BALANCING ROBOT

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This report is submitted in partial fulfillment of the requirements for the award of
Bachelor of Electronic Engineering (Industrial Electronics) With Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

APRIL 2009

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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DEDICATION

For the viewing of :

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ACKNOLEDGEMENT

Assalamualaikum W.B.T

First of all I would like to thank Allah S.W.T for giving me His blessing. With His Generous and Kindness I was able to completely finish writing this report successfully.

I would also like to extend my deepest gratitude to my supervisors, Mr. Khairuddin Bin Osman for his consistent supervision, guidance, support, and encouragement throughout this project.

My highest appreciation goes to my beloved parents and family members for giving me their full supports and prayers during my studies at Universiti Teknikal Malaysia Melaka This also goes to all of my beloved friends for giving me their full commitment and their best effort.

Last but not least, my deepest gratitude goes to all the person who involve directly and indirectly to contribute in completing this project. May Allah bless us all with His Love and Kindness. Thank you.

ABSTRACT

Modern control engineering is closely related to electrical, electronic and computer engineering. This is because, electronic circuits can be easily described using control theory techniques. There are lots of control techniques nowadays used to control system whether it is stable or not. Inverted pendulum is a typical example of an unstable control system and has been used for educational purposes by many researchers throughout the world. Therefore, the main objective of this project was to design and fabricate a robot capable of sustaining a vertical orientation by balancing on only two wheels. The balancing robot is a highly unstable two wheeled robot where the largest mass which is the battery pack, will be positioned high above the axle, making the robot similar to an inverted pendulum with a low natural frequency. The robot will naturally tend to tip over, and, the further it tips, the stronger the force causing it to tip over. By using appropriate system controller and sensors, stability of the robot will be achieved.

ABSTRAK

Kawalan kejuruteraan moden adalah berkait rapat dengan kejuruteraan elektrikal, kejuruteraan elektronik dan juga kejuruteraan komputer. Ini kerana, litar elektrik dan elektronik boleh digambarkan melalui teknik teori kawalan. Kini, terdapat pelbagai teknik kawalan yang digunakan untuk mengawal sesebuah sistem sama ada sistem tersebut stabil ataupun tidak. Pendulum songsang adalah satu contoh mudah sistem kawalan yang tidak stabil dan ia kini sering diguna pakai oleh para pengkaji seluruh dunia. Oleh itu, objektif utama projek ini adalah untuk mereka dan memfabrikasi sebuah robot yang berupaya untuk menahan kedudukan menegak dengan mengimbangkan kerangkanya dengan hanya 2 tayar. Robot imbangan ini, adalah sebuah robot yang tidak stabil dimana, bebannya iaitu bateri diletakkan diparas atas gandar, membuatkan robot tersebut menyerupai pendulum songsang dengan frekuensi natural yang rendah. Robot tersebut, akan sentiasa berkeadaan untuk jatuh dan semakin jauh ia condong semakin kuat dayanya untuk jatuh. Namun dengan menggunakan sistem kawalan dan pengesan yang sesuai, kestabilan robot tersebut akan dapat dicapai.

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CHAPTER 1

INTRODUCTION

1.1 Project Introduction

A robot is a mechanical or virtual artificial agent. In practice, it is usually an electro-mechanical system which, by its appearance or movements, conveys a sense that it has intent or agency of its own. The word robot can be refer to both physical robots and virtual software agents. The robot has been used despite of human itself because of it numerous advantages compare to human. Their accuracy, functionality and reliability have been a special features for the robot that lead to a usage of robot in most of applications. The robot can help human to achieve what is cannot be achieved by human itself such as working in a hazardous location and in a danger situation.

In this thesis, the key topics related to balancing a two-wheeled autonomous robot will be discuss. The two-wheeled autonomous robot is a highly unstable robot. The advantages of a two-wheeled autonomous robot are the flexibility and maneuverability over unpaved terrain, small holes or obstacles comparing with other 3 point based supporting robot.

Beside that, a two wheeled balancing robot is also a good platform for researchers to investigate the efficiency of various controllers in control system. Some examples of good control system which was usually used are Linear Quadratic Regulator, Pole-Placement Controller, Fuzzy Logic controller, Proportional Integrated Derivative Controller and others.

In this research, the theory of an inverted pendulum will be used. The robot wheels are independently capable to rotate in two directions, each driven by a DC motor to prevent the tipping. The largest mass which is the battery pack will be positioned high above the axle, making the robot similar to an inverted pendulum. The robot will naturally tend to tip over, and, the further it tips, the stronger the force causing it to tip over.

From figure 1.1, we can see that the angle of the robot relative to the robot original axis was measure using a sensor. The precise type of sensor that will be used is a linear potentiometer. The measured tilted angle will then send to the PIC microcontroller. The PIC microcontroller was used to process the data from the sensors to control the motors accordingly in order for the robot to be balance.

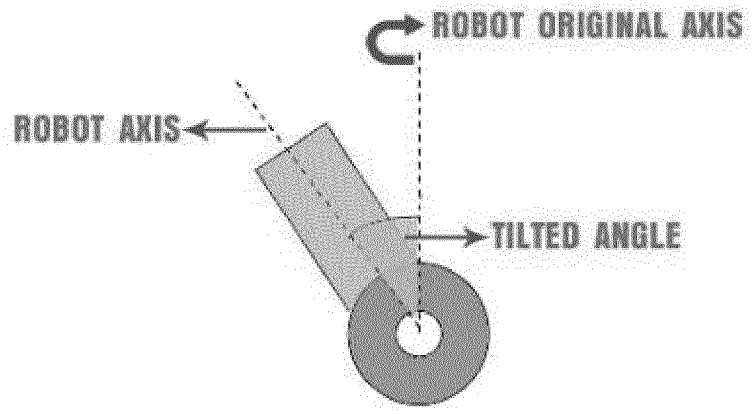

Figure 1.1 : Balancing Robot Axis

1.2 Project Objectives

The main objective of this project is to design and fabricate a two-wheeled autonomous robot which has the ability to balance itself on a flat terrain. This means that, when the robot is switch ON, it will be able to control itself so that it will not fall to the ground by moving forward or reverse.

To achieve this, good and powerful control system algorithm systems need to be used in order to smoothen the robot ability to balance. The most commonly used control system will be implemented which is the Proportional Integrated Derivative Controller system. This second objectives was to study the performance of a digital PID control system for the balancing system.

The last objectives of the thesis are to studies an inverted pendulum concept robot. Even though there have been many researches done on this topic, the main aim is to control the robot inexpensively and effectively without sacrificing the robustness and reliability of the system controller.

1.3 Project Problem Statement

By referring to the previous research done by other researcher, several difficulty can be noticed. It is important to seek out these problems to prevent fatal errors while the project was being done. Besides that, if action was taken to prevent the errors, the project will be done successfully according to the given time frame.

This project will focus on how to control the movement of the robot so that it can balance the pendulum based on sensor input and the physical design of the robot itself. This is because, the environment itself may cause the balancing robot to be unstable even though the simulation of the program control shows differently.

1.4 Project Work Scope

The project work scopes are all about the concern area in order to accomplish the project objectives. For this project, the scope which needed to follow are as follows :

a) To fabricate a two wheels robot.
The structure of the robot must be symmetrical and the center of the gravity of the robot must be higher.

b) To balance a two wheels robot by using the inverted pendulum concept.
Do a research, analyze the information and make problem solving for project development.

c) To figure out the best way and good control system to balance the robot itself base on sensor input.
Pick the best system controller to be applied to the robot.

d) Learnt to configure the PIC microcontroller
Design a control system to communicate between the sensor and the motor to stabilize its chassis.

1.5 Thesis Structure

This report contains of five chapters that explain the details about this project. The first chapter is the project introduction. This chapter contain of project introduction, project objectives, project problem statement, and project work scope.

The second chapter is the literature review which contains the findings of the research regarding the topic of two wheeled balancing robot. The project concept that will be done was explain briefly in this chapter such as the types of sensor, system controller, types of actuator, micro controller and others.

The third chapter is the Project Methodology. This chapter will explain the project framework from the beginning until it is completed. Flowchart for each of the development was attached for better understanding.

The fourth chapter will be on the chassis/hardware development part. In this section, the chassis design and the final product development was stated. Next, the fifth chapter will be on the circuit development. Here, the process of designing and developing the circuit will be stated. Then, the 6^{th} chapter will be the software developing section. This section will tells us the controller system used for the robot. The seventh chapter is the robot development section. The final development of the project will be included in this section.

The eighth chapter will be the results and discussion. This chapter will show that what have been done for this project and also problems and solution occurs during the period of fabricating and development of the project.

The last chapter is about project application of the project, discussion and conclusion of the project. This chapter also contain of suggestion to improve this project for future works. The overall conclusion of this project showed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Over the last decade, the research on balancing a two-wheeled autonomous robot has really gained momentum and attracted many researchers or robotics enthusiasts from around the world. Therefore, prior to undertaking research projects on balancing a two-wheeled autonomous robot, conducting a literature review is critical as this will provide much needed information on the technology available and methodologies used by other researches. This chapter will provides the summary of several research on key topics related to balancing a two-wheeled autonomous robot from around the world and research findings from reading, observing and information seeking.

2.2 Inverted Pendulum Concept

An inverted pendulum (also called a cart and pole) consists of a thin rod attached at its bottom to a moving cart. Whereas a normal pendulum is stable when hanging downwards, a vertical inverted pendulum is inherently unstable, and must be actively

balanced in order to remain upright, typically by moving the cart horizontally as part of a feedback system.

The inverted pendulum is a classic problem in dynamics and control theory and widely used as benchmark for testing control algorithms. Variations on this problem include multiple links, allowing the motion of the cart to be commanded while maintaining the pendulum, and balancing the cart-pendulum system on a seesaw. The inverted pendulum is related to rocket or missile guidance, where thrust is actuated at the bottom of a tall vehicle. The largest implemented use is on huge lifting cranes on shipyards. When moving the shipping containers back and forth, the cranes move the box accordingly so that it never swings or sways. It always stays perfectly positioned under the operator even when moving or stopping quickly [12].

Another way that an inverted pendulum may be stabilized, without any feedback or control mechanism, is by oscillating the support rapidly up and down. If the oscillation is sufficiently strong (in terms of its acceleration and amplitude) then the inverted pendulum can recover from perturbations in a strikingly counterintuitive manner. If the driving point moves in simple harmonic motion, the pendulum's motion is described by the Mathieu equation [12].

In practice, the inverted pendulum is frequently made of an aluminum strip, mounted on a ball-bearing pivot; the oscillatory force is conveniently applied with a jigsaw. Figure 2.1 shows the example of and inverted pendulum.

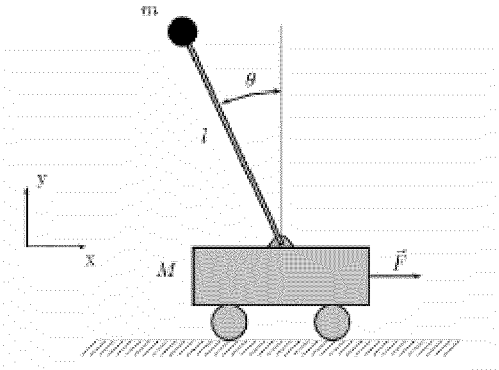

Figure 2.1: Example of Inverted Pendulum Cart

2.3 Balancing robot

In the recent years, researchers have applied the idea of mobile inverted pendulum model to various problems like designing walking gaits for humanoid robot, robotic wheelchairs and personal transport system. Below are several researches that has been done by other researches from around the world.

Researchers at the Industrial Electronics Laboratory at the Swiss Federal Institute of Technology have built a Digital Signal Processor control two wheeled robot (JOE) (figure 2.2), based on the inverted pendulum with weights attached to the system to simulate a human driver. A linear state space controller utilizing sensory information from a gyroscope and motor encoders is used to stabilize this system. This robot is able to traverse on all terrain. The direction of robot can be controlled by using RC remote control [2].

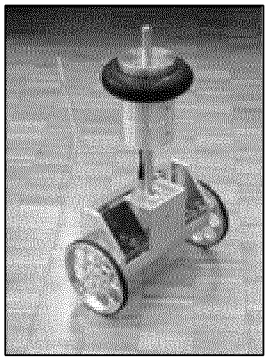

Figure 2.2 : JOE

Another good example is the NBot (figure 2.3), a two-wheeled balancing robot similar to JOE built by David .P Anderson, this robot uses a commercially available inertial sensor and position information from motor encoder to balance the system. NBot is able to traverse on all terrain and the direction of the robot is programmed [7].

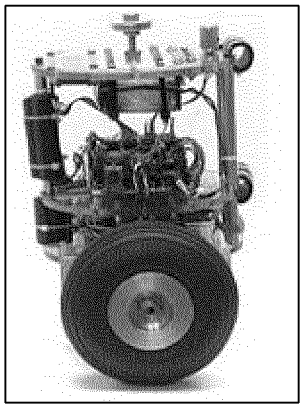

Figure 2.3 : NBot

Steven Hassenplug has successfully constructed a balancing robot called Legway (figure 2.4) using the LEGO Mindstorms robotics kit. Two Electro-Optical Proximity Detector (EOPD) sensors are used to provide the tilt angle of the robot to the controller. Steven Hassenplug is using BrickOS, a C/C++ like programming language specifically for LEGO Mindstorms to control the robot [8].

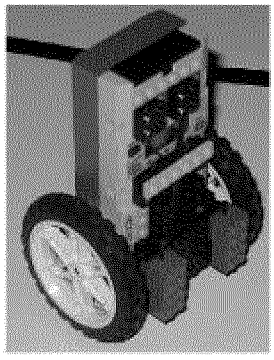

Figure 2.4 : Legway