INVERTED PENDULUM 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
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30 April 2009

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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : **INVERTED PENDULUM ROBOT**

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Dedicated to ***my mother*** *and* ***my late father***

ABSTRACT

Inverted pendulum is a typical unstable system and has been used for educational purposes to understand the process design of an automatic control system in most universities in the world. Nowadays, many researchers utilizing the balancing robot control theory technique to make creative inventions. Two wheeled balancing robots that are becoming more popular due the advantages of a two wheeled balancing robot that are the flexibility and maneuverability over unpaved terrain, small holes or obstacles comparing with other 3 point based supporting robot. Analysis, design, and control of the inverted pendulum are simple but it can be the basic knowledge that are useful to analyze the complex systems such as balancing robot, the movement and the smoothness operation of the robot. Therefore, in this project, it will focus on how to balance a two wheel robots that has a platform above. The platform height is defined from the centre of the wheel. The robot is using microcontroller PIC16F877A as the brain of the robot and application software based on C language has been designed to enable user control this robot. Generally, the robot control algorithm is designed so that the robot is able to move forward by using the dc motors.

ABSTRAK

Pendulum songsang merupakan satu sistem yang tidak stabil yang kebanyakan universiti seluruh dunia menggunakannya sebagai bahan pembelajaran tentang proses rekabentuk sistem kawalan automatik di dalam kuliah atau makmal-makmal. Pada zaman ini, banyak penyelidik sedang menerokai teori-teori tentang kawalan sistem untuk mencipta sesuatu yang kreatif. Robot Keseimbangan beroda dua mempunyai kebaikannya sendiri seperti mempunyai keupayaan untuk melintas di atas permukaan yang tidak rata berbanding dengan robot yang mempunyai tiga titik sokongan sebagai struktur bawahannya. Maka, dalam kajian ini akan memfokuskan tentang bagaimana hendak mengawal kestabilan suatu robot yang mempunyai pelantar dengan ketinggian tertentu dengan hanya menggunakan dua buah roda sahaja. Dengan menggunakan mikro pengawal PIC16F877A sebagai otak kepada robot ini dan Melalui komputer,satu aturcara aplikasi menggunakan bahasa C telah dihasilkan untuk membolehkan pengguna mengawal alat kawalan ini.. Secara umumnya algoritma robot ini direka,untuk membolehkannya bergerak ke depan dan belakang dengan keupayaan dua buah motor.

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3 DESIGN AND CONSTRUCTION ROBOT

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LIST OF ABBREVIATIONS

PIC	-	Programmable Interrupted Controller
DC	-	Direct Current
PCB	-	Printed Circuit Board
CG	-	Centre Gravity
PLC	-	Programmable Logic Controller
CCD	-	Charged Coupled Device
I/O	-	Input/ Output
CPU	-	Central Processing Unit
GUI	-	Graphical User Interface
ADO	-	Applications and a Complex Database Object Library
IDE	-	Interactive Development Environment
RAD	-	Rapid Application Development
COM	-	Component Object Model
DCOM	-	Distributed
ADC	-	Analog to Digital Conversion
UV	-	Ultra Violet

LIST OF APPENDICES

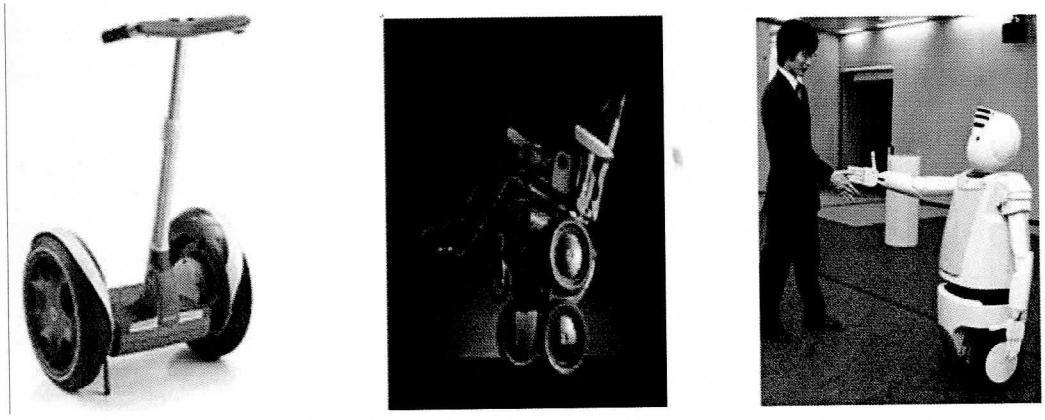
CHAPTER 1

INTRODUCTION

1.1 Project Background

The inverted pendulum robots have gained momentum over the last decade in a number of control and robotics research groups around the world. The advantages of a the inverted pendulum robot are the flexibility and maneuverability over unpaved terrain, small holes or obstacles comparing with other 3 point based supporting robot. Beside that, two wheeled balancing robot is a good platform for researchers to investigate the efficiency of various controllers in control system. The research on two wheeled balancing robot is based on inverted pendulum model. Therefore, a two wheeled balancing robot needs a good controller to control itself in upright position automatically. Nowadays, various types of controllers were implemented on two wheeled balancing robot for examples Linear Quadratic Regulator, Pole-Placement Controller, Fuzzy Logic controller, Proportional Integrated Derivative Controller. Such robot are characterized by the ability to balance on its two wheels and spin on the spot. This additional ability allows easy navigation on various terrains and traverse small steps or curbs. These capabilities have the potential to solve a number of problems and challengers in society and industrial. For example, in USA they are utilizing this technology to invent a motorized wheelchair. This motorized wheelchair would help the

disable people to move around all various types of terrain like slope and stair by just pressing a navigation button. Beside that, this technology also implemented in a personal vehicle called 'SEGWAY', it helps humans to travel short distances in a small area, university, factories as opposed to using cars which is more polluting [1]. Further more, this technology also implement in entertainment field. Hitachi Company was implementing this technology in designing a two wheeled humanoid robot called "E-MIEW" in 2 years ago [1].



(a) (b) (c)

Figure 1.1: The Application of Balancing Robot. (a) Segway (b) Robotic Wheelchair (c) Entertainment Robot, E-MIEW Hitachi

1.2 Project Objective

1. To understand the concept and theory of two-wheeled balancing robot.
2. To learn PIC characteristic and programming.
3. To design and write the control algorithm for the robots.
4. To understand the working mechanism of two-wheel balancing robot.
5. To design a two-wheeled robot circuit that has self-balancing mechanism.

1.3 Problem Statement

Stability problem arises in the inverted pendulum robot. By creating a good control system, the stability problem in the pendulum can be solved. This project will focus on solving the stability problem using a closed loop system controlled by PIC. The inverted pendulum problem in dynamics and control for testing control algorithms and upgrade the simple design to provide better for human.

1.4 Project Scope

The scope of work is very important for the execution of a project or a thesis. In this project, this section is divided into four sections.

1. Inverted Pendulum Robot Research
   (a) To search for information in books, internet sources and others.
   (b) To analyze the information and make problem solving for the project development.

2. PIC Programming
   (a) To create the programming syntax language using C language.
   (b) To design the software to implement in the microcontroller for stabilizing the balancing robot.

3. Inverted Pendulum Robot Construction
   (a) To design simulation circuit design by using circuit maker, Proteus and another software.
   (b) To design an electronic circuit for the robot to interface the sensor inputs and DC motors to the microcontroller.

1.5 Thesis Layout

Chapter 1 is about the balancing robot project background, objectives and scope of project. Thus, the reader will have a brief idea on this project.

In chapter 2, it will provide the summary of literature reviews on key topics related to balancing a two-wheeled autonomous robot.

In chapter 3, the balancing robot design and construction project overview will be discussed and how to build the structure of two wheeled balancing robot and material selected. Beside that, the design of the main controller circuit and other peripherals interface circuit of the balancing robot will be discussed and discuss about the programming aspect of the project.

In chapter 4, the result of each experiment test and the whole achievement of the project will be discussed. Lastly, Chapter 5 will discuss about the conclusion of this project and suggestions for future research.

1.6 Methodology of Project

1.6.1 Brief insight of the Inverted Pendulum Robot project

Literature review prior to undertaking research projects is critical as this will provide much needed information on the technology available and methodologies used by other research counterparts around the world. All the information about Inverted Pendulum Robot was gathered from books, journal, paper work from internet and other sources. All the information is useful to construct the inverted pendulum robot.

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1.6.2 Project Methodology Flow Chart.

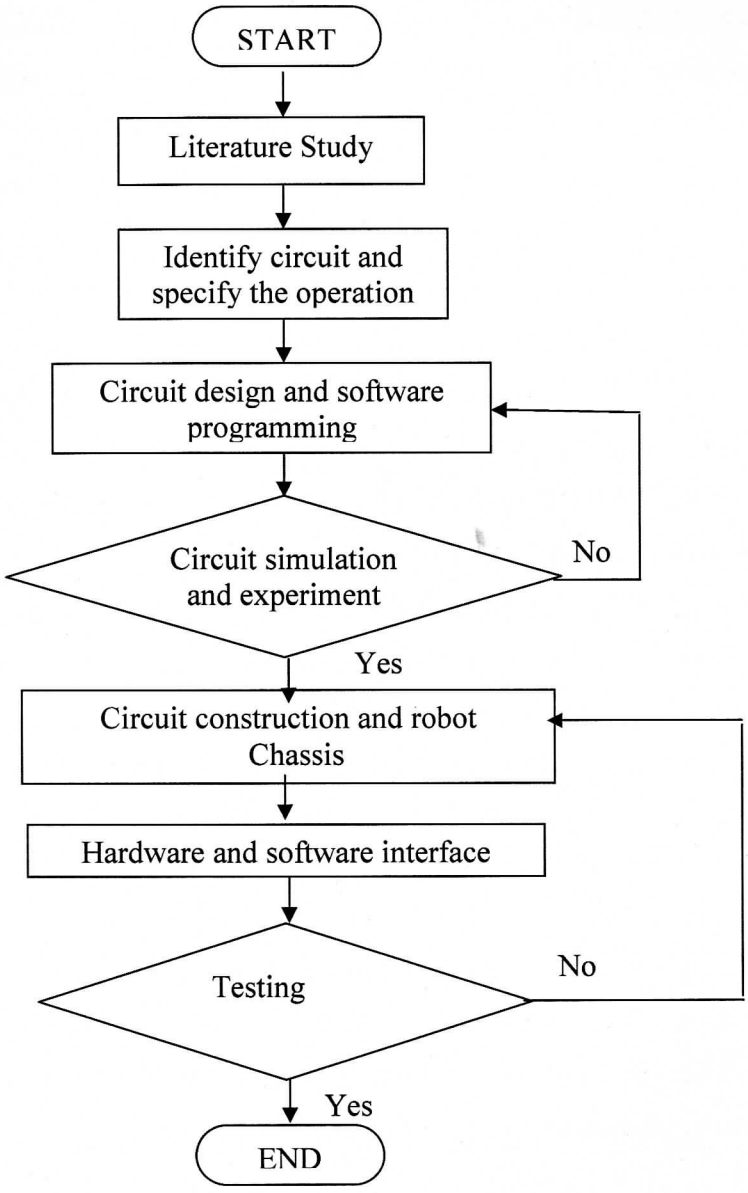

Figure 1.2: Project Methodology Flow Chart

1.6.3 Explanation about the Project Methodology Flow Chart

Firstly, Literature review prior to undertaking research projects is critical as this will provide much needed. All the information about Inverted Pendulum Robot was gathered from books, journal, paper work from internet and other sources. All the information is useful to construct the inverted pendulum robot. Beside that, analyze the information and make problem solving for the project development. Then, Identify involves the circuit for electronics component selections and specify the operation. After that, Circuit and software programming is designed. The programming syntax language using C language is create. The circuit design simulation using circuit maker, Proteus and another software for experiment. When done, construct the circuit and robot chassis develop. The whole circuit board is designed using Protel DXP 2004 PCB design tool and board is fabricated in printed circuit board for reliability purposes. The electronic components are soldered on the board after the PCB board finishes the etching process. Once the circuit construction is complete, an initial testing has to be done. The testing of circuits is done to determine and locate any of the following circuit conditions: an open circuit, a short circuit with another conductor in the same circuit, a ground, which is a short circuit between a conductor and ground, leakage (a high-resistance path across a portion of the circuit, to another circuit, or to ground), and a cross (a short circuit or leakage between conductors of different circuits). If the circuit does not function accordingly, the trouble shooting process must take place in order to know the failure of the circuits and the process goes back to reconstruction stage until a good working circuit it is obtained. Lastly, the robot was able to maintain its balance executing movements like drive forward and backwards when the programming was implemented in hardware successfully.

CHAPTER 2

LITERATURE REVIEW

Conducting literature review prior to undertaking research projects is critical as this will provide much needed information on the technology available and methodologies used by other research counterparts around the world on the topic. This chapter provides the summary of literature reviews on key topics related to inverted pendulum robot.

2.1 Inverted Pendulum

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 [7].

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 see- 7 saw

. 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 [7].

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 [7].

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.

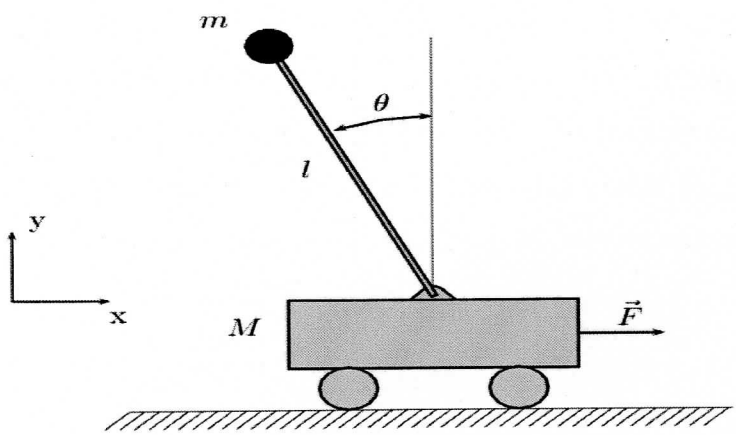

Figure 2.1: Example of Inverted Pendulum Cart