MOBILE BALANCING ROBOT WITH TWO WHEELS

MOHD FIJAM BIN ABDUL HALIM

DEGREE OF BACHELOR OF MECHATRONIC

2010

"I hereby declare that I have read through this report entitled "Mobile Balancing Robot With Two Wheel" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Mechatronic)"

Signature	:	....
Supervisor's Name	:	MAZREE BIN IBRAHIM
Date	:	12/05/2010

MOBILE BALANCING ROBOT WITH TWO WHEELS

MOHD FIJAM BIN ABDUL HALIM

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APRIL 2010

I declare that this report entitle "Mobile Balancing Robot with Two Wheel" 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 : MOHD FIJAM BIN ABDUL HALIM

Date : 22 APRIL 2010

To my beloved mother, father and all praise to God almighty

ACKNOWLEDGEMENT

In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my project supervisor, Mr. Mazree Bin Ibrahim, for encouragement, guidance critics and friendship. I am also very thankful to my main evaluation panel member Mr. Aminurrashid Bin Noordin for his guidance, advices and motivation. Without their continued support and interest, this project would have not been the same as presented here.

My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members

ABSTRACT

This project is about designing and implementing brushless DC motor as balancing control for two wheel mobile robots. Usually two wheel balancing robot use drive torque control to balance the robot. By controlling drive torque, the robot abilities to accelerate and change direction freely are limited. Implementing brushless DC motor as balancing control will improve the mobility aspect. In this project brushless DC motor will act as balancing control by correcting the tilt angle of robot body so the balance equation can work. Accelerometer is used to sense tilt and indicate position of robot relatively to the floor. This robot is used line tracking sensor to move and change direction of robot. PIC controller is used as the main controller system.

ABSTRAK

Projek ini adalah mengenai reka cipta dan implementasi brushless DC motor sebagai mekanisme pengimbang untuk robot mudah bergerak dua tayar. Biasanya robot pengimbang dua tayar menggunakan kawalan daya pandu untuk imbangkan robot. dengan mengawal daya pandu, keupayaan robot umtuk memecut dan mengubah arah sesuka hati terhad. Implementasi brushless DC motor sebagai pengawal imbangan akan menambah baik aspek kemudahan bergerak. Dalam projek ini, brushless DC motor akan berfungsi sebagai pengawal imbangan dengan membetulkan darjah kecondongan badan robot supaya persamaan imbangan berfungsi. Accelerometer digunakan untuk mengesan kecondongan dan menentukan posisi robot dari permukaan lantai. Robot ini menggunakan pengesan garisan untuk bergerak dan mengubah arah. Pengawal PIC digunakan sebagai system kawalan utama.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

T	-	Torque
M	-	Moment of arm
g	-	Acceleration of gravity
θ	-	Angle
ω	-	Angular rate
Kω	-	Factor based upon robot mass and moment arm
K	-	Gain
m	-	Mass
h	-	Height
l	-	Length
r	-	Radius
d	-	Diameter
m	-	Meter
Kg	-	Kilogram
F_g	-	Force due to gravity
F_p	-	Force exerted on the effectors by the environment
w	-	The *x*-coordinate of the wheel
C	-	The *x*-coordinate of the mass of the robot body

S_x, S_y	-	The x and y coordinates of the robot shoulder
V_{dd}	-	Positive supply voltage
Rad	-	A unit of plane angle, equal to $180/\pi$ (or $360/(2\pi)$) degrees

LIST OF ABREVIATIONS

EMF	-	Electromagnetic force
AVR	-	Modified Havard architecture 8-bit RISC
DC	-	Direct current
SSC2	-	Pulse proportional serial servo controller
PID	-	Proportional, integral, derivative gain
DSP	-	Digital signal processor
IMU	-	Inertial measurement unit
GC	-	Gravity center
C	-	General purpose computer language
IFC	-	Interface free controller

LIST OF APPENDICES

ACKNOWLEDGEMENT

In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my project supervisor, Mr. Mazree Bin Ibrahim, for encouragement, guidance critics and friendship. I am also very thankful to my main evaluation panel member Mr. Aminurrashid Bin Noordin for his guidance, advices and motivation. Without their continued support and interest, this project would have not been the same as presented here.

My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members

CHAPTER 1

INTRODUCTION

The "Balancing Mobile Robot with Two Wheel" project is to identify and developed a self balancing robot using brushless DC motor as balancing mechanism. The brushless DC motor will be used to balanced robot while moving and in static position. This chapter will discuss about the background of the project, objective, scope of the project and problem statement.

1.1 Background of the project

Balancing robots usually use motor drive torque and act as inverted pendulum to balance itself. The basic idea for a two wheeled dynamically balancing robot is simple: drive the wheels in the direction that the upper part of the robot is falling [1]. Most of the balancing robot used motor drive torque control and body postural control to balance the robot which is restricted the usage of motor drive. Implementation of a brushless DC motor as balancing mechanism is to remove the restriction on motor drive so that the robot can move freely and utilized the drive motor full potential.

1.2 Problem Statement

A major disadvantage of two wheel robot compare to three or more wheeled robot is that control effort is always required for dynamic balancing which is usually balanced use drive motor torque control. The use of drive motor is limited in order to keep the robot balanced. Hence, the implementation of brushless DC motor as balancing mechanism can remove the restriction on drive motor of two wheeled balancing robot. However there are a few problem surfaces in order to implement the brushless DC motor as balancing mechanism. The problems occurred are:

i. Inertia effect when robot start and stop moving: counter act the force using inverted pendulum
ii. Acceleration and deceleration effect on robot balance: counter act the force using inverted pendulum
iii. The time taken for brushless DC motor to act before robot completely fell down: increase or decrease speed of brushless DC motor

All of these problems have been overcome in order to succeed the implementation of brushless DC motor as balancing mechanism.

1.3 Objective

The main objective of this project is to apply linear actuator as balancing mechanism for two wheel mobile robots. In order to verify linear actuator capability as balance mechanism, the robot will be balanced while static and moving using linear actuator. The specifics objectives of this project are:

i. To implement brushless DC motor as balancing mechanism
ii. To analyze the effect of drive motor speed on robot
iii. To analyze the contra and pro between drive motor balancing and separated balancing mechanism.

1.4 Scope

The scope of this project is to implement brushless DC motor as balancing mechanism and the explanation of the two wheel robot design, system, function and result of the implementation. In general, at the end of this project will determine the compatibility of brushless DC motor as balancing mechanism.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a review of previous research project that are related of this project will be discussed. The theory and method use for drive motor torque control and body postural control are also described in this chapter.

2.1 Previous Project

2.1.1 Gyrobot – A Two Wheel Balancing Robot

Gyrobot was build by Larry Barello based on Atmel AVR series of microcontroller for AVR tool product development. This project using drive motor torque control to balance robot by counteract force of base. Basically the angle of tilt is multiply with a factor and uses that value to drive the wheels. The base of robot will balance with appropriate factors. This robot build based upon the AVR Robot Controller board (ARC 1.0) which is based upon the Atmel at90s8535 processor. Gyrobot used a BEI Systron/Donner gyroscope to measure the angular displacement from vertical that indicate the rate of turn. Angular displacement at any given moment of time can be found by integrating the rate of turn. Gyroscope used has a drift of 0.05 deg/sec over 100 seconds. The solution to drift is to use an absolute tilt device, such as Analog Device ADXL2002 accelerometer which is very sensitive to acceleration and only give an accurate indication of down (acceleration due to gravity) when the rest of platform is stable. The basic idea is to use tilt sensor to adjust the integrated rate of gyro data when the system is at equilibrium. Drive motor of Gyrobot is control base on the velocity or position of the base relative to the ground determined with Quadrature encoders on both wheels.

The main theory to balance Gyrobot is to use drive motor torque to counteract the force apply by base. Angle in the balance torque equation is deviation from balance point.

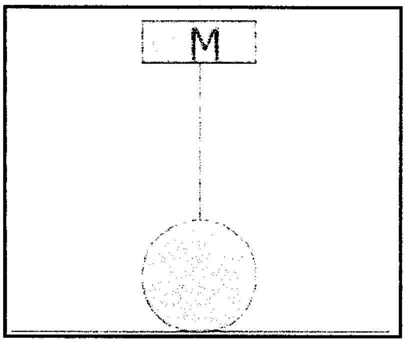

Figure 2.1: Balanced position of robot

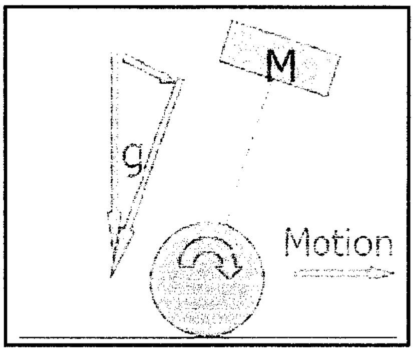

Figure 2.2: Tilted position of robot

Balance torque, $T = Mg \sin \theta$ (2.1)

Restoring torque = ω $K\omega$ (2.2)

Drive motor torque control needed to move the Gyrobot. In this case, the Gyrobot use positive velocity feedback to overcome back emf problem as the velocity increases, DC motors have less torque. Balance angle need to be adjusted by adding an error to the angle, where the robot will drive a little backwards then forwards trying to maintain the balance angle. Error can be simply a negative drive value. Intermediate solutions is applied to determining the tilt of the platform by simply filter the rate gyro and tilt sensor outputs and remove what is undesirable and sum the results to achieve a wide bandwidth, low or no drift indication of current tilt. The undesirable outputs are motion induced acceleration in the tilt sensor and long term drift in the rate gyro. The current algorithms in Gyrobot only use the integrated output of the rate sensor to provide tilt information. This is good for several minutes until the angular offset becomes too large for the robot and it falls over. The current Gyrobot algorithm is:

$$T = \theta_{error}\,(K\theta+\omega)(K_{rate} + v_{error})(Kv + \text{integrated } v_{error})Kv \qquad (2.3)$$

Velocity error is the difference between the commanded velocity and the actual velocity and integral velocity error is an accumulation of velocity error used to maintain the forward velocity over uneven terrain

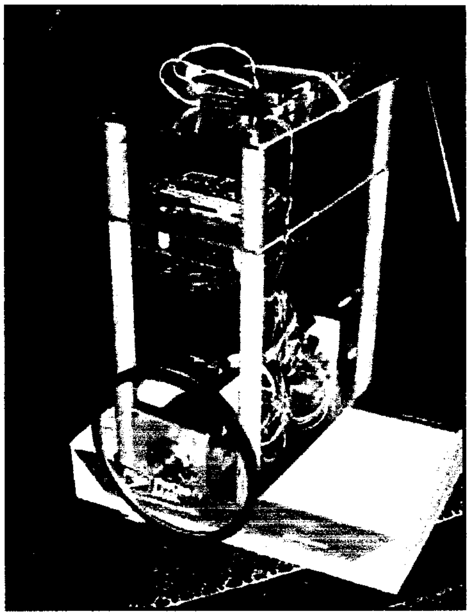

Figure 2.3: Gyrobot

2.1.2 Inverted Pendulum Balancing Robot

This robot was build by Daniel Bauen and Brent Ziegler for a senior mechanical engineering robotics class at the Woodruff School of Mechanical Engineering, Georgia Institute of Technology. The robot balances on two wheels, relying on the inverted pendulum dynamics. A Parallax brand Basic Stamp 2SX was used to control the robot. The Basic Stamp is a very simple microcontroller and is programmed using Basic. The motor speed commands send by Basic Stamp in a serial format to the SSC2. The angular position of the robot relative to gravity is measured by a potentiometer with a feeler attached to its dial that senses the position relative to the floor. Therefore the robot must currently be on a level surface to balance properly. However the potentiometer cannot simply be connected