DEVELOPMENT OF MOTOR SPEED CONTROL SYSTEM BY USING ACCCELERATION CHARACTERISTIC AT FOREARM FOR REMOTE CONTROL CAR

Adam Farhan Bin Mohd Dasril

Bachelor of Mechatronics Engineering

June, 2013

"I hereby declare that I have read through this report entitle "*Development of Motor Speed Control System by Using Acceleration Characteristic at Forearm for Remote Control Car* " and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering"

Signature : ……..

Supervisor's Name : ……..

Date : ……..

DEVELOPMENT OF MOTOR SPEED CONTROL SYSTEM BY USING ACCCELERATION CHARACTERISTIC AT FOREARM FOR REMOTE CONTROL CAR

ADAM FARHAN BIN MOHD DASRIL

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

I declare that this report entitle "*Development of Motor Speed Control System by Using Acceleration Characteristic at Forearm for Remote Control Car*" 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.

Signature : ……..

Name : ……..

Date : ……..

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim,

Alhamdulillah, thanks to Allah SWT, for His blessing in giving me the opportunity, good health and also fresh idea to complete this Final Year Project (FYP). I would like to express my gratitude and appreciation to all those who involve in completing this project. First and foremost, I would like to give my special thanks to Dr. Muhammad Fahmi Bin Miskon, a lecturer Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) who also assigned as my supervisor who had help and guide me a lot during this whole project. He inspired me greatly to work in this project. His willingness to give out the valuable information, suggestions and guidance throughout the process of preparing this Final Year Project is so much enormously helped.

Besides, I also want to express my thanks to the others lecturers and technical staffs of Faculty of Electrical Engineering for their cooperation and also for gave me the permission to use all the necessary tools and machinery to complete my project. Not to forget my special thanks to Mr Zamani Bin Md Sani (FYP1) and Dr. Mariam Binti Md Ghazaly (FYP2) who worked hard and did their job smoothly to make sure that all student get the information for final year project.

My deepest thanks and appreciation to my parent, family, and others for their supports, encouragements, cooperation, and constructive suggestion for the project and report completion from bottom till finish. Last but not least, thanks to all my colleague and friends who had given me idea and support during the whole process in completing this project.

ABSTRACT

Speed control system is one of the systems that play an important role in the modern technologies with the use of actuators such as DC motors. The used of DC motors can be seen on toys like racing cars like remote control car (RC). Therefore, the speed control system is very important in this field because there are many users of this remote control car suffered damage as a result they are not able to control the speed of the toy car and even had to throw it away. Most of the remote control car is designed with speed that is constant and go forward and reverse only. In addition, the present remote control is also designed with a relatively large size and even has a lot of control buttons, thus hindering the users to control them. Therefore, the project is carried out to develop a motor speed control system by using ADXL345 accelerometer sensor that is placed in the forearm so that the motor can generate based on the desired speed when the acceleration features is detected. The relationship between position and distance were also analyzed so that the accelerometer sensor can provide a good input signal. For the motor speed control, PWM techniques (Pulse-Width-Modulation) are used because it is easy to operate. This control system is controlled by relationship where the higher degrees from its origin position (90^0), the faster the speed motor. Performance of the system then analyze in the two experiments. The first experiment is to determine the most suitable position among the five positions from the wrist until Antibranchial muscle (near elbow). While the second experiment, carried out to analyze the relationship between duty cycle and the motor speed rotation. The experiment is done by using different speeds while ensuring that the system is able to function in repeated usage. The results showed that the most suitable position sensor is at position 2 (0.18m from elbow) with the 2^0 angle offset which the minimum for all positions and the system can run with the average accuracy of 56.27% in repeated usage with varying speeds.

ABSTRAK

Sistem kawalan kelajuan adalah salah satu sistem yang memainkan peranan penting dalam teknologi moden dengan penggunaan penggerak seperti DC motor. Penggunaan DC motor dapat dilihat dalam mainan seperti kereta kawalan jauh (RC). Kawalan kelajuan penting kerana terdapat ramai pengguna kereta kawalan jauh yang mengalami kerugian kerana mereka tidak mampu untuk mengawal kelajuan motor kereta kawalan jauh mereka sehingga terpaksa buang begitu sahaja. Kebanyakannya direka dengan kelajuan yang sekata di mana ianya hanya bergerak ke hadapan dan belakang. Alat kawalan jauh juga direka dengan saiz yang besar serta mempunyai banyak butang kawalan, lalu menyukarkan pengguna untuk mengawalnya. Oleh itu, projek ini dijalankan bagi mencipta sistem kawalan kelajuan dengan menggunakan ADXL345 pengesan pecutan yang diletakkan di lengan supaya motor mampu digerakkan berdasarkan kelajuan yang dikehendaki apabila ciri-ciri pecutan dikesan. Hubungan antara kedudukan dan jarak juga dikenalpasti supaya pengesan pecutan boleh memberi isyarat input yang baik. Bagi mengawal kelajuan motor, teknik PWM (Pulse-Width-Modulation) digunakan kerana ia adalah mudah untuk dioperasikan. Semakin jauh sudut darjah dari kedudukan asalnya (90^0) semakin laju motor berpusing. Prestasi sistem kemudian dianalisis dengan melalui dua ujikaji. Pertama, menentukan kedudukan yang paling sesuai antara lima posisi dari pergelangan tangan sehingga otot Antibranchial (hampir dengan siku). Kedua, menganalisis hubungan antara '*duty cycle*' dan kelajuan putaran motor. Ujikaji dilakukan dengan menggunakan kelajuan yang berbeza di samping memastikan bahawa sistem itu dapat berfungsi dengan tepat dalam penggunaan berulang. Hasil kajian menunjukkan bahawa kedudukan pengesan yang paling sesuai adalah pada kedudukan 2 (0.18m daripada siku) di mana 'offset'nya adalah rendah iaitu sebanyak 2^0 sudut dan sistem ini mampu berjalan dengan lancar dengan purata ketepatan sebanyak 56.27% secara berulang kali dengan kelajuan yang berbeza.

LIST OF CONTENTS

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	**i**
	ABSTRACT	**ii**
	TABLE OF CONTENTS	**iv**
	LIST OF TABLES	**vii**
	LIST OF FIGURES	**vii**
	LIST OF SYMBOLS	**x**
	LIST OF APPENDICES	**xi**
1	**INTRODUCTION**	**1**
	1.1 Motivation	1
	1.2 Problem Statement	2
	1.3 Objective	3
	1.4 Scope	3
2	**LITERATURE REVIEW**	**5**
	2.1 Upper Limb Anatomy	5
	2.2 Design of Present or Existing Speed Control	7
	2.2.1 Method of Motor Speed Control	7
	2.2.2 Method of Accelerometer Sensor Positioning	9
	2.2.3 Method of Reducing Noise and Amplify Signal	10
	2.2.4 Selection of Microcontroller	11
	2.3 Performance Analysis	12

	2.3.1 Accelerometer Sensor	12
	2.3.2 Experimental Test Performance	14
	2.3.3 Pulse-Width-Modulation (PWM)	17
	2.4 Summary of Section	18
3	**METHODOLOGY**	**19**
	3.1 System Overview	19
	3.2 Prototype Development	20
	3.2.1 Hardware Selection	20
	3.2.2 Hardware Development Draft	23
	3.2.3 Real Hardware Development	24
	3.2.4 Software (Coding)	25
	3.3 System Flowchart	30
	3.4 Project Setup	31
	3.4.1 Sensing System	31
	3.4.2 Monitoring System and Data Logging	32
	3.4.3 Collecting Data	32
	3.4.3.1 Experiment 1	34
	3.4.3.2 Experiment 2	42
4	**RESULT AND DISCUSSION**	**45**
	4.1 Experiment 1	45
	4.1.1 Position 1	46
	4.1.2 Position 2	47
	4.1.3 Position 3	48
	4.1.4 Position 4	49
	4.1.5 Position 5	50
	4.1.6 G_z Value at All Positions	52
	4.2 Experiment 2	55

5	**CONCLUSION AND RECOMMENDATIONS**	**59**
	5.1 Conclusion	59
	5.2 Recommendation	60
REFERENCES		61
APPENDICES		63

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Elbow movement range	7
3.1	Declaration and initialize the system instruction	26
3.2	PWM motor speed control instruction (mapping)	28
3.3	Smoothing instruction	28
3.5	Conversion of LSB to G Force instruction	29

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	High efficiency DC motor	2
2.1	Degree of freedom (DOF) for upper-limb	6
2.2	Flexion motion for elbow	6
2.3	PWM output current signal	8
2.4	Sensor positioning for method [5]	10
2.5	Arduino Duemilanove microcontroller board[3]	11
2.6	Accelerometer sensor working	13
2.7	Experiment movement in X, Y, Z direction [3]	14
2.8	Accelerometer sensor signal in reaching object experiment [3]	15
2.9	Accelerometer sensor result in lifting object using lower arm (a) and upward reach (b)	16
2.10	PWM timing diagram	17
3.1	Block diagram of the system	19
3.2	ADXL345 accelerometer sensor	20
3.3	ADXL345 function block diagram,	21
3.4	Arduino UNO Rev 3 development board	22
3.5	Hardware development draft	23
3.6	Schematic circuit	24
3.7	Real Hardware development	25
3.8	Function flow chart	30
3.9	Theorem Pythagoras technique to obtain angle	33
3.10	Position involve in sensor positioning	36
3.11	Distance between each positions	36
3.12	0^0 Wrist's sensor position 1	37

3.13	90^0 Wrist's sensor position 1	37
3.14	0^0 sensor position at Position 2	38
3.15	90^0 sensor position at Position 2	38
3.16	0^0 sensor position at Position 3	39
3.17	90^0 sensor position at Position 3	39
3.18	0^0 sensor position at Position 4	40
3.19	90^0 sensor position at Position 4	40
3.20	0^0 sensor position at Position 5	41
3.21	90^0 sensor position at Position 5	41
3.22	Experiment 2 setup experiment	43
4.1	Position 1 result	46
4.2	Position 2 result	47
4.3	Position 3 result	48
4.4	Position 4 result	49
4.5	Position 5 result	50
4.6	Z-axis opposing gravity	51
4.7	Y-axis opposing gravity	51
4.8	Comparison between position 1, 2, 3, 4, and 5 on x-axis	52
4.9	Offset at different position	53
4.10	Comparison of five different position acting on z- axis	54
4.11	Relationship between duty cycle and motor speed for the system	57

LIST OF SYMBOLS

F	-	Force
Vs	-	Voltage supply
m	-	Mass
a	-	Acceleration
k	-	Spring
c	-	Damper
mV	-	milivolt
µA	-	micro ampere
Hz	-	Frequency
g	-	gravitational force
T	-	Period
θ_{xyz}	-	Triple axis's angle
G_y	-	G force for y-axis
G_z	-	G force for z-axis
(^{0})	-	Degree
rad	-	Radians

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Experiment 1 (Position 1)	63
B	Experiment 1 (Position 2)	65
C	Experiment 1 (Position 3)	67
D	Experiment 1 (Position 4)	69
E	Experiment 1 (Position 5)	71
F	Experiment 2	73
G	Full Coding	74

CHAPTER 1

INTRODUCTION

1.1 Motivation

Asian countries had been under pressure for the last two decade due to high energy price. In order to encounter the problem, developing country like Japan had implemented variable speed motor for energy saving [1]. Europe country like America kept on using low cost motor drives which have around 10% lower efficiency than adjustable motor drive for energy saving. Therefore, motor speed control is high demand in lot of industries and used by many applications around the world in order to saving energy and to reduce accident in transportation and manufacturing sector.

To control the speed of the motor, an appropriate motor need to be identified and one of the best motor is Direct Current motor (DC). DC motor nowadays play significant role in modern life where it is applied to many applications in our daily life. DC motor has many advantages such as can provide high starting torque and the speed control is possible to control the speed in variety of speed [2]. Based on the researcher made by Tokai University (2009), DC motor had conversion efficiency of more than 96% [3]. One of the usages applications of DC motor is remote control toys industries like racing cars. Recent studies show that RC cars happen to involve in accident that ultimately damage the car in total when the motor reach its maximum speed. For people who already spent thousands of their money in RC, this is a big problem to them.

DC motor can be control in sensor or sensorless mode. In order to solve the remote control problem where it is heavy and involving buttons and toggle, a speed control system that use sensor in needed. This will contribute a lot to the RC industries.

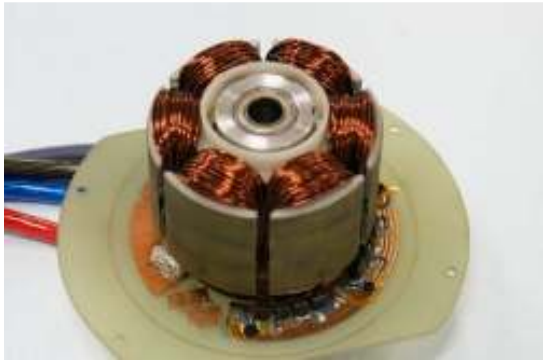

Figure 1.1: High efficiency DC motor

1.2 Problem Statement

In developing the motor speed control system where it need to be control based on the forearm movement, several problem had to be faced on involving the application, sensor positioning, the sensor itself and the whole system. So the first one, the present design remote control for Remote Control (RC) Cars showed that the remote control only control the cars in constant speed (ms^{-1}) and cannot be move in variety of speed. Due to the constant speed in forward and reverse motion of the RC car and its remote control involving button and toggle, it is hard for the player to control the car where make it easier to crash and damage.

In addition, this motor speed control project involved acceleration characteristic at forearm which can be detected by using accelerometer sensor. So, different positions of the sensor based on its distance (m) from the pivot will give different reading of the angle of the arm motion in the repeated usage of the control system which eventually affects the accuracy (degree) of the system.

Moreover, present accelerometer sensor designs which have been used before showed that accelerometer have high sensitivity but the charge or signal produced is very small which in milivolt (mV) range. Due to the Signal-to-Noise ratio of the accelerometer sensor which signal is in small range, milivolt (mV), the signal can easily be distracted by the noise signal. Therefore, an amplifier is needed to amplify the charge or signal of accelerometer sensor for the motor to produce the desired speed.

Nowadays, there are many ways to control the speed of the motor either using open-loop controller or close-loop controller. So, to develop the system where it has the high accuracy and can use in repeated usage, a proper and correct technique is needed. Therefore, the speed control system that be develop is able replace the present design of remote control.

1.3 Objective

This project consists of two objectives;

i. To investigate the relationship between position and distance to find the position of accelerometer sensor for better input signal.

ii. To develop a speed control system using accelerometer sensor ADXL345 at the forearm so that the motor produce the desired speed when acceleration characteristic is detected.

1.4 Scope

In order to achieve the objective of the project, there are several scope had been outlined. The scope of this project were divided into two part based on two objectives state in previous section.

- Find the best position for the sensor
    i. Accelerometer sensor is the only sensor that been test out.
    ii. Focus on lower arm part (0^o until 90^o only).
    iii. Five position for the sensor is been test out from wrist until Antibrachial muscle.
    iv. Project only focuses on Y- and Z- axis with one DOF only.
- Map instantaneous sensor to produce desired motor's speed
    i. External noise and disturbance are neglected.
    ii. Only speed control system is emphasizing in this project, other control system is neglected.
    iii. Project is carry out by develop using sensor, microcontroller, amplifier, filter and AD converter and DC motor

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This section describes some of the important aspect in sensor detecting acceleration characteristics at forearm to give the signal to the system so that the motor will generated desired speed. The first part describes the upper limb of a man, which comprises the motion of shoulder and elbow of human upper limb. Then second part is the description of present or existing speed control that have been tested out before and existing solution for the problem that occurred on sensor implementation, data logging, and position fixed. The third aspect discussed is its performance analysis.

2.1 Upper Limb Anatomy

Human upper limb contain of three parts which are shoulder, elbow and wrist. It consists of seven degree of freedom (DOF): three at the shoulder, two at the elbow and the remaining two at the wrist as shown is Figure 4.1. Since this project focuses on the forearm, the other motions in the upper limb will not be considered in this study. The detail of flexion motion at forearm is shown in Figure 2.1 and Table 2.1.

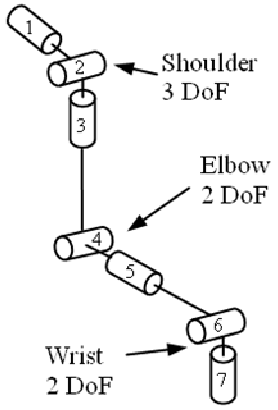

Figure 2.1: Degree of freedom (DOF) for upper-limb

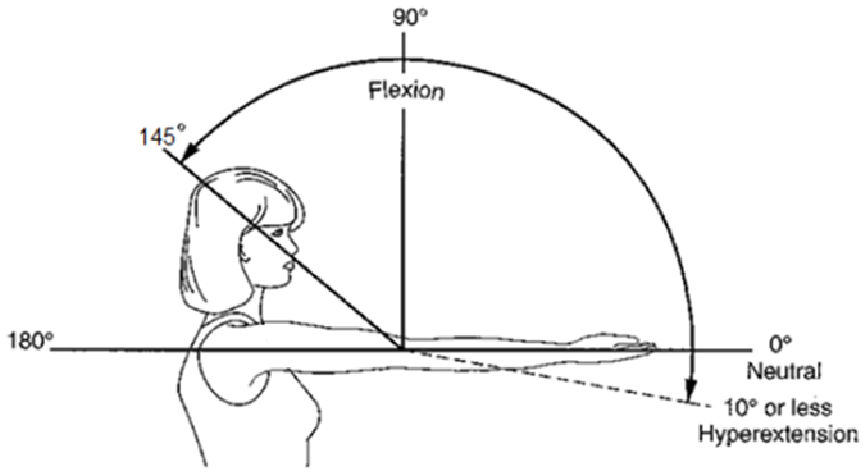

Figure 2.2: Flexion motion for elbow

(Source: http://users.rowan.edu/~stahld07/ rom_lab.html)

Table 2.1: Elbow movement range

Joint/Segment	Movement	Degree (^{o})
		Human
Elbow	Flexion	145
	Hyperextension	0-10

Based on Table 2.1, the elbow flexion motion of human elbow are ranges from -10^0 until 145^0. Therefore, the selected range of flexion motion is from 0^o to 90^o.

2.2 Design of Present or Existing Speed Control

There were several designed which have been tested out before and each design has their own result. The application or material use can affect the final result of the whole system. This part is included of method to control the motor speed, sensor positioning, method to reduce noise and microcontroller selection.

2.2.1 Method of Motor Speed Control

Variety speed of a motor can give a lot of benefit to mankind but to do so, a good speed control system is needed. There are affective ways on how to control motor speed especially for DC motor and each one of them has their own advantages and disadvantages.

One on the method that can be use is using the Pulse-Width-Modulation technique. Qiang Li et. al [4] control the speed of a motor by using Pulse-Width-Modulation (PWM) technique where they control the duty cycle of the power (voltage and current). Six theory of PWM method were present in this research and some of them are H_PWM_L_PWM and PWM_ON where they control the digital signal by on and off the system to produce the desired speed.

Based on their researcher, it proved that PWM technique is an effective control system where it has widely used around the world. Besides, this method control the speed of the motor in an easy way and its efficiency is up to 90%. Furthermore, it can also save the cost because it has the high power handling capability. The output for this method is shown in Figure 2.3 below.

As a conclusion, this method has good capability and effective to control the speed of the motor and it even has some credit for its simplicity and it is easy to operate where it can reduce the time taken to develop the system.

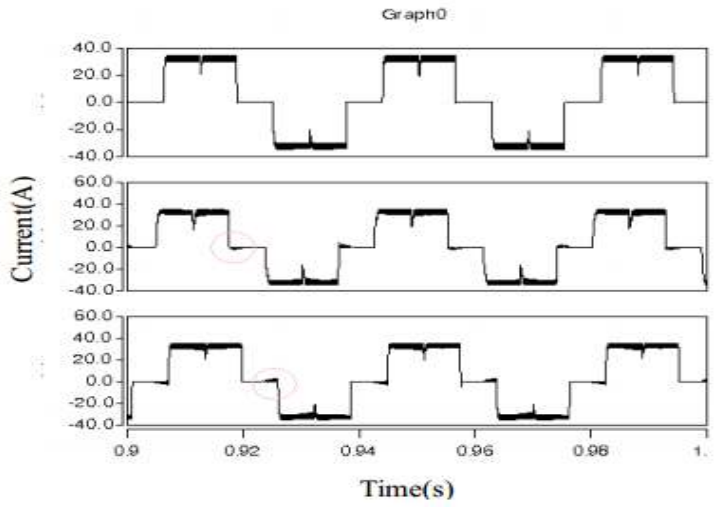

Figure 2.3: PWM output current signal [4]

2.2.2 Method of Accelerometer Sensor Positioning

In order to position the accelerometer sensor, previous researcher had carried out their design and come out with advantage and disadvantages in each design.

For the method 1, Radzi Bin Ambar et.al [5] had position their ADXL335 accelerometer sensor at forearm without mention any specific position because accelerometer sensor is an ideal sensor in term of inclination relative to the group. In this case, any position of the sensor should give good input signal for the system. In order to fix the accelerometer sensor position, a Velcro strap is use on the arm. For the method 2, M. S. Ahmad et.al [7] had position their ADXL335 accelerometer sensor at the wrist as shown in Figure 2.4 because wrist's inclination help the reading of the input signal to be more accurate. They use Velcro straps in order to fix the sensor. On the other group, Julie Hollander and P. Hunter Peckham [6] had position the micro machined silicon accelerometer near the elbow because they state that the magnitude of the component gravitational acceleration vector can be measured directly using accelerometer sensor.

Based on these three methods, method [5] and [7] can give more accurate result because the positions have flat surface area but the material use is quiet expensive. In contrast, method [6] is inexpensive but it cannot generate accurate reading because muscle near the elbow have incline surface when the contraction of the muscle during hand movement and can affect the input signal.

As a conclusion for the accelerometer sensor positioning, it is hard to find a method that the accuracy is acceptably good but at the same time had low cost. In overall, method [5] and [7] can be use to achieve the objective but the ADXL335 accelerometer sensor need to be change to reduce the cost.