Design of Circuitry and Programming of a Climbing Robot for MIRoC 2014 Competition

by

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Dissertation submitted in partial fulfilment of
the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic)

MAY 2014

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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr Mohd Haris Md Khir)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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AHMAD FAEZ AHMAD FAHMI

ABSTRACT

The climbing robot created for this project is aimed to join the Malaysian International Robot Competition (MIRoC) 2014. Arduino microcontroller was chosen to control the movement of a climbing robot. Designing and testing of the actuator system, circuitry and programming must be done in order to produce a robot with the most efficient algorithm of movement. Servo motors are used for the actuator system of the robot. The robot faces problem when climbing when there is too much friction between the gripper of the robot and the rope to be climbed. Thus, the gripping force produced by the robot must be considered and compared with the weight of the robot. The angle of the gripper at the moment the robot is climbing also plays an important role in this. Of course, the study of kinematics with regards of the mechanisms of the robot can be really helpful in making sure the smooth movement of the robot when climbing.

ACKNOWLEDGEMENTS

An award of gratitude should be given to the supervisor for this project, Dr Mohd Haris Md Khir for his great help and support for this project. He helped a lot in the preparation of tools and materials. At the same time, his guide was really helpful in making sure the success of this project, especially in the field of robotics. My deepest appreciation also goes to my colleagues and friends who are helpful either directly or indirectly in the process of completing the project.

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CHAPTER 1

INTRODUCTION

1.1 Background

Malaysian International Robot Competitions (MIRoC) 2014 is an international robotic competition held and organized every year by Universiti Malaysia Perlis (UniMAP) in Perlis. The competition is divided into three categories which are the fire fighting robot, paintball robot, and rope climbing robot competitions. Rope climbing robot competition is a game that imitates one of the military physical training tasks which is climbing a rope. The main intention of the project chosen is to have a robot that can climb a rope and thus joining the competition. The robot to be created controlled by a microcontroller board and with a correct algorithm, should be able to complete the tasks especially climbing.

1.2 Problem Statement

The rope climbing robot needs to carry a dart and start climbing up to 3 meters of rope 1. A dart is placed on the robot before the start of the game manually. Upon reaching the end of rope 1, the rope climbing robot needs to grab to rope 2 which is located on the right/left in the game field. The robot then needs to travel to touch the round plate located at the end of rope 2. After touching the round plate, the center of rope 2 becomes the next destination for the robot in which the robot needs to stop to drop a dart. The dart should be aimed on the target plate on the ground. The robot is regarded as completing the task when the dart aimed on the target plate falls on the target plate. The target plates have five sections with the variance in colours and marks when the dart reaches them. The red colour carries 10 marks, the yellow colour carries 8 marks, the blue colour carries 6 marks, the green colour carries 4 marks and the black colour carries 2 marks.

All in all, the problems faced for this project can be stated as choosing and testing:

1. Microcontroller board for programming
2. Actuators such as DC motors and servos
3. Algorithm to be programmed into microcontroller board

1.3 Objectives

The objectives for the project can be stated as follows:

1. To select a suitable microcontroller board and actuator system
2. To design and test the circuitry for the robot
3. To build the most efficient algorithm for the movements of the robot

1.4 Scope of Study

This project requires the study and research about the suitable actuator system for the robot to be created. The actuators to be used are RC (radio control) servo motors. No DC (direct current) motors or stepper motors are required as RC servo motors are very suitable to provide mechanisms with accurate and precise movements. The servo motors in general are known to have the capability to rotate accurately with regards of angle.

For the electronics side, the microcontroller board to be used can be chosen from those that use C programming language. C programming language is easy to be dealt with and that language is very common nowadays and thus, many microcontroller boards are available to be programmed in that language. Research can be narrowed down to on-board microcontroller board only and there is no need for supercomputers. Thus, small microcontroller boards can be chosen for the project. This is an advantage because by using a small microcontroller board, the space to be provided for the robot to put the electronic parts can be saved pretty much.

CHAPTER 2

LITERATURE REVIEW

2.1 Microcontroller Board

By using a suitable microcontroller, the movement of a robot can be controlled effectively, for example by controlling each leg independently [1]. The control system of a robot can consist of three modules, which are top controller, microcontroller and motors [2]. The top controllers are usually personal computers used to send the required programming to microcontrollers. There are different microcontrollers available in the market that can be used to control and observe the performance of a robot [3]. These robot controllers play an important role in ensuring that a robot operates well and has a good coordination with any mechanism attached to it [4]. The motors used are usually direct current (DC) motors for the main movement of the robot, where high torque is required [5]. To increase the reliability of the boards used, some circuits can be added to reduce noise in the boards, for example Schmitt trigger circuit [6].

The board to be used for this project is USB 6824 DAQ produced and sold by IRATech Company Limited [7]. As a matter of fact, IRATech Company provides many types of products and solutions related to automations and also robotics [8]. Based on the architecture of the controller board, there are a few timers in the board with different channels each [9]. This means that the board can control more than 10 servo motors if required provided that each servo motor receives enough power supply. Like most microcontroller boards, this board operates using 5V DC power supply [10]. To send programs to this board, Segger J-Link JTAG Debugger is needed [11]. This J-Link adapter connects the board to the USB port of a personal computer. The software to be used with this board is µVision IDE provided by Keil Company [12].

2.2 Servo Motor

In robotic systems, servo motors can be quite useful when they are programmed correctly by following the capabilities of a robot [13]. By learning the control system of a robot, the programming of the robot's servo motors becomes much easier especially when the robot's position response follows closely as intended [14]. The servo motors that are planned to be used are those from Servoking corporation with the model number DS-695 [15]. This servo number is of a standard size, the largest of which offered by the company.

Normally inside a servo motor, there are a small DC motor, a control circuit and a potentiometer [16]. When the DC motor rotates, the resistance of the potentiometer changes and thus the control circuit determines how much the rotation is and in which direction it is.

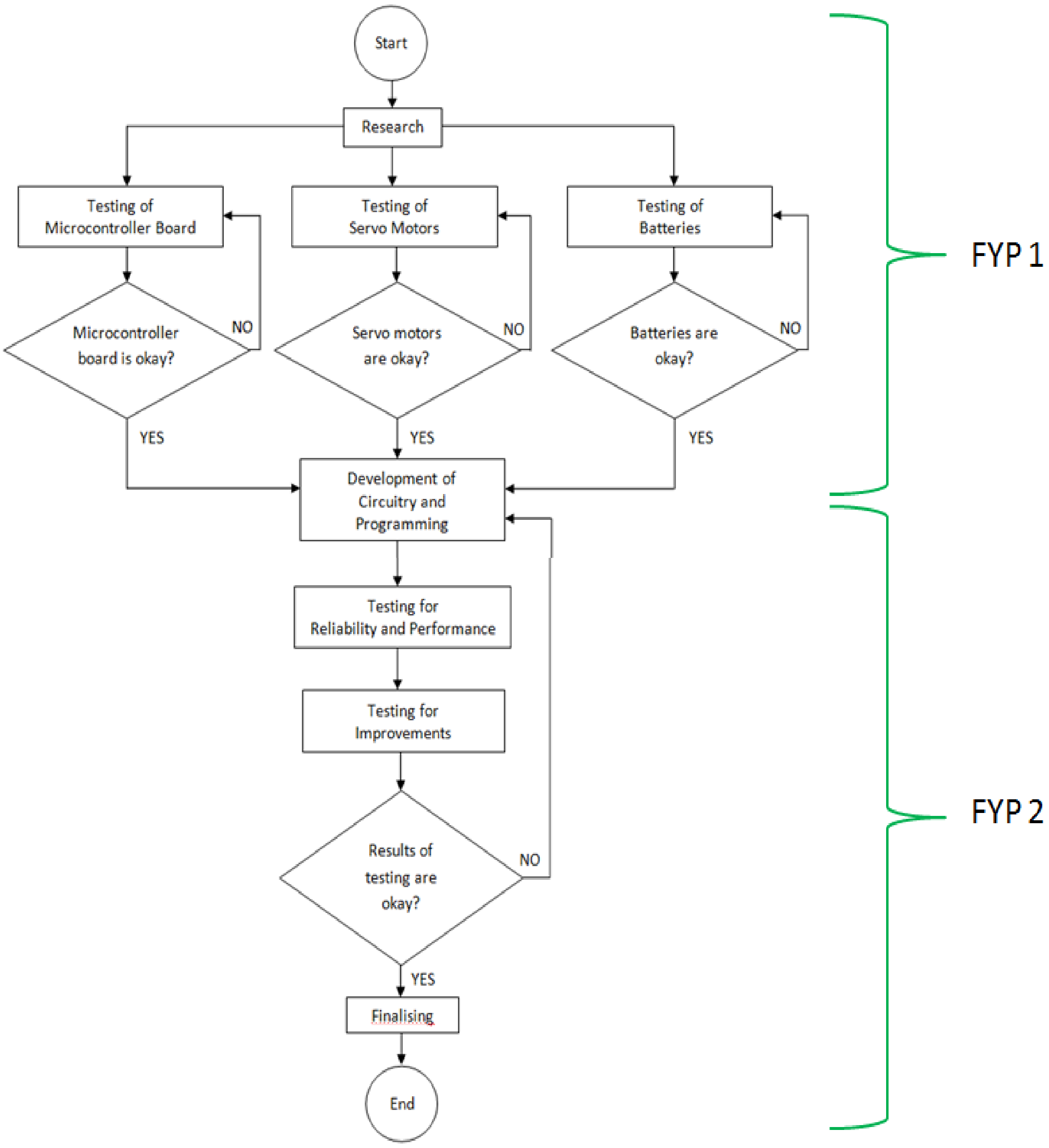
2.3 Robot System

A robot that uses mechanisms like legs for climbing is harder to control rather than most robots that use motorized tires to move [17]. Thus, the programming for these robots that use leg mechanisms must be done well and accurately so that the robots are able to move as expected and wanted [18]. Robots can perform better when their control system takes into consideration the friction compensation of surfaces [19]. This is because the non-linear friction torque that comes from the mechanical structures of robots contributes to the speed error of the motors used in the robots [20].

CHAPTER 3

METHODOLOGY

3.1 Research Methodology



3.2 Key Milestones

TABLE 1. KEY MILESTONES (FYP 1)

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Topic Selection														
2	Extended Proposal Submission														
3	Proposal Defence														
4	Interim Draft Report Submission														
5	Interim Report Submission														

TABLE 2. KEY MILESTONES (FYP 2)

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Progress Report Submission														
2	Pre-SEDEX														
3	Draft Final Report Submission														
4	Dissertation Submission														
5	Technical Paper Submission														
6	Viva														
7	Project Dissertation Submission														

3.3 Gantt Chart

TABLE 3. GANTT CHART (FYP 1)

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Topic Selection														
2	Early Research Work														
3	Proposal Defence														
4	Testing of Components														

TABLE 4. GANTT CHART (FYP 2)

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Development of Circuitry and Programming														
2	Testing for Reliability and Performance														
3	Testing for Improvements														
4	Finalising and Report Work														

3.4 Tools And Software

The tools and software to be used for this project are as stated below:

- Geared DC motors
- Motion controller board
- Proximity sensor
- C compiler

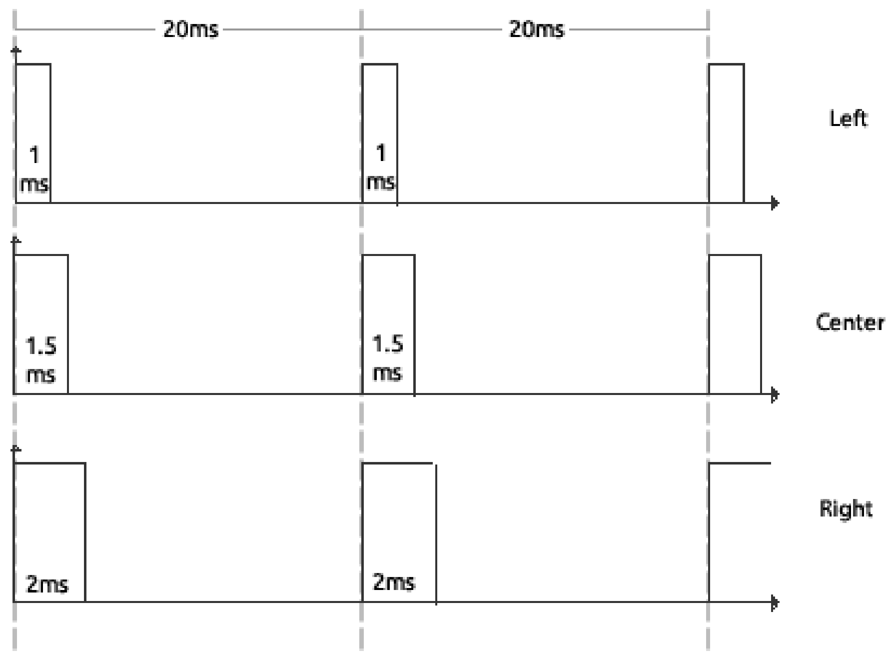
CHAPTER 4

RESULTS AND DISCUSSION

Two types of servo motors are tested for the actuator system of the rope climbing robot. They are G15 Cube Servo motors and Servoking motors. Both are rated to have a very high torque which is about 15 – 20 kg/cm. The high torque makes it possible for both types of the servo motors to be used for the robot. However, there is a main difference between both types. Servoking motors only allow the rotation of angle up to 180˚ but Cube Servo motors allow the angle rotation up to 360˚. From this information, it is known that Servoking motors are only suitable for mechanism that use small angle of rotation while Cube Servo motors are suitable for various angle rotations, especially those that exceed 180˚. This makes Cube Servo motors to be more versatile compared to Servoking motors.

The movement of Servoking motors, like regular servo motors, are controlled using pulse-width modulation. It can be described as the following:

FIGURE 1. SERVO MOTOR CONTROL



G15 Cube Servo motors, on the other hand, have many parameters such as angle, speed and mode that can be controlled through programming. The table below summarises the parameters in the control register of Cube Servo motors that can be controlled by sending certain values:

TABLE 5. VALUES FOR CONTROL REGISTERS

Area	Address (Hex)	Parameter	Read only/ Read Write	Factory default value (Hex)	Minimum value (Hex)	Maximum value (Hex)
EEPROM	0 (0x00)	Model (L)	R	'G' (0x0F)	-	-
	1 (0x01)	Model(H)	R	15 (0x47)	-	-
	2 (0x02)	Firmware Revision	R		-	-
	3 (0x03)	ID	RW	1 (0x01)	0 (0x00)	253 (0xFD)
	4 (0x04)	Baud Rate	RW	103 (0x67)	3 (0x03)	255 (0xFF)
	5 (0x05)	Return Delay	RW	250 (0xFA)	1 (0x01)	255 (0xFF)
	6 (0x06)	CW Angle Limit (L)	RW	0 (0x0000)	0 (0x0000)	1087 (0x043F)
	7 (0x07)	CW Angle Limit (H)	RW			
	8 (0x08)	CCW Angle Limit (L)	RW	1087 (0x043F)	0 (0x0000)	1087 (0x043F)
	9 (0x09)	CCW Angle Limit (H)	RW			
	10 (0x0A)	Reserved	-	-	-	-
	11 (0x0B)	Temperature Limit	RW	70 (0x46)	0 (0x00)	120 (0x78)
	12 (0x0C)	Lowest Voltage Limit	RW	65 (0x41)	65 (0x41)	178 (0xB2)
	13 (0x0D)	Highest Voltage Limit	RW	150 (0x96)		
	14 (0x0E)	Max Torque (L)	RW	1023 (0x03FF)	0 (0x0000)	1023 (0x03FF)
	15 (0x0F)	Max Torque (H)	RW			
	16 (0x10)	Return Packet Enable	RW	2 (0x02)	0 (0x00)	2 (0x02)
	17 (0x11)	Alarm LED	RW	36 (0x24)	0 (0x00)	127 (0x7F)
	18 (0x12)	Alarm Shutdown	RW	36 (0x24)	0 (0x00)	127 (0x7F)
	19 (0x13)	Reserved	-	-	-	-
	20 (0x14)	Down Calibration (L)	R			
	21 (0x15)	Down Calibration (H)	R			
	22 (0x16)	Up Calibration (L)	R			
	23 (0x17)	Up Calibration (H)	R			

For the project, the robot uses a total of two Servoking motors and four Cube Servo motors. This is in line with the requirements of mechanisms of the robot. For the grippers of the robot, one at the front and another one at the back, Servoking motors are used to control them. The Cube Servo motors are used to control the joints of the robot, in which two Cube Servo motors at the centre of the robot are responsible for the most crucial movement of the robot when the robot changes rope from inclined rope to horizontal rope.

The robot was having difficulties to climb the slanting rope in MIRoC (Malaysian International Robot Competition) 2014. The robot is thought to be too bulky and heavy to climb. At the same time, the gripping mechanism of the robot did not have enough frictional force to enable the robot to stay at its current position while climbing the slanting rope. As a result, the robot kept sliding back to a lower position while it was climbing. This is also perhaps due to the heavy nature of the robot. This is because the gripping mechanism designed and fabricated for the robot is thought to be suitable only for robots with less weight and for heavier robots, the gripping system fails to provide sufficient frictional force to prevent the robot from sliding.

That much said, the problems that arise were tried to be solved by manipulating the algorithm of the robot. This was done by changing any movement of the robot through programming where possible to accommodate for the heavy parts of the robot. For example, the front part of the robot was chosen to be the less heavy arm of the robot in hope that it makes the robot possible to climb. However, the problem comes when the heavier arm of the robot tried to move up the rope, where its heavy nature makes it difficult to climb. In the situation where the front part of the robot chosen is the heavier part, the problem that arise was already seen the moment that part tried to move to a higher position, in which the less heavy part of the robot cannot withstand the movement of that heavier part. As a result, the robot still kept sliding while climbing.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The designing of the motorization and electronic circuits of a robot must be done well and systematically in order to have a robot that really operates as intended. Moreover, the robot to be handled in this project is a rope climbing robot. Unlike normal robots that move using tires and wheels, this type of robot in this project is harder to handle because it uses the climbing mechanisms that imitate the climbing movement of people or monkeys. To have a very fruitful result, thorough studies and deep analysis should be conducted. The first version of the robot fabricated seems to fail to climb. A proper analysis should be done to find the roots of the problem and ways to solve it. From the analysis done, improvements can be done so that the rope climbing robot can move more quickly and efficiently.

For future projects, multiple types of mechanisms can be considered for rope climbing robots. With the use of kinematics, the most suitable mechanism to create a very fast robot can be chosen after conducting an appropriate analysis by comparing the capabilities of the possible mechanisms for a rope climbing robot.

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