MEREKABENTUK DAN MENBINA ROBOT AUTOMATIK

(DESIGN AND FABRICATION OF AUTNOMOUS ROBOT)

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Chapter 1.0 ABSTRACT

This thesis is concerned the design and fabrication of the pre-programming autonomous robot. The aim of the thesis is to make machines by hand from design to construction, to compete in the Asia-Pacific Robot Contest 2005. The title of the Robot Contest 2005 is Climb on the Great Wall to light the holy fire.

The autonomous robot must be move automatic without the control of the operator. The robot has to move from starting zone to the torch to shoot the ball into the torch. In order to move to the torch, the robot must able to turn 90 degree and move in straight line.

The robot is an embedded system, which means that it integrates hardware and software in its design and operation. The hardware includes the entire structure of the robot, motors, wheel, BASIC Stamp Controller, and other component. The software is the BASIC Stamp program that use to control the step moving and shooting of the robot.

The robot's hardware only uses light materials. The weight of the robot is less than 10kg. The size of the robot is less than 50cm x50cm and height is less than 150cm when start, and less than 200cm when moving. The power supply use by the robot is only 24 VDC.

ABSTRAK

Tesis ini adalah mengenai merekabentuk dan menbina robot automatik yang berprogram. Tujuan tesis ini adalah menghasilkan mesin dengan menggunakan tangan dari merekabentuk ke pembinaan, untuk bertanding dalam pertandingan Asia-Pacific Robot Contest 2005. Tajuk pertandingan robot ini adalah 'Panjakan ke atas tembok besar dan menyalakan 'holy fire''.

Robot automatik ini mesti bergerak dengan automatik tanpa kawalan daripada operator. Robot ini dikehendaki bergerak dari zon permulaan sehingga ke lampu besar (Torch) dan memasukkan bola ke dalam lampu besar tersebut. Untuk bergerak ke lampu besar, robot ini mesti boleh memusing 90 darjah dan boleh bergerak secara lurus.

Robot ini merupakan system berpacak, di mana ia mencantumkan alat-alat dengan program komputer dalam merekacipta dan pembinaan. Alat-alat yang digunakan termasuk struktur robot, motor, roda, Pegawal BASIC Stamp dan komponen-komponen yang lain. Program komputer yang digunakan ialah program BASIC Stamp yang boleh mengawal pergerakan robot secara langkah dan memasukkan bola kemudian.

Robot ini hanya menggunakan alat-alat dan komponen-komponen yang ringan. Berat robot ini adalah kurang daripada 10kg. Saiz robot ini adalah kurang daripada 50cm x 50cm dan ketinggian adalah kurang daripada 150 cm sebelum bermula, dan ketinggian kurang daripada 200 cm selepas bermula. Kuasa electrik yang digunakan adalah 24 VDC.

CHAPTER 1: INTRODUCTION

1.0 Background of problem

The purpose of designing this Robot is based on the requirement of the ABU Asia-Pacific Robot Contest 2005 China. The objective of this competition is to climb on the Great Wall and Light the holy fire. The main task of the robot is to grip the ball and cross the obstacles and throw the ball into the torches. The game field of the competition is shown in the picture below.

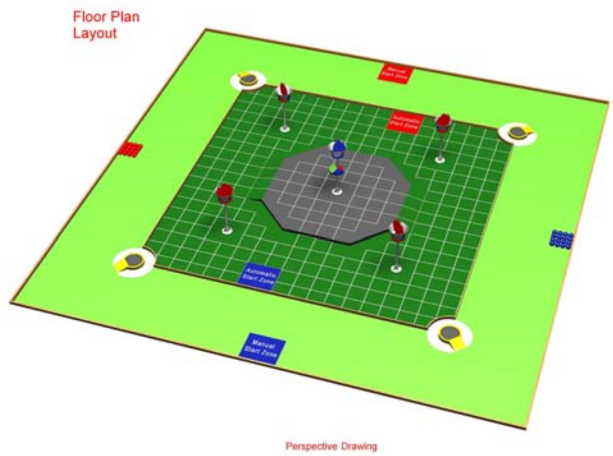

Figure 1.0: Game Field

The game field is 14m x 14m in a square form and consists of Manual Zone, Bonfire Zone and Automatic Zone including the Beacon Tower Zone.

Automatic Zone is 9m x 9m in a square form and Automatic Machine Start Zone is 1m x 1m in square area. Only Automatic Machine may be operated in Automatic Zone. An octagon upland are, called the Beacon Tower Zone of 10cm in height is located in the center of the Automatic Zone. Five Torches are located in the Automatic Zone. The highest Main Torch of 1.8m in height is set in the center of the Beacon Tower Zone. The outer four Torches of 1.5m height are distributed around it. The Main torch can rotate around the axis of its own pole if external force is applied. The outer Torches can not be rotated.

Four Bonfire Zone of 0.12m in diameter are located in the four corners of the Automatic Zone. A Fuel Disk with a diameter of 600mm is located in the center of the

Bonfire Zone. The Fuel Disk is 100mm above the ground with an edge 50mm in width. The depth of the disk is 30mm. A slope of 350mm in width links the Disk and the ground.

Manual Zone surrounds the Automatic Zone and Bonfire Zones. Two Fuel stocks for both teams are located in the Manual Zone oppositely each other, and 16 Fuel Balls will be located in each Fuel Stock. Manual Machine Start Zone sized 1m x 1m in a square form is located in the middle of the side of Manual Zone. The Machine in the Automatic Zone must be autonomous and the Machine in the Manual Machine Zone must be manual and only can control by one operator. A Retry is permitted once per game for each team.

The power supply of the Machine must be below 24VDC and the sum of total weight of each team's machines must not exceed 50kg. The duration of matches shall last for three minutes. All machines must be built so that they will not harm the operators, the referees and the audience.

1.1 Problem statement

The project's main purpose is to design an autonomous robot in the Automatic Zone and to throw the ball into the four Outer Torches.

Since the size of the entire robot in the Automatic Machines Zone cannot exceed 1m x 1m and the weight of all robots must be lower than 50kg, the materials used in this robot must be as light as possible. An aluminum is a better choice to fabricate the frame of the robot because the cost and weight of this materials. And the height of the robot cannot exceed 1.5m when start, so that the robot must be able to extent after the game started.

Since the robot is autonomous, it should able to reach its destination and shoot the ball by itself. A preprogramming controller has to be used to control the movement of the robot. The robot must have a sensor to sense the line in the ground and move according to the line to the destination. They also have to avoid crash with the opponent robot, so that the robot should have a sensor to sense the obstacle in front.

When reaches the torch, the robot also have to recognize the colour of the Torch to avoid throw a ball into the opponent basket. So, a sensor has to place at the end effector of the robot.

All this problem must be taken into consideration when fabricating a robot. So that, the robot must be able to move, avoid obstacle and recognize the basket and shoot the ball.

1.2 Objective

The objective is to design and fabricate the automatic robot to compete in the Robocon Contest 2005. So, it should able to fulfill the requirement of the competition. The main objective of this robot is as below:

- ✓ The Automatic Robot must be able to move automatic without control of human operator.
- ✓ The Automatic Robot should able to repeat and restart again.
- ✓ The Automatic Robot must not exceed the total weight and maximum size and height.
- ✓ The automatic mobile robot should able to move stable and flexible for complete the tasks.
- ✓ The automatic mobile robot is using easily available power sources that are common for all components.
- ✓ The Robot should able to detect the line and move to the destination and shoot the ball into the basket.

1.3 Limitation

a) The maximum weight of entire Robots must be less than 50kg.

b) The maximum height of the Robots when start must be less than 1.5m and the height after started must less than 1.8m.

c) The total size of Automatic Robot must be less than 1m x 1m square areas.

d) The total size of Manual Robot must be less than 1m x 1m square areas.

e) The power supply to the Robot must be below 24VDC.

f) The Robot must be able to finish the task within 3 minutes.

1.4 Approach and Organization

The design of the Robot is started after understanding the rule of the contest and defining the problem statement. The next step is to develop the design for the robot and fabricate the Robot. The fabrication of the robot can be divided into several parts. After all part is finished, the process of installation and assemble of the Robot is preceded. Afterwards, a program is edited and saved into the controller of the Robot. Testing of the Robot is needed to make sure the performance of the Robot is satisfied. The test result will be used for further improvement of the Robot ability.

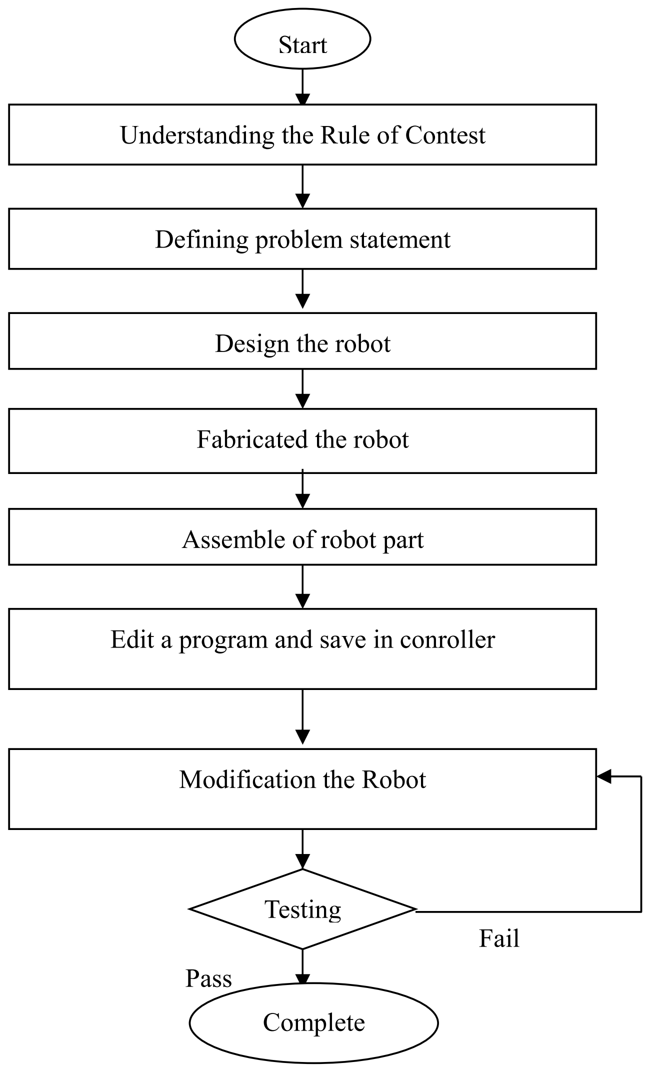

Figure 1.1: Flow Chart for Planning

CHAPTER 2 LITERATURE REVIEW

2.0 Introduction

The word robot means different things in different application. In Europe, robotics is defined as “the science of robotology,” and robotology is defined as “the means by which robot machines are put together and made to work”. Robots are used in areas that require flexible automation. It is a reprogrammable multifunctional manipulator, designed to move materials, parts, tools, or other devices by means of variable programmed motions and to perform a variety of other tasks.

Nowadays, the word "robot" is often applied to any device that works automatically or by remote control, especially a machine that can be programmed to perform tasks normally done by people. Earlier this century, "robot" usually meant a manlike mechanical device capable of performing human tasks or behaving in a human manner. What all robots have in common is that they perform tasks that are too dull, dirty, delicate or dangerous for people.

A robot is a system that consists of Mechanical parts and Electrical parts. Mechanical parts consist of Manipulator, End effectors and Actuators. Whereas, Electrical parts is include types of motors, sensors and Micro-controller. This two parts are integrated together to form a complete robot that have it own special function.

2.1 Motors

The simplest way to add motion to robots is through the use of DC motors. This is because DC motors are cheap, small and efficient, and they can be found in a wide range of sizes, shape, and power ratings. We can use motors to move any mechanism directly or by adding gears or tracks to change the speed or increase the power. When using a DC motor in a robotic project, the following properties must be considered.

A. Direction

When power from a DC power supply, the direction the shaft rotates depends on the direction of the current flowing through it. By reversing the current, we can reverse the direction of any device by a DC motor.

B. Speed

The speed of a motor depends on the voltage and the load. We must consider two situations when using a DC motor. The motor operates without any load or with a constant load. In the second case, the motor operates with a variable load.

C. Voltage

The specified voltage indicates the nominal voltage or the applied voltage that makes the motor run in its normal condition. The nominal voltage indicates the maximum recommended operating voltage.

D. Current

When a motor is powered at the nominal voltage, the current depends on the load. The current increases with the load. It is important to allow the motor to run with excessive loads that can stall it.

E. Rotational power

The power of a motor is given by the product of its voltage and current. It is normal to rate the amount of force that a motor produce in terms of its torque (rotational power). The force that DC motor can deliver no only depends on the motor but also on the mechanism coupled to it. The power can be changed by using a gearbox mechanism.

2.1.1 Types of Motor

a) Power window motor

Power window motor is a type of DC motor and it is designed specially to lift the car window automatically. The power window motor is using in robot because the cost is less and the torque is high. It can operate in 12 volts current and produces a high-speed revolution with a high torque. The gearbox mechanism is built in the power window motor, so that the torque of the motor is high. With the feature of high torque, it is suitable to be use as an end effector of the robot; the robot can lift heavy things easily.

b) Stepper motor

Stepper motors may be used for locomotion, movement, positioning and many other functions where we need precise control of the position of a shaft, lever, or other moving part of a robot. The stepper motor is a device that produces rotation through equal angles, the so-called *steps*, for each digital pulse supplied to its input. It converts digital information into proportional mechanical movement. Stepper motors are available in three basic types: permanent magnet stepper, variable reluctance stepper, and hybrid stepper. The way the windings are organized inside a motor determines how it works. The most common type is the two phase stepper motor, four phase stepper motor and six phase stepper motor.

c) Servomotor

A servomotor is a motor whose output shaft can be moved to a specific angular position by sending it a coded signal. As long as the coded signal is applied to the input of the servo, it will maintain the position of the shaft. If we change the coded signal, the angular position of the shaft also changes. There is a basic difference between servomotor and stepper motor, the use of feedback of the servo motor. There have a position encoder attached to the drive motor that reports the actual position of the motor shaft back to the controller. If any error exists, the servo controller may take corrective action to ensure that the motor moves to the proper position. Servo motor doesn’t have the problem of torque falls off as motor speed increases.

2.1.2 Control of the DC motor （H-bridge）

H-bridges are very important for the robotics and it allow the DC motor to be controlled directly from electrical signals. The H-bridge use in this project is double-pole; double throw (DPDT) transistor contacts. When the transistor A and D is high, the motor will turn in one direction. Whereas, when the transistor B and C is high, the motor will turn in the opposite direction. With control the direction of the motor the movement direction of the robot can control easily.

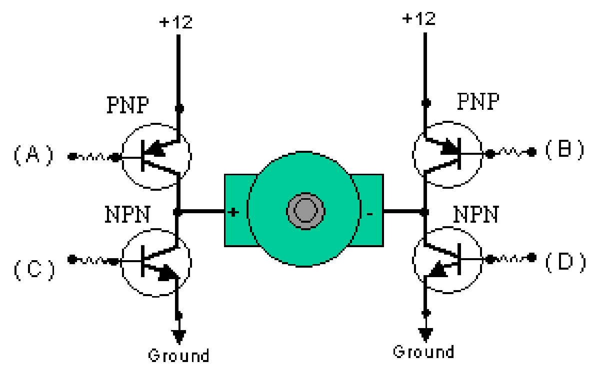

Figure 2.0: H-bridge

2.2 Sensor

The addition of sensors to a machine changes it from a dumb machine into an intelligent machine. Sensors can furnish a robot with information about its own condition and position, along with information about the outside world, without sensors, a robot requires an almost perfect world in order to do its tasks. They are many types of sensors use in robotic, but in this literature review, we only discuss the sensor use in our robot.

2.2.1 Fiber-optic sensor

The fiber-optic sensor is designed to detect the color of a surface. This types of sensor detect only two range of colour. This Fiber-optic sensor will provides laser beam to the target and collect the reflection to detect the different colour. When the colour is above the threshold value, it is high and an output of 1 will be send by a blue colour cable. Whereas, when a colour below the threshold value, it is low and 0 outputs will be send by a blue colour cable.

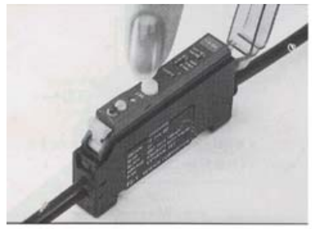

Figure 2.1: Keyence Fiber-optic sensor (FS-T1)

2.3 Microcontroller

A microcontroller is used as a brain of the robot. It controls the movement of the robot, make decisions, and interacts with a human operator by integrates the entire electrical and mechanical device in the robot. The microcontroller used in this project is basic stamp.

2.3.1 Basic Stamp

The Basic Stamp product line is a family of small computers that run Parallax BASIC programs. They can be used for direct control of TTL logic and other devices or to acquire data from sensors or control units via their I/O ports. Light emitting diodes, pushbuttons, reed switches, sensors, and driver stages can be connected directly to the I/O ports. To program the Basic Stamp, we just have to connect it to an IBM PC and run the software to edit and download the program.

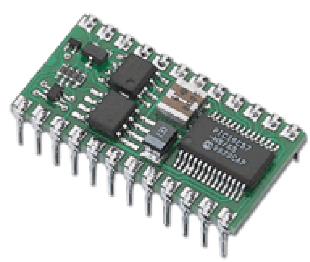

Figure 2.2: BASIC Stamp 2

2.4 Basic Mechanics

2.4.1 Gears

Gears are mechanisms which are very widely used to transfer and transform rotational motion. They are used when a change in speed or torque of a rotating device is needed. Rotary motion can be transferred from one shaft to another by a pair of rolling cylinders. The transfer of the motion between the two cylinders depends on the frictional forces between the two surfaces in contact. There are many types of gears, helical spur, rack and pinion, sector, linear miter and bevel gear arrangement. The speed and torque of the rotational shaft can be increased by:

Speed change: $v_1/v_2=n_1/n_2$

Torque change: $M_2/M_1= n_1/n_2$

V_1 and V_2= tangential speed of the gears

M_1 and M_2= turning moment

n_1 and n_2= number of teeth

Figure 2.3: Gears

2.4.2 Belt and Chain drives

Belt drives are essentially just a pair of rolling cylinders with the motion of one cylinder being transferred to the other by a belt. Belts drives use the friction that develops between the pulleys attached to the shafts and the belt around the arc of contact in order to transmit a torque. The transmitted torque is due to the differences in tension that occur in the belt during operation. This difference results in a tight side and a slack side for the belt.

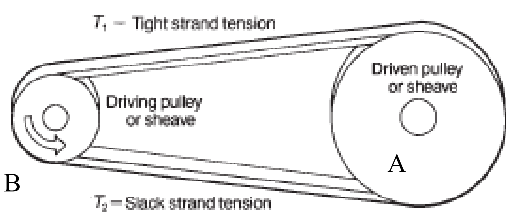

Figure 2.4: Belt and Chain drives

Torque on A = $(T_1-T_2)\, r_A$

Torque on B = $(T_1-T_2)\, r_B$

Power = $(T_1-T_2)\, v$

T_1 = tension on the tight side

T_2 = tension on the slack side

r_A = radius of pulley A

r_B = radius of pulley B

v = belt speed

2.4.3 Spring

Springs are elastic devices that can be twisted, stretched, or pulley by external forces. They return to their original shape when the external force is released. There are many types of spring, flat, spiral, helical and torsion. Springs can store energy and released the energy when needed.

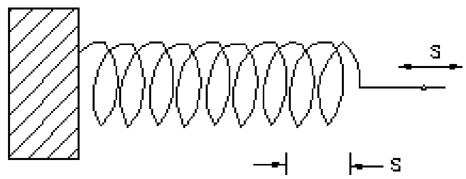

Figure 2.5: Spring

Force, F= k x s

Work, W= F x (S/2)

K = spring rate
S = deformation

2.4.4 Bearings

The function of the bearing is to guide with minimum friction and maximum accuracy the movement of one part relative to another. Whenever there is relative motion between two surfaces, the resulting frictional forces generate heat which wastes energy and results in wear. One particular importance is the need to give suitable support to rotating shafts. There are many types of bearing including Ball Bearings, Roller Bearings, Ball Thrust Bearings, Roller Thrust Bearings, and Taper Roller Bearings. Each of the bearings is suitable to use in difference condition.

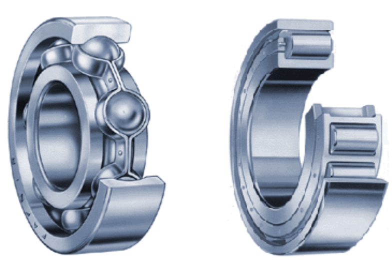

Figure 2.6: Ball Bearing and Roller Bearing

2.4.5 End effectors

The purpose of the end effector is to perform the robot's operating functions, such as gripping, positioning, drilling, spray painting, welding, gluing, grinding and so on. The end effector can be a gripper or other device to pick up and hold an object. In this project, the end effector should be able to grip a ball and throw it into a basket. The end effector suitable used in this function is gripper. There are many types of gripper that design to special function as figure below.

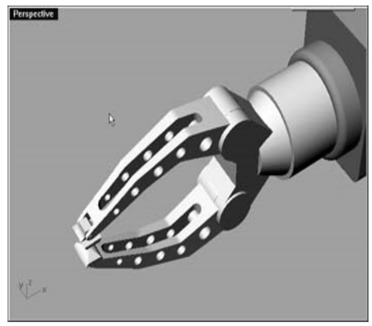

Figure 2.7: Gripper

Chapter 3: METHODOLOGY

3.0 Introduction

In general, a robot can be divided into mechanical parts and electrical parts. Mechanical parts include the manipulator, end effectors, actuators. Meanwhile, electrical parts include controller, wiring, motor, program and sensor. In this autonomous robot design, the robot has some limitations:

a) The weight of the robot must be less than 10kg.
b) The starting height of the robot must be less than 1.5m and maximum height must less than 2.0m.
c) The size of the robot cannot exceed 50cm x 50cm when start.
d) The voltage that can be used by the robot must less be than 24 volts.
e) The robot must complete its task within 3minutes.
f) The robot has to load a ball sized 15cm and weight 150g.

In 3 minutes, the robot have to run to the outer torch that is far from the starting zone and rise to the height more than 1.5m and then shot the ball into the torch. The path of the robot is shown in the Figure 3.0. So that, the robot must be able to move in a straight line and the distance moved by the robot must be accurate.

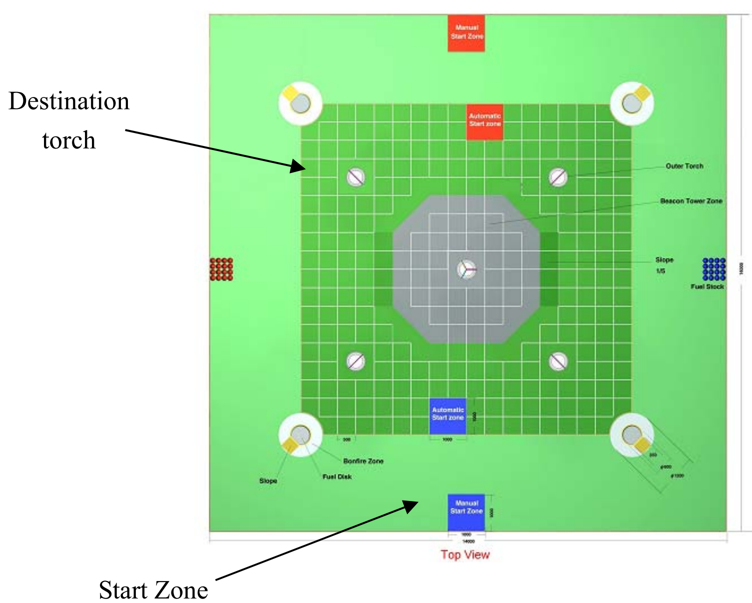

Figure 3.0: Destination of the Robot

3.1 Conceptual Design

To fulfill the task of the robot, the robot designed must be light but stable. The base of the robot should be stable, if not the robot will collapse when moving with a high speed. Beside that, the robot also will collapse when it crashes with opponent's robot. Since opponent's robot also goes to the same destination, the robot also must move faster. It must arrive at the outer torch before opponent's robot. If not, it will be blocked by opponent's robot. The end effector should have a space to load on two balls with 15cm diameter and shoot it into the torch when the destination is arrived.

3.2 Strategic of the robot

In the contest of the robocon, the bucket of the opponent's robot is beside our bucket. The possibility that our robot is crash with the opponent's robot is high. There are two methods to avoid this problem.

1. Adding a sensor on the robot.
2. Set a different program to the controller of the robot.

Table 3.0: Decision Matrix for Strategic

Requirement	Important factor	Sensor	Difference program
Speed	10	3	10
Less Complex	5	4	7
Cost	7	3	7
Reliability	8	10	8
Total Weight		151	248

From the table above, it can be seen that between these two solutions, the second method is preferable because the contest duration is 3 minutes. If a sensor is added to the robot, the robot will move slower because it takes time to sense the opponent's robot while moving. This will cause the whole process of movement to become slow. Beside that, if a sensor is added to the robot, the wiring and programming process will become more complex. The cost of a sensor is quite high although the reliability to sense the opponent's robot is high. By using the second method, the robot will move faster because the program is already set in the robot. The operator just has to choose the way that it will not crash with opponent's robot. Although its reliability is lower than using sensor, the cost and complexity of using this method is lesser. So that, the robot should use a difference program to choose the difference way to avoid crashing with the opponent's robot.

3.3 Mechanical Parts

3.3.1 Moving Mechanism

In order the robot to move to the torch without any mistake, the moving mechanism of the robot must be very accurate. This is the most important thing in the robot. There are two types of motion that the robot can use. The first is differential motion and the other is synchronous motion.

The differential motion is shown in the Figure 3.1 below. There are two motors to control two tires. A motor is connected directly to the motor with a shaft. This type of motion uses the concept of difference speed of the motor to control the direction of the robot. When two motors are moving with the same speed in same direction, the robot will go straight. But when the motor is moving in the difference speed or difference direction, the robot will rotate.

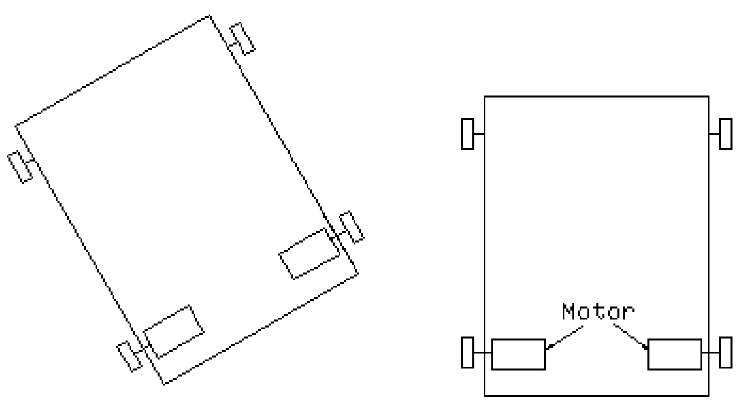

Figure 3.1: Differential Motion

Table 3.1: Comparison of the Differential Motion

	Moving with Same speed		**Difference speed straight forward**	
Motor left	**CW**	**CCW**	**Fast**	**Slow**
Motor right	**CCW**	**CW**	**Slow**	**Fast**
Results	**Straight forward**	**Straight Backward**	**Turn Right**	**Turn Left**

The Synchronous motion is shown as Figure 3.2 below. It can be seen that there is one motor to control the two tires in the back and one motor to control two tires in the front. The motor at the back is used to control the motion forward and backward. Meanwhile, the motor in the front is used to control the direction. When the Motor front does not rotate and the motor back is rotating in clockwise direction, the robot will go straight forward. When it turns, the motor in front has to rotate. When the front motor rotate clockwise, the robot will turn right. Meanwhile, when it rotates in counterclockwise direction, the robot will turn left. For the backward turning, it is as shown in the Table 3.2 below.

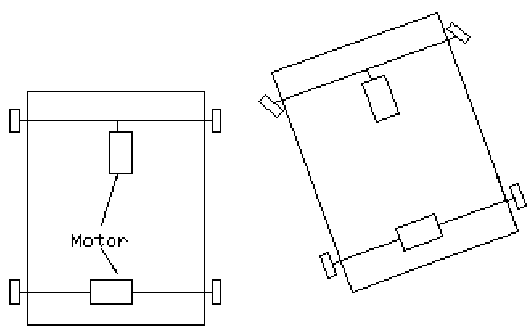

Figure 3.2: Synchronous Motion

Table 3.2: Comparison of Synchronous Motion

	Directions				
Motor Front	CW	CW	CCW	CCW	-
Motor Back	CW	CCW	CW	CW	CW
Results	Forward right	forward left	Backward Left	Backward Right	Straight forward

There are 4 methods to control the motion of the robot. Each

1. The synchronous drive by using Power Window motor.
2. The synchronous drive by using vexta motor AXHD30k-GFH2G5.
3. The differential drive with Power Window motor.
4. The differential drive with VEXTA motor AXHD30k-GFH2G5.

All of this combination has their own advantages, but the best methods to use in this robot will depend on the characteristic of straight moving, Simplicity, Light Weight, Reliability, Cost and Ease of control.

- Straight moving – the ability of the robot to move in straight line.
- Simplicity – the degree of complex the robot is fabricated.
- Light weight – the weight of the robot to use this method.
- Reliability – the reliability of the robot to complete its tasks.
- Cost – the cost to fabricate the robot by using this method.
- Ease of Control – the easy method to control the robot.

Table 3.3: Decision Matrix for moving mechanism

Requirement	**Important Factor**	**Methods**			
		1	**2**	**3**	**4**
Straight moving	10	8	9	5	9
Simplicity	8	5	5	7	7
Light Weight	9	5	6	6	7
Reliability	10	2	6	6	9
Cost	7	9	5	9	5
Ease of control	9	5	8	6	9
Total Weight		293	351	337	415

From the Decision Matrix in the table above, it can be proved that the method 4 which is differential driver that using VEXTA motor AXH230KC-A is the best choice to use in the moving mechanism of the robot. Since this differential method can move straight easily because the speed of the motor can be controlled easily. By setting both motor on tires with the same speed, the robot will move straight. The mechanism to use this method is easy; it can be done by just attaching a tire to the shaft of both motor. The reliability of using this method is high if compared to using power window motor, although the cost of using the VEXTA motor is high. By using differential driver, the robot can make a small radius turning if compared to using synchronous driver that will make a big radius turning. When turning, it can stop one motor and the other motor rotate to make a small radius turning. This is the advantage of differential driver because the game field is small and small radius is easier to make a calculation for the distance move.

3.3.2 Moving Torque of the Robot

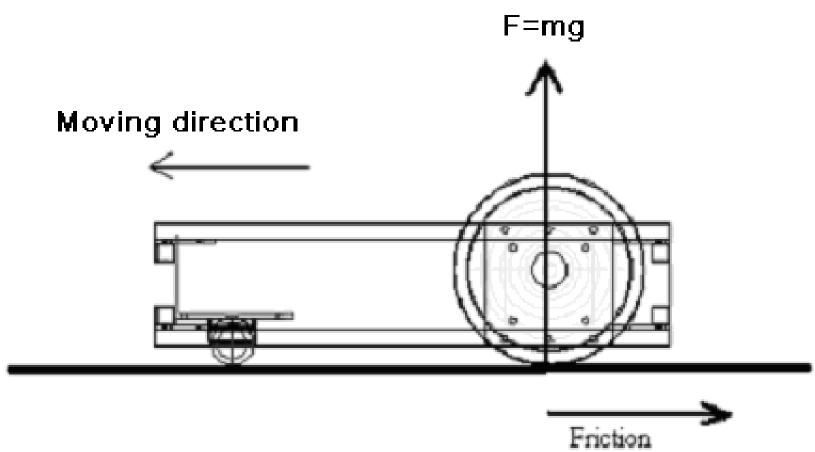

Figure 3.3: Force on the moving mechanism

The moving mechanism of the robot is shown in the figure above. The base of the robots is 35cm x 40cm in size. The mass of the robot is about 7.5kg (including the ball). There are two motor that are used to drive the robot. So the torque required moving the robot is:

Assumption: All weight in the robot is uniformly distributed on two wheels and the dynamic friction of the tires with ground is 0.5.

Maximum weight is used: 10kg

Total weight W = total weight X g

= 10X 9.81

= 98.1 N

Two motors is used for driving, so

$W_{\text{one wheel}} = 98.1/2 = 49.05$ N

Torque for driving

$F_R = 49.05 \times 0.5 = 24.525$ N

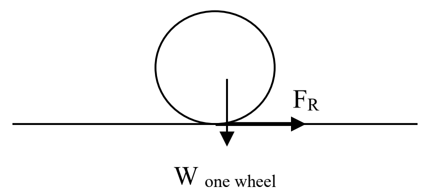

Figure 3.4: Force on wheel

For driving the motor from static state,

$F_{\text{Drive}} - F_r = ma$

When static, ma = 0

So that, $F_{\text{drive}} = F_r$

Radius for wheel, r = 6.4cm

Torque, $T = F_r \times r = 24.525 \times 6.4 \times 10^{-2} = 1.5696$ Nm

The torque requires for driving the robot from initial state is 1.5696 Nm.

Assume the efficiency for power transmission system is 95% (direct mount)

Motor must provide the torque, $T_{\text{motor}} = \frac{1.5696}{0.95} = 1.6522Nm$

The VEXTA motor AXH230K-GFH2G5 has the maximum torque of 6 Nm. The maximum static torque required to move this robot is 1.65 Nm. So, this servo motor is considered suitable to use in this robot.

3.3.3 Manipulator

3.3.3.1 Chassis

The chassis is the bottom structure of the robot. It plays an important role for the moving of the robot. If the chassis of the robot is not suitable, the robot will not move in a straight line. Beside that, the robot may collapse when moving if the chassis is not stable.

There are 3 ideas of chassis that is considered suitable to use in this robot:

1) Chassis 1:

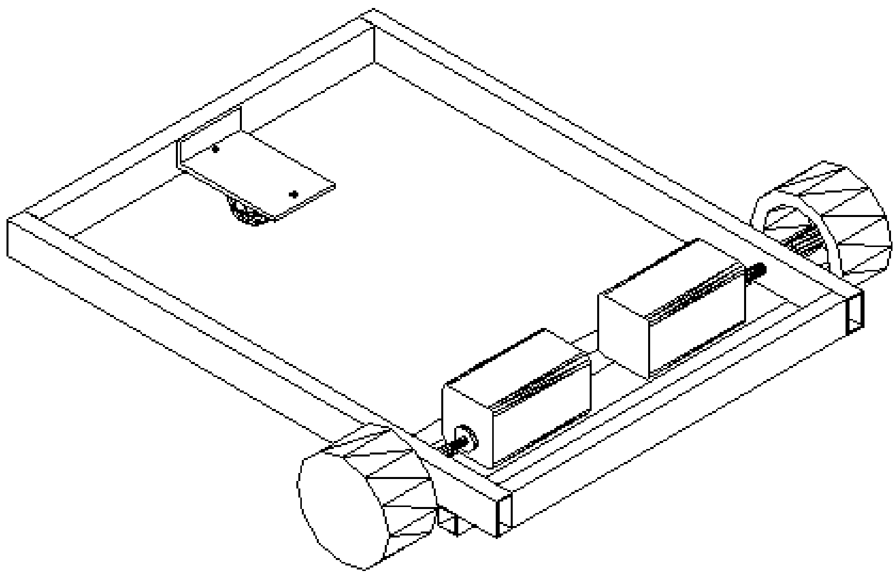

Figure 3.5: Chassis of idea 1

This chassis use only 1 layer of structure. The 4 main structure uses aluminum hollow bar of size 12.7mm X 25.4mm. The shaft of the motor is through the middle of the main structure as shown in the figure above. The two servo motors are held by adding two support structures. Although this chassis is light, the shaft is through the middle of the main structure, it wills cause the middle of the structure to become weak and fracture may occur.

2) Chassis 2:

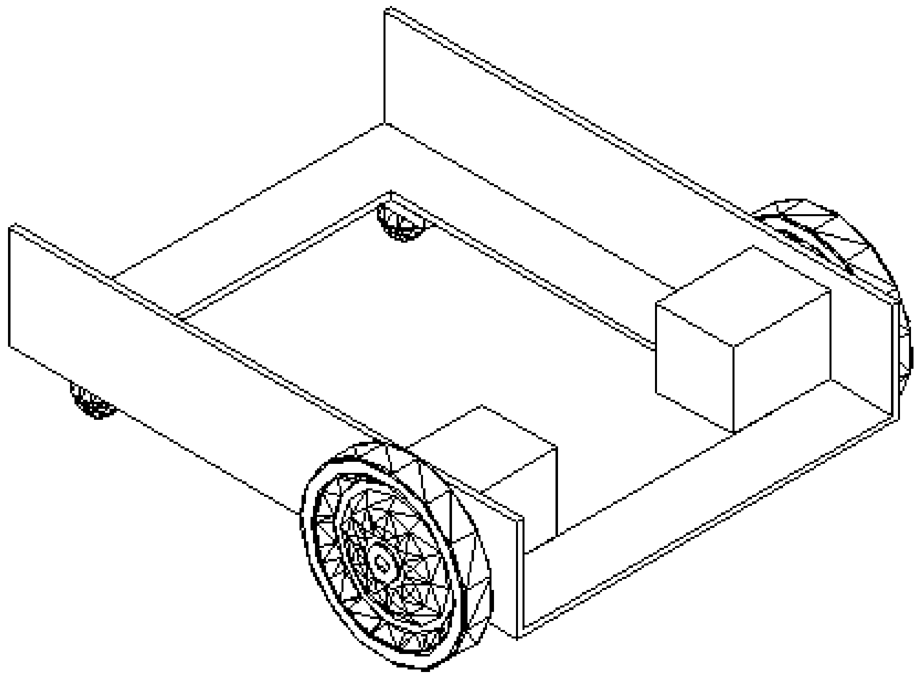

Figure 3.6: Chassis of idea 2

This chassis is only made by a size 40cm X 46 cm aluminum plate. The longer side of the aluminum is bending 90 degrees as shown in the figure above. The bend part is 8cm high. The center of the plate is made hollow to reduce the weight of the robot. The motor is attached to the two side of the plate. Although this chassis is easier to build and the parts is easy to attach to the chassis but the center of the chassis is not tough. Since the center is only a plate of aluminum, it will be bent when too much load is put on the robot.

3) Chassis 3

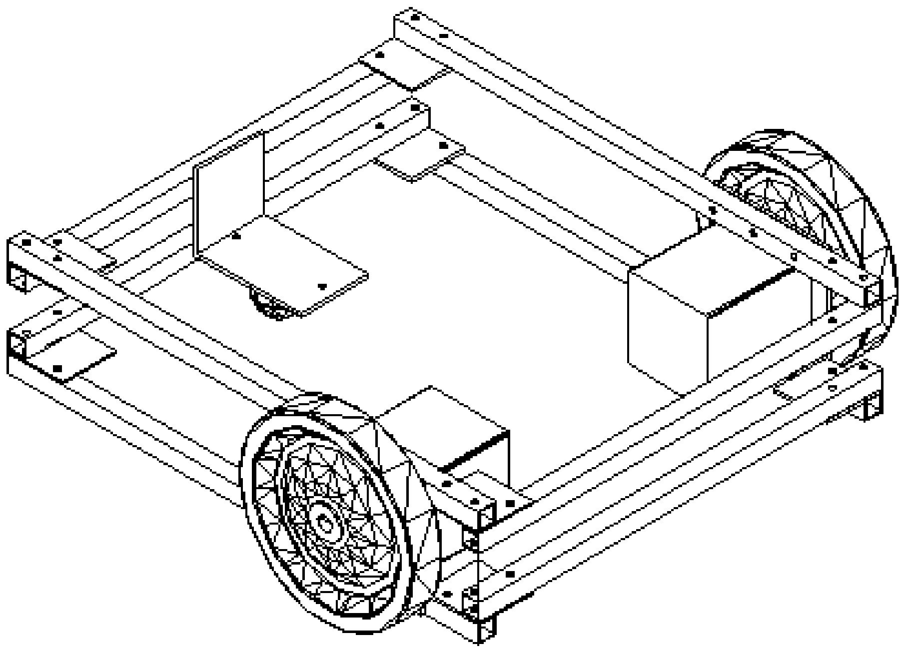

Figure 3.7: Chassis of Idea 3

This chassis is built by two layer of rectangular aluminum hollow bar of size 12.7mm X 12.7 mm. These two layers of rectangular are joined by an aluminum plate thick 5mm as shown in the figure above. The two servo motors are attached to the structure in this aluminum plate. A wheel is attached directly to the shaft of the motor.

This chassis is lighter if compared to chassis 2 and the structure is tougher if compared to chassis 1. It is more suitable to be used in the robot because of the weight and the structure is tougher if compared to the two chassis mentioned previously.

3.3.3.2 The Lifting Mechanism

The starting height of the robot is 150cm but the torch is also 150cm. so, the robot's end effector have to lift to the height of more than 150cm but less than 200cm. There are many lifting mechanism that is considered suitable to be used in the robot fabrication. For example, rack and pinion, Acme Screw and Rider Nut, Robot's arm and Pre-Stress Rubber String.

i) Rack and Pinion

Rack and pinion is a mechanism which uses a circle gear and a linear gear. Circle gear is named pinion and the linear gear is named rack. While the pinion is rotated in the clockwise direction, the rack will move upward as shown in the Figure 3.8.

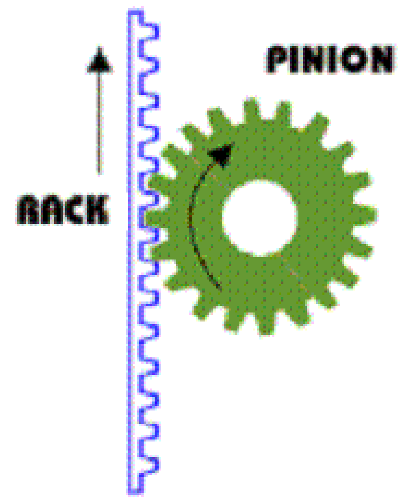

Figure 3.8: Rack and Pinion

ii) Acme Screw and Rider Nut

Acme screw and rider nut is using a same theory of the screw and nut. The screw named acme screw and is fixed with the shaft of the motor, but the rider nut is free to rotate. While the motor is rotating, the acme screw will rotate in the same direction. This causes the rider nut to move upward and downward according the rotated direction of the motor.

Figure 3.9: Acme Screw and Rider Nut

iii) Pre-stress Rubber string

This Pre-stress rubber string is using a same concept with the toy gun. There are two rod that have been stressed by a rubber string and is held by a screw. One rod is fixed in a position but the other one is free to move upward and downward. When the screw is released, the second rod will be shot upward as shown in the Figure 3.10 because the stress rubber.

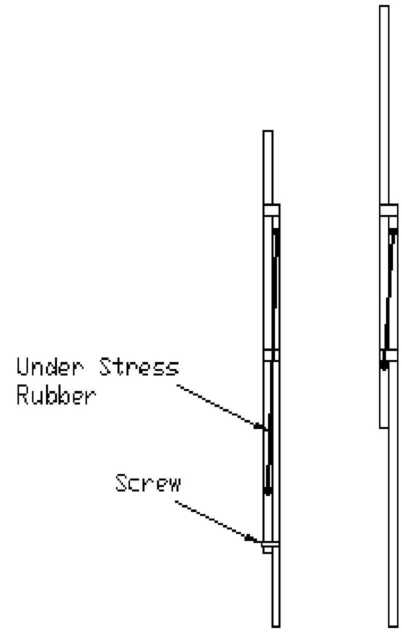

Figure 3.10: Pre-stress Rubber string

iv) Robot's Arm

This Robot's arm is using an arm like a human. The bottom of one rod is fixed in the base of the robot and there is a joint to join to another end part of the other rod. When the joint is rotate by motor or the join is pulled by string. The non-fixed rod will be lifted upward as shown in the Figure 3.11.

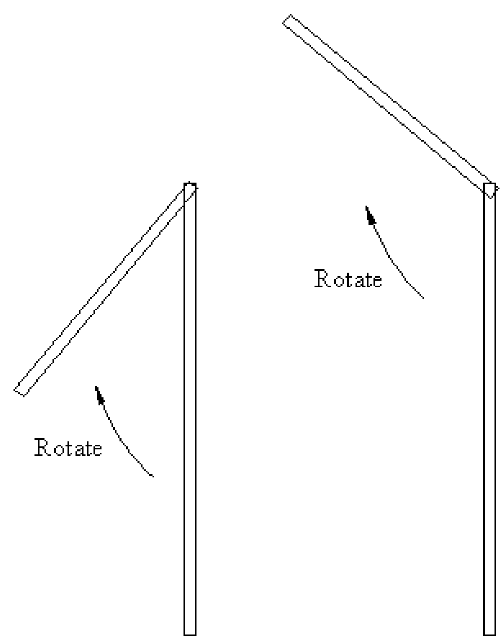

Figure 3.11: Robot's Arm