SOFTWARE PID CONTROL OF AN INVERTED PENDULUM USING THE PIC16F684

SAMSUN BIN CHOMBA

MAY 2006

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)."

Signature : ....

Supervisor's Name: Miss Chong Shin Horng

Date : 04 May 2006

"I hereby declared that this report is a result of my own work except for the excepts that have been cited clearly in the references."

Signature : ....

Name : .Samsun Bin Chomba

Date : 04 May 2006

SOFTWARE PID CONTROL OF AN INVERTED PENDULUM USING THE PIC16F684

SAMSUN BIN CHOMBA

This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor of Electrical Engineering (Industry Power)

Faculty of Electrical
Kolej Universiti Teknikal Kebangsaan Malaysia

MAY 2006

To my beloved parent, family and friends

ABSTRACT

The aim of this project is to implement a positional Proportional-Integral-Derivative (PID) feedback controller to bring inherently unstable system into stability by using the microcontroller PIC16F684. The project are consist 2 main parts software and hardware development. The software is used to control the microcontroller PIC16F684 with using C programming. The hardware is inverted pendulum built to demonstrate this type of control (PIC16F684).

ABSTRAK

Projek ini bertujuan untuk mengimplementasikan kedudukan kawalan tindakbalas Kadaran- Gabungan- Terbitan supaya kestabilan sistem semulajadi yang tidak stabil dapat distabilkan menggunakan mikrokawalan PIC16F684. Projek yang dilaksanakan mengandungi dua bahagian utama iaitu pembangunan perisisan dan pembangunan perkakasan. Perisian yang dibangunkan digunakan untuk mengawal mikrokawalan PIC16F684 dengan menggunakan pengaturcaraan C. Perkakasan yang dibangunkan iaitu bandul pembalikan digunakan untuk demonstrasi jenis kawalan PIC16F684.

LIST OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

PID stands for Proportional-Integral-Derivative. This is a type of feedback controller whose output, a control variable (CV), is generally based on the error (e) between some user-defined set point (SP) and some measured process variable (PV) [7]. Each element of the PID controller refers to a particular action taken on the error:

- Proportional: error multiplied by a gain, Kp. This is an adjustable amplifier. In many systems Kp is responsible for process stability: too low and the PV can drift away; too high and the PV can oscillate.
- Integral: the integral of error multiplied by a gain, Ki. In many systems Ki is responsible for driving error to zero, but to set Ki too high is to invite oscillation or instability or integrator windup or actuator saturation.
- Derivative: the rate of change of error multiplied by a gain, Kd. In many systems

  Kd is responsible for system response: too high and the PV will oscillate; too low and the PV will respond sluggishly. The designer should also note that derivative action amplifies any noise in the error signal.

A PID controller has 3 terms: Kp (proportional), Ki (integrator) and Kd (differentiator). Each term plays a different role, and characteristics of each term are summarized in table 1.1 below.

Table 1.1: Characteristics of PID

Term in PID	Characteristics
Kp	Increases the overshoot
Ki	Eliminates the steady state
Kd	Control the rise time (sensitivity)

An inverted pendulum is a physical device consisting in a cylindrical bar (usually of alluminum) free to oscillate around a fixed pivot. The pivot is mounted on a carriage, which in its turn can move on a horizontal direction. The carriage is driven by a motor, which can exert on it a variable force. The bar would naturally tend to fall down from the top vertical position, which is a position of unsteady equilibrium [8].

The system including pendulum, cart, motor can be modeled as a linear system if all the parameters are known (masses, lengths, etc.), in order to find a controller to stabilize it. If not all the parameters are known, one can however try to 'reconstruct' the system parameters using measured data on the dynamics of the pendulum.

The PIC (Programmable Interface Controller) line of microcontrollers was originally developed by the semiconductor division of General Instruments Inc. The first PICs were major improvement over existing microcontroller because they were programmable, high output current, input/output controller built around RISC (Reduced Instruction Set Code) architecture [1].

PIC16F684 is Microchip's new component development with new features including interrupts, on board A/D (analog to digital) conversion, on board comparators and more. For this project the PICs act as like brain of this PID controller and load to the PIC16F684.

1.1 Objectives And Scope Project

The main objectives and aim of this project are to implement a PID controller in an inherently unstable system using PIC16F684. Besides, the objective for this project is to develop the software programming of PID controller to control the PIC16F684 and to investigate the trend of control technology development to stabilize an inherently unstable system especially at industry. The PID controller design should convert over to digital system inherently unstable system into stability because the PICmicrocontroller only accept the binary code. The binary code referring to '0' and '1'.

The project develop are consist two main parts software and hardware development. The software is used to control the microcontroller PIC16F684 with using C programming. The hardware is inverted pendulum built to demonstrate this type of PID controller.

For this project there have three scope of project must focusing in process to create the right project development. The first scope is this project can or able implement a PID controller in an inherently unstable system into stable system using PIC16F684. This very important to make sure the main objectives of this project achieve. Besides that, the second scopes are focusing related to PIC and software use to able this project success. These scopes are PIC 16F684 will be used in this project and the C programmer is important to display all the results at the computer. Last scopes focusing to hardware development to fulfill this project become the success project development. The hardware is an inverted pendulum is used to demonstrate this type of control.

1.2 Report Outline

In this project report there have 5 chapters altogether. Chapter 1 gives some brief introduction about this project. The introduction is related to keywords of this project which say in project proposal. The keywords are Proportional-Integral-Derivative (PID), an inverted pendulum as hardware development and

Programmable-Interface-Controller (PIC) as tool of brain of the PID controller. PIC16F684 with 14 pin are choose as PIC. This chapter also focusing the objectives will achieve and scope of this project which must focusing properly. This chapter also includes the report outline for this project, project background and also some problems statement of this project.

The literature review in order to get an idea about the project will be discussed in chapter 2. In this chapter, it reviews the related works that have been done by other people all over the world.

Then in chapter 3 is methodology. This part very important show about the method use to get the idea and finishing this project. Normally for this chapter, all the method use will explain detail to make sure that people understand and can make as reference for future recommendation. It consists two main sections where this chapter is the main part of this report. The two main sections are:

a. Software Development
b. Hardware Development

Chapter 4 brings further discussion about the project, the results and also analysis based on the results.

In chapter 5, it gives the conclusion and recommendation about the project that has been done. Recommendation referring to future project develop with used other method or other solution to improve project has been done.

1.3 Project Background

This project consist three major part are software development with C programmer, load the software development loads into PIC16F684 and demonstrate by inverted pendulum.

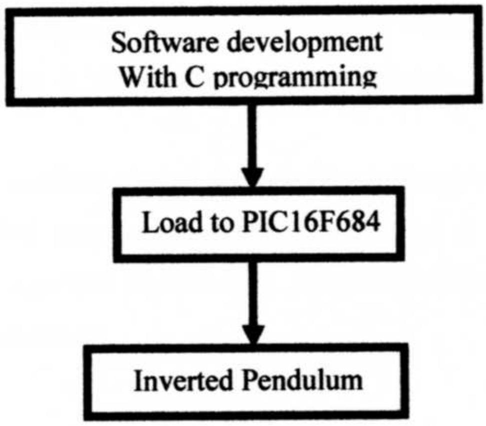

Figure 1.1: The major part of project.

Software development by using C programmer is the major part of this project. The software development is playing an important role to achieve the objectives and determine either this project success or not. The software development will follow the flow chart and must consider two main flow charts are main routine and interrupt service routine.

When the software development by using C programmer is success and runs, the software will loads into PIC16F684. The load process will used the special equipment for loads. After the load process is succeeding, a next step is tune of PID constants KP, KI, and KD follow the steps of PID tuning.

The inverted Pendulum will show the result of this project where it should move follow the objectives and instruction in C programmer.

1.4 Problem Statement

The project is purpose to implement a PID controller to bring an inherently unstable system into stability. If system is unstable, transient response and steady state errors are moot point. A system is unstable if the natural response approaches infinity as time approaches infinity. A system also unstable if its closed-loop transfer function have at least one pole in the right side of the s-plane and/or poles of multiplicity > 1 on the imaginary axis. An unstable system cannot be designed for a specific transient response or steady-state error requirement.

Example, most modern aircraft are open loop unstable by design, and active control feedback (called stability augmentation system) is used to stabilize the system and adjust the transient performance. This relative instability of the aircraft provides high manoeuvrability.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews existing project created to get an idea about the project design, conception and any information that related to improve the project. There are many PID controller projects that have been done by other people with differences concept and design.

In August 2003, Tim Calllinan was built the project with title "Artificial Neural Network identification and control of the inverted pendulum". This project takes the area of Artificial Neural Networks (ANN) and applies it to the inverted pendulum control problem. The inverted pendulum is typically used to benchmark new control techniques, as it's a highly non-linear unstable system. Neural networks have unique characteristics, which enable them to control non-linear systems. Feed forward and recurrent neural networks are used to model the inverted pendulum. Multi-output online identification was also researched. A neuro-controller for the inverted pendulum was developed. Traditional control methods were utilized to develop a control law to stabilize the inverted pendulum. A feed forward network was trained to mimic the control law. The neuro-control shows that if a disturbance occurs in the system, the neural network learns to counteract this disturbance. Finally the knowledge learned in identification and control was applied to the real time inverted pendulum rig. An online adaptive neural network was developed to model the real time system.

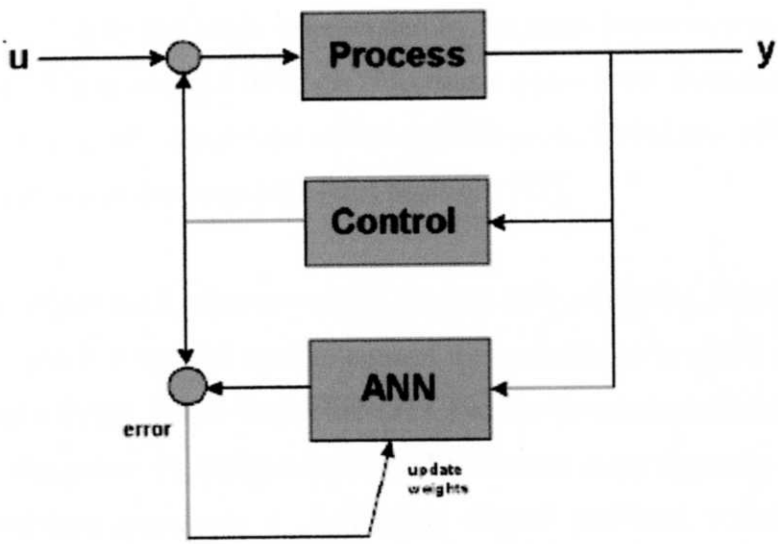

Figure 2.1: Supervised learning using an existing controller

Besides that, one project related to our project is "Inverted Pendulum" written by Steve Che-Ming Chou, Daniel Goldberg, Henry Ho, Kelvin Lau, Ying Chi Ng, Jamie Roust, Andrew Tercjak, and Richard Vetter which built in 21 march 2001. This project include system designed and constructed consists of an industrial sized 48V/5A DC motor, inverted pendulum physical setup, motor control circuitry, load cell torque calculation circuitry, PIC micro controller, LED display module, and finally MATLAB and D-space software that exists on a PC computer containing a DSP board and separate Texas Instruments processor. The physical setup also includes a plexiglas safety shield that covers the entire inverted pendulum arrangement. The system runs on a 48V power supply that sits directly behind the physical set-up and below the protective shielding. All system hardware and software has been implemented and tested, verifying the competency of this design [12]. For this project a kind of PIC microcontroller used is PIC16F877.

Other project related to stabilize the controller system by A. Benaskeur and A. Desbiens built with title "Application of adaptive backstepping to the stabilization of the inverted pendulum".Aa non-linear Lyapunov-based controller use to stabilize the famous cart-pole system. The novelty is in the use of two-loop cascade controller. The inner loop uses an adaptive nonlinear controller, obtained by the back stepping recursive approach. It ensures the stabilization and the convergence towards zero of the angle tracking error and the (unknown) rod length estimation error. The reference signal to be tracked by the angle is generated by the outer loop linear controller. The controlled part of the system (rod angle) has thus a quasi-linear dynamics, which can be modeled by a double-integration with a variable gain. An indirect MRA controller is used to compensate the outer loop (cart position) [12].

This project used other controller besides PID controller. For this project it used fuzzy controller but still used to control the unstable system into stability. The application of a Fuzzy Logic Controller (FLC) to the inverted pendulum problem is presented in this paper. FLCs have been used to control many dynamic systems. The inverted pendulum represents a challenging control problem, which continually moves toward an uncontrolled state. Three versions of an FLC for the inverted pendulum problem are discussed in this paper including their strengths, weaknesses and performance. Techniques for manually tuning a complex FLC are also implemented in this project and addressed in this paper.

CHAPTER 3

METHODOLOGY

In this chapter, it describes the methodology of this project with more details so that it will give us more information about how the methodology can influence the results that we get. The methodology is very important because consists of all steps of works required to accomplish the project. This project consist to main part are software development and hardware development.

3.1 Software Development

A microcontroller is nothing without software. To program PICs requires a binary file of coded ones and zeros. Microchip offers an assembly language for PICs and a free assembler to get you going. Assembly language can be tough for a beginner, though. It is easier for a beginner or hobbyist with limited time to use a higher-level language and a compiler to convert that higher-level language into an assembly language problem [1].

Before develop software for the microcontroller, a understanding of a flow chart is very important. This flow chart will shows about a steps of software program that it must do follow a code order. For this project, there have two flow chart where should understands and follow the steps to create the right software development.

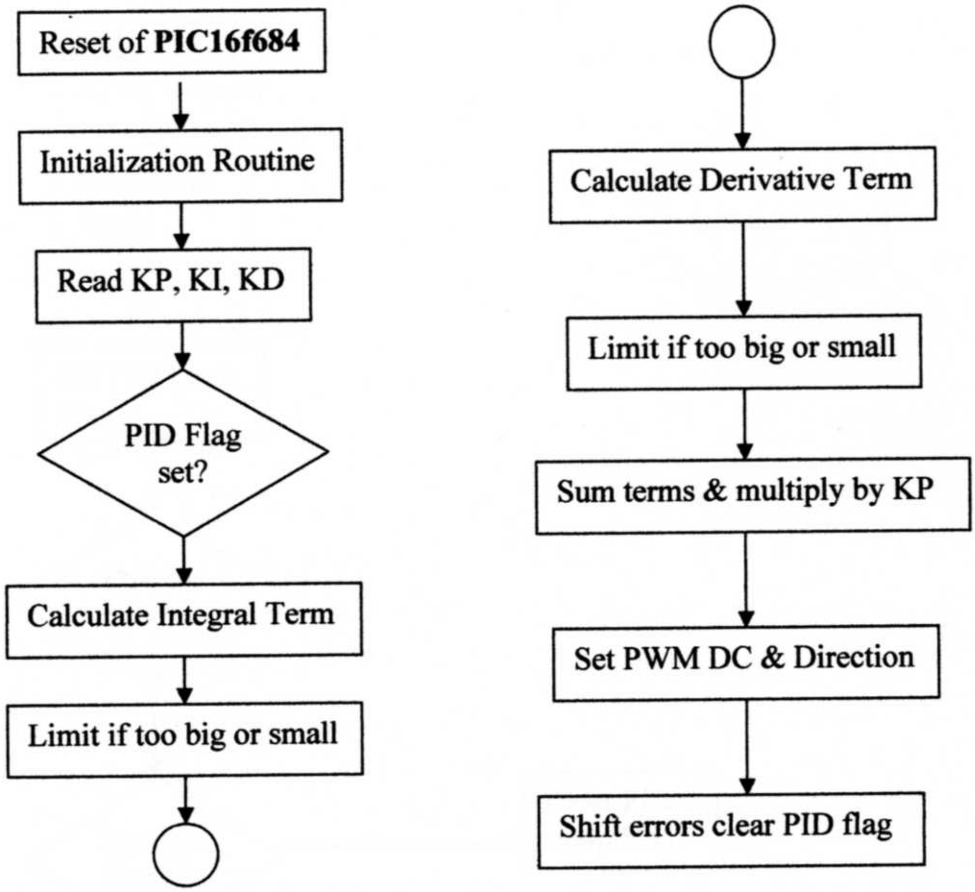

Figure 3.1: Flow Chart for Main Routine