ_{out} : Output Torque

Gear Pair Equation: The relationship between number of teeth and speed.

$$\frac{n_{in}}{n_{out}} = \frac{\omega_{out}}{\omega_{in}} \quad (3.3)$$

Where:

n_{in} : Number of Input Teeth

n_{out} : Number of Output Teeth

τ_{in} : Input Torque

τ_{out} : Output Torque

Gear Pair Equation: The relationship between radius and speed.

$$\frac{r_{in}}{r_{out}} = \frac{\omega_{out}}{\omega_{in}} \quad (3.4)$$

Where:

n_{in} : Radius of Input Gear

n_{out} : Number of Output Gear

τ_{in} : Input Torque

τ_{out} : Output Torque

In this project, the RTVP needs a high torque power transmission instead of high speed to make sure the system is fully operates. This is due to the load and the environment that the robot will fully operates. Thus, the Equation (3.1) and (3.4) is neglected for further analysis. Higher torque is needed because the weight of the robot itself is quite heavy in order to operates on different environment which are flat, hard, rocky and uneven surface. Thus, it is essential for RTVP to gain more power to move on the any type of surfaces environment.

From Equation (3.1):

$$\frac{n_{out}}{n_{in}} = \frac{\tau_{out}}{\tau_{in}}$$

Input teeth = 10

Output teeth = 30

Input torque from the motor = 0.9N.m

$$\frac{10}{30} = \frac{\tau_{out}}{0.9}$$

$$\tau_{out} = 0.3 \text{ N.m}$$

Output teeth = 30

Input teeth = 10

Input torque from the motor = 0.9N.m

$$\frac{30}{10} = \frac{\tau_{out}}{0.9}$$

$$\tau_{out} = 2.7 \text{ N.m}$$

The number of teeth of the drive sprocket to the number of teeth of the driven sprocket are specified relationship between two sprockets of the drive ratio. The chain will transfer the power from the drive train from one sprocket to another sprocket through the tension from the chain. Figure 3.11 shows the drive ratio for RTVP.

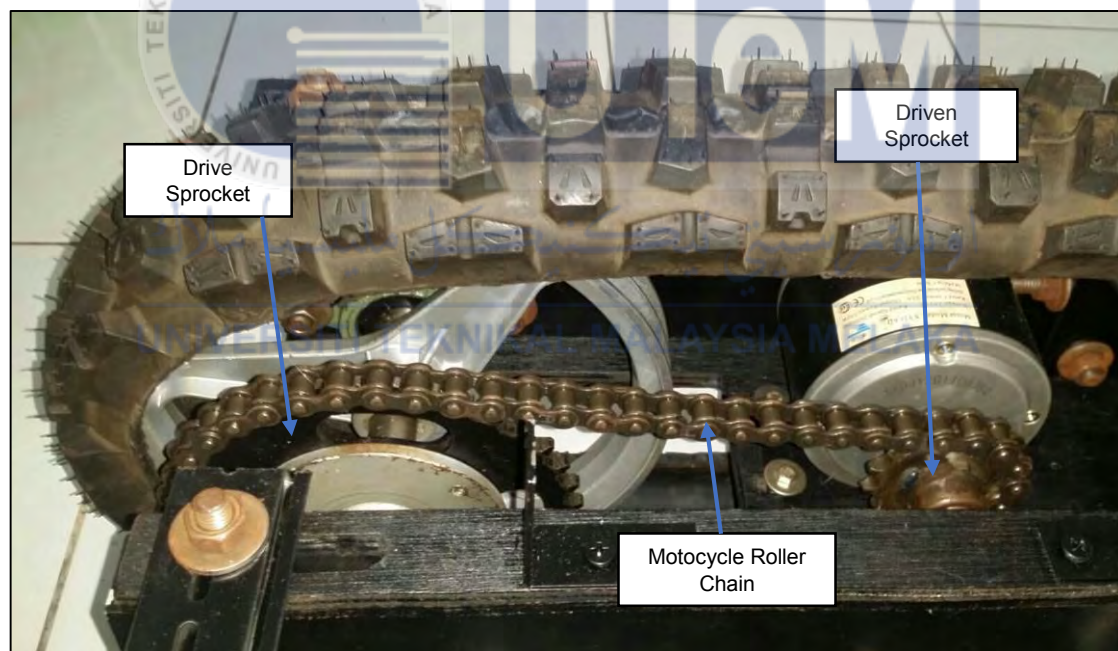


Figure 3.11 : The drive ratio for RTVP

The sprocket ratio from Figure 3.11 is 3:1. So, the *Drive Sprocket* turn to 3 revolutions before the *Driven Sprocket* turns to 1 revolutions. The rule for determining the ratios is this:

$$\text{Ratio} = \frac{\text{Driven Sprocket}}{\text{Drive Sprocket}} \quad (3.5)$$

$$\text{Ratio} = \frac{30}{10}$$

$$\text{Ratio} = \frac{3}{1}$$

$$\text{Ratio} = 3 : 1$$

As a conclusion, when the input gear is smaller than the output gear, the output torque is higher than the input torque. Thus, in designing the power transmission for the RTVP, the input gear must have the least number of teeth compare to the output gear in oorder to gain the higher torque. Based on the calculation, the design could have 10 teeth for the input gear and 30 teeth for the output gear which is the value of input torque is depends on the type of motor that will be used later on. So, since the transmission has the higher torque, the output velocity of the rotation will be lower than the input velocity.

3.7.1.4 Chain Length Calculation

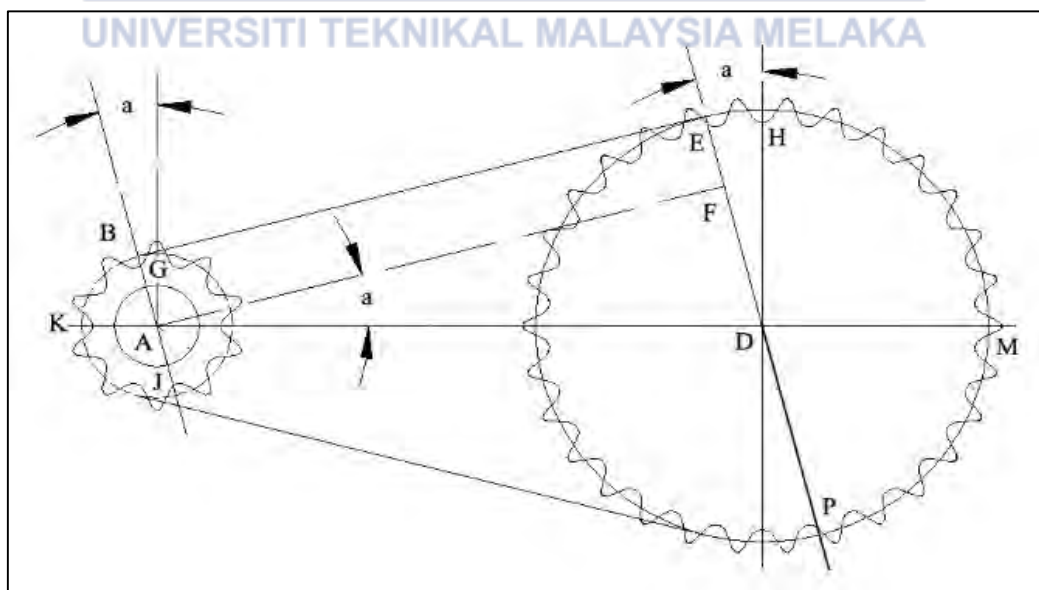


Figure 3.12: Chain length dimension

Specifications:

$$\begin{aligned}
 \text{Pitch (P)} &= \frac{1}{4}'' = 0.250'' \\
 PR &= \text{Pitch Diameter} \times 0.5 \\
 \text{Drive Sprocket (n)} &= 10 \text{ teeth} \\
 \text{Driven Sprocket (N)} &= 30 \text{ teeth} \\
 \text{Center Distance (C)} &= 6''/0.250 = 24 \text{ (expressed in pitch units)} \\
 \text{The chain length} &= 2(\text{Tangent line length BE} + \text{arc ME} + \text{arc BK})
 \end{aligned}$$

Step 1:

Calculation for pitch circle radius to drive the sprocket.

$$\begin{aligned}
 AB &= \frac{P}{\sin \left[\frac{180^\circ}{n} \right]} = \frac{0.250''}{\sin \left[\frac{180^\circ}{10} \right]} = \frac{0.250''}{\sin 18^\circ} = \frac{0.250''}{0.309} \\
 &= 0.809'' \times 0.5 = 0.4045'' \\
 DE &= \frac{P}{\sin \left[\frac{180^\circ}{n} \right]} = \frac{0.250''}{\sin \left[\frac{180^\circ}{30} \right]} = \frac{0.250''}{\sin 6^\circ} = \frac{0.250''}{0.1045} \\
 &= 2.392'' \times 0.5 = 1.196''
 \end{aligned}$$

Step 2:

Calculation for the length of side DF.

- Line AF is parallel with line BE and is perpendicular with AB and DE.
- Line BE is tangent with circles M and K.
- Line DF = DE – AB = 1.196'' - 0.791''

Step 3:

Calculation for angle a.

$$\sin a = \frac{\text{Side Opposite}}{\text{Hypotenuse}} \quad (3.6)$$

$$\text{Substitute, } \sin a = \frac{DF}{AD}$$

$$\sin a = \frac{DF}{AD} = \frac{0.791''}{6''} = 0.1318$$

$$< a = \sin^{-1} 0.1318 = 7.57^\circ$$

Step 4:

Calculation for the length of the chain between the pitch circle tangent points, BE.

$$a = 7.57^\circ \quad \text{cosine of } 7.57^\circ = 0.991$$

$$\text{cosine } a = \frac{\text{Side Adjacent}}{\text{Hypotenuse}} \quad (3.7)$$

$$\text{cosine } a = \frac{AF}{AD}$$

$$0.991 = \frac{AF}{6''}$$

$$AF = 0.991 \times 6''$$

$$AF = \frac{0.991 \times 6''}{0.250} = 23.784$$

$$AF = BE. \text{ So, } BE = 23.784 \text{ pitch units}$$

Step 5:

Calculation for the pitch lengths of chain wrapped around each of the sprockets.

$$ME = MH + HE = \frac{N}{4} + N \frac{a}{360} = 8.13 \quad (3.8)$$

$$KB = KG - BG = \frac{n}{4} - n \frac{a}{360} = 2.3 \quad (3.9)$$

Final Step:

From the calculations that have done, the chain length for 2 sprockets.

$$L = 2[BE + ME + KB] = 68.4 \text{ pitch units} \quad (3.10)$$

or

$$L = 2\left[C \cos a + \frac{N + n}{4} + \frac{a}{360}(N - n)\right]$$

$$L = 2\left[23.78 + \frac{30 + 10}{4} + \frac{7.57^\circ}{360}(30 - 10)\right] = \mathbf{68.4 \text{ pitch units}}$$

3.7.2.5 Electrical Circuit Simulation

Electrical simulation for this project is use Proteus 7.9 software. This software provides a powerful working environment which the user can easily design different electronics circuits from the simple interface like power supply, generators, resistor and micro-controller or micro-processor. Figure 3.13 shows the interface of Proteus 7.9 software and Figure 3.14 shows the electrical wiring on Proteus 7.9 software.

The features of Proteus 7.9 software are:

- i. Easy to use tool.
- ii. Simple but effective interface.
- iii. Circuit designing and schematic making made easy.
- iv. Provide a powerful working environment.
- v. Real time design simulation with VSM.
- vi. Can route and edit different component using ARES feature.

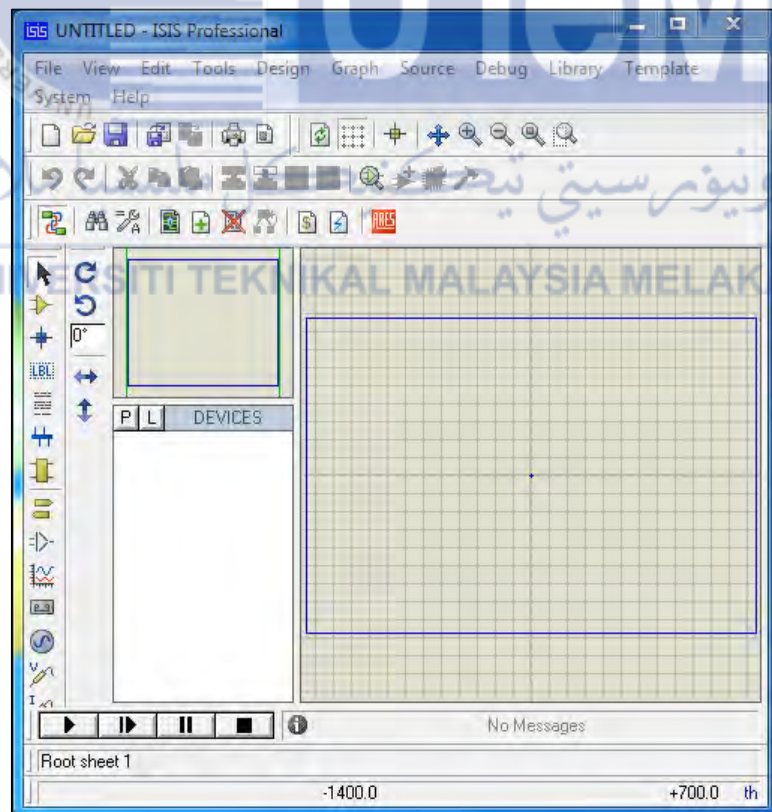


Figure 3.13: The interface of Proteus 7.9 software

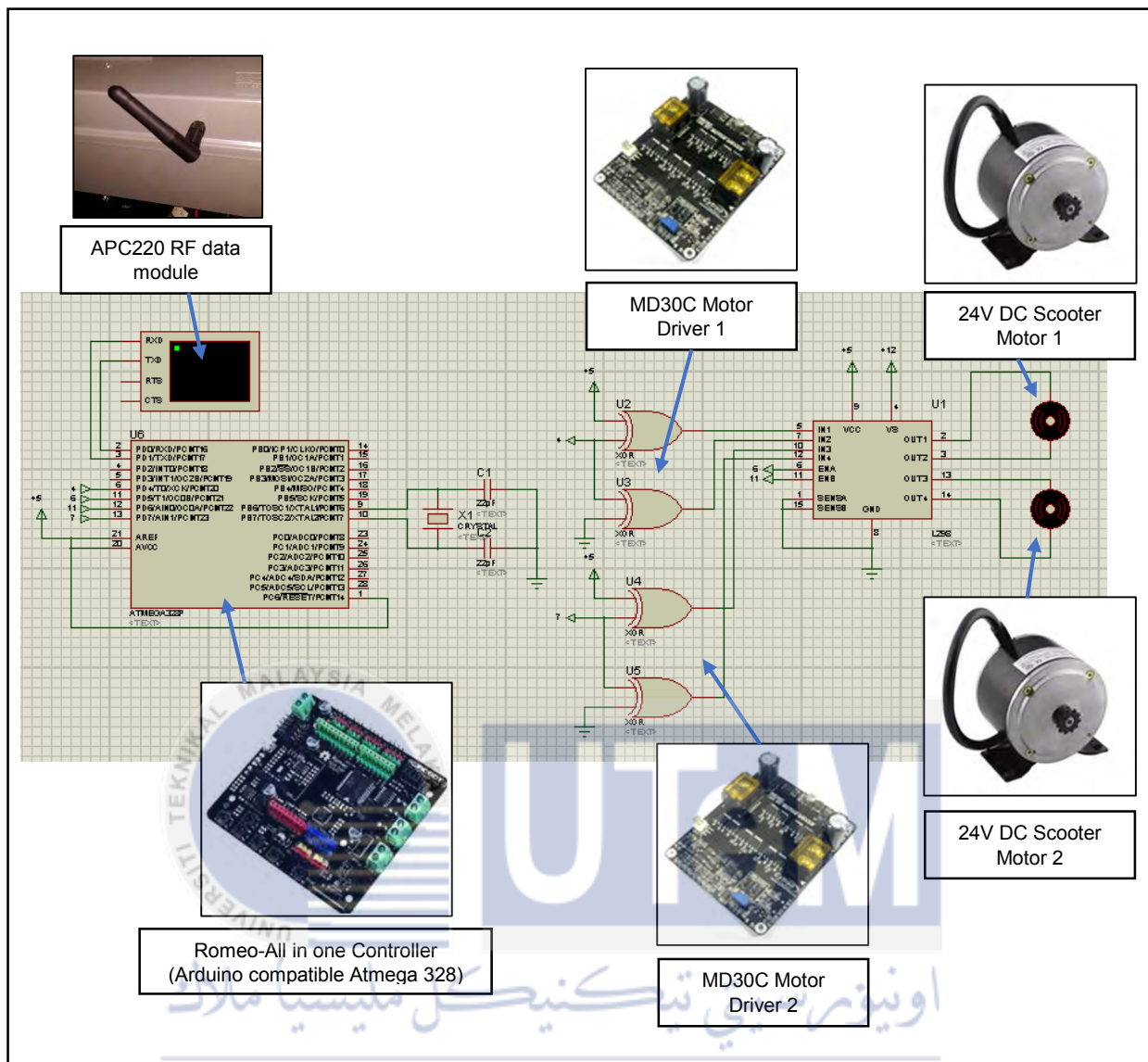


Figure 3.14: The electrical wiring on Proteus 7.9 software

The electrical part for this project uses the Romeo-All In One Controller (Arduino compatible Atmega 328) and two types of MD30C motor driver. The Romeo-All In One Controller is selected as a micro-controller for this project because it can be easily expanded with most Arduino Shields and it is supported by thousands of open source codes. In addition, the integrated two ways DC motor driver and wireless socket gives a much easier way to handle for this project. The MD30C is selected for this project because it is designed to drive medium to high power brushed DC motor with current capacity up to 80A peak and 30A continuously. It is not only provides faster switching time, but also designed in fully NMOS which are more efficient and no heatsink or fan is required. So, it is very compatible to drive the 24V DC Electric Scooter Motor with 20A rate current and 350W power. Figure 3.15 shows the electrical part for this project.

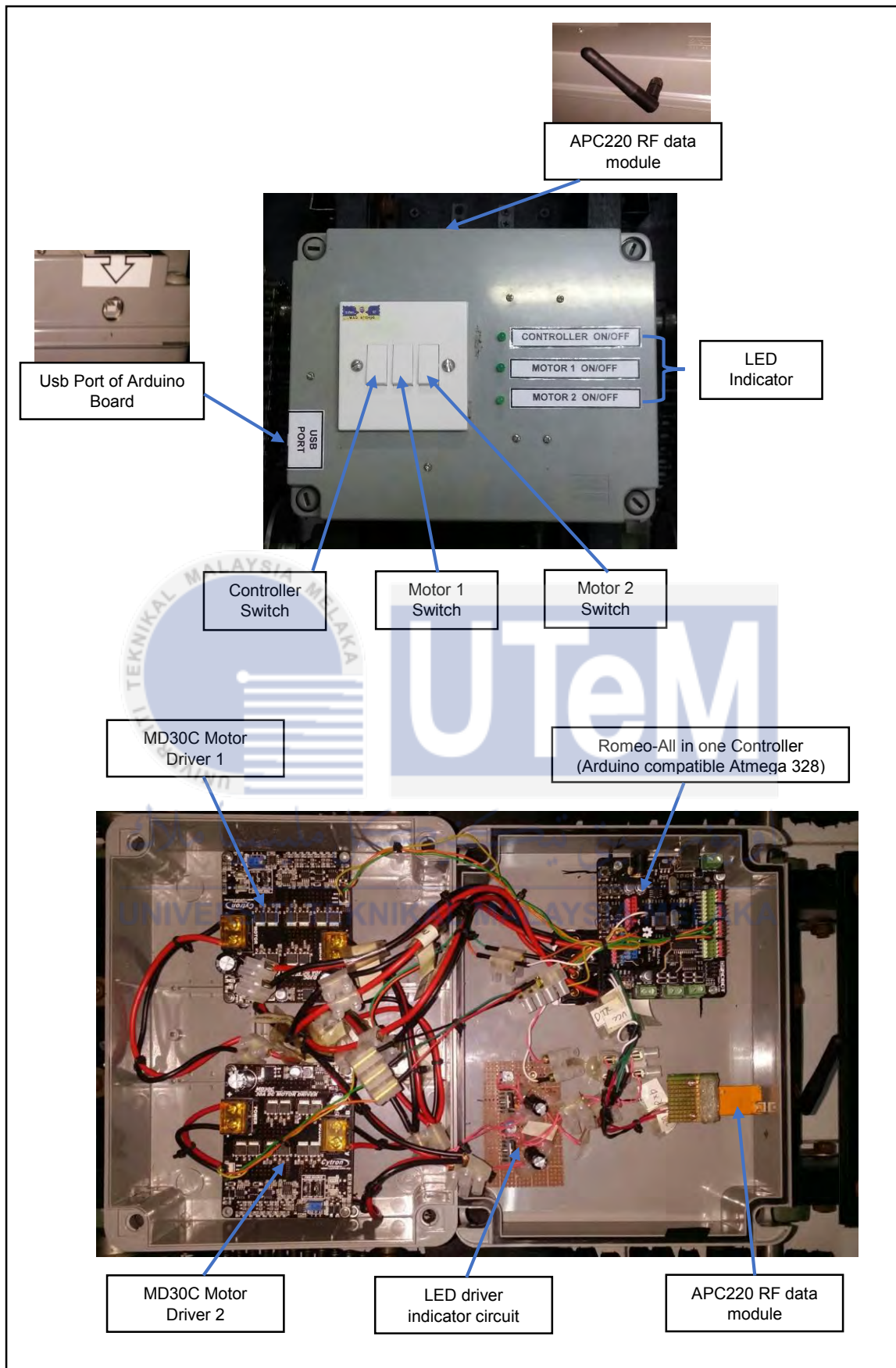


Figure 3.15: The electrical part for this project

3.7.2 Software Development

Software development for this project is using arduino 1.6.6 software. It is an open-source Arduino Software (IDE) that is easy to write a code and upload it to the board. This software runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on processing and other open-source software. The most important, it can be used with any Arduino board. Figure 3.16 shows the enviroment of arduino 1.6.6 software.



Figure 3.16: The enviroment of arduino 1.6.6 software

3.7.2.1 Flowchart for Programming of Robot Controller

Programming flow chart for robot controller will illustrate the workflow about to receive a data from RF transmitter. The operations of RF receiver start when it receives the data from RF transmitter. For example, if the RF receiver receives the data of "W" from RF transmitter, then the robot will move forward. If the RF receiver receives the data of "S" from RF transmitter, then the robot will move reverses. The robot will turn to right when it receives the data of "D" from RF transmitter and will turn to the left when it receives the data of "A" from RF transmitter. Figure 3.17 shows the programming flow chart for the robot controller.

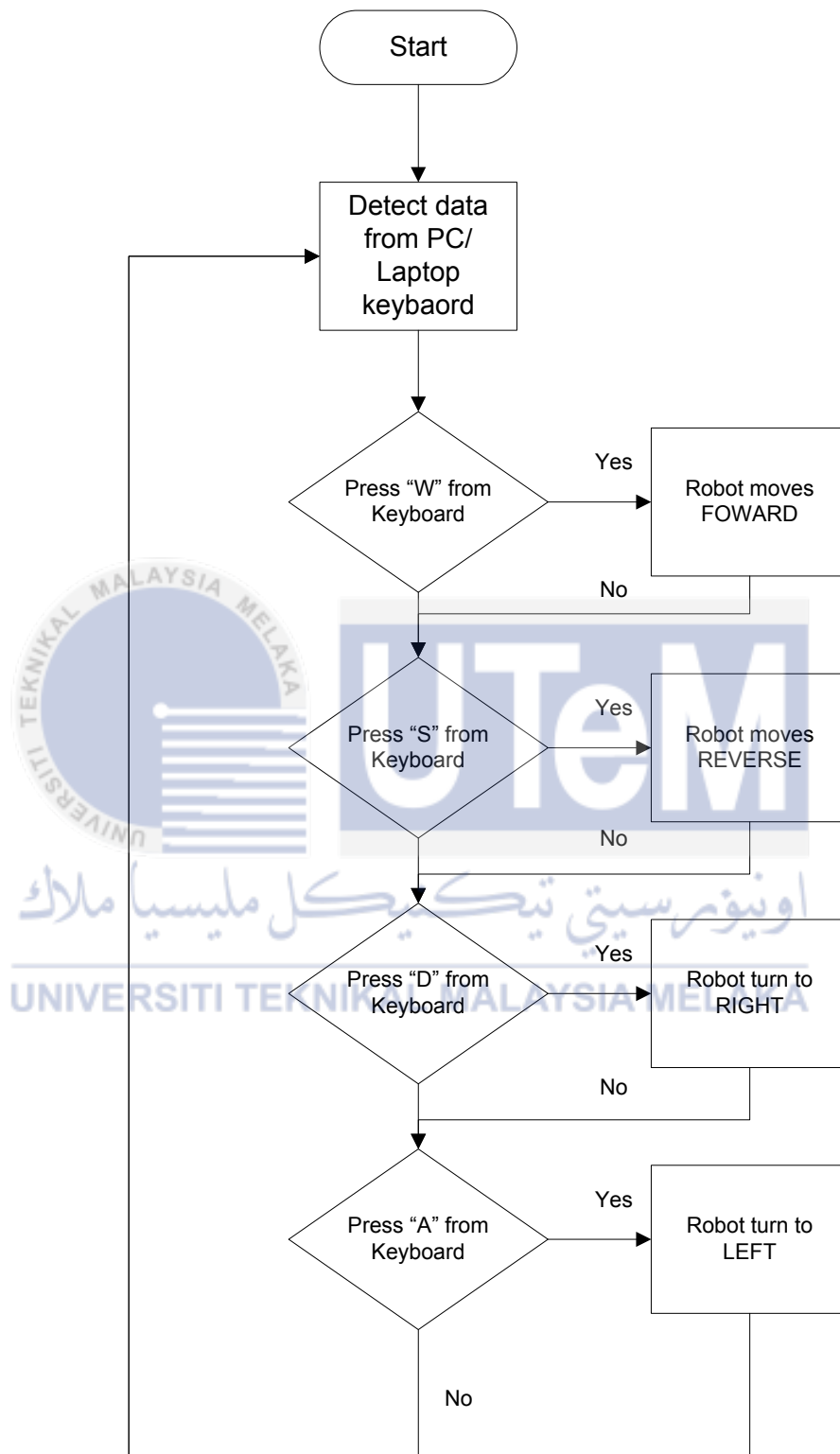


Figure 3.17: Programming flow chart for robot controller

3.7.2.2 Communication Between PC and Arduino Board Wirelessly

The communication between PC and Arduino board is using APC220 RF data module. It is a highly versatile, low power radio solution that is easy to setup and integrate into any project that requires a wireless RF link. It is perfect for robotic applications which is need a wireless control. These modules having two APC220 which are need to connect with MCU through TTL interface and the other one need to connect with PC through a TTL/USB converter. Figure 3.18 shows the APC220 Radio Data Module and Table 3.4 shows the pin definitons of APC220.

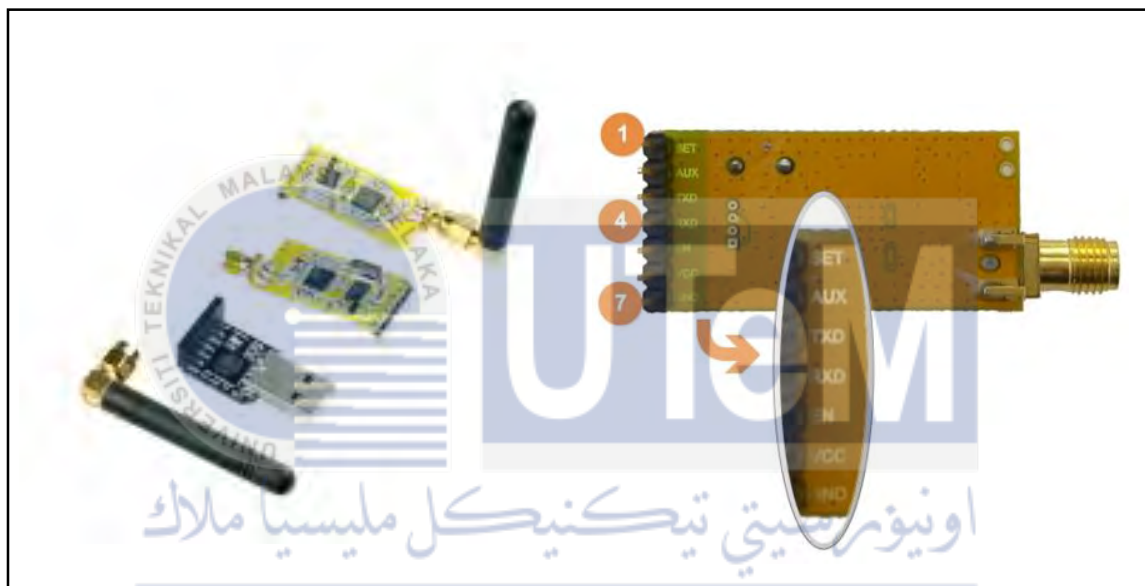


Figure 3.18: APC220 Radio Data Module

Table 3.4: The pin definitons of APC220

Pin	Definition	Detail
1	SET	Set Parameter (low)
2	AUX	UART Signal-Receive(low) Transmit(high)
3	TXD	UART TX
4	RXD	UART RX
5	EN	Disable the device when apply <0.5V Enable the device when leave it disconnected or apply >1.6V
6	VCC	3.3V-5.5V Power
7	GND	0V Ground

The APC220 RF module can be set up in several connections such as connection of APC220 to PC via RS232-TTL converter that illustrated in Figure 3.19, connection of APC220 to MCU that illustrated in Figure 3.20, connection from PC to MCU via APC220 that illustrated in Figure 3.21 and connection from PC to PC via APC220 that illustrated in Figure 3.22.

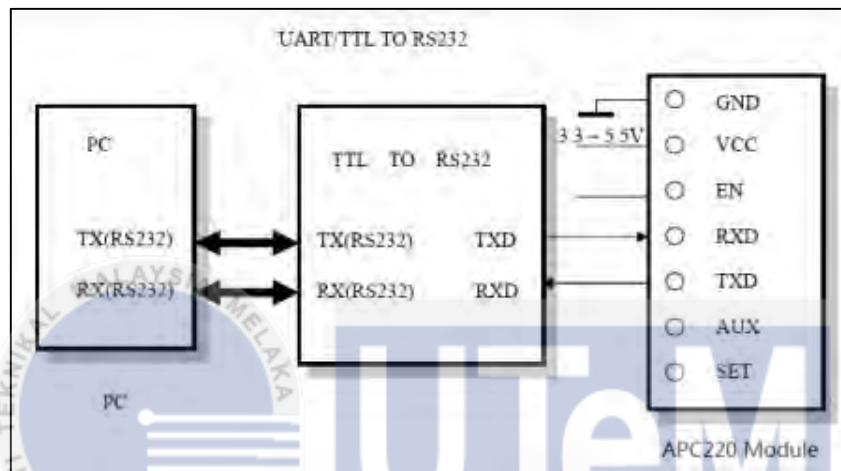


Figure 3.19: The connection of APC220 to PC via RS232-TTL converter

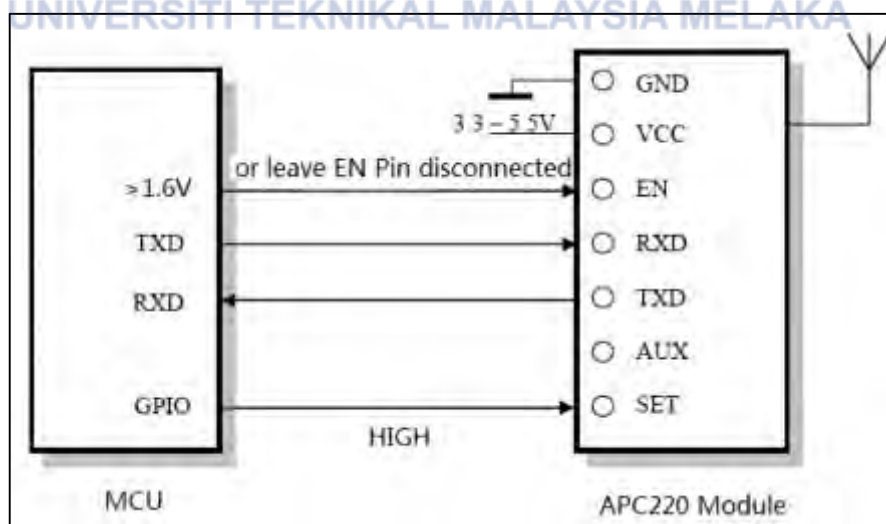


Figure 3.20: The connection of APC220 to MCU

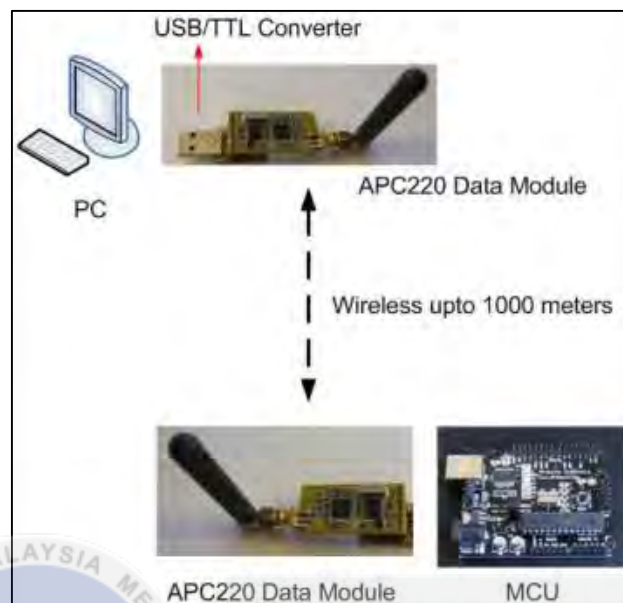


Figure 3.21: The connection from PC to MCU via APC220

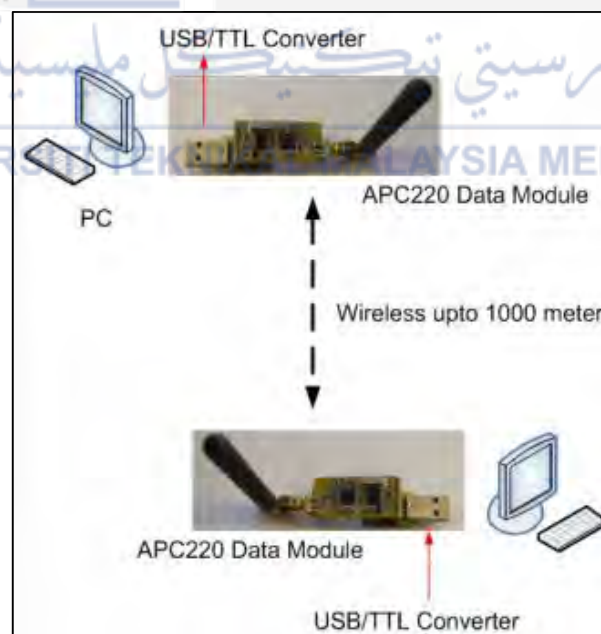


Figure 3.22: The connection from PC to PC via APC220

Table 3.5: Setting parameter of APC220 RF module

Parameter	Range	Default
RF frequency	Resolution 1KHz, Accuracy $\pm 100\text{Hz}$	434MHz
RF TRx Rate	1200, 2400, 4800, 9600, 19200bps	9600bps
RF Power	0-9	9
Series Rate	1200, 2400, 4800, 9600, 19200, 38400, 57600bps	9600bps
NET ID	0-65535 (16 bit)	12345
NODE ID	123456789012	
Series Patity	Disable, Odd Patity, Even Patity	Disable

The communication test between PC and Arduino Board wirelessly is set up by using Serial Assistant application or simply use on the Arduino IDE serial monitor application. After that, one of APC220 module must be attach into PC/laptop, and another one of APC220 module must be attach into Arduino board as illustrated in Figure 3.23 and Figure 3.24. In order to avoid error on device, both of APC220 modules that plugin into PC/laptop and Arduino board must be set up with the same parameter setting. The parameter can be refer in Table 3.5.



Figure 3.23: The attachment of APC220 module into PC/laptop



Figure 3.24: The attachment of APC220 module into Arduino board

3.7.2.3 Graphic User Interface (GUI) Controller.

The GUI is used for this project as a controller for RTVP to move from the left side and the right side as well maneuver in straight line, turn back and rotate 360 degree. The main function of GUI is to enable the features through usb port utility and RS-232 serial interface to the arduino board. It is developed by using JAVA program and running on Processing software. The interface of Processing software is illustrated in Figure 3.25 and the interface of GUI for RTVP controller is illustrated in Figure 3.26.

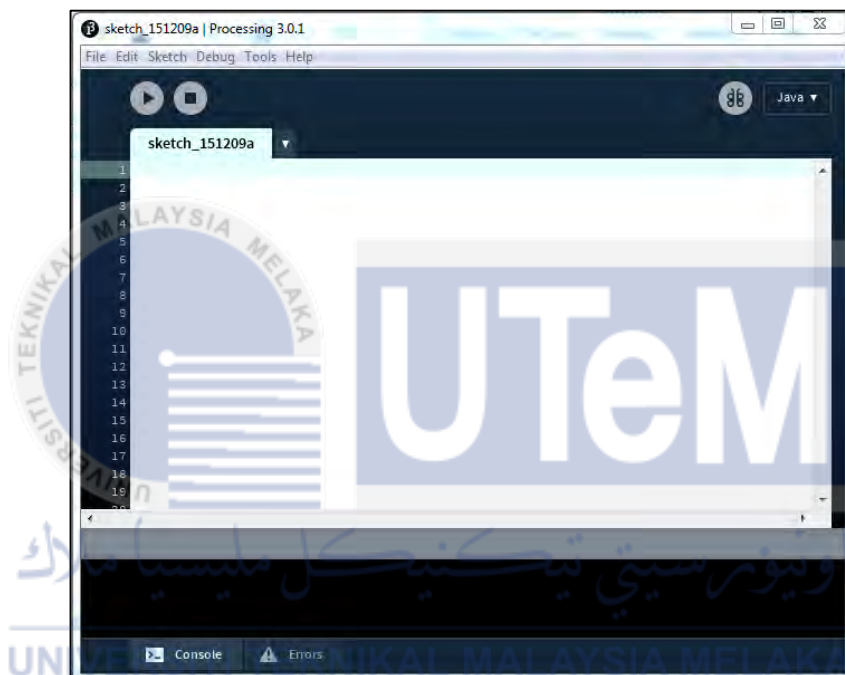


Figure 3.25: The interface of Processing software

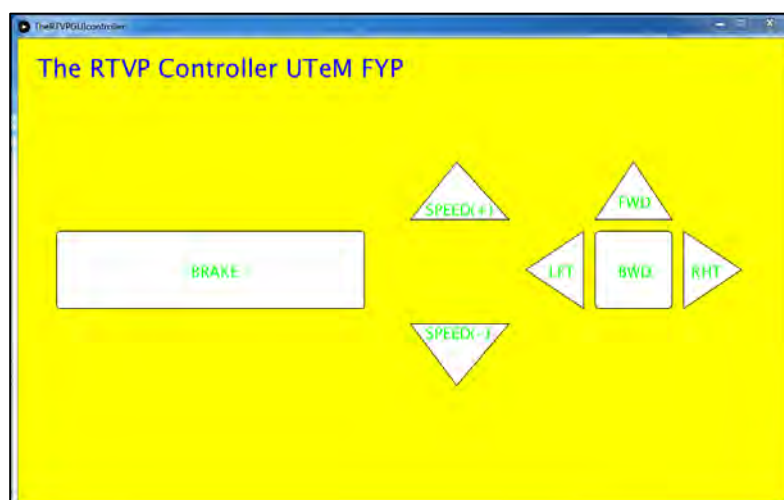


Figure 3.26: The interface of GUI for RTVP controller

3.8 Experiment and Project Set Up

3.8.1 Experiment 1:

Simulation for the chassis of Robot Track Vehicle Platform by using SolidWorks Simulation Xpress software.

Objectives:

1. To identify and describe the chasis of RTVP specifications.
2. To analyze the design of chasis by using SolidWorks Simulation Xpress software.

Equipment and Apparatus:

1. SolidWorks Premium 2013 software.
2. PC/Laptop.

Procedures:

1. The chasis of RTVP is designed by using the SolidWorks software based on the design scope of the robot tracked system.
2. The chasis design is named as Robot Tracked Vehicle Platform Chasis.
3. The chasis design is applied the material used to start the simulation.
4. The force and pressure is applied to the chasis design.
5. The Simulation Study application is applied before get the results of strain, stress, displacement and safety analysis tests.
6. The study is launched and viewed the final results.

3.8.2 Experiment 2:

Forward and backward movement on the road test.

Objectives:

1. To determine the speed of RTVP in forward movement.
2. To determine the speed of RTVP in reverse movement.

Equipment and Apparatus:

1. The RTVP wirelessly operated.
2. APC220 RF module that connected to PC/laptop.
3. Stopwatch.
4. Measuring Tape.

Procedure

1. The RTVP is positioned on the ground.
2. The RTVP is controlled wirelessly by using APC220 RF module that connected to PC/laptop.
3. The time is taken every 2 second when the robot platform is start moving.
4. The position of the robot platform are marked after 2s, 4s, 6s, 8s and 10s.
5. The experiment is repeated 3 times for a better result.
6. The steps 2 to 5 are repeated for a reverse movement.
7. The data is observed and recorded.

3.8.3 Experiment 3:

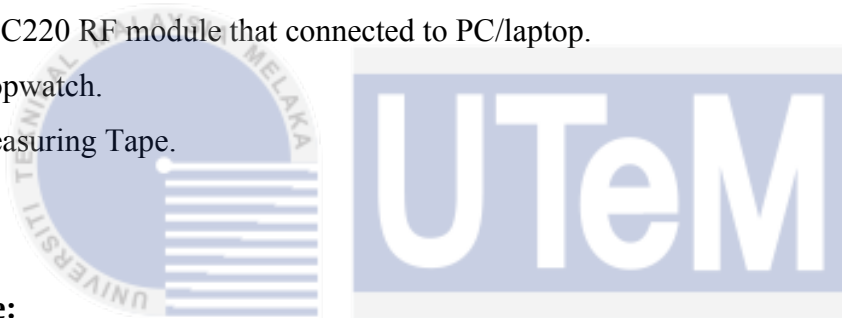
Right and left turn on the road test, (90° , 180° , 270° and 360°).

Objectives:

1. To find the speed of the RTVP while turning to the right in different degrees.
2. To find the speed of the RTVP while turning to the left in different degrees.

Equipment and Apparatus:

1. The RTVP wirelessly operated.
2. APC220 RF module that connected to PC/laptop.
3. Stopwatch.
4. Measuring Tape.



Procedure:

1. The line is marked with a distance of 2m in a straight line that parallel to the direction of the RTVP to make a 90° turning to the left and right.
2. The RTVP is positioned at a ground.
3. The RTVP is controlled wirelessly by using APC220 RF module that connected to PC/laptop.
4. The data is recorded when the robot platform is pass through the mark and completely turning to the right in 90° condition.
5. The experiment is repeated 3 times for a better result.
6. The steps 2 to 5 are repeated for a different degrees test and also for a left turning movement test.
7. The data is observed and recorded.

3.8.4 Experiment 4:

Obstacle test on difference heights of ladder.

Objective:

1. To determine the ability of the RTVP to run on the different heights of ladder.
2. To find the speed of the RTVP while pass through to the different heights of ladder.

Equipment and Apparatus:

1. The RTVP wirelessly operated.
2. APC220 RF module that connected to PC/laptop.
3. Stopwatch.
4. Measuring Tape.
5. 4.2cm, 5.5cm, 10.3cm, 15.7cm and 17.6cm heights of ladder.

Procedure:

1. The RTVP is placed in front of the 4.2cm height of ladder.
2. The RTVP is controlled wirelessly by using APC220 RF module that connected to PC/laptop.
3. The data is recorded when the robot platform is pass through to the third ladder successfully.
4. The experiment is repeated 3 times for a better result.
5. The steps 1 to 4 are repeated for a 5.5cm, 10.3cm, 15.7cm and 17.6cm heights of ladder.
6. The data is observed and recorded.

3.8.5 Experiment 5:

Different condition of the surfaces test.

Objectives:

1. To determine the ability of the RTVP to run on different surfaces condition.
2. To find the speed of the RTVP while moving on different surfaces condition.

Equipment and Apparatus:

1. The RTVP wirelessly operated.
2. APC220 RF module that connected to PC/laptop.
3. Stopwatch.
4. Measuring Tape.
5. Different condition of the surfaces such as stone and grass surface.

Procedure:

1. The RTVP is placed on the stone surface condition.
2. The RTVP is controlled wirelessly by using APC220 RF module that connected to PC/laptop.
3. The position of the RTVP are marked after 2s, 4s, 6s, 8s, and 10s.
4. The experiment is repeated 3 times for a better result.
5. The steps 1 to 4 are repeated for a condition of grass surface.
6. The data is observed and recorded.

3.9 Summary

This chapter is starting with the project methodology which is about the planning process of the overall implementation of the project from the beginning until successfully done. After that, it follows with the block diagram of the project which are focus on combination of RF Transmitter and RF Receiver block diagram. This chapter also contains the material and component selections for electrical parts and mechanical parts. After that, the explanation about the chain drive system and gear configuration that are use for this project which are involves with certain calculations such as the calculations of drive ratios and chain length. Lastly, the experiment and project set up is also provided which are five experiments need to conduct in order to investigate and determine the ability of the RTVP performance. The next chapter will be explain about the results and discussion of this project based on the experiments that have been done.



CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will discuss about the analysis and results from the experiments that have been done in order to identify the performance and ability of the RTVP. The analysis will be covered all about the variety of posture, motion model and power consumption including the center of gravity of the robot. This result and analysis test will ensure the final product is free from bugs and errors to maintain reliable performance.

4.2 Project Design

Project design is about the design characteristic of the robot platform that consist of three parts such as chassis, wheels and tracks. It is also involves with 3D drawing that shows the views of the design such as top, front and side view. The overall design of the RTVP is designed by using the SolidWorks software.

4.2.1 Design Characteristic of the Robot Tracked Vehicle Platform

This part covers design criteria of the RTVP. There are three main parts of the robot which are chassis body, 4 pcs of wheels with one pair of tracks and one pair of articulation. Figure 4.1 shows the full design characteristics of the RTVP and Table 4.1 shows the specification of the RTVP. Figure 4.2 and Table 4.2 shows the mass properties of the design.

Table 4.1: The specification of the Robot Tracked Vehicle Platform

Items	Dimensions
Length	30 inch
Height of The Chassis	10 inch
Width	25 inch
Height Chassis to The Ground	3.78 inch
Type of Wheels	9 inch wheel size that combined with a modified off road motorcycle tire.
Gear Ratio	3:1 (use sprocket and chain)
Motor Type	24V DC Electric Scooter Motor 350W
Material	Aluminium hollow, sheathing plywood, rubber, steel and plastic.
Weight	32.8 kg

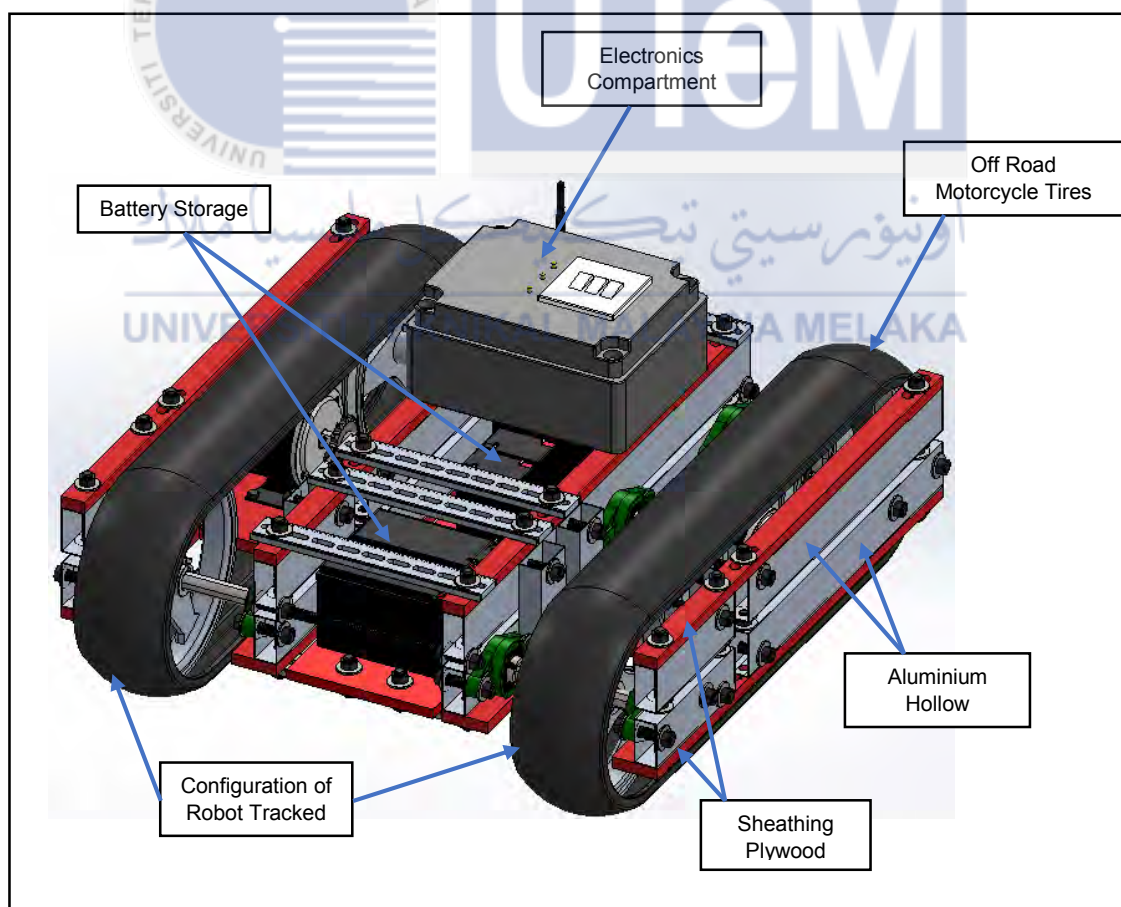


Figure 4.1 : The full design characteristics of the RTVP

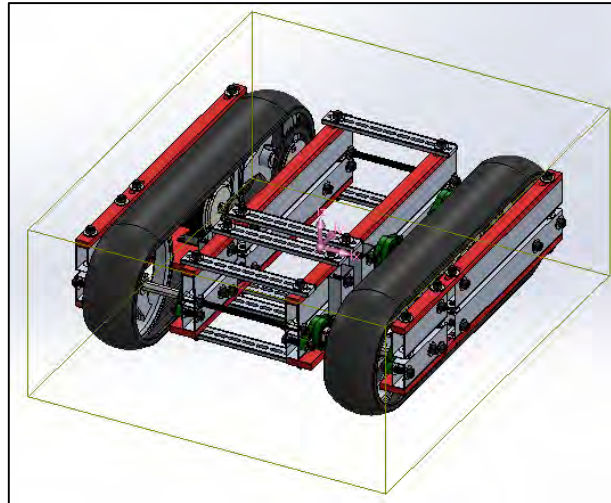


Figure 4.2: The mass properties of the design

Table 4.2: Mass properties of the design by using SolidWorks software

Mass properties of the Robot Tracked Vehicle Platform		
1. Mass = 23.24 kilograms		
2. Volume = 11212390.22 cubic millimeters		
3. Surface area = 4915309.44 square millimeters		
4. Center of mass: (millimeters)		
X = 315.77		
Y = 390.15		
Z = 638.82		
5. Principal axes of inertia and principal moments of inertia:		
(kilograms * square millimeters) Taken at the center of mass.		
I _x = (1.00, -0.00, 0.00)		P _x = 1108029.19
I _y = (0.00, -0.00, -1.00)		P _y = 1231136.93
I _z = (0.00, 1.00, -0.00)		P _z = 2183105.20
6. Moments of inertia: (kilograms * square millimeters) Taken at the center of mass and aligned with the output coordinate system.		
L _{xx} = 1108030.22	L _{xy} = -960.63	L _{xz} = 146.07
L _{yx} = -960.63	L _{yy} = 2183104.05	L _{yz} = 523.72
L _{zx} = 146.07	L _{zy} = 523.72	L _{zz} = 1231137.04
7. Moments of inertia: (kilograms * square millimeters)		
Taken at the output coordinate system.		
I _{xx} = 14130569.77	I _{xy} = 2862388.06	I _{xz} = 4688493.35
I _{yx} = 2862388.06	I _{yy} = 13985308.95	I _{yz} = 5793204.36
I _{zx} = 4688493.35	I _{zy} = 5793204.36	I _{zz} = 7086414.96

4.2.2 3D Drawing with Tolerance

This part shows about the 3D drawing which are the top view, side view, and front view of the Robot Tracked Vehicle Platform. All of the designs are done by using the SolidWorks software. Figure 4.3 shows the 3D drawing, Figure 4.4 shows the side view, Figure 4.5 shows the top view and Figure 4.6 shows the front view of the RTVP.

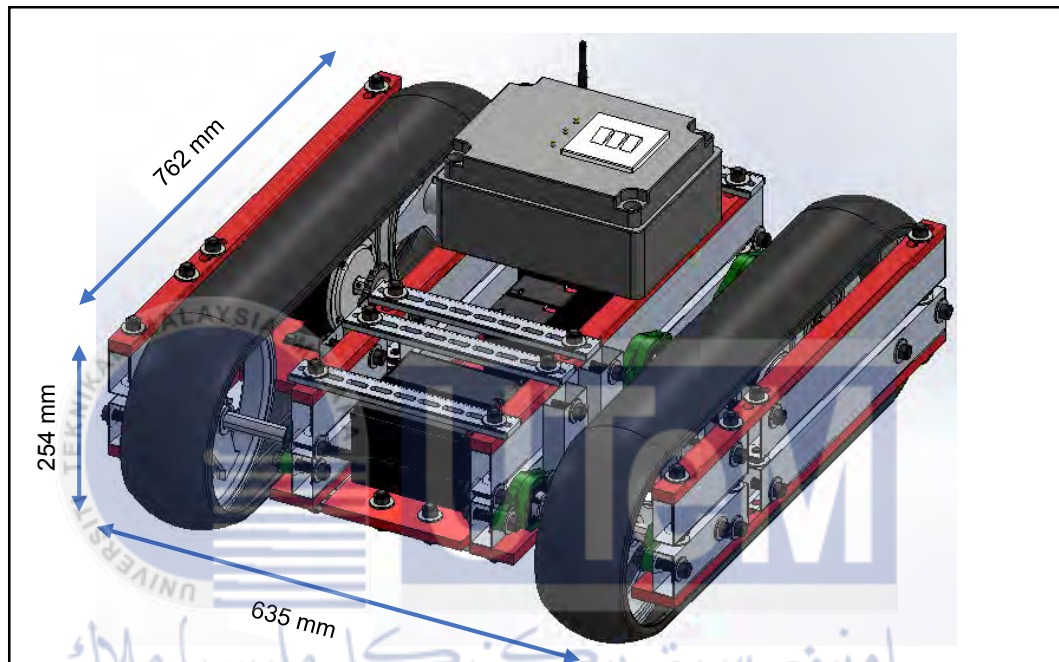


Figure 4.3: 3D drawing of the RTVP

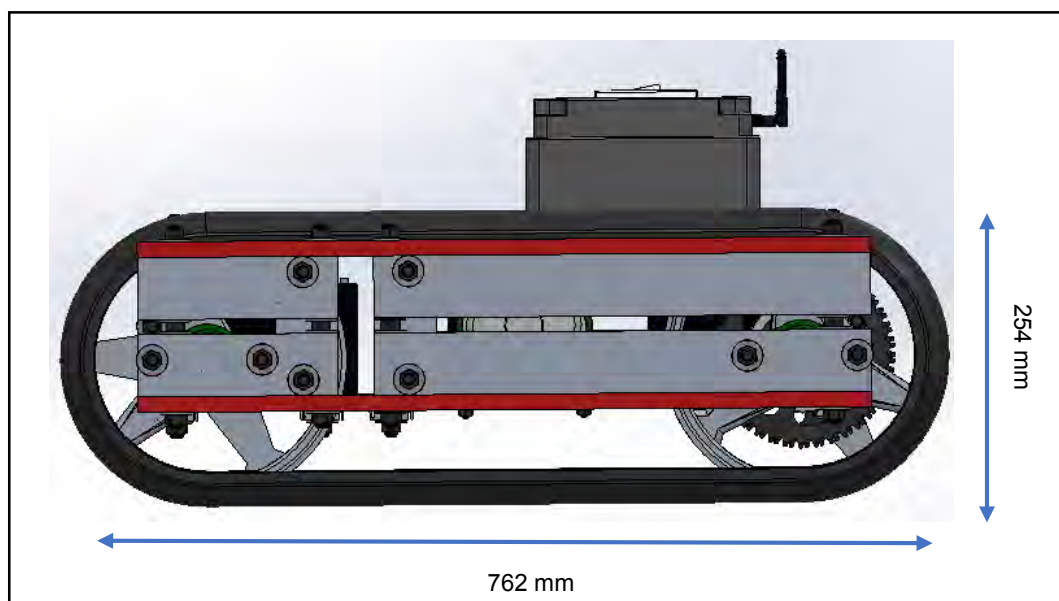


Figure 4.4: Side view of the RTVP

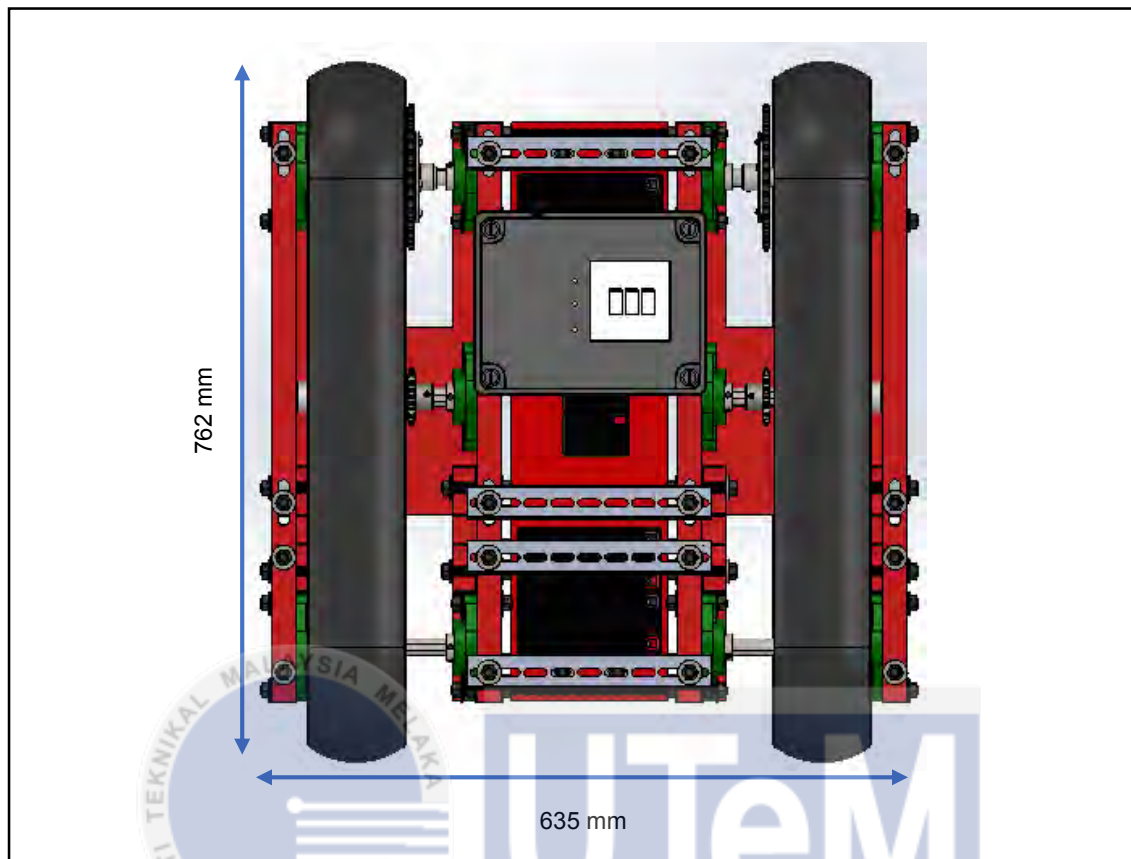


Figure 4.5: Top view of the RTVP

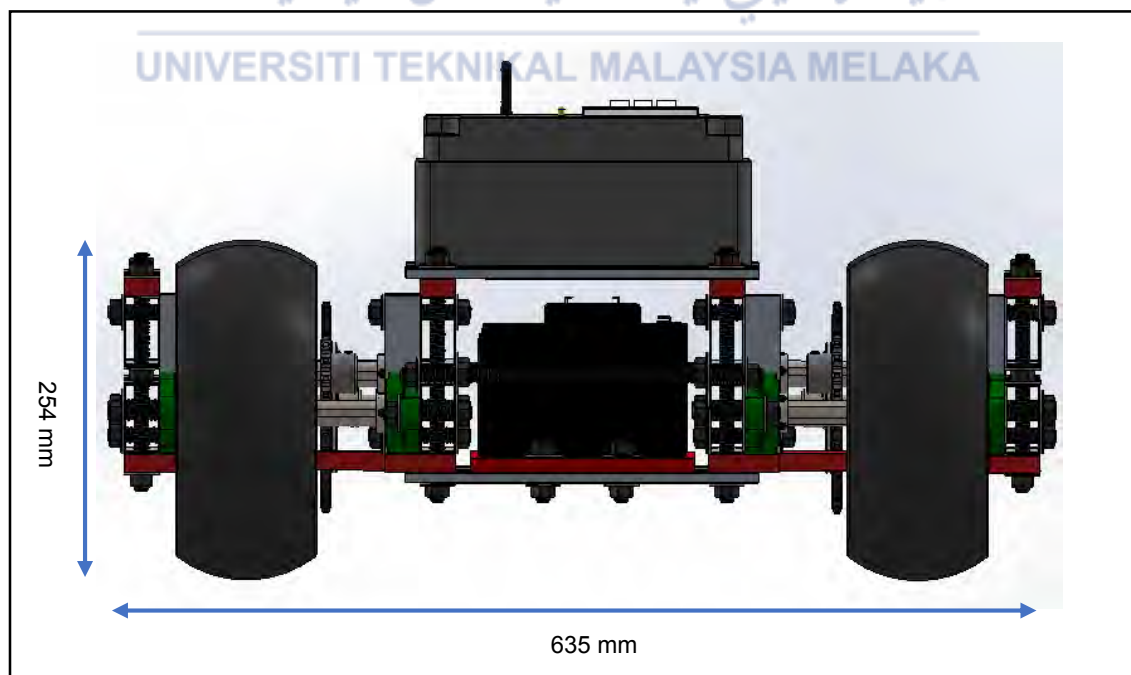


Figure 4.6: Front view of the RTVP

4.2.3 Completed Mechanical Construction

Mechanical part is very important part in designing the RTVP which is came out from the mechanism of a tank. There are several elements that need to be consider in designing the robot platform such as material, size and stability in order to meet the specifications of the completed design. In addition, the idea of the mechanical structure is need to meet the standard mechanical part that available in local market and easy to handle for fabrication and assemble process. So, this will help improving the maneuverability of the robot platform and produce a final product with low cost of manufacturing. Figure 4.7 shows the mechanical construction from the 3D view, Figure 4.8 shows the mechanical construction from the front view, Figure 4.9 shows the mechanical construction from side view and Figure 4.10 shows the mechanical construction from top view.



Figure 4.7: Mechanical construction from 3D view

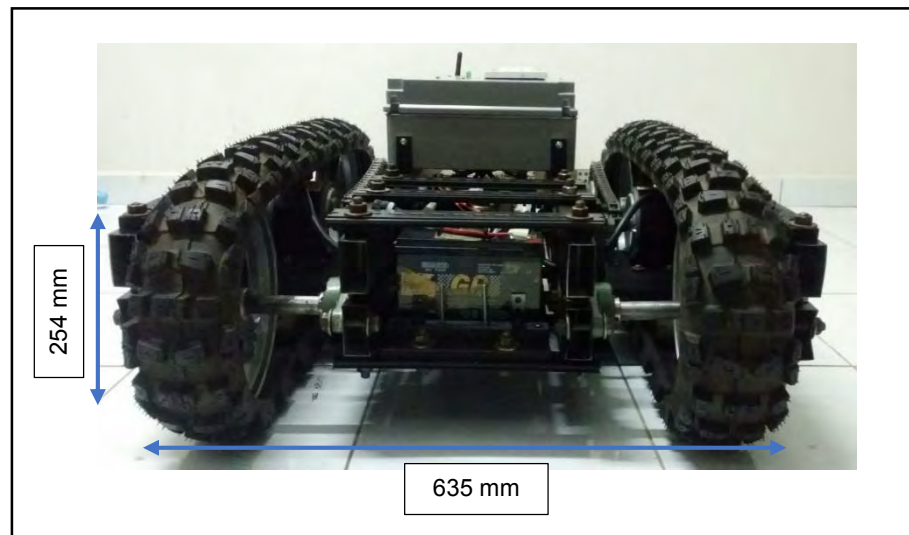


Figure 4.8: Mechanical construction from front view



Figure 4.9: Mechanical construction from side view

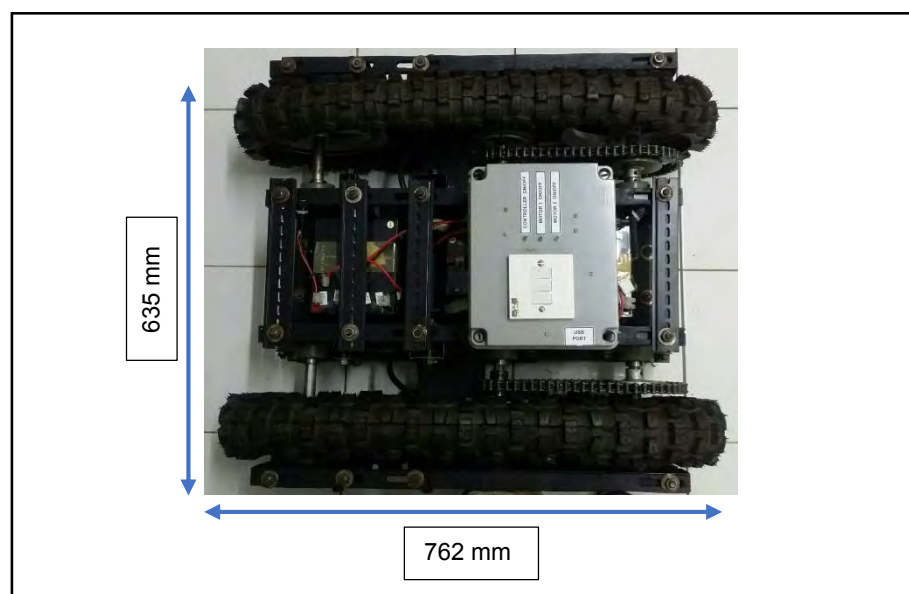


Figure 4.10: Mechanical construction from top view

4.3 Analysis of the Chassis Body

Experiment 1:

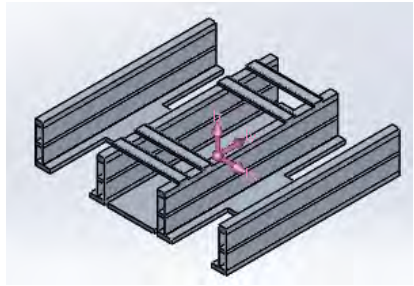
Simulation for the chassis of Robot Track Vehicle Platform by Using SolidWorks Simulation Xpress Software.

The analysis of the chassis body is done by using SolidWorks Simulation Xpress Wizards that offers in the SolidWorks Premium 2013 software. The simulation of the design will provide the results of the Finite Element Analysis (FEA) such as assumptions, material properties, load, fixtures, mesh informations and study results. In addition, this topic will provides a details explanation about the analysis of the robot chassis body. This test is basically to identify and descibe the specification of the robot platform in term of force, pressure and stress. The simulation test are applied external load as follows:

Force : 2500 N
Pressure : 50000 N/m²

The simulation is done by imitate fixtures and external load to the chassis body of the robot platform. The material selection is Aluminum 6063-O, Extruded Rod (SS) which is enough to withstand the pressure and force to fulfill the requirement needed in developing the robot platform chassis. Table 4.3 shows the mass properties for chassis of the RTVP.

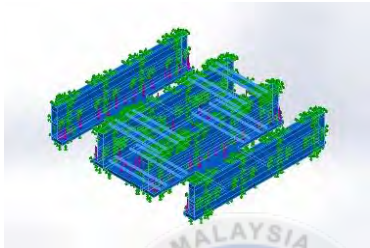
Table 4.3: The mass properties for chassis of the RTVP

Robot Platform Chassis	Mass Properties
	1. Density = 2700.00 kilograms per cubic meter
	2. Mass = 16.64 kilograms
	3. Volume = 6162021.61 cubic millimeters
	4. Surface area = 2072699.61 square millimeters
	5. Center of mass: (millimeters)
	X = -0.03 Y = 44.37 Z = 1.03

4.3.1 Assumptions

The assumptions for this analysis is cover about solid bodies of the robot chasis. It makes the calculations of volumetric properties such as mass, volume, density and weight. Table 4.3 shows the result for assumptions of solid bodies.

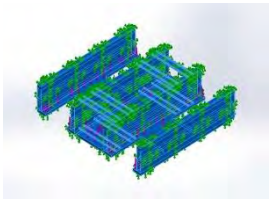
Table 4.4: Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties
	Solid Body	Mass : 16.6375 kg Volume : 0.00616202 m ³ Density : 2700 kg/m ³ Weight : 163.047 N

4.3.2 Material Properties

The material properties for this body chassis of the robot is AISI 1035 Steel (SS). The model type for this simulation is Linear Elastic Isotropic (LEI) and default, failure criterion is Max von Mises Stress. The value of yield strength and tensile strength will be calculated from this analysis. Table 4.5 shows the result for material properties of chassis body.

Table 4.5: Material Properties

Model Reference	Properties
	Name : 6063-O, Extruded Rod (SS) Model type : Linear Elastic Isotropic. Default failure criterion : Max von Mises Stress. Yield strength : 4.13685e+007 N/m ² Tensile strength : 9e+007 N/mm ²

4.3.3 Load and Fixtures

Load and fixtures are about the environment of the load and fixtures condition from each restraint of the model. It will automatically adjust the changes in geometry and also fully associative. Table 4.6 shows the results for fixtures and Table 4.7 shows the result for load.

Table 4.6: Fixtures

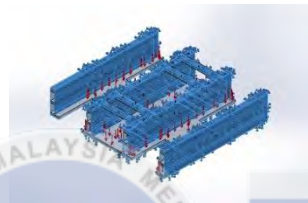
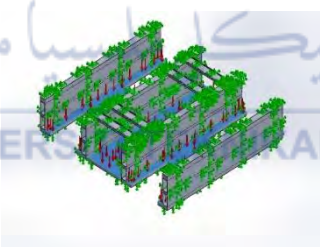
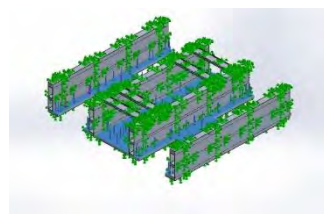
Fixture Name	Fixture Image	Fixture Details
Fixed-1		Entities : 36 face(s) Type : Fixed Geometry

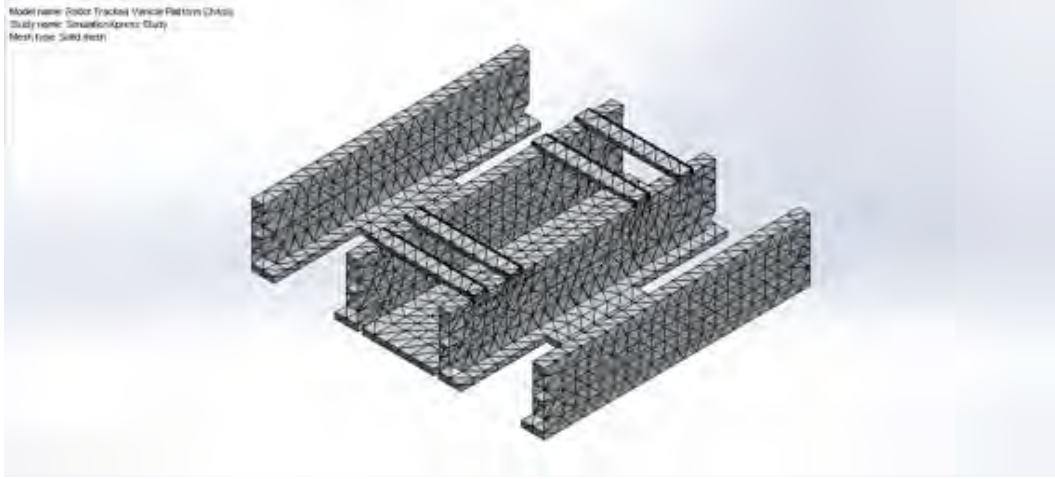
Table 4.7: Load

Load Name	Load Image	Fixture Details
Force-1		Entities : 3 face(s) Type : Apply normal force Value : 2500N
Pressure-1		Entities : 3 face(s) Type : Normal to selected face Value : 50000 Units : N/m ²

4.3.4 Mesh Information

Mesh information is very important because it is a crucial step to analysis the design. There are three elements that automatically create which are shelled, mixed mesh of solid and beam elements. In general, the quality of the mesh will determine the accuracy of the solution. So, the good quality of the mesh the better of the accuracy will be provided. Table 4.8 shows the details results for mesh information.

Table 4.8: Details of mesh information

Mesh type	Solid Mesh
Mesher Used	Standard mesh
Automatic Transition	Off
Include Mesh Auto Loops	Off
Jacobian points	4 Points
Element Size	1.13361in
Tolerance	0.0566806 in
Mesh Quality	High
Total Nodes	22822
Total Elements	11569
Maximum Aspect Ratio	99.561
% of elements with Aspect Ratio < 3	25.6
% of elements with Aspect Ratio > 10	47.9
% of distorted elements(Jacobian)	0
Time to complete mesh(hh:mm:ss)	00:00:12
	

4.3.5 Study Result

Study results from the analysis will show the optimum characteristic according to the design variables, functions and constraints. It will provide the study results for stress, displacement, deformation and factor of safety. Table 4.9, Table 4.10, Table 4.11 and Table 4.12 are showing all of the study results from the analysis that have done.

Table 4.9: Result for Stress

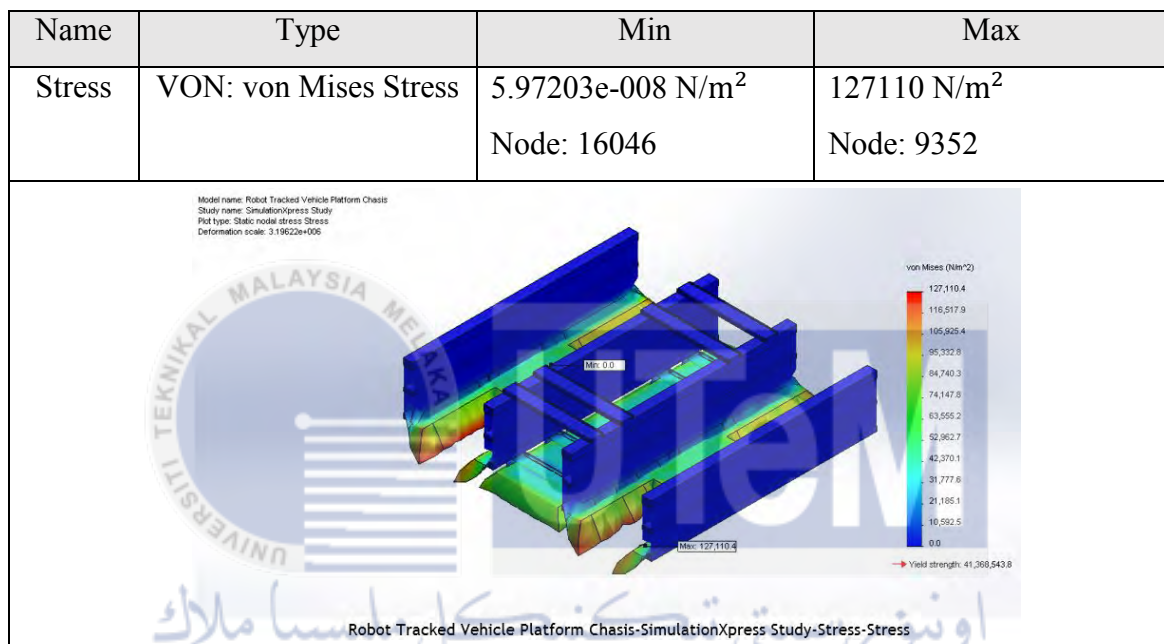


Table 4.10: Result for Displacement

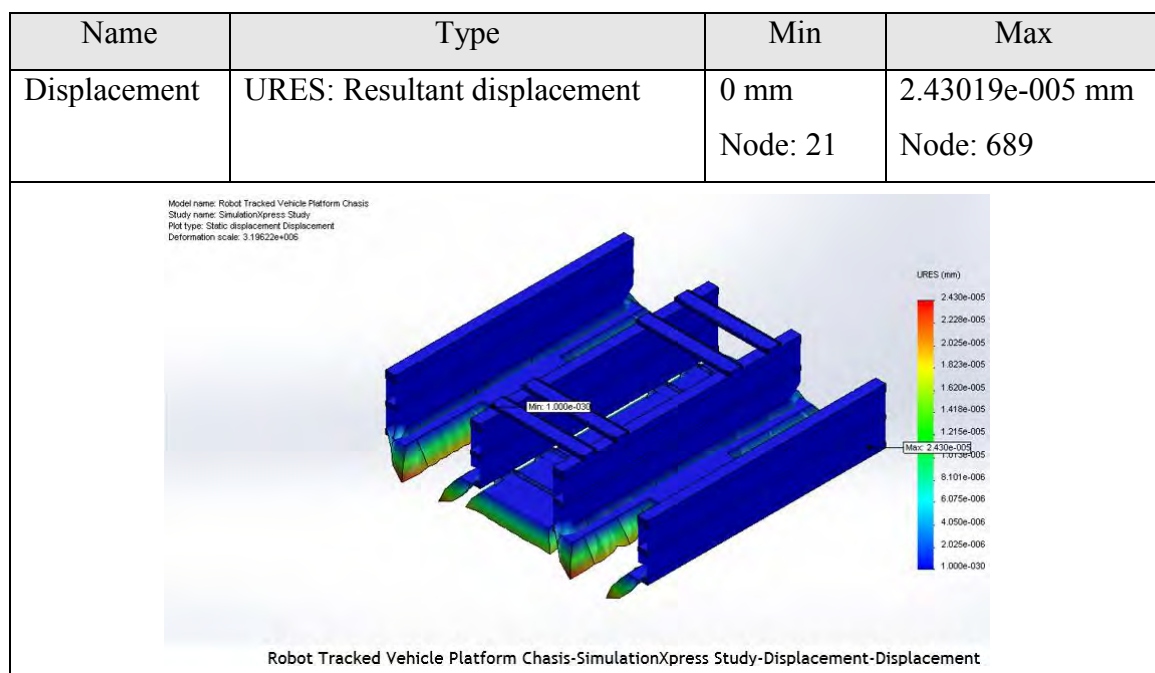


Table 4.11: Result for Deformation

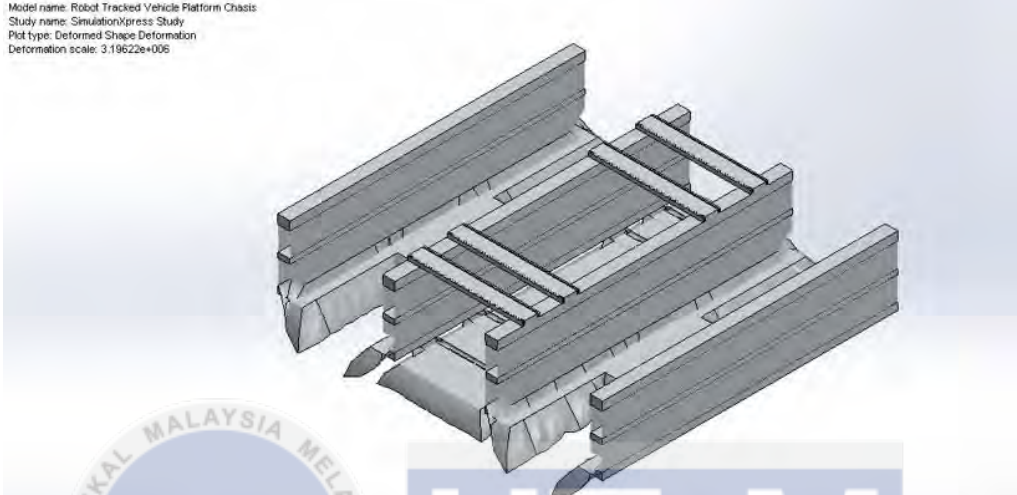
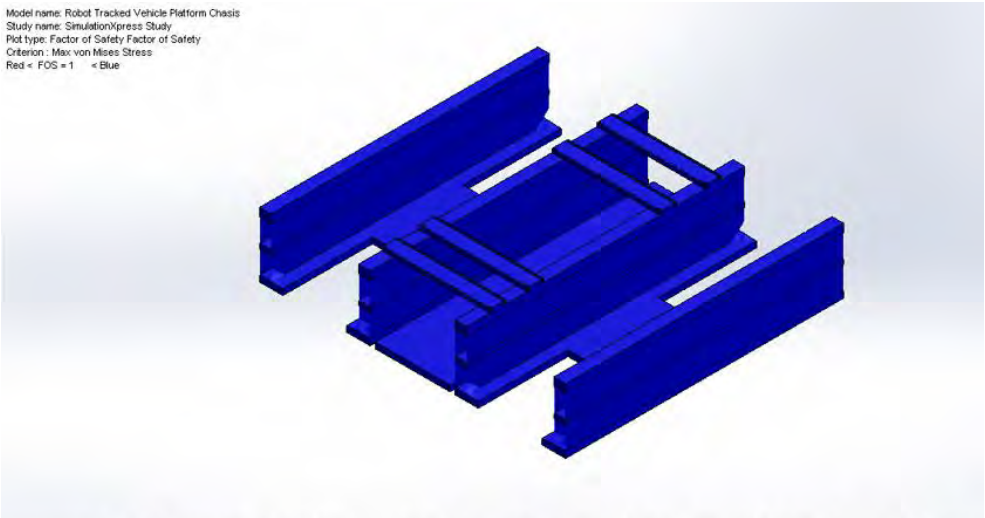
Name	Type
Deformation	Deformed Shape
Model name: Robot Tracked Vehicle Platform Chasis Study name: SimulationXpress Study Plot type: Deformed Shape Deformation Deformation scale: 3.19622e+006  Robot Tracked Vehicle Platform Chasis-SimulationXpress Study-Displacement-Deformation	

Table 4.12: Result for Factor of Safety

Name	Type	Min	Max
Factor of Safety	Max von Mises Stress	9850.44 Node: 10735	1e+016 Node: 2175
Model name: Robot Tracked Vehicle Platform Chasis Study name: SimulationXpress Study Plot type: Factor of Safety Factor of Safety Criterion: Max von Mises Stress Red < FOS = 1 < Blue  Robot Tracked Vehicle Platform Chasis-SimulationXpress Study-Factor of Safety-Factor of Safety			

4.4 Field Test of Robot Tracked Vehicle Platform

4.4.1 Experiment 2:

Forward and backward movement on the road test.

For this experiment, the RTVP was tested to move in forward and reverse on the road condition. The objective of this experiment is to determine the speed of robot platform in forward and reverse movement. The right and left of DC scooter motor must turn in clockwise to move the robot platform in forward and the right and left of DC scooter motor must turn in anti-clockwise to move the robot platform in reverse movement. This robot platform will be controlled wirelessly by using APC220 that connected to PC/laptop. Table 4.13 shows the result test of foward movement.

Table 4.13: Result Test of Foward Movement

Test	Time (s)				
	Distance (m)				
	2s	4s	6s	8s	10s
1	0.7m	1.4m	2.1m	2.7m	3.5m
2	0.8m	1.6m	2.0m	2.9m	3.9m
3	0.7m	1.3m	1.9m	2.7m	3.8m
Average (s)	0.73m	1.43m	2.00m	2.76m	3.73m
Velocity (m/s)	0.37m/s	0.36m/s	0.33m/s	0.35m/s	0.37m/s
Acceleration (m/s²)	0.19m/s ²	0.09m/s ²	0.06m/s ²	0.04m/s ²	0.02m/s ²

Calculation for average of foward movement:

$$\text{Average of } t, 2s = \frac{0.7m + 0.8m + 0.7m}{3} = 0.73m$$

$$\text{Average of } t, 4s = \frac{1.4m + 1.6m + 1.3m}{3} = 1.43m$$

$$\text{Average of } t, 6s = \frac{2.1m + 2.0m + 1.9m}{3} = 2.00m$$

$$\text{Average of } t, 8s = \frac{2.7m + 2.9m + 2.7m}{3} = 2.76m$$

$$\text{Average of } t, 10s = \frac{3.5m + 3.9m + 3.8m}{3} = 3.73m$$

Calculation for velocity of foward movement:

$$\text{Velocity of } t, 2s = \frac{0.73m}{2s} = 0.37m/s$$

$$\text{Velocity of } t, 4s = \frac{1.43m}{4s} = 0.36m/s$$

$$\text{Velocity of } t, 6s = \frac{2.00m}{6s} = 0.33m/s$$

$$\text{Velocity of } t, 8s = \frac{2.76m}{8s} = 0.35m/s$$

$$\text{Velocity of } t, 10s = \frac{3.73m}{10s} = 0.37m/s$$

Calculation for acceleration of foward movement:

$$\text{Acceleration of } t, 2s = \frac{0.37m/s}{2s} = 0.19m/s^2$$

$$\text{Acceleration of } t, 4s = \frac{0.36m/s}{4s} = 0.09m/s^2$$

$$\text{Acceleration of } t, 6s = \frac{0.33m/s}{6s} = 0.06m/s^2$$

$$\text{Acceleration of } t, 8s = \frac{0.35m/s}{8s} = 0.04m/s^2$$

$$\text{Acceleration of } t, 10s = \frac{0.37m/s}{10s} = 0.02m/s^2$$

From the result test of foward movement in table 4.13 shows that the average test in the first 2 seconds the robot platform move up to 0.73 meters and then in 4 seconds it move up to 1.43 meters. After that, for the next 6 seconds it move 2 meters and then in 8 second it move 2.76m. At the end, its move up to 3.73 meters in overall of 10 seconds. The data shows that in the first 2 seconds, the total acceleration is $0.19m/s^2$ and in the next 4 seconds the total acceleration is $0.09m/s^2$. The last 6 seconds, the total acceleration is $0.06m/s^2$. So, it shows that the accelerations of robot platform slows down in the period of time. Means that, the more test that are carried out, the speed of robot platform will become slower because of the power supply is having a voltage drop due to over use. Based on the result in Table 4.13, the graph for the forward movement on road test is plotted in Figure 4.11.

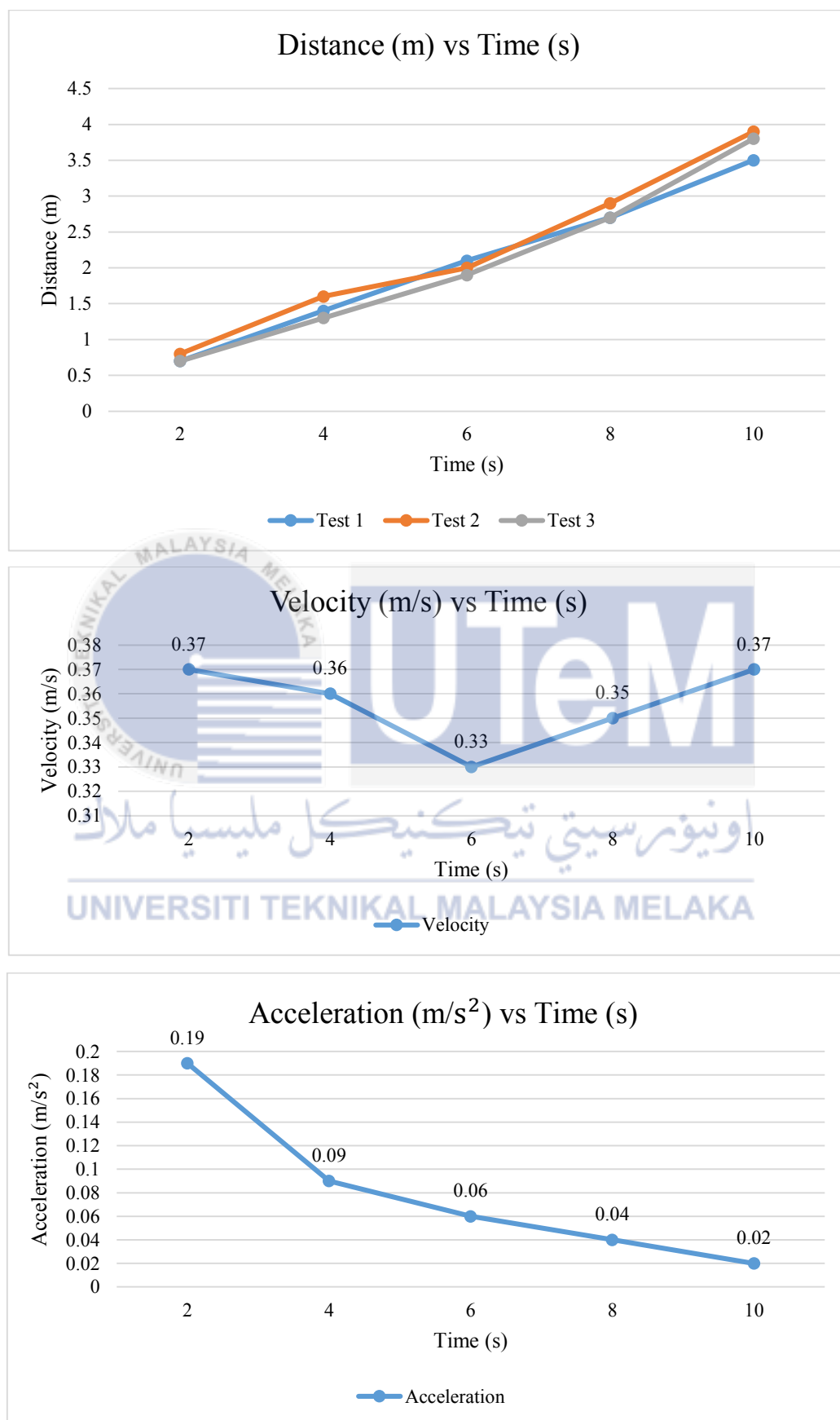


Figure 4.11: The graph for the forward movement on the road test

Table 4.14: Result Test of Reverse Movement

Test	Time (s)				
	Distance (m)				
	2s	4s	6s	8s	10s
1	0.6m	1.3m	2.0m	2.5m	3.3m
2	0.6m	1.2m	1.8m	2.6m	3.4m
3	0.7m	1.1m	1.8m	2.5m	3.4m
Average (s)	0.63m	1.20m	1.87m	2.53m	3.36m
Velocity (m/s)	0.32m/s	0.30m/s	0.31m/s	0.32m/s	0.34m/s
Acceleration (m/s²)	0.16m/s ²	0.08m/s ²	0.05m/s ²	0.04m/s ²	0.03m/s ²

Calculation for average of foward movement:

$$\text{Average of } t, 2s = \frac{0.6m + 0.6m + 0.7m}{3} = 0.63m$$

$$\text{Average of } t, 4s = \frac{1.3m + 1.2m + 1.1m}{3} = 1.20m$$

$$\text{Average of } t, 6s = \frac{2.0m + 2.0m + 1.9m}{3} = 1.87m$$

$$\text{Average of } t, 8s = \frac{2.5m + 2.6m + 2.5m}{3} = 2.53m$$

$$\text{Average of } t, 10s = \frac{3.3m + 3.4m + 3.4m}{3} = 3.36m$$

Calculation for velocity of foward movement:

$$\text{Velocity of } t, 2s = \frac{0.63m}{2s} = 0.32m/s$$

$$\text{Velocity of } t, 4s = \frac{1.20m}{4s} = 0.30m/s$$

$$\text{Velocity of } t, 6s = \frac{1.87m}{6s} = 0.31m/s$$

$$\text{Velocity of } t, 8s = \frac{2.53m}{8s} = 0.32m/s$$

$$\text{Velocity of } t, 10s = \frac{3.36m}{10s} = 0.34m/s$$

Calculation for acceleration of foward movement:

$$\text{Acceleration of } t, 2s = \frac{0.32m/s}{2s} = 0.16m/s^2$$

$$\text{Acceleration of } t, 4s = \frac{0.30m/s}{4s} = 0.08m/s^2$$

$$\text{Acceleration of } t, 6s = \frac{0.31m/s}{6s} = 0.05m/s^2$$

$$\text{Acceleration of } t, 8s = \frac{0.32m/s}{8s} = 0.04m/s^2$$

$$\text{Acceleration of } t, 10s = \frac{0.34m/s}{10s} = 0.03m/s^2$$

For the reverse movement, Table 4.14 shows that the average test in the first 2 seconds of the robot platform move up to 0.65 meters and then in 4 seconds it move up to 1.20 meters. After that, for the next 6 seconds it move 1.97 meters and for the next 8 seconds it move 2.53 meters . At the end, its move up to 3.36 meters in overall of 10 seconds. The data shows that in the first 2 seconds, the total acceleration is $0.16m/s^2$ and in the next 4 seconds the total acceleration is $0.08m/s^2$. The last 6 seconds, the total acceleration is $0.05m/s^2$. So, it shows that the accelerations of robot platform slows down in the period of time. Means that, the situation is same with the experiment in foward movement which is the more test that are carried out, the speed of robot platform will become slower because the voltage of the power supply will drop due to over use. Based on the result in Table 4.14, the graf for the reverse movement on road test is plotted in Figure 4.13. Figure 4.12 shows the forward and backward movement on the road test.

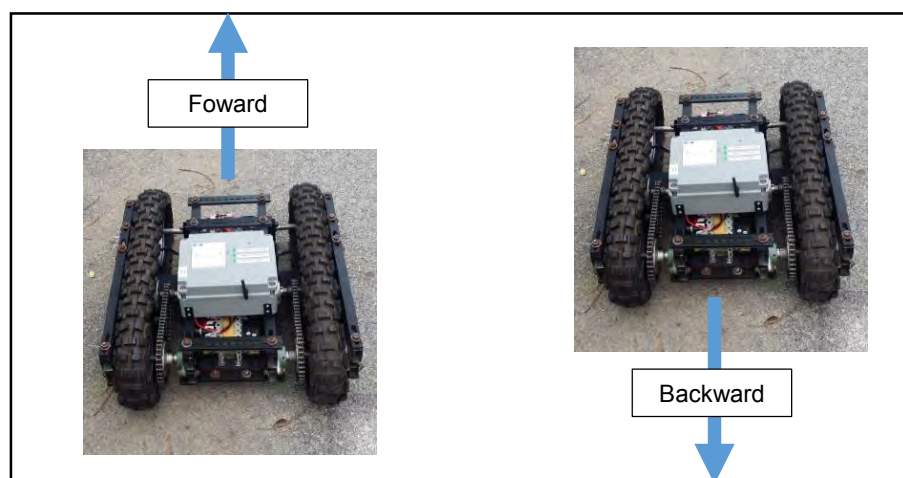


Figure 4.12: The forward and backward movement on the road test

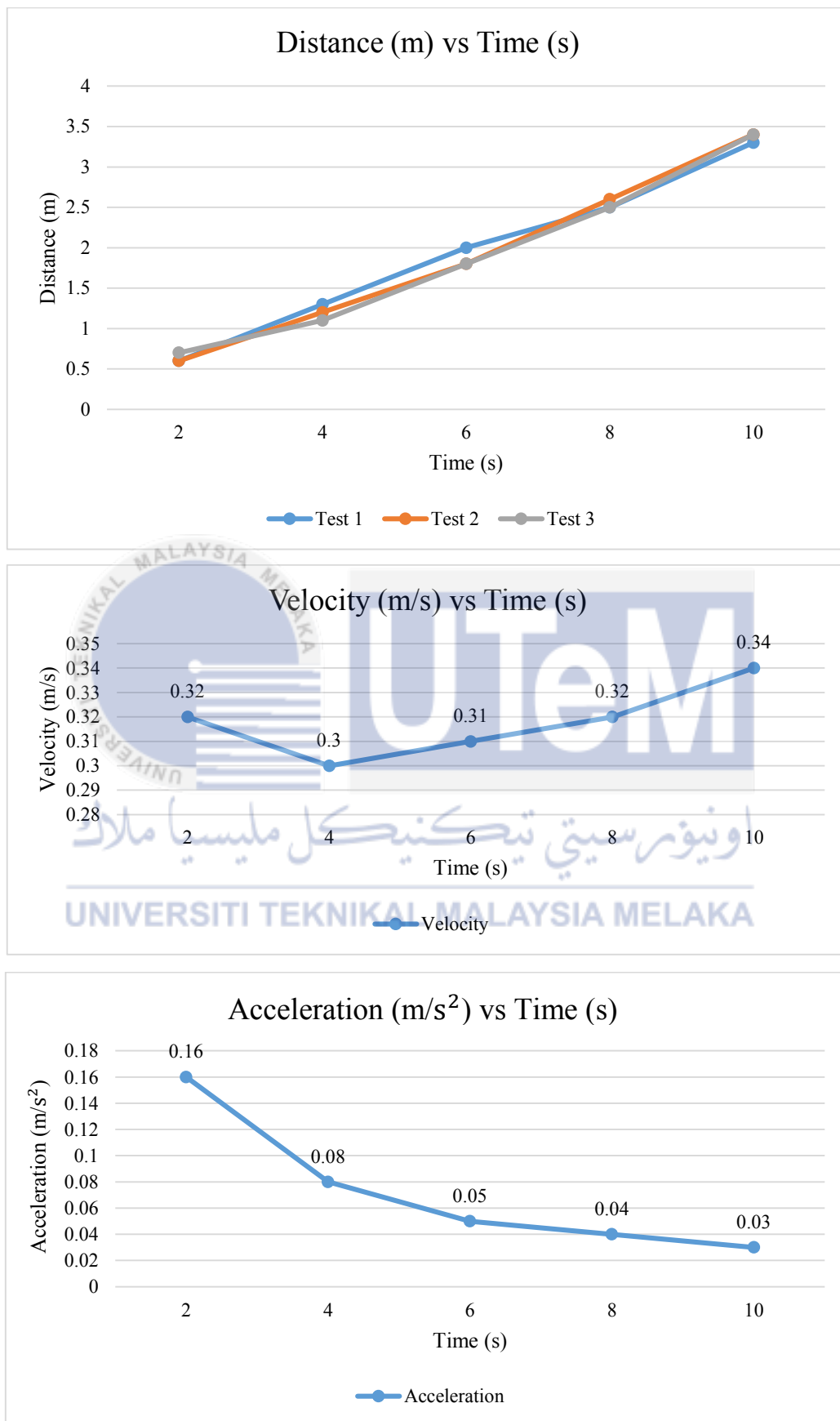


Figure 4.13: The graph for the reverse movement on the road test

By comparing the average speed in forward and reverse movement, the speed of forward movement is much better than reverse. It is because the two DC motor are only attached to the back wheels as a driver to move the robot platform by using a 3:1 gear ratio. Other than that, the load of the power sources may contribute for the DC motor to be slowed down. So, this experiment can be conclude that the objective to study the performance of the RTVP in terms of forward and reverse movement are successfully achieved.

4.4.2 Experiment 3:

Right and left turn on the road test, (90° , 180° , 270° and 360°).

For this experiment, the RTVP was tested to turn in right and left on the road condition. The objective of the experiment is to determine the speed of the robot platform while turning to the right and left in different degrees. The left of the DC scooter motor must turn in clockwise and the right of the DC scooter motor must turn in anti-clockwise to turn the robot platform to the right movement. The right of the DC scooter motor must turn in clockwise and the left of the DC scooter motor must turn in anti-clockwise to turn the robot platform to the left movement. The selected degrees of turning for testing are 90° , 180° , 270° and 360° which are complete for one rotation. This robot platform will be controlled wirelessly by using APC220 that connected to PC/laptop. Table 4.15 shows the result test for the right turning movement and Table 4.16 shows the result test for the left turning movement.

Table 4.15: The result test for the right turning movement

Test	Degree of Turning ($^\circ$)			
	Time (s)			
	90°	180°	270°	360°
1	2.3s	4.0s	5.8s	8.1s
2	2.1s	3.8s	5.6s	8.0s
3	1.9s	3.8s	5.7s	8.1s
Average (s)	2.1s	3.8s	5.7s	8.0s
Angular Velocity (rad/s)	0.75 rad/s	0.83 rad/s	0.83 rad/s	0.79 rad/s

Calculation for average of the right turning movement:

$$\text{Average of } \theta, 90^\circ = \frac{2.3s + 2.1s + 1.9s}{3} = 2.1s$$

$$\text{Average of } \theta, 180^\circ = \frac{4.0s + 3.8s + 3.8s}{3} = 3.8s$$

$$\text{Average of } \theta, 270^\circ = \frac{5.8s + 5.6s + 5.7s}{3} = 5.7s$$

$$\text{Average of } \theta, 360^\circ = \frac{8.1s + 8.0s + 8.1s}{3} = 8.0s$$

Calculation for angular velocity of the right turning movement:

$$\text{Angular Velocity of } \theta, 90^\circ = \left(\frac{90\pi}{180}\right)/2.1s = 0.75 \text{ rad/s}$$

$$\text{Angular Velocity of } \theta, 180^\circ = \left(\frac{180\pi}{180}\right)/3.8s = 0.83 \text{ rad/s}$$

$$\text{Angular Velocity of } \theta, 270^\circ = \left(\frac{270\pi}{180}\right)/5.7s = 0.83 \text{ rad/s}$$

$$\text{Angular Velocity of } \theta, 360^\circ = \left(\frac{360\pi}{180}\right)/8.0s = 0.79 \text{ rad/s}$$

Calculation for average angular velocity of the right turning movement:

$$\text{Average Angular Velocity} = \frac{0.75 + 0.83 + 0.83 + 0.79}{4} = 0.80 \text{ rad/s}$$

Table 4.16: The result test for the left turning movement

Test	Degree of Turning (°)			
	Time (s)			
	90°	180°	270°	360°
1	2.1s	3.8s	5.8s	7.9s
2	2.0s	3.6s	5.8s	8.0s
3	1.9s	3.6s	5.7s	7.9s
Average (s)	2.0s	3.7s	5.7s	7.9s
Angular Velocity (rad/s)	0.79 rad/s	0.85 rad/s	0.83 rad/s	0.80 rad/s

Calculation for average of the left turning movement:

$$\text{Average of } \theta, 90^\circ = \frac{2.1s + 2.0s + 1.9s}{3} = 2.0s$$

$$\text{Average of } \theta, 180^\circ = \frac{3.8s + 3.6s + 3.6s}{3} = 3.7s$$

$$\text{Average of } \theta, 270^\circ = \frac{5.8s + 5.8s + 5.7s}{3} = 5.7s$$

$$\text{Average of } \theta, 360^\circ = \frac{7.9s + 8.0s + 7.9s}{3} = 7.9s$$

Calculation for angular velocity of the left turning movement:

$$\text{Angular Velocity of } \theta, 90^\circ = \left(\frac{90\pi}{180}\right) / 2.0s = 0.79 \text{ rad/s}$$

$$\text{Angular Velocity of } \theta, 180^\circ = \left(\frac{180\pi}{180}\right) / 3.7s = 0.85 \text{ rad/s}$$

$$\text{Angular Velocity of } \theta, 270^\circ = \left(\frac{270\pi}{180}\right) / 5.7s = 0.83 \text{ rad/s}$$

$$\text{Angular Velocity of } \theta, 360^\circ = \left(\frac{360\pi}{180}\right) / 7.9s = 0.80 \text{ rad/s}$$

Calculation for average angular velocity of the left turning movement:

$$\text{Average of Angular Velocity} = \frac{0.79 + 0.85 + 0.83 + 0.8}{4} = 0.82 \text{ rad/s}$$

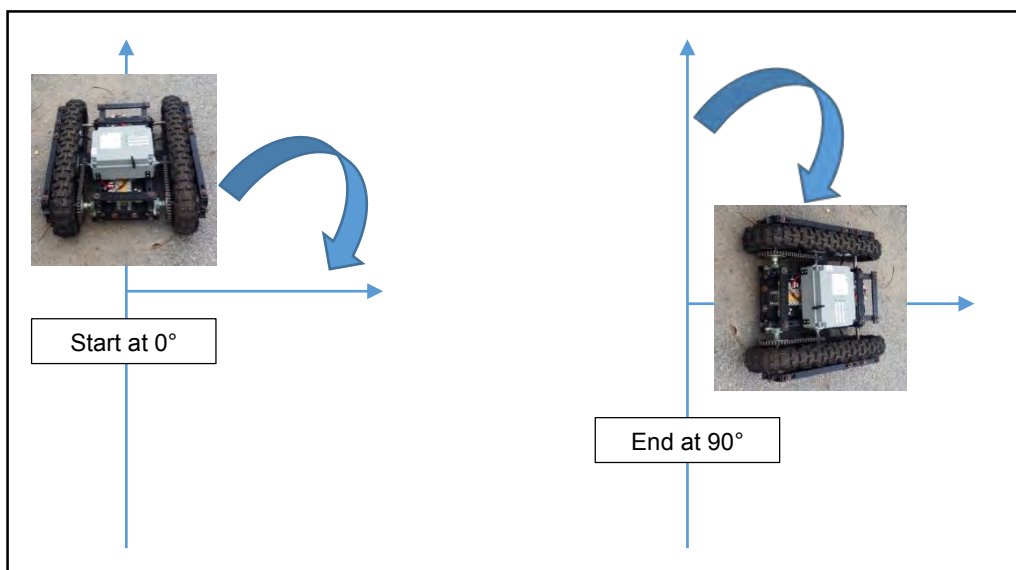


Figure 4.14: Right and left turn on the road test of 90°

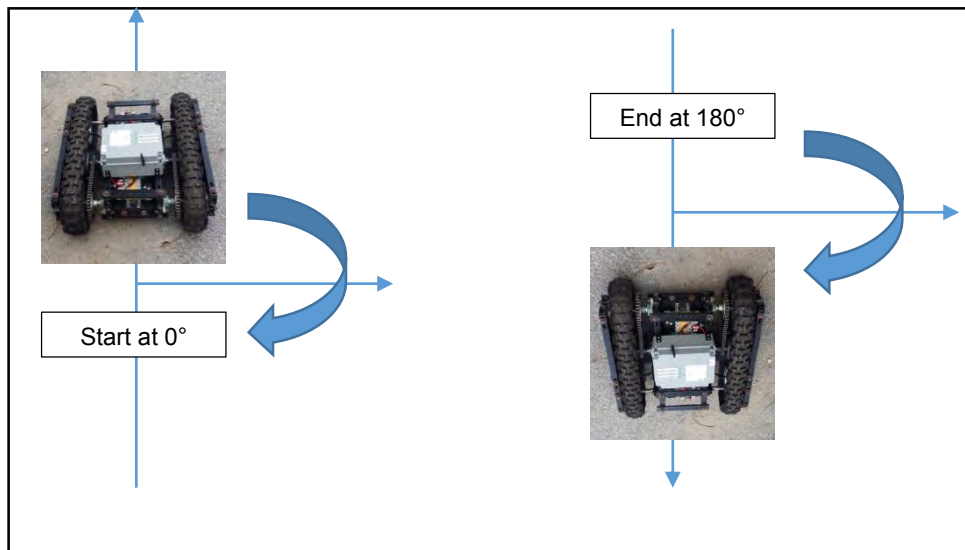


Figure 4.15: Right and left turn on the road test of 180°



Figure 4.16: Right and left turn on the road test of 270°

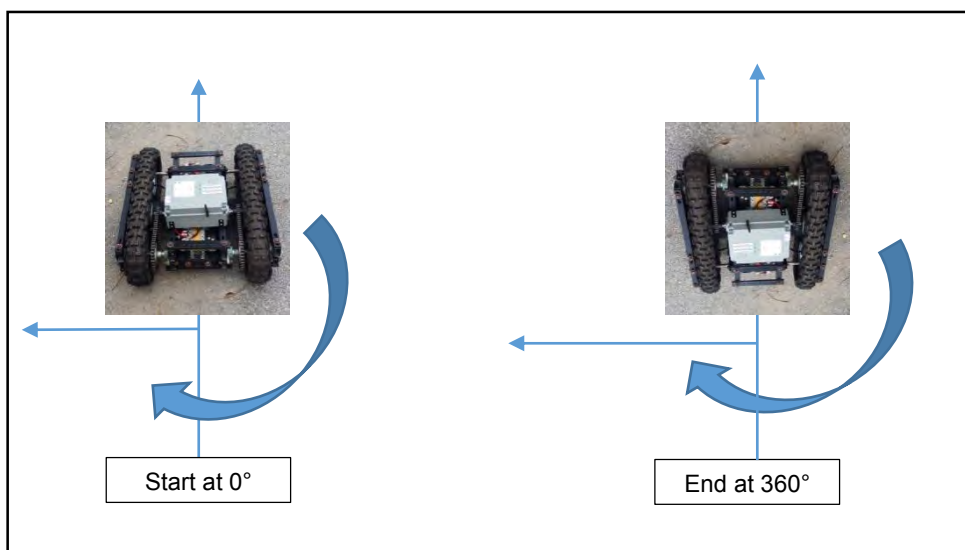


Figure 4.17: Right and left turn on the road test of 360°

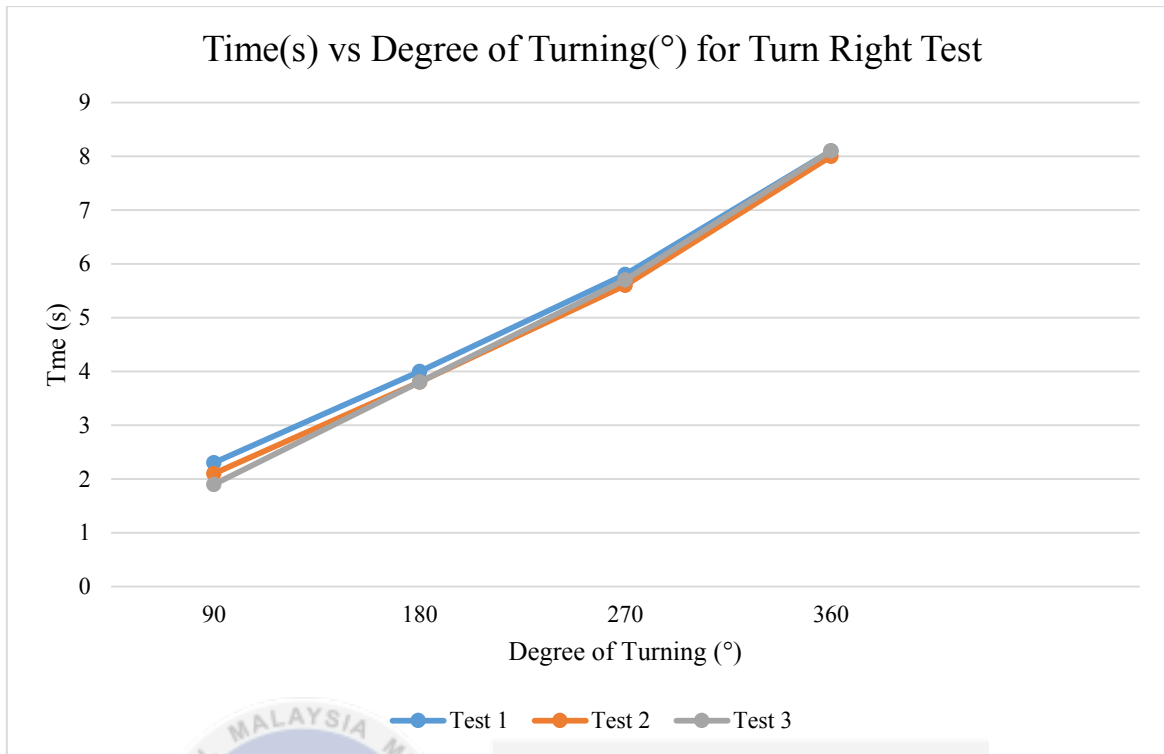


Figure 4.18: The graf for the right turning movement on road test

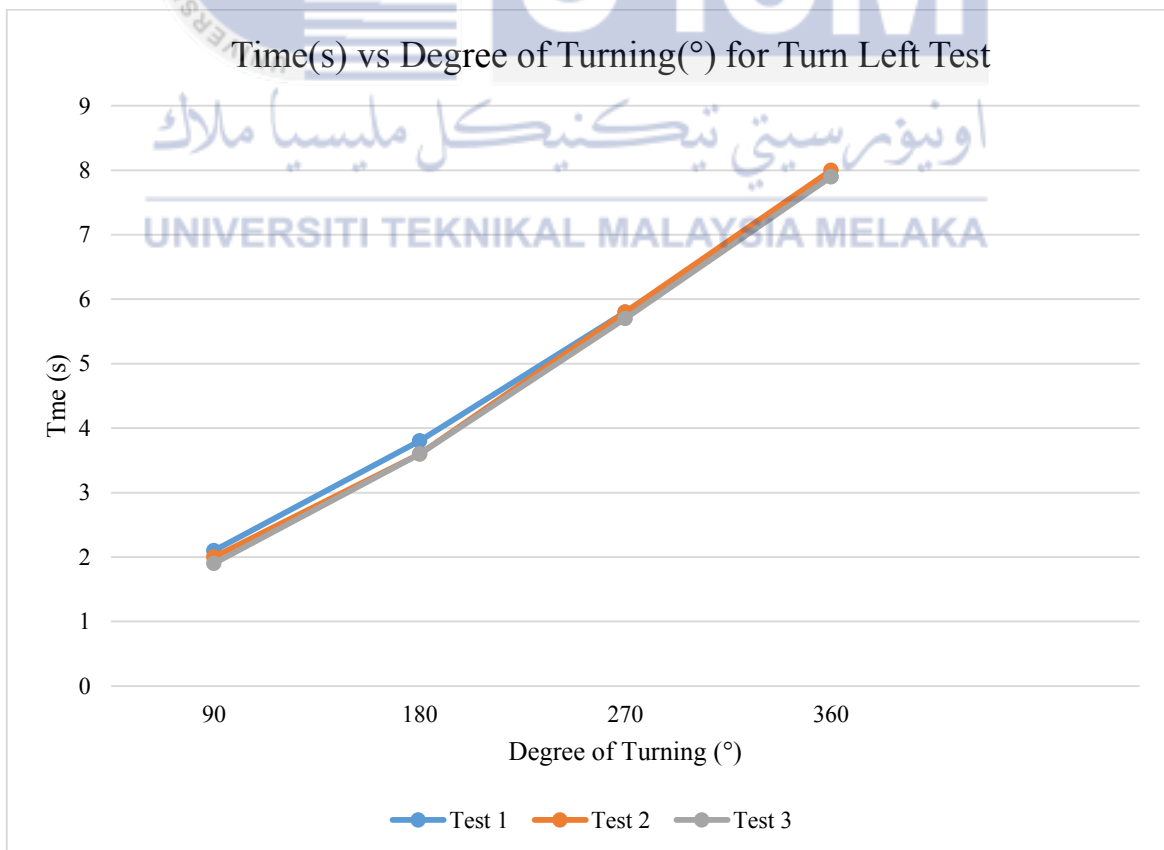


Figure 4.19: The graf for the left turning movement on road test

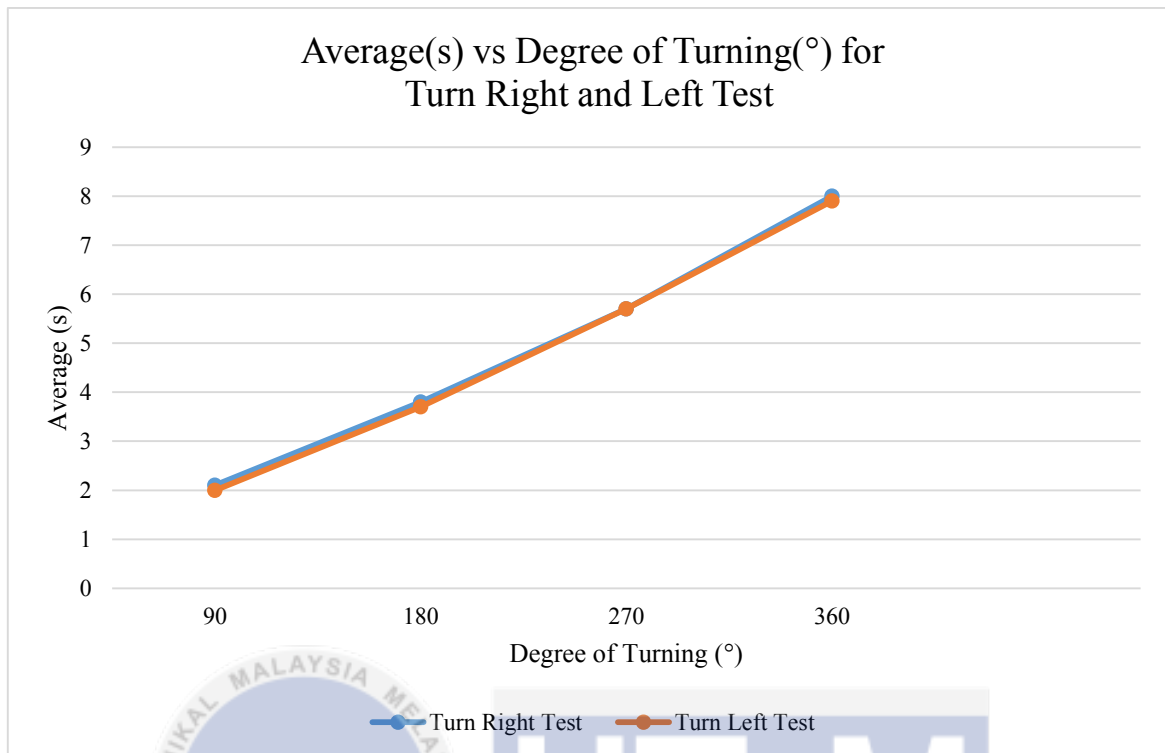


Figure 4.20: The average(s) vs degree of turning(°) for the turn right and left test

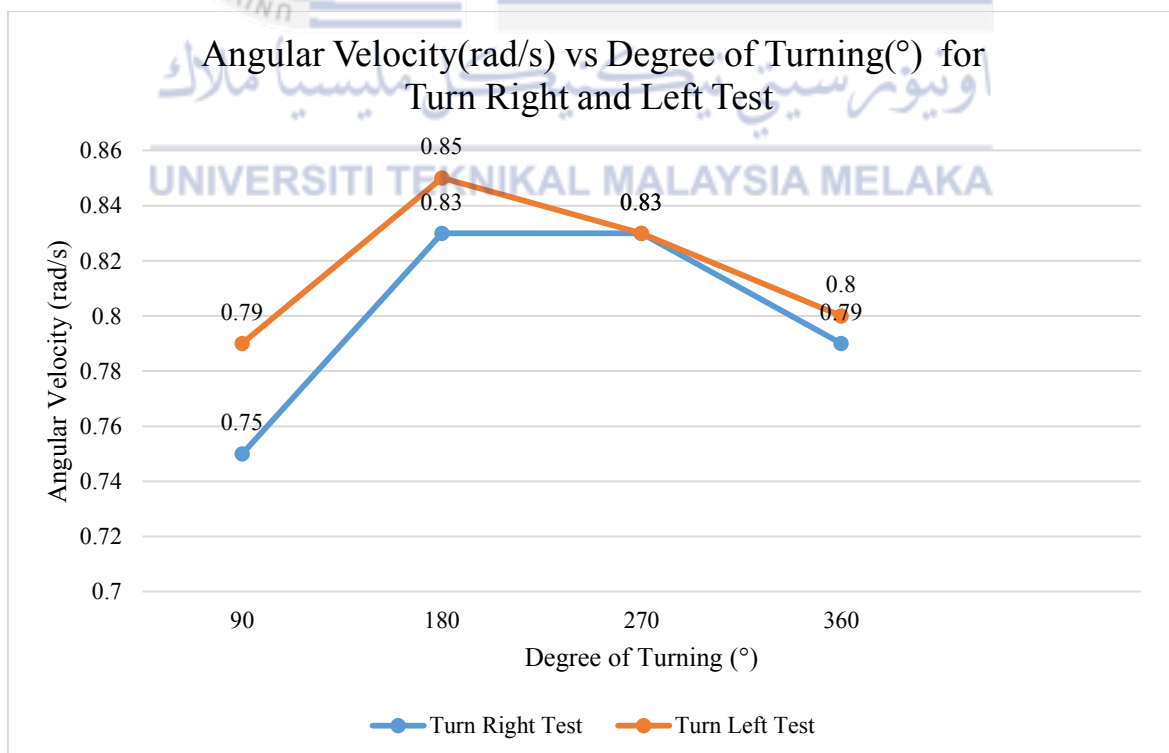


Figure 4.21: The angular velocity(rad/s) vs degree of turning(°) for the turn right and left test

From the results on the test for the right and left turning, the data shows that the average value of angular velocity is difference 0.02 rad/s. This is happened because the power sources that supplied for both DC scooter motors are from the different sources of 24V lead acid battery. So, the voltage drop for each power supplies are differences due to the usage when testing the robot platform in different degrees of turning. The other reasons that will effect the difference of turning movement in difference degrees of turning are due to the rotation of both tracks are not same because of the position of the wheels which are slightly differ from each other. Based on the result in Table 4.15 and Table 4.16, the graph for the right turning movement on the road test is plotted in Figure 4.18 and the graph for the left turning movement on road test is plotted in Figure 4.19. Figure 4.20 shows the average(s) vs degree of turning($^{\circ}$) and Figure 4.21 shows the angular velocity(rad/s) vs degree of turning($^{\circ}$) for the turn right and left test. By comparing the data of the right and left turning in different degrees to complete one rotation, this experiment can be conclude that the objective to determine the speed of the robot platform while turning to the right and left in different degrees movement are successfully achieved.

4.4.3 Experiment 4:

Obstacle test on difference heights of ladder.

For this experiment, the RTVP was tested to overcome the obstacle on difference heights of ladder. The selected heights of ladder are 4.2cm, 5.5cm, 10.3cm, 15.7cm and 17.6cm which is located at Faculty of Electrical Engineering UTeM. All ladders that can be used for obstacle test are the ladders made from cement. The first objective of this experiment is to determine the ability of the robot platform to run on the different heights of ladder. The second objective is to find the speed of the robot platform while pass through to the different heights of ladder. The robot platform will be controlled wirelessly by using APC220 that connected to PC/laptop. The robot platform will be controlled to move only in forward movement during testing to overcome the obstacle on difference heights of ladder is conducted. The data is recorded when the robot platform is pass through to the third ladder successfully and the experiment is repeated 3 times for a better result. Table 4.17 shows that the result for obstacle test on difference heights of ladder.

Table 4.17: The result for obstacle test on difference heights of ladder

Heights of Ladder (m)	Pass/Fail	Time (s)			Average (s)	Average Speed (m/s)
		Test 1	Test 2	Test 3		
0.0042m	Pass	2.3s	2.3s	2.4s	2.3s	-
0.0055m	Pass	2.8s	2.7s	2.9s	2.8s	-
0.0103m	Pass	4.5s	4.3s	4.3s	4.4s	-
0.0157m	Pass	6.0s	5.7s	6.0s	5.9s	-
0.0176m	Fail	0	0	0	0	-
Gradient (m/s)		0.0031m/s	0.0034m/s	0.0032m/s	-	0.0032m/s

Calculation for average of the result for obstacle test:

$$\text{Average of } h, 0.0042\text{m} = \frac{2.3\text{s} + 2.3\text{s} + 2.4\text{s}}{3} = 2.3\text{s}$$

$$\text{Average of } h, 0.0055\text{m} = \frac{2.8\text{s} + 2.7\text{s} + 2.9\text{s}}{3} = 2.8\text{s}$$

$$\text{Average of } h, 0.0103\text{m} = \frac{4.5\text{s} + 4.3\text{s} + 4.3\text{s}}{3} = 4.4\text{s}$$

$$\text{Average of } h, 0.0157\text{m} = \frac{6.0\text{s} + 5.7\text{s} + 6.0\text{s}}{3} = 5.9\text{s}$$

Calculation for gradient of the result for obstacle test:

$$\text{Gradient for Test 1, } m_1 = \frac{(0.0157 - 0.0042)}{(6.0 - 2.3)} = 0.0031\text{m/s}$$

$$\text{Gradient for Test 2, } m_2 = \frac{(0.0157 - 0.0042)}{(5.7 - 2.3)} = 0.0034\text{m/s}$$

$$\text{Gradient for Test 3, } m_3 = \frac{(0.0157 - 0.0042)}{(6.0 - 2.4)} = 0.0032\text{m/s}$$

Calculation for average speed of the result for obstacle test:

$$\text{Average Speed, } m_1 = \frac{(0.0031 + 0.0034 + 0.0032)}{3} = 0.0032\text{m/s}$$

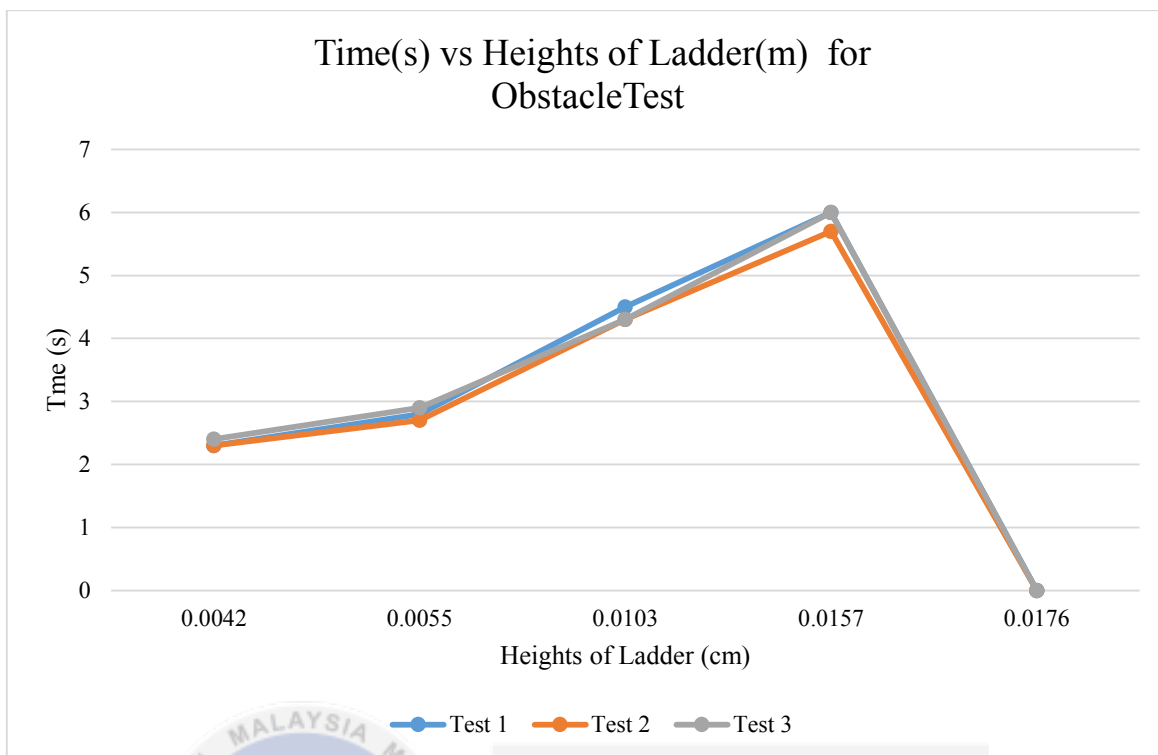


Figure 4.22: The time(s) vs heights of ladder(m) for the obstacle test

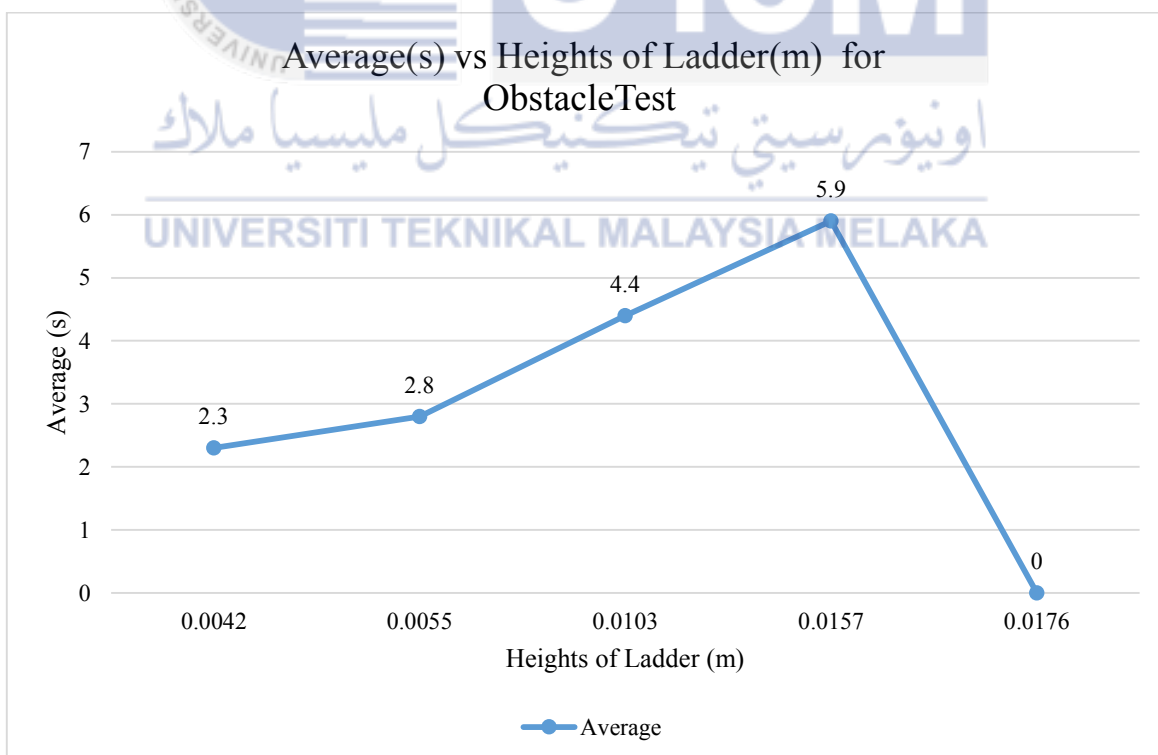


Figure 4.23: The average(s) vs heights of ladder(m) for the obstacle test



Figure 4.24: Obstacle test on difference heights of ladder

Based on the result of obstacle test on difference heights of ladder, the average time taken for robot platform to climb the height of 0.0042m ladder is 2.3s. For the second test, the average time taken for robot platform to climb the height of 0.0055m ladder is 2.8s. It follows with the third test which is also increase in average time taken of 4.4s for robot platform to climb the height of 0.0103m of ladder. Means that, the time taken is increase when the robot platform climb on higher height of ladder. For this experiment, the robot platform are able to climb successfully on the heights of 0.0042m, 0.0055m, 0.0103m, and 0.0157m of ladder. But the robot platform is failed to overcome the height of 0.0176m of ladder. This failure test need to overcome for the next modification in future such as for the tracked locomotion system which are able to climb on the higher obstacles and also improvement for electrical part by changing the higher torque lightweight DC motor which are can give more power and stability for the robot platform when climbing on the obstacles. Based on the results in Table 4.17, the graph for the time(s) vs heights of ladder(m) is plotted in Figure 4.22 and the graph for the average(s) vs heights of ladder(m) for the obstacle test is plotted in Figure 4.23. This experiment can be conclude that the robot platform can climb up to 0.0157m height of ladder which are the height of mostly ladder that can be found on mostly building. So, the objective to determine the ability and speed of the robot platform on climbing the different heights of ladder are successfully achieved.

4.4.4 Experiment 5:

Different condition of the surfaces test.

For this experiment, the RTVP is tested to move in different condition of the surface which are on stone and grass. The first objective for this experiment is to determine the ability of the robot platform to run on different surfaces condition. The second objective is to find the speed of the robot platform while moving on different surfaces condition. The robot platform will be controlled wirelessly by using APC220 that connected to PC/laptop. The robot platform will be controlled to move only in forward movement during testing on different condition of the surfaces test. The position of the robot platform are marked after 2s, 4s, 6s, 8s, and 10s and it is repeated 3 times for a better result. Table 4.18 shows that the result for the surface test on the stone and Table 4.19 shows that the result for the surface test on the grass.

Table 4.18: The surfaces test on the stone

Test	Time (s)				
	Distance (m)				
	2s	4s	6s	8s	10s
1	0.41m	0.78m	1.23m	1.76m	2.10m
2	0.38m	0.78m	1.20m	1.74m	2.33m
3	0.40m	0.79m	1.21m	1.76m	2.32m
Average (m)	0.42m	0.78m	1.21m	1.75m	2.25m
Velocity (m/s)	0.21m/s	0.20m/s	0.20m/s	0.22m/s	0.23m/s
Acceleration (m/s²)	0.11m/s ²	0.05m/s ²	0.03m/s ²	0.03m/s ²	0.02m/s ²

Calculation for average on the stone test:

$$\text{Average of } t, 2s = \frac{0.41m + 0.38m + 0.47m}{3} = 0.42m$$

$$\text{Average of } t, 4s = \frac{0.78m + 0.78m + 0.79m}{3} = 0.78m$$

$$\text{Average of } t, 6s = \frac{1.23m + 1.20m + 1.21m}{3} = 1.21m$$

$$\text{Average of } t, 8s = \frac{1.76m + 1.74m + 1.76m}{3} = 1.75m$$

$$\text{Average of } t, 10s = \frac{2.10m + 2.33m + 2.32m}{3} = 2.25m$$

Calculation for velocity on the stone test:

$$\text{Velocity of } t, 2s = \frac{0.42m}{2s} = 0.21m/s$$

$$\text{Velocity of } t, 4s = \frac{0.78m}{4s} = 0.20m/s$$

$$\text{Velocity of } t, 6s = \frac{1.21m}{6s} = 0.20m/s$$

$$\text{Velocity of } t, 8s = \frac{1.75m}{8s} = 0.22m/s$$

$$\text{Velocity of } t, 10s = \frac{2.25m}{10s} = 0.23m/s$$

Calculation for acceleration on the stone test:

$$\text{Acceleration of } t, 2s = \frac{0.21m/s}{2s} = 0.11m/s^2$$

$$\text{Acceleration of } t, 4s = \frac{0.20m/s}{4s} = 0.05m/s^2$$

$$\text{Acceleration of } t, 6s = \frac{0.20m/s}{6s} = 0.03m/s^2$$

$$\text{Acceleration of } t, 8s = \frac{0.22m/s}{8s} = 0.03m/s^2$$

$$\text{Acceleration of } t, 10s = \frac{0.23m/s}{10s} = 0.02m/s^2$$

Calculation for gradient average speed on the stone test:

$$\text{Gradient for Test 1, } m_1 = \frac{(2.1-0.41)}{(10-2)} = 0.21m/s$$

$$\text{Gradient for Test 2, } m_2 = \frac{(2.33-0.38)}{(10-2)} = 0.24m/s$$

$$\text{Gradient for Test 3, } m_3 = \frac{(2.32-0.4)}{(10-2)} = 0.24m/s$$

$$\text{Average Speed, } m_1 = \frac{(0.21+0.24+0.24)}{3} = 0.23m/s$$

Table 4.19: The surfaces test on the grass

Test	Time (s)				
	Distance (m)				
	2s	4s	6s	8s	10s
1	0.45m	0.91m	1.4m	1.83m	2.25m
2	0.44m	0.90m	1.3m	1.80m	2.25m
3	0.44m	0.92m	1.4m	1.80m	2.21m
Average (m)	0.44m	0.91m	1.37m	1.81m	2.24m
Velocity (m/s)	0.22m/s	0.23m/s	0.23m/s	0.23m/s	0.22m/s
Acceleration (m/s²)	0.11m/s ²	0.06m/s ²	0.04m/s ²	0.03m/s ²	0.02m/s ²

Calculation for average on the grass test:

$$\text{Average of } t, 2s = \frac{0.45m + 0.44m + 0.44m}{3} = 0.44m$$

$$\text{Average of } t, 4s = \frac{0.91m + 0.90m + 0.92m}{3} = 0.91m$$

$$\text{Average of } t, 6s = \frac{1.4m + 1.3m + 1.4m}{3} = 1.37m$$

$$\text{Average of } t, 8s = \frac{1.83m + 1.80m + 1.80m}{3} = 1.81m$$

$$\text{Average of } t, 10s = \frac{2.25m + 2.25m + 2.21m}{3} = 2.24m$$

Calculation for velocity on the grass test:

$$\text{Velocity of } t, 2s = \frac{0.44m}{2s} = 0.22m/s$$

$$\text{Velocity of } t, 4s = \frac{0.91m}{4s} = 0.23m/s$$

$$\text{Velocity of } t, 6s = \frac{1.37m}{6s} = 0.23m/s$$

$$\text{Velocity of } t, 8s = \frac{1.81m}{8s} = 0.23m/s$$

$$\text{Velocity of } t, 10s = \frac{2.24m}{10s} = 0.22m/s$$

Calculation for acceleration on the grass test:

$$\text{Acceleration of } t, 2s = \frac{0.22m/s}{2s} = 0.11m/s^2$$

$$\text{Acceleration of } t, 4s = \frac{0.23m/s}{4s} = 0.06m/s^2$$

$$\text{Acceleration of } t, 6s = \frac{0.23m/s}{6s} = 0.04m/s^2$$

$$\text{Acceleration of } t, 8s = \frac{0.23m/s}{8s} = 0.03m/s^2$$

$$\text{Acceleration of } t, 10s = \frac{0.23m/s}{10s} = 0.02m/s^2$$

Calculation for gradient average speed on the grass test:

$$\text{Gradient for Test 1, } m_1 = \frac{(2.25-0.45)}{(10-2)} = 0.23m/s$$

$$\text{Gradient for Test 2, } m_2 = \frac{(2.25-0.44)}{(10-2)} = 0.23m/s$$

$$\text{Gradient for Test 3, } m_3 = \frac{(2.21-0.44)}{(10-2)} = 0.22m/s$$

$$\text{Average Speed, } m_1 = \frac{(0.23+0.23+0.22)}{3} = 0.23m/s$$

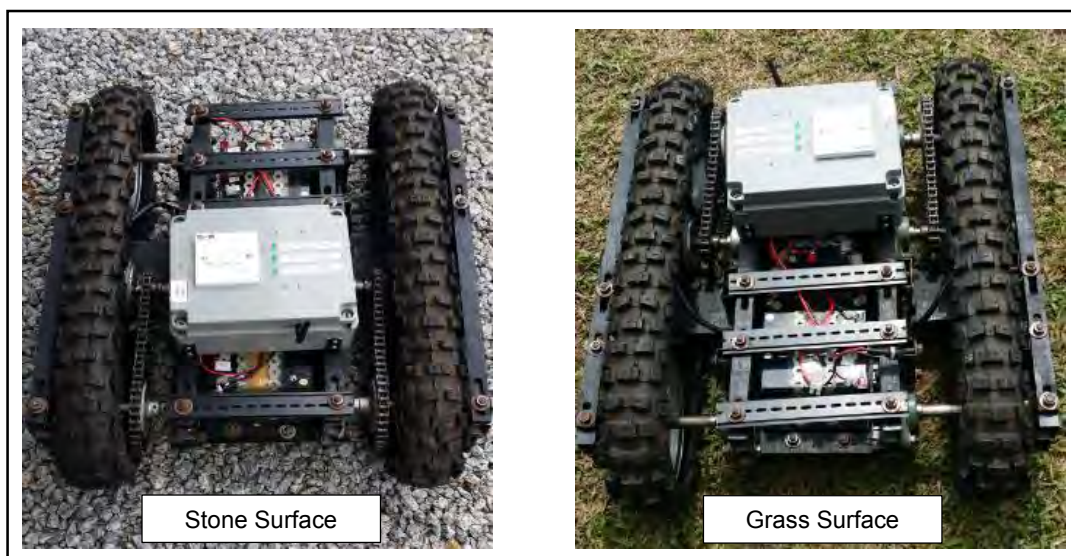


Figure 4.25: The different condition of the surfaces test

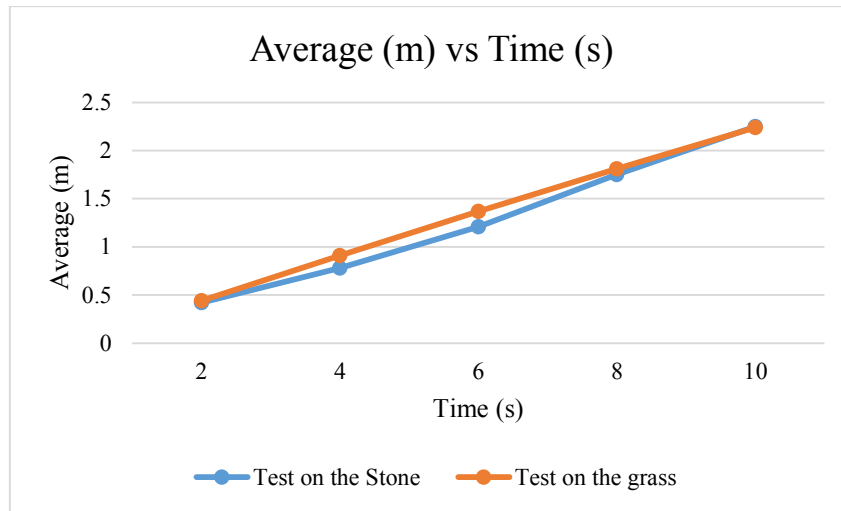


Figure 4.26: The average(m) vs time(s) on the stone and grass test

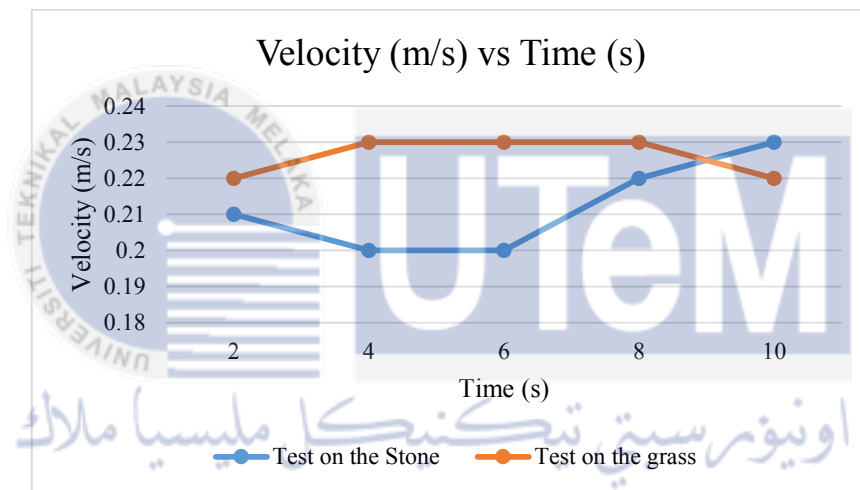


Figure 4.27: The velocity(m) vs time(s) on the stone and grass test

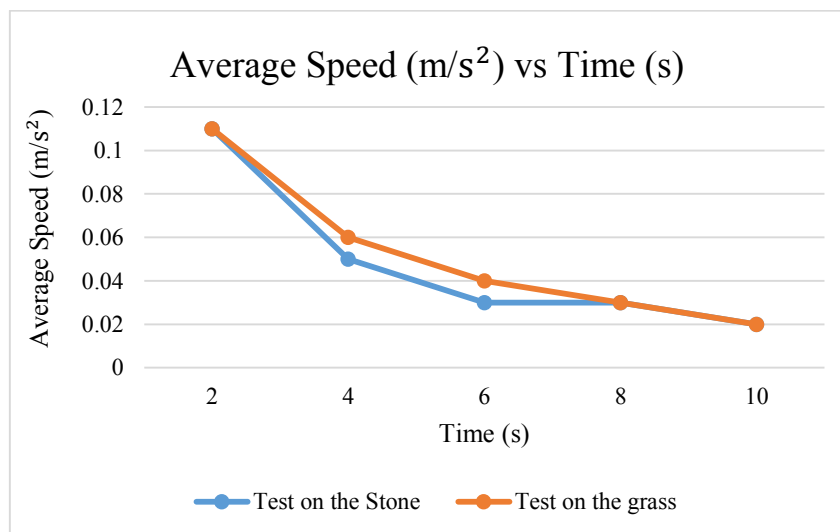


Figure 4.28: The average speed(m/s^2) vs time(s) on the stone and grass test

Based on the plotted graf on the stone and grass test, it shows that the average test in 2 seconds on the stone surface test, the robot platform was moved up to 0.42m and then in 10 seconds, it was moved up to 0.78m. After that, for the next 6 seconds and 8 seconds, the robot platform were moved up to 1.21m and 1.75m. Lastly, the robot platform was moved up to 2.25m in 10 seconds. While for the grass surface test, the average test in the first 2 seconds, the robot platform was moved up to 0.44m and then in 4 seconds, it was moved up to 0.91m. After that, for the next 6s and 8s, the robot platform were moved up to 1.37m and 1.81m. Lastly, the robot platform was moved up to 2.24m in 10s. From the result, there are difference in distance between the sand and grass surfaces in overall time of 10 seconds. At the first 2 seconds, it was 0.04 m difference in distance. At the 4 seconds and 6 seconds, it were 0.13m and 1.16m differences in distance. For the next 8 seconds and 10 seconds, it were 0.06m and 0.01m differences in distance. So, from these results, it shows that the robot platform was moved on the stone surface has lower distance of period of time than the grass surface. Figure 4.25 shows the different condition of the surfaces test while Figure 4.26, Figure 4.27 and Figure 4.28 shows the plotted graph on the stone and grass test. Based on the final result of this experiment, the objective to determine the ability and speed of the robot platform to run on the different surfaces condition are successfully achieved.

4.5 Summary

This chapter is about the results and discussions for this thesis that contains all the data, calculations, performances, final design and final result of the RTVP project. This part covers the results of the project design such as the 3D drawing with telorence, design characteristics of the RTVP and simulation of the chasis structure by using SolidWorks Simulation Xpress Wizards. In addition, there are four others experiments that have been done which is field test experiment such as forward and backward movement test, right and left turn test, obstacle test on difference heights of ladder and lastly, different condition of the surfaces test. The field test experiment is very important to done perfectly in order to achieve the whole objectives for this project. The next chapter is a conclusions that will conclude the overall chapter in this thesis and the recommendations will explain all about the improvement of the project for a better results in the future research.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter is the last chapter that can conclude about the whole process and development of this project. This chapter also covers some recommendations for more satisfactory projects in the future work.

5.2 Conclusion

The main purpose of this project is to design and develop the hardware of the robot platform by using the parallel mechanism configuration track structure. It uses the Romeo-All In One Controller (Arduino Compatible Atmega 328) as a micro-controller which is a user friendly product because of the compact size and easy to setup for programming part. It also has 14 channels digit I/O which is helpful for controlling process and reducing space for electrical part. There are three main parts of the robot which are mechanical, electrical and software part that are successfully done and achieved the objective of the project.

This project can give more benefits and useful for many sectors, especially for search and rescue task as well as for domestic purpose. Finally, this project needs more efforts to encourage the uses of the robot track by designing a good quality and low cost production with advanced technology system. Overall, the whole objectives for this project such as design and develop the RTVP by using SolidWorks by identify the size and the parts functionality of the robot, develop a communication system between robot platform with PC by using the APC220 RF module and analysis the movement of the robot platform that can go over the obstacles and move in an uneven surface was successfully achieved perfectly.

5.3 Recommendations

This project has a few weaknesses and need some recommendations to improve some part of the project for a better results in the future research. The future recommendations for this project are :

- i. Develop the system that can make an autonomous robot platform.
- ii. Use the aluminium alloy for whole of the body chassis to reduce the overall weight and increase the durability of the robot platform.
- iii. Install a small camera in front of the robot platform to observe and monitor the environments and the movement of the robot.
- iv. Add a sensor such as distance detector sensor or infrared sensor for early detect the obstacles.
- v. Improve the main of the mechanical part which is the tracked locomotion system of the robot platform by adding a pair of track in front and in the back of the robot platform.
- vi. Improve the electrical part of the robot platform by changing the higher torque lightweight DC motor which are can give more power and stability for the robot platform when climbing on the obstacles.

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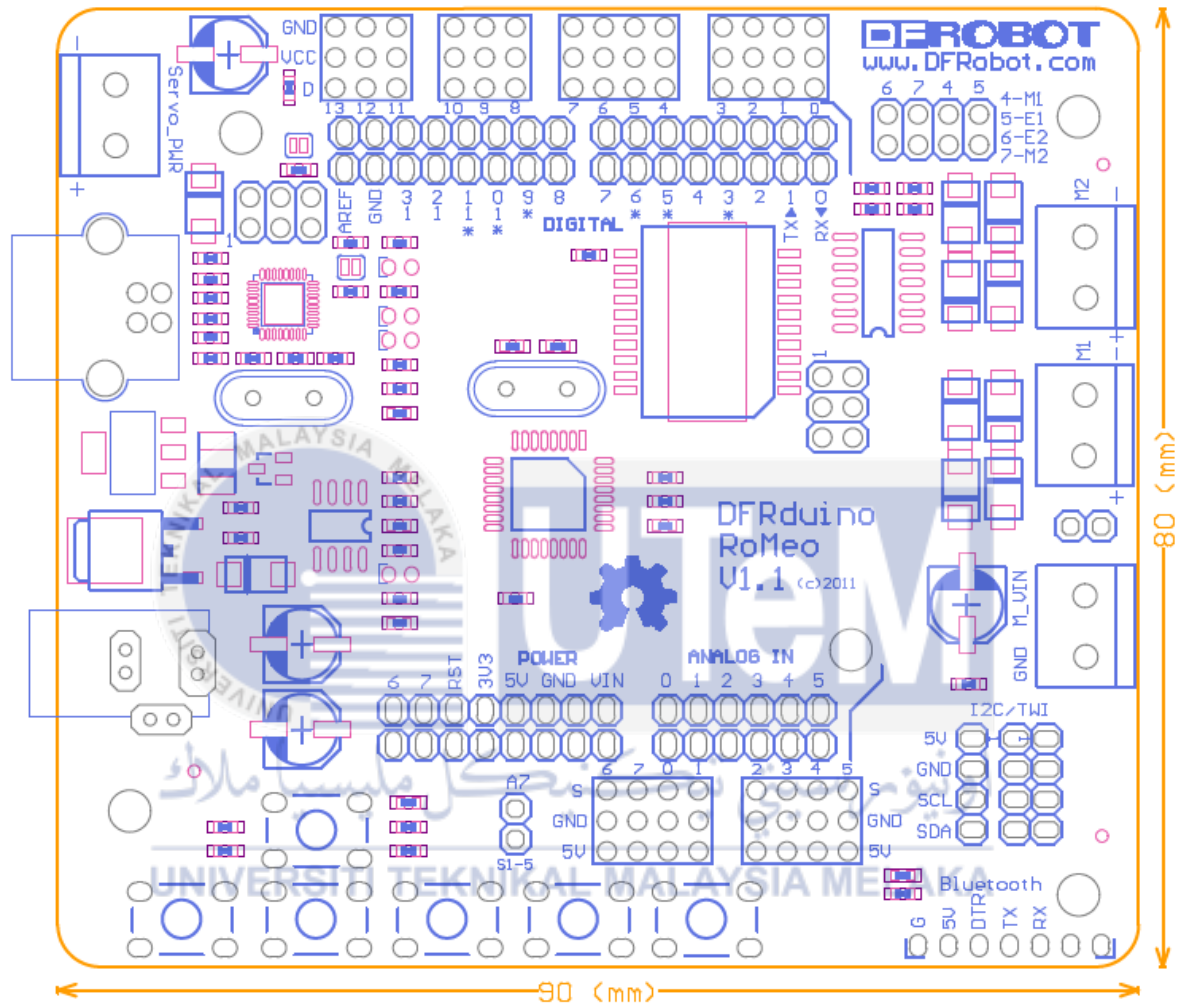
Gantt Chart

<u>Week</u>	1	2	3	4	5	6	7	8	9	10	11	12
Briefing												
Registration												
Gantt Chart												
Literature Review												
Introduction												
Objective												
Scope												
Project Background												
Methodology												
Preliminary Result												
Budget												
Submit												
Ready For Slide												
Finish Slide												
Presentation												
Plan FYP 2												

[illegible]

APPENDIX B

DFRduino Romeo V1.1 layout



APPENDIX C

350W Electric Scooter Motor Datasheet



所有尺寸单位为: mm
All dimensions unit: mm

电压范围 Voltage range	额定功率 Rated Power	额定转速 Rated rotating speed	额定效率 Rated efficiency	尺寸B Size B	所配控制器 Displacement controller
DC 24V-48V	250W	2600rpm	$\geq 75\%$	81	XK-022B
DC 24V-48V	300W	2600rpm	$\geq 75\%$	91	XK-022A
DC 24V-48V	350W	2600rpm	$\geq 75\%$	96	XK-022A

APPENDIX D

GUI (Graphical User Interface) Coding

```

import processing.serial.*; //Importing the Serial library.
Serial myPort; // Creating a port variable.
int r,g,b; // initializing colours.
String T= "ROBOT TRACKED PLATFORM CONTROLLER UTeM FYP"; // Creating
word strings for the interface.
String T1= "FWD";
String T2= "RHT";
String T3= "LFT";
String T4= "BWD";
String T5= "BRAKE";
String T6= "SPEED(+)";
String T7= "SPEED(-)";
void setup()
{
    size(1000,600); // Creating the display window and defining its' size.
    r = 0; // Setting up the colours.
    g = 0;
    b = 0;
    println(Serial.list()); // IMPORTANT: prints the availabe serial ports.
    String portName = Serial.list()[0]; // change the 0 to a 1 or 2 etc, to match your port (Play
    with it until you find the one that works for you- It's probably 11!)
    myPort = new Serial(this, portName, 9600); // Initializing the serial port.
}
void draw()
{
    background(255,255,0); // Setting up the background's colour- Yellow.

    fill (255,255,255); // Painting the Arrows White.
    rect(750, 250, 100, 100,7); // BWD rectangle

```

```

triangle(750, 235, 800, 160, 850, 235); //FWD triangle
triangle(735, 350, 660, 300, 735, 250); //RHT triangle
triangle(865, 250, 940, 300, 865, 350); //LFT triangle
triangle(638, 235, 570, 160, 510, 235); //PWM(+) triangle
triangle(638, 370, 570, 450, 510, 370); //PWM(-) triangle
rect(50, 250, 400, 100,5); //BRAKE rectangle
textSize(32); // Defining the headline's size- 32
fill (0,0,255); // painting the headline blue.
text(T, 25, 50); // placing the headline in a specific location
textSize (20); // The arrow keys text size- 20
fill (0,255,0); // painting it green.
text(T1, 780, 220); //FWD
text(T2, 875, 310); //RHT
text(T3, 690, 310); //LFT
text(T4, 780, 310); //BWD
text(T5, 225, 310); //BRAKE
text(T6, 530, 230); //PWM(+)
text(T7, 530, 390); //PWM(-)
}
void keyPressed()
{
  switch (keyCode) { //Switch case: Sending different signals and filling different arrows
red according to which button was pressed.
    case UP: //In case the UP button was pressed:
      myPort.write('1'); // Send the signal 1
      println("UP!"); // + Print "UP!" (Debugging only)
      fill(255,0,0); // + Fill the up triangle with red.
      triangle(750, 235, 800, 160, 850, 235);
      break;

```

APPENDIX E

Controller (Arduino Board) Coding

```
//Standard PWM DC control
int M1 = 4; //M1 Direction Control
int M2 = 7; //M2 Direction Control
int E1 = 5;
int E2 = 6;
int time = 500;
int pwm = 130;
int type = 0;
int prev_type = 0;
void stop(void) //Stop
{
    analogWrite(E1,0);
    analogWrite(E2,0);
}
void advance() //Move forward
{
    analogWrite(E1,pwm);
    digitalWrite(M1,HIGH);
    analogWrite(E2,pwm);
    digitalWrite(M2,HIGH);
}
void back_off () //Move backward
{
    analogWrite(E1,pwm);
    digitalWrite(M1,LOW);
    analogWrite(E2,pwm);
    digitalWrite(M2,LOW);
}
void turn_L () //Turn Left
```

```

{
  analogWrite(E1,pwm);
  digitalWrite(M1,HIGH);
  analogWrite(E2,pwm);
  digitalWrite(M2,LOW);
}

void turn_R ()      //Turn Right
{
  analogWrite(E1,pwm);
  digitalWrite(M1,LOW);
  analogWrite(E2,pwm);
  digitalWrite(M2,HIGH);
}

void setup(void)
{
  pinMode(M1, OUTPUT);
  pinMode(M2, OUTPUT);
  pinMode(E1, OUTPUT);
  pinMode(E2, OUTPUT);
  Serial.begin(9600); //Set Baud Rate
  Serial.println("Run keyboard control");
}

void loop(void)
{
  if(Serial.available()){
    char val = Serial.read();
    if(val != -1)
    {
      switch(val)
      {
        case UP://Move Forward
          type = 1; //move forward in max speed
          break;
        case '1'://Move Backward

```

```

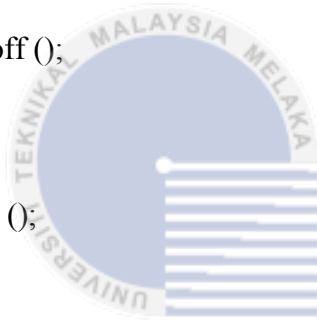
    type = 2; //move back in max speed
    break;
case '2'://Turn Left
    type = 3;
    break;
case '3'://Turn Right
    type = 4;
    break;
case 'z':
    Serial.println("Hello");
    break;
case ' ':
    type = 0;
    break;
case '4':
    if(pwm < 250)
    {
        pwm = pwm + 20;
        Serial.println(pwm);
    }
    else {
        Serial.println("Already maximum speed ");
    }
    break;
case '5':
    if(pwm > 10)
    {
        pwm = pwm - 20;
        Serial.println(pwm);
    }
    else {
        Serial.println("Already minimum speed");
    }
    break;

```

```

    }
}
else stop();
}
switch(type)
{
case 0:
    stop();
    break;
case 1:
    advance ();
    break;
case 2:
    back_off ();
    break;
case 3:
    turn_L ();
    break;
case 4:
    turn_R ();
    break;
}
}

```



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