DEVELOPMENT OF ROPE CLIMBING ROBOT AND FIRE FIGHTING ROBOT FOR MALAYSIAN UNIVERSITY ROBOT COMPETITION (MUROC)

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ABSTRACT

In general, this paper presents an overview of the design and the implementation of the Rope Climbing Robot and Fire Fighting Robot. This robot was used in the Malaysian University Robot Competition (MURoC) 2013 which organized and held at University Malaysia Perlis (UniMAP). Rope Climbing Robot is a game based on an imaginary of the military physical training while Fire Fighting Robot is a game based on an imaginary fireman rescuing the victims and extinguishes the fires. Overall, one Rope Climbing Robot and three Fire Fighting Robot has been successfully developed which fulfil the competition guideline and rules. However, only one of each robot is allow participating in the competition. UTHM team were achieved the top five in group position and gain a lot of experience during fourth edition of MURoC which has been successfully organised in April 2013. As conclusion, an enthusiastic participation has shown that robotic technology had flourished in Malaysia and has become one of the niche areas in almost every institution of higher learning.

ABSTRAK

Umumnya, kertas kerja ini menyajikan gambaran rekabentuk dan pelaksanaan Robot Mendaki Tali (*Rope Climbing Robot*) dan Robot Pemadam Kebakaran (*Fire Fighting Robot*). Robot ini digunakan di dalam Pertandingan Robot Universiti Malaysia (MURoC) 2013 yang dianjurkan dan diadakan di Universiti Malaysia Perlis (UniMAP). Robot Mendaki Tali adalah permainan berdasarkan imaginasi dari latihan fizikal pertahanan manakala Robot Pemadam Kebakaran adalah permainan yang berdasarkan kepada imaginasi anggota penyelamat menyelamatkan mangsa kebakaran dan memadamkan api. Secara keseluruhannya, satu Robot Mendaki Tali dan tiga Robot Pemadam Kebakaran telah dihasilkan yang mematuhi garis panduan dan peraturan pertandingan. Bagaimanapun, hanya satu daripada robot-robot tersebut dapat menyertai pertandingan. UTHM telah berjaya menempatkan diri dalam lima kelompok teratas dalam kumpulan dan memperolehi banyak pengalaman dalam pertandingan MURoC edisi keempat yang telah dijalankan pada bulan April 2013. Kesimpulannya, kesungguhan penglibatan yang telah ditunjukkan bahawa teknologi robot telah berkembang di Malaysia dan telah menjadi salah satu daerah ceruk di hampir setiap Institusi Pendidikan Tinggi.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysian University Robot Competition (MURoC) is a robot competition that is organized by Universiti Malaysia Perlis (UniMAP) and sponsored by Microchip. The objective of MURoC is to test the competitors on their knowledge and skills on interpreting, designing a solution, and fabricating the mechanism that will address the challenges of each game.

MURoC is a significant project to UniMAP because the idea came from His Royal Highness Tuanku Syed Faizuddin Putra Ibni Tuanku Syed Sirajuddin Jamaluallail, the UniMAP's Chancellor in an effort to produce creative and innovative students. The establishment of this competition is one of the strategies to produce scientists and engineers who could compete internationally and at the same time to measure their creativity and problem solving skill.

Indirectly, this competition also aims to test the creativity and the ability of participants in translating their knowledge and skills in the process of creating a robot. This is in line with the ministry's aspiration to produce students who are creative

There are three games involved in this competition named Fire Fighting Robot (FFR), Paintball Robot (PR) and Rope Climbing Robot (RCR). These competitions are open to all IPTA/IPTS and secondary school in Malaysia where all the robots contested are developed by the students themselves.

1.2 Rope Climbing Robot

Rope Climbing Robot is a game based on an imaginary of the military physical training. The rules and regulations of MURoC stated that RCR will carry a ball, climbs up to a rope of 4.5 meters and touches the end plate. After touching the end plate, the robot must return, stop at the middle of the rope, drops the ball on the target plate and stops immediately in three minutes. The task is considered to be complete when the robot successfully drops the ball on the target plate and stops immediately. The target plate has three sections with different colours and marking schemes. Red colour at the centre point carries 30 marks, yellow for 20 marks and green with 10 marks. Each match divided into two teams, red and blue team. Each match has one minute to set up the robot on the rope and three minutes to compete. There are a total of five task to archive – "carry and climb", "touch the round plate", "return back", "stop and drop" and "dropping ball on target" with respective marks according to its colour.

1.3 Fire Fighting Robot

Fire Fighting Robot competition is a game based on an imaginary fireman rescuing the victims and extinguishes the fires. The Robot will move around the house (game field) to rescue the victims as much as possible and extinguish all the fire in three minutes. The victim is a standard ping pong ball with an orange in colour. The fire is a standard emergency candle with 0.6 inch diameter. There are two main task that involved in this games where the task of rescue the victims (the task of rescue), and the task of extinguish the fire (the task of fire fighting).The robot shall collect the victims around the house and transport it back to the starting zone. The robot shall identify and extinguish the fires around the house without touching the fire source. The team whose Fire Fighting Robot has completed rescued the victims, extinguish the fires and return back to the starting zone shall achieve the rescue and be the winner, which ends the match [1].

1.4 Objective

The objectives of this project are:

(i) To develop a fire fighting robot to participate in Malaysian University Robot Competition (MURoC).

(ii) To develop a rope climbing robot to participate in Malaysian University Robot Competition (MURoC).

(iii) To evaluate robot performance in terms of functionality, hardware robustness and task completion.

1.5 Scope

The scopes of this project are:

(i) Guideline as stated in "Rope Climbing Robot Games Competition Rules and Regulations" in terms of dimension, switch operation, power supply limitation, weight and movement to perform a given task within a specific duration.

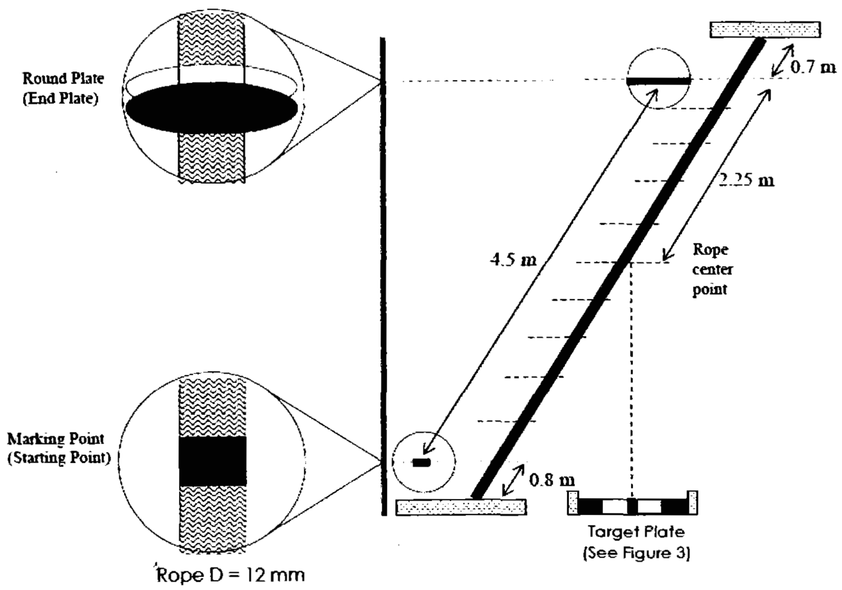
(ii) Guideline as stated in "Fire Fighting Robot Games Competition Rules and Regulations" in terms of dimension, switch operation, power supply limitation, weight and movement to perform a given task within a specific duration.

CHAPTER 2

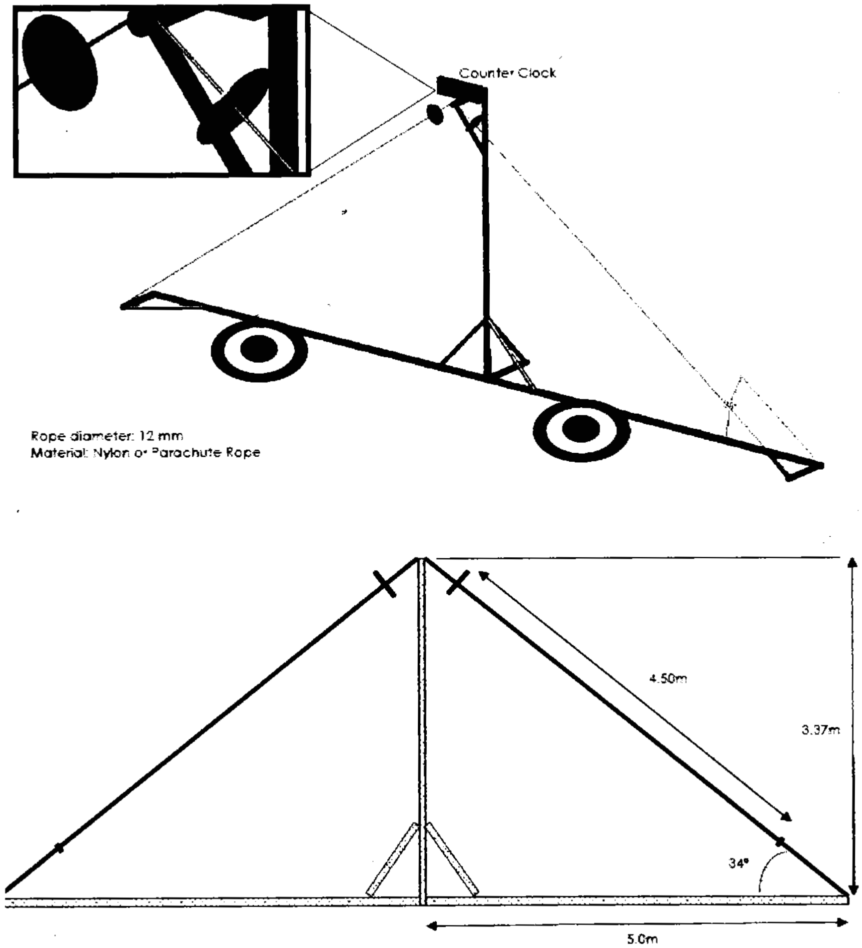
DEVELOPMENT OF ROPE CLIMBING ROBOT

2.1 Introduction to Rope Climbing Robot Competition

Rope Climbing Robot is a game based on an imaginary of the military physical training. The Rope Climbing Robot will carry a ball (See Figure 2.3) and climbs up to 4.5 meters rope and touches the round plate (end plate). After touching the round plate, the robot must return back and stop at the centre of a rope (2.25 meter from round plate), drops the ball on the target plate and stop immediately in three minutes. The robot is considered completing the task when the robot successfully drops the ball on the target plate and stops immediately. The target plate has three sections with different colours and marks. Red colour at the centre point carries 30 marks, yellow for 20 marks and green with 10 marks. See Figure 2.1(a-b) and Figure 2.3 for more explanations. Each match is contested by red and blue teams. A match lasts three minutes.



(a)



(b)

Figure 2.1: Rope: Structure and Specifications

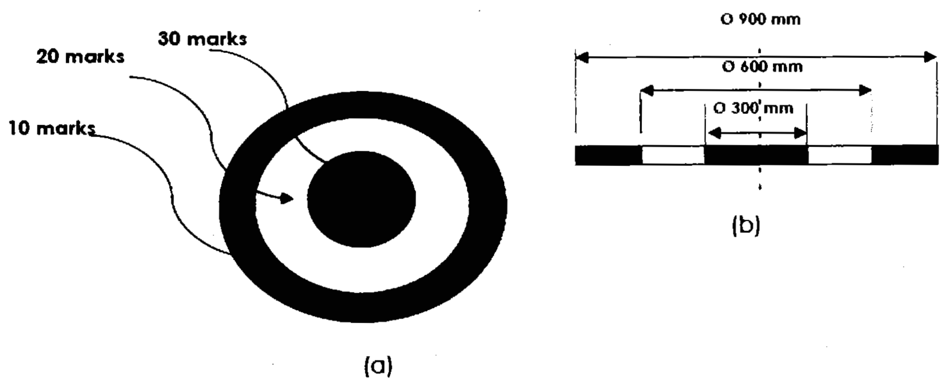


Figure 2.2: Target Plate Dimension

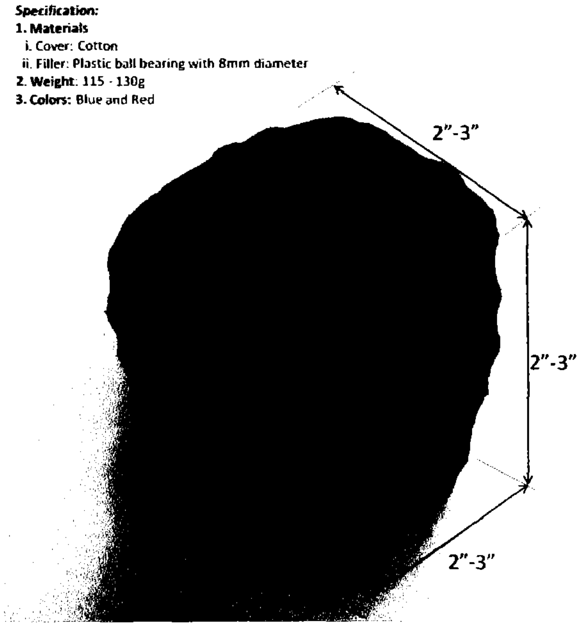


Figure 2.3: Ball Specification

Once the match has begun, each team shall complete the tasks in the following order:

(i) The tasks of robot carrying a ball (See Figure 2.3) and climbing the rope. The robot shall carry a ball and climb the rope up to 4.5 meters.

(ii) The task of touching the round. The robot shall touch the round plate (end plate).

(iii) The task of returning back to the centre of the rope. The robot shall return back to the middle of the rope (2.25 meter from end plate) after touching the round plate (end plate).

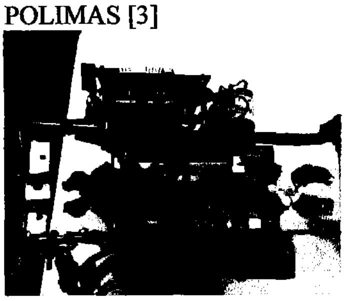
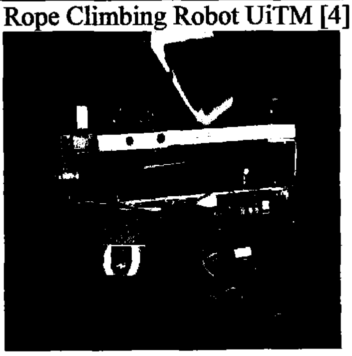
(iv) The task to stop and drop a ball on the target plate (See Figure 2.2) at the rope centre point. The robot shall stop and drop a ball on the target plate at the middle way of returning back from the top of the rope (2.25 meter from end plate).

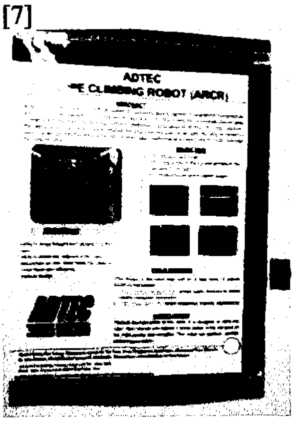
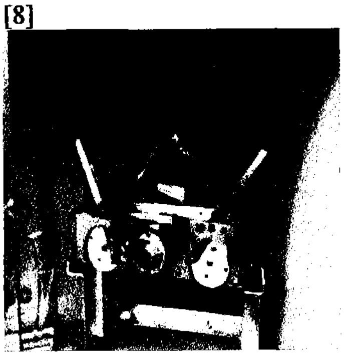
(v) The tasks of ball dropping perfectly on the target plate without bouncing outside of the target plate. The ball must be dropped perfectly on a target plate without bouncing outside of the target plate. The ball must be dropped within the three sections given that have different colours and marks. Red colour at the centre point carries 30 marks, yellow for 20 marks and green with 10 marks. See Figure 2.1(a-b) and Figure 2.3 for more explanations.

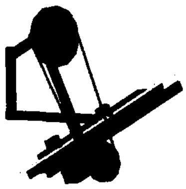
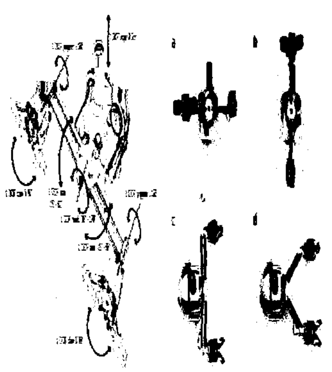
2.2 Related Research and Project of Rope Climbing Robot

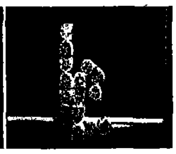
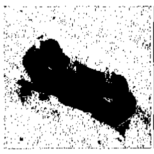
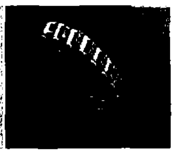
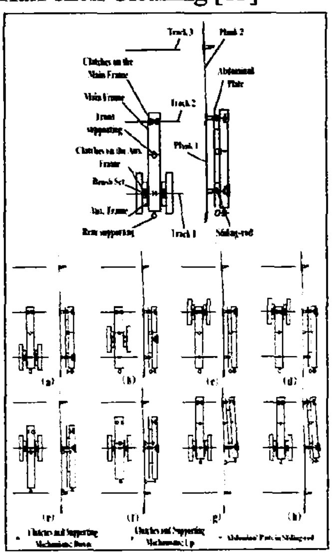
Table 2.1 shows MURoC 2012 robot and related research. The electronic component, hardware design and climbing concept of related research and project will be the guide for this project.

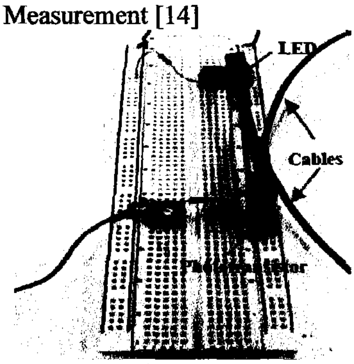
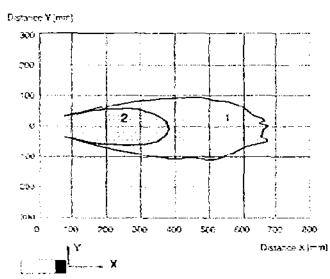
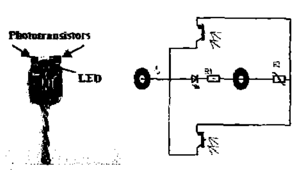
Table 2.1: Related Research and Project

No.	Title	Implementation	Comment
1.	Rope Climbing Robot UniMAP [2] 	▪ Controller: PIC16F877A. ▪ Moving mechanism: 3 micro servo motor, 2 DC motor, 2 belts. ▪ Sensing device: Limit switch. ▪ Strategy: Use 2 micro servo motor with a sharp hock grip and release the rope. Use DC motor and belt for move the gripper in high speed.	▪ Efficient, smooth, stable and fast.
2.	Rope Climbing Robot POLIMAS [3] 	▪ Controller: PIC16F877A. ▪ Moving mechanism: 1 DC motor, 1 belt, 6 flexible grippers. ▪ Sensing device: Limit switch. ▪ Strategy: Use the pulley to determine the gripper grip or release the rope.	▪ Concept is good but can't grip the rope well at competition.
3.	Rope Climbing Robot UiTM [4] 	▪ Controller: PIC16F877A. ▪ Moving mechanism: 1 DC motor, 2 servo motor, 1 solenoid valve. ▪ Sensing device: Limit switch. ▪ Strategy: Using piston concept. One gripper fix, other one moving sliding by DC motor.	▪ Using sliding concept.

No.	Title	Implementation	Comment
4.	Rope Climbing Robot UPM [5] 	▪ Controller: PIC16F876. ▪ Moving mechanism: 1 DC motor, 3 servo motor. ▪ Sensing device: Limit switch, Ultrasonic sensor. ▪ Strategy: Using train wheel moment concept drive the front gripper arm.	▪ Using sliding concept.
5.	Rope Climbing Robot KKTM [6] 	▪ Controller: PIC16F876. ▪ Moving mechanism: 7 servo motor. ▪ Sensing device: Limit switch. ▪ Strategy: Imitate worm movement.	▪ High cost.
6.	Rope Climbing Robot ADTEC [7] 	▪ Controller: PIC16F877A. ▪ Moving mechanism: 3 servo motor, 1 DC motor. ▪ Sensing device: Limit switch. ▪ Strategy: Imitate worm movement.	▪ Deisgn a special gripper like a piston.
7.	Rope Climbing Robot UTHM [8] 	▪ Controller: PIC18F4550. ▪ Moving mechanism: 1 servo motor, 1 DC motor. ▪ Sensing device: 1 limit switch, 1 IR senor. ▪ Strategy: Imitate sloth bear movement. One DC motor drive two gears and move four hocks constantly. Design special hock for hold the rope.	▪ Light body weight, stable and accurate. ▪ Award best design.
8.	Robo-Sloth: A Rope-Climbing Robot [9]	▪ Guides are needed in the design so that the entire weight of the robot does not fall on the clamping mechanism. ▪ The normal force from the rope	▪ This robot more in mechanical design, designing of electric part are

No.	Title	Implementation	Comment
		will produce a torque such that it will unclamp the gripper. As shown in figure beside, two rollers are placed on either side of the clamp such that when the robot is suspended from a horizontal rope, the robot hangs on the rollers. ▪ The rollers will allow the rope to pass freely between the clamp (rolling friction is minimal and can be ignored).	easier. ▪ This robot using belt concept for rotate the roller to climb the rope.
9.	How to Climb a Rope [10]	▪ Grab the rope with both hands above your head. ▪ Pull down on the rope while jumping a bit and you will be lifted into the air. ▪ Wrap the rope around one leg, and use your feet to pinch the rope, thus anchoring yourself. ▪ Reach up as high as possible with your arms (some say no higher than your nose), and grip the rope tightly. ▪ Release the rope from your feet. Using your abdominals, bring your knees up to your chest. Re-secure your feet on the rope. ▪ Stand up with your legs, and re-reach as high as possible with your arms. ▪ Repeat the inch-worm process until the top of the rope has been reached. ▪ Loosen the grip of your feet on the rope when coming down. Support your weight evenly between your feet and hands, slide your feet down and place hand-over-hand on the way down.	▪ The basic step how human climbs rope.
10.	The Hand-bot, a Robot Design for Simultaneous Climbing and Manipulation [11] 	▪ The hand-bot has two arm on its front side. They can bend/ extend forward (independently) and rotate with respect to the robot body. ▪ At the end of each arm, the hand-bot has a gripper. Each gripper can rotate with respect to its arm and can open and close its claws. To grasp objects and structures of different thickness, the gripper claws have parallel compliance mechanism. ▪ When no object is present, a spring maintains a large opening angle between the claws. Once the claws squeeze an object, the points of contact are different than the	▪ This robot arm and gripper are very flexible. ▪ This robot grippers can rotate 360 degree and grasp and release the object. ▪ Robot head can rotate the arm with gripper 180° and bend (-15°) or extend forward60°.

No.	Title	Implementation	Comment
		points of rotation which generates a moment that aligns the claws in parallel with the object. ▪ This provides a strong force over a large range of thickness.	
11.	Modular Robot Climbers [12]   (i) PolyBot fence climber (ii) M-TRAN II Climbing up   (iii) Superbot sand climber (iv) PolyBot rolling up stairs	▪ This modular robot using module traversing terrain by climbing, and present various methods of climbing such as climb across a horizontal rope, climb up a vertical rope, and climb up stairs. ▪ Modular robot capable of adapting its configuration or topology as well as its locomotion and manipulation based on the environment and the corresponding objectives by systems such as Superbot, M-Tran and Polybot. ▪ It have successfully demonstrated the versatility of modular robots in accomplishing complex tasks in unstructured dynamic environments, yet locomotion and manipulation in certain terrains like left side picture .	▪ By using module to bend and extend the body to move like a worm. ▪ More flexible than [11] can traverse on slope surface, stairs, ropes and cables.
12.	Mechanical Design and Dynamcis of an Autonomous Climbing Robot for Elliptic Half-shell Cleaning [13] 	▪ The robot is in its home state: clutches on the main and auxiliary frame are all in the down-state to hold the sliding-rod on track 1 and on track 2 respectively; the abdominal plate is inserted in both sliding-rods; the two supporting mechanisms are all in the up-state. ▪ Clutches on the auxiliary frame are raised, and the auxiliary frame is pulled up along the main frame. ▪ The motion of the auxiliary frame stops when the clutches on it are right above track 2. Then the clutches are lowered to grip the sliding-rod. ▪ Clutches on the main frame are raised; the front supporting mechanism touches down on plank 1. ▪ The main frame moves up. When the abdominal plate is out of the sliding-rod on track 1 and the rear supporting mechanism is above plank 1, the main frame stops moving and the rear supporting mechanism touches down on plank 1. ▪ The front supporting mechanism is raised, and the main frame	▪ This robot using clutches grip the sliding-rods for hold the robot, and auxiliary frame pull up the main frame to climb up and down the building. ▪ This robot imitate monkey climbing skill. One hand grasp the rope another hand extend to move forward or backward.

No.	Title	Implementation	Comment
		continues to move up. When the front supporting mechanism is above plank 2, it touches down on plank 2. ▪ The upward movement of the main frame does not stop until track 3 is detected by the front ultrasonic sensor. Then the front or rear supporting mechanisms are adjusting to position the robot parallel to plank 2. ▪ Afterwards, the main frame moves up to insert the abdominal plate into the sliding-rod on track 3. ▪ The motion of the main frame stops when the clutches on it are right above track 3. Then the clutches are lowered to grip the sliding-rod on track 3. The robot is now in its home state again, and the process of climbing up to the next strip is over.	
13.	Using Ultrasonic and Infrared Sensors for Distance Measurement [14]  Figure (a)  Figure (b)  Figure (c)	▪ The author using (a) LED, Fiber Optic cables and Phototransistor, (b) Ultrasonic Sensor Properties and (c) Infrared Sensor Properties methods to prove that low cost ultrasonic and infrared sensors are able to give reliable distance measurement.	▪ Ultrasonic sensor will be more suitable for this project because the lighting system of competition hall will affect the infrared sensor sensitive.

Based on Table 2.1 above, this project will apply the method of [2] and [9] concept to design a robot. The proposed project will utilize a high torque and high RPM DC motor which can support the robot's weight to climb the rope. Furthermore, the motor is also able to drive the chain belt system to link and synchronous the slider with the grippers in high speed. Besides that, an ultrasonic sensor is added to detect the target plate in order to release the ball accurately onto the red target. Lastly, a servo motors is modified to mimic as a human hand to carry the ball when climbing the rope and drop the ball to the target plate.

2.3 Rope Climbing Robot Framework

This project starts with the design of the interface board for PIC18F4550 microcontroller. It will be easier to troubleshoot and it is more flexible to add on other electronic devices later on. After PIC interface board is archived, focus is shift to design the L298 motor driver board which function to control and drive the DC motor. Motor driver is use to control DC motor rotation to either grip or release the rope and to control the slider for climbing up or going down the rope. After the circuit section is completed, the hardware of the robot is continued. The design structure of the gripper is the first step as it remains to be a crucial part for hardware development. The gripper itself plays an important role as it should grip onto the rope tightly and to ensure that the robot does not slip while it is climbing a 34° slope angle. Lastly, the robot structure is continued and cleaned up throughout the progress.

2.4 Rope Climbing Robot Block Diagram

Figure 2.4 shows rope climbing block diagram where the PIC18F4550 microcontroller uses to control the robot in this project. Two units of 11.1V LiPo batteries are used to supply all the devices. Ultrasonic are used to detect the distance within the centre of rope and the target plate. Three limit switches are used for control the gripper and trigger the system for climbing or going back to the centre of rope. Two motor drivers, L298 are used to control three DC motors. One DC motor for drive the chain belts for slide the front gripper and other two DC motor for grip or release the rope. The last component used is the servo motor to release the ball onto the target plate.

This project was used two type software, SolidWorks 2010 and Proteus Professional V7.7. SolidWorks 2010 is used to design the general hardware appearance. With the help of this software, before the actual implementation of the robot, robot model is able to be forecasted. This provides a clearer the path to start to construct the robot and discover the error in the logic of the structure. Proteus Professional V7.7 is used to design and simulate the electrical circuit. This software is able to simulate the predicted circuit outcome of the robot.

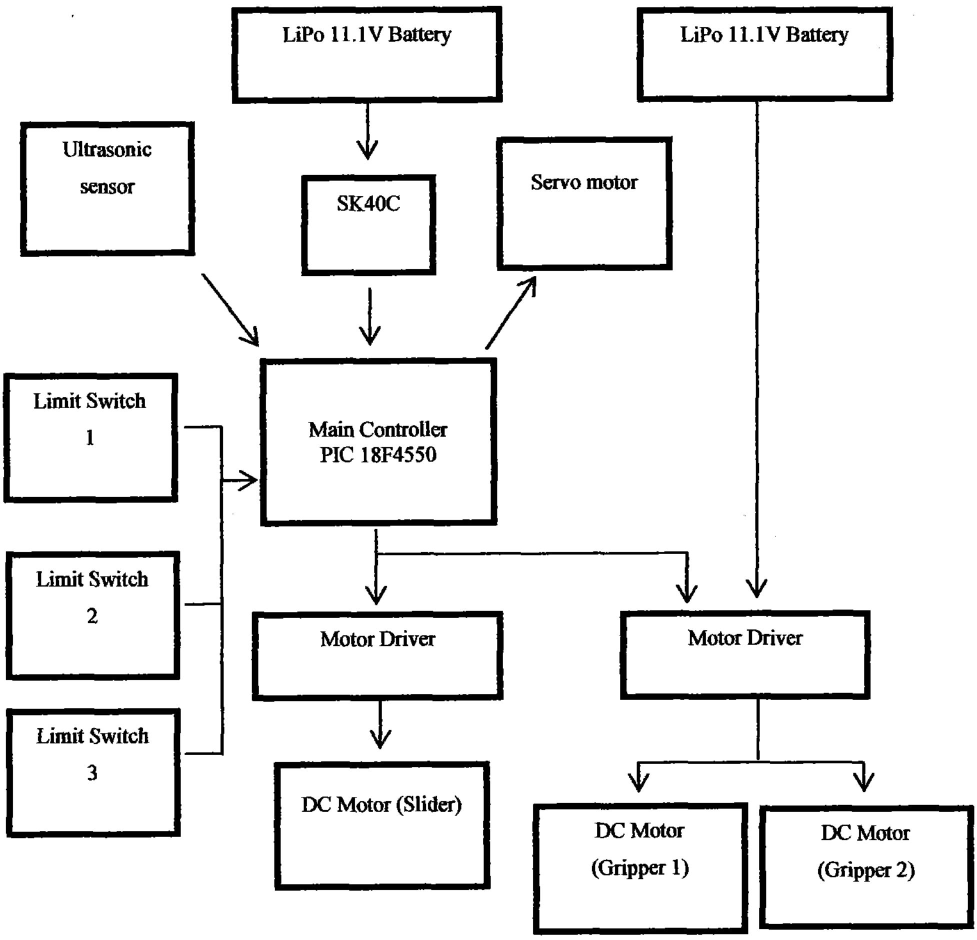


Figure 2.4: Rope Climbing Robot Block Diagram

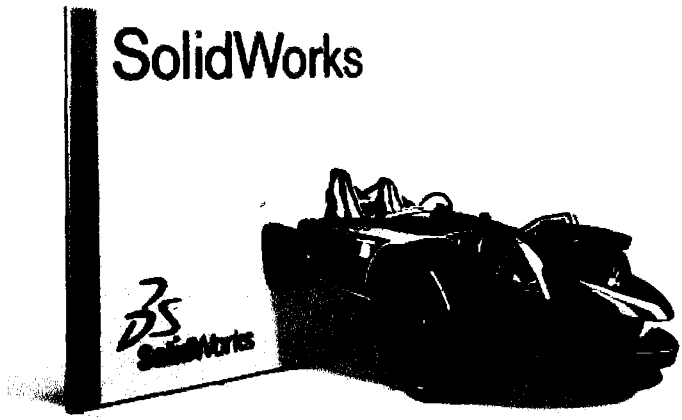


Figure 2.5: SolidWorks 2010 Interface

SolidWorks is a 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows. This software enable transform the ideas into a visual in 2D and 3Das well as an easy to use powerful toolsets which can assembly part by part to a prototype or product.

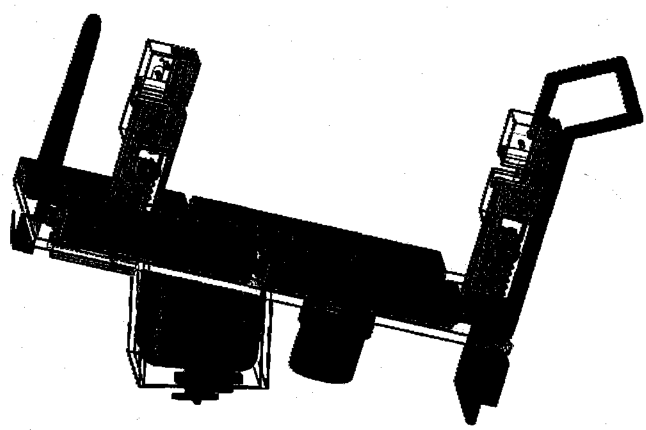


Figure 2.6: Robot Design

Figure 2.6 is the ideal robot sketching in SolidWorks 2010. The first concept of this project is design two hooks which place in front and backside for balance the robot also reduce the robot climbing force. A cage for ball is place at the centre below the robot. A LCD places behind for display the distance between robot and the floor. There is two grippers apply in this project. One gripper is fixed at the back side another gripper is flexible, screw with the slider's chain belt. The slider system is fixed at the middle part of the robot as the backbone of the structure.

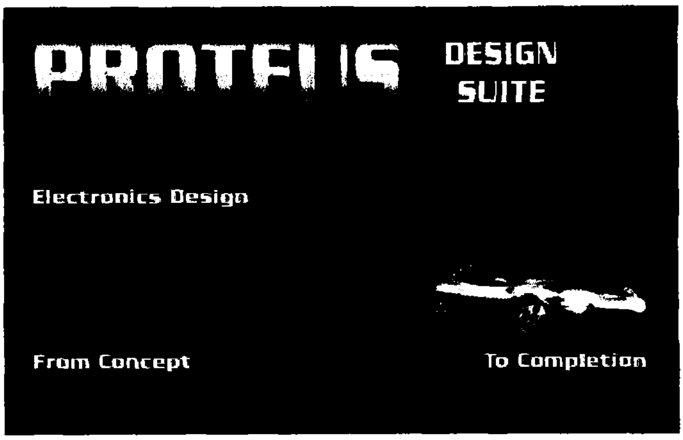


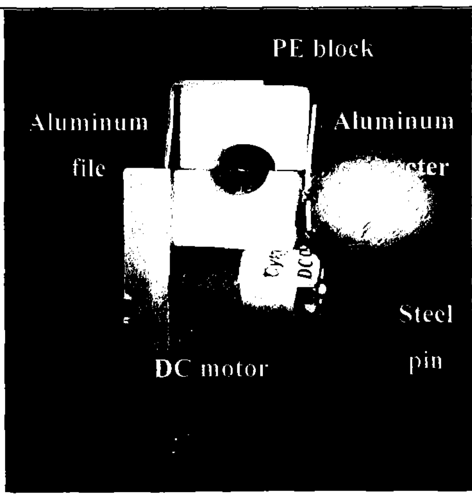
Figure 2.7: Proteus Professional V7.7 Interface

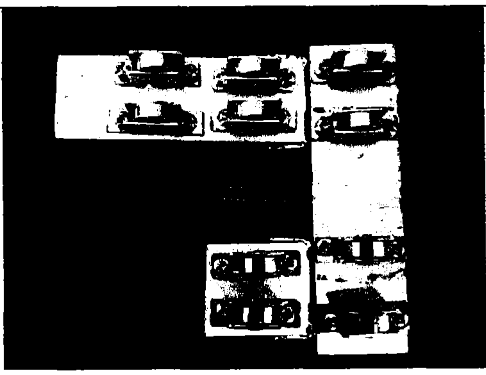
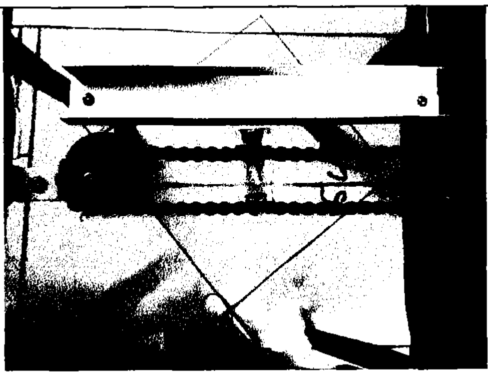
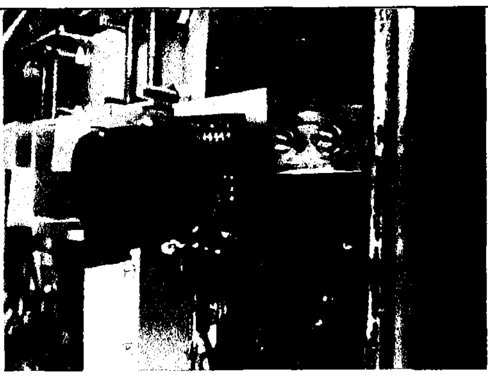
Proteus is software for circuit simulation and PCB design. This software's system components have ISIS schematic capture for drawing and simulate the electric circuit. Besides that system component, ARES convert the designed electric circuit to PCB layout by auto-router to connection the components pin with track.

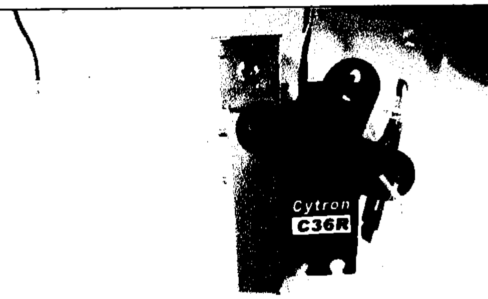
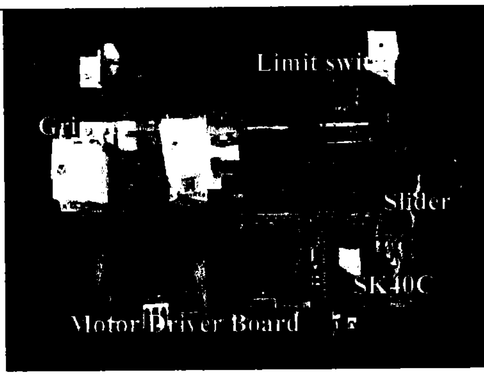
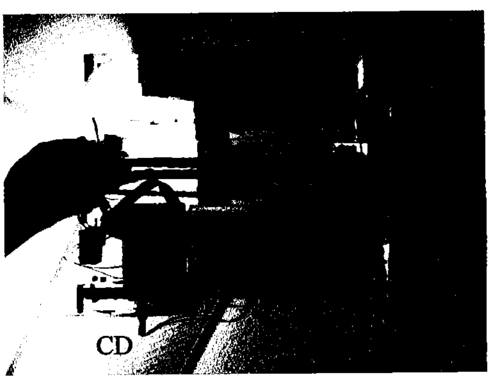
2.5 Robot Fabrication Flow

Table 2.2 shows the robot fabrication flow and explanation the function of each mechanism part.

Table 2.2: Fabrication Flow of Robot

Step	Figure	Description
1.		▪ PE block, aluminium connecter, pin, aluminium file and DC motor are the component for the robot gripper. ▪ Combination of these components accomplishes the gripper. ▪ The propose to put the steel pin at the PE block for tightly grip the rope avoid the robot slip. ▪ The aluminum connecter used to limit the expansion of the gripper block and lock the rope in the gripper block.

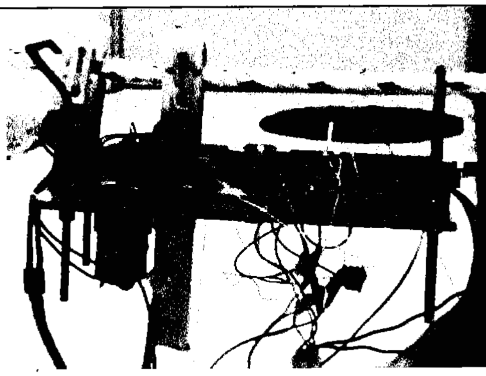
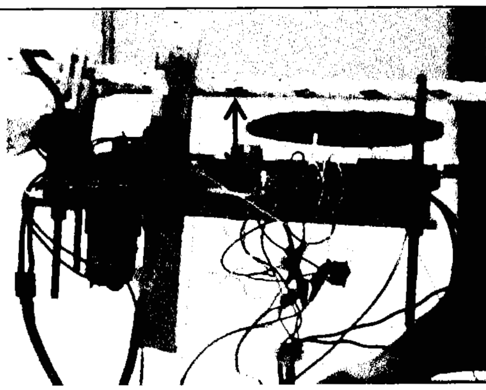
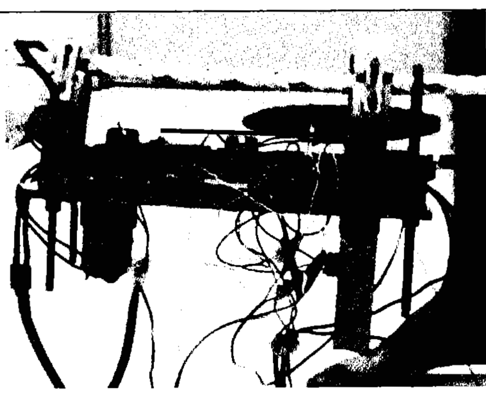
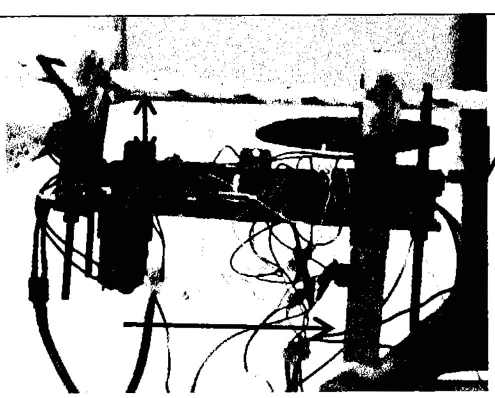
Step	Figure	Description
2.		▪ Several free wheel rollers were screwed on the aluminium files and combined together become a rolling bracket for the gripper. ▪ The component being design for reduce the fiction between the gripper's bracket and the robot's body. ▪ With this bracket also reduce the slider moving force because rounded surface are much more beneficial as it reduces friction between the gripper and the robot's body. ▪ It also provides a smooth motion for the gripper and slider.
3.		▪ Acrylic being chooses as the material for the robot's body. ▪ It is because acrylic is a useful, clear plastic that resembles glass, but has properties that make it superior to glass in many ways. ▪ Besides that, it is many times stronger than glass, making it much more impact resistant and therefore safer. ▪ Another great advantage of acrylic is that it is only half as heavy as glass. ▪ This makes working with acrylic much easier. It can also be sawed and drill, whereas glass must be scored or break.
4.		▪ After construct the robot's grippers and body continue with the slider for the flexible gripper. ▪ Combination of DC motor, spur gear and a chain belt will be a slider for the RCR.
5.		▪ Ultrasonic range finder was fixed at the bottom side of the RCR with a flexible aluminum bracket. ▪ The aluminum bracket can easily adjust the ultrasonic angle to detect the game field.

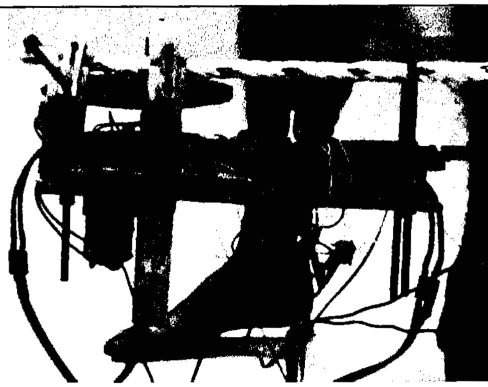
Step	Figure	Description
6.		▪ Servo motor, C36R was used to modify for carried the ball. ▪ Servo motor was screwed at the specific aluminum similar with ultrasonic for fixed the servo position. ▪ A steel clip was screwed with the servo motor and tied a string at the servo plate. ▪ When servo motor rotated will draft the string to pull the clip then the ball will be release to the target plate.
7.	 	▪ The overview of the robot after combines the previous part.

2.6 Robot Climbing Sequence

Table 2.3 illustrates the robot climbing sequence. Robot's complete climbing cycle from sequence 1 until sequence 5. This sequence repeat until the front limit switch touches the end plate. Then robot will invert the climbing sequence for going back to the centre of the rope and release the ball to the target plate.

Table 2.3: Robot Climbing Sequence

Step	Figure	Description
1.		Front gripper and back gripper grip the rope.
2.		Front gripper releases the rope.
3.		Slider move front gripper to front terminal and triggers the front slider's limit switch.
4.		Front gripper grip and back gripper release the rope.

Step	Figure	Description
5.		Slider move whole robot forwards until trigger the backside slider's limit switch. Back gripper grip and front gripper release the rope. Invert sequence above will be the climb down sequence.

CHAPTER 3

DEVELOPMENT OF FIRE FIGHTING ROBOT

3.1 Introduction to Fire Fighting Robot Competition

Fire Fighting Robot is a game based on an imaginary fireman rescuing the victims and stops the fires. The Fire Fighting Robot will move around the house (game field) to rescue the victims as much as possible and stop the fire in three minutes. The robot is considered rescue when the robot returns to the starting zone. Each match is contested by red and blue teams which have different route of game field. A match lasts three minutes [15]. The victim is a standard ping pong ball with an orange in colour. The ball must be placed at the top of standard rubber O-ring with 0.5 inch outside diameter and 2 mm thickness. The dimension of this ball is 40 mm in diameter as shows in Figure 3.1.

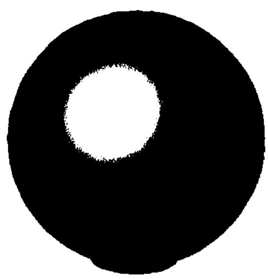


Figure 3.1: Specifications for the Victims (Ping Pong Ball)

The fire is a standard emergency candle with 0.6 inch diameter. The minimum and maximum height of the candle is 2 inch to 6 inch (Figure 3.2). The candle will be placed in the container with 100 mm diameter and 20 mm thickness.

Figure 3.2: Specifications for the Fire (Emergency Candle)

Figure 3.2: Specifications for the Fire (Emergency Candle)

Figure 3.3 and Figure 3.4 shows the game field and its dimension. This competition is contested by red and blue teams with different route of game field. There are 10 ping pong ball and 5 candles placed around the game field where different locations have different points for the ball and the candle. The total points for one game field are 51 points.

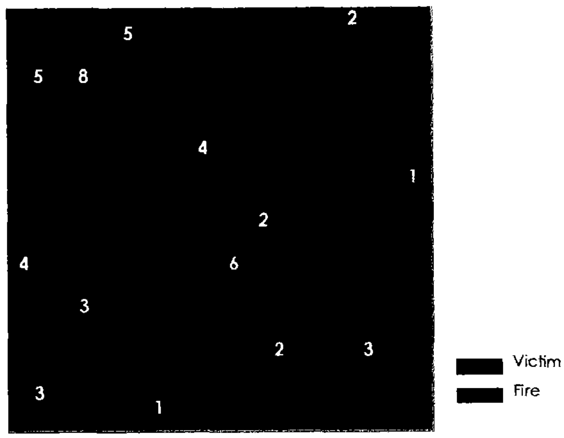


Figure 3.3: Fire Fighting Robot Game Field

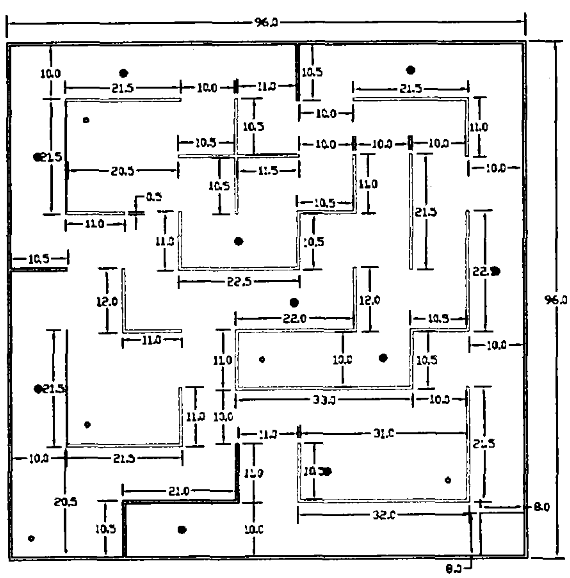
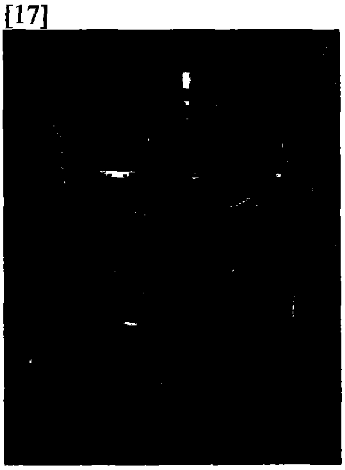


Figure 3.4: Dimension of Fire Fighting Robot Game Field

3.2 Related Research and Project of Fire Fighting Robot

Table 3.1 shows different types of fire fighting robot from previous MURoC competition. Each of those robots has different chassis design with different mechanism used for the controller, moving mechanism, sensor and navigation and also the strategy used for the rescue and to extinguish the fire. Here there are two types of mechanism used for the ball collecting process which are using vacuum and using mechanical mechanism. All of these robots are using fan as the module to extinguish the fire.

Table 3.1: Summarized for Previous Fire Fighting Robot Project

No	Title	Implementation	Comment
1.	Fire Fighting Robot UTHM [16] 	▪ Controller: PIC16F877A ▪ Moving Mechanism: Stepper Motor (wheel), DC motor (Fan) ▪ Sensing Device: IR sensor, Compass Module, LDR sensor. ▪ Strategy: Using Vacuum mechanism to collect ball. Robot capable of moving at a different maze route according to the specified mode.	▪ The robot moving slowly. ▪ Many errors at the robot movements so it is wasting time when retry done many times. ▪ Cannot collect the ping pong ball effectively. ▪ The fan is turned off even the candle is still lit.
2.	Fire Fighting Robot UiTM-FKEE [17] 	▪ Controller: PIC16F877A with 16X2 Characters LCD. ▪ Moving Mechanism: DC motor with differential drive method for its steering. ▪ Sensing Device: Infrared sensor, Analog distance sensor. ▪ Strategy: Using small DC motor (fan) to extinguish the fire. Vacuum is used as a mechanism to collect ball.	▪ Many errors at robot movement. Always stuck at the wall maze.

No	Title	Implementation	Comment
3.	Fire Fighting Robot USM [18] 	▪ Controller: PIC16F877A with development kit. ▪ Moving Mechanism: Using DC motor for Fan. ▪ Sensing Device: Compass Sensor, and Analog Distance Sensor.	▪ The robot always stuck at the wall maze.
4.	Fire Fighting Robot GMI [19] 	▪ Controller: PIC16F877A ▪ Moving Mechanism: DC motor (wheel) and Caster ▪ Sensing Device: IR & Digital compass ▪ Strategy: Using retry as strategy to save time so that the robot can move to the other path of the maze. Using vacuum to collect the ball. Using small DC motor (fan) to extinguish the fire.	▪ The robot extinguishes fire effectively but its moving slowly. ▪ The robot collect ball effectively.
5.	Fire Fighting Robot UPM [20] 	▪ Controller: PIC18F4680 ▪ Moving Mechanism: DC Geared Motor. ▪ Sensing Device: Sharp GP2YOA21YK IR Sensor, HMC6352 compass module used as a feedback sensor, and Gyroscope adxrs300. ▪ Strategy: Using the robot speed as the advantage. Using vacuum to collect the ball. Using small DC motor (fan) to extinguish the fire.	▪ The robot extinguishes fire effectively. ▪ The robot moving fast. ▪ There is sometime where the robot cannot collect the ball because of the robot moving fast and hit the ball cause the ball move away. ▪ The rates of the robot's movement error are less.

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