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PID OF AN INVERTED PENDULUM

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"I hereby declare 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 (Control, Instrumentation and Automation)"

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Date : 13 May 2009

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This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree of Bachelor In Electrical Engineering (Control, Instrumentation and Automation)

Fakulti Kejuruteraan Elektrik

Universiti Teknikal Malaysia Melaka

May 2009

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

Signature :

Name : ERIC CHEE SAI HOO

DATE : 13 May 2009

To my dearly loved father and mother

To all teachers and supervisor

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I wish to express my deepest gratitude to my supervisor, Mr. Syed Najib bin Syed Salim for guiding me in this project. This success of this project is highly influenced by his information, suggestions and ideas.

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ABSTRACT

Inverted pendulum has been a popular platform for control engineers to research and test their controller. Controller for an inverted pendulum is widely ranged; from Proportional-Integral-Derivative (PID) to Fuzzy Logic, to Fuzzy PID and etceteras. This project will implement a PID controller to an inverted pendulum. Controller implementation can be done in both hardware and software. A software controller is selected in this project and is written with Microsoft Visual C#. Communication between software (computer) and inverted pendulum hardware (motor and rotary encoder) linked with serial cables and a decoder/driver. Microprocessor (PIC) from MICROCHIP is used to build the decoder/driver and its function limited to passing data. For software controller, it is equipped with a graph plotting tool to monitor the position of the inverted pendulum's pole. A simulation is done using Matlab to simulate responses of the balancing system. Outcomes from few experiments, the observations clearly show that the inverted pendulum is able to be controlled and balanced. Results from conventional PID and cascade PID are analyzed and suggestions are given so that in future, better results could be obtained.

ABSTRAK

Pendulum songsang merupakan perkakasan yang selalu digunakan oleh jurutera kawalan untuk penyelidikan dan ujian terhadap sesuatu pengawal. Pengawal untuk pendulum songsang terdiri daripada pelbagai jenis iaitu dari Pengawal Perkadaran-Pengamiran-Kerbezaan atau PID kepada Logik Samar atau 'Fuzzy Logic', seterusnya gabungan Pengawal Perkadaran-Pengamiran-Kerbezaan dan logik samar atau 'Fuzzy PID' dan sebagainya. Bagi projek ini ianya dilaksanakan mengunakan pengawal 'PID'. Pelaksanaan pengawal ini melibatkan perkakasan dan perisian. Perisian computer yang dipilih dalam projek ini ditulis dengan menggunakan perisian 'Microsoft Visual C#'. Komunikasi di antara perisian (komputer) dan pendulum songsang adalah melalui kabel RS-232 serta penyahkod/pengerak. Mikro-pemproses daripada MICROCHIP digunakan untuk membina litar penyahkod yang mana fungsinya terhad kepada penghantaran data. Perisian untuk pengawal juga disertakan bersama ruangan graf yang boleh memaparkan kedudukan sudut pendulum songsang tersebut. Simulasi pula akan dibuat menggunakan MATLAB untuk melihat sambutan keluaran merujuk kepada sistem imbangan. Hasil yang diperolehi daripada beberapa eksperimen yang dibuat akan dinyatakan dengan jelas menerusi sambutan keluaran yang diperolehi yang mana melalui pemerhatian yang buat menunjukkan bahawa ianya mampu mengawal kedudukan pendulum songsang serta dapat mengimbanginya. Keputusan yang diperolehi merujuk kepada dua konfigurasi iaitu 'conventional PID' dan 'cascade PID' akan dianalisa dan cadangan penambahbaikan turut dinyatakan didalam laporan ini.

CONTENT

LIST OF TABLE

LISTS OF FIGURE

LIST OF SYMBOLS AND TERMS

PID	-	Proportional-Integral-Derivative
PI	-	Proportional-Integral
PD	-	Proportional-Derivative
PWM	-	Pulse Width Modulation
PCB	-	Printed Circuit Board
DC	-	Direct Current
PIC	-	Programmable Intelligent Computer
PC	-	Personal Computer
SP	-	Setpoint
PV	-	Present value
GUI	-	Graphical User Interface
GC	-	Garbage Collector
Kp	-	Proportional Gain
Ki	-	Integral Gain
Kd	-	Derivative Gain
SSE	-	Steady State Error
OS%	-	Overshoot
Ts	-	Settling time
Tp	-	Peak Time

Tr	-	Rise Time
ZOH	-	Zero Order Hold

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background

Inverted pendulum is a popular platform for control engineers to test the controller. Conventionally, a pendulum is a ball tied to an end of a string. The ball is left freely. Another end of the string is fixed on a same location. Whenever an external force is applied to the ball, it will swing, for example, to the left. Due gravitational force, damping factor and air friction, the swing will eventually stop, and then it will swing back in the reverse direction (right). This sequence will repeat itself but each cycle, the swing angle will decrease. The pendulum will stop when the angle reach zero (with respect to surface perpendicular).

Inverted pendulum is revolutionized from pendulum hence inverted pendulum applies the same theory. But, instead of pendulum hanging downward, inverted pendulum is hanging upward. With no external force, the pole which replaces string, unable to maintain at the perpendicular position (zero angle). Any external force is considered extra for the balancing process. In order to balance the pole, controller must be implemented.

Proportional-Integral-Derivative (PID) controller is used to maintain the pole's position. PID is a conventional way of controlling a system. Practically, PID is the simplest, easiest and cheapest method comparing to other method. It is also the most developed method in which various tuning, setting and developing method available.

1.2 Concept

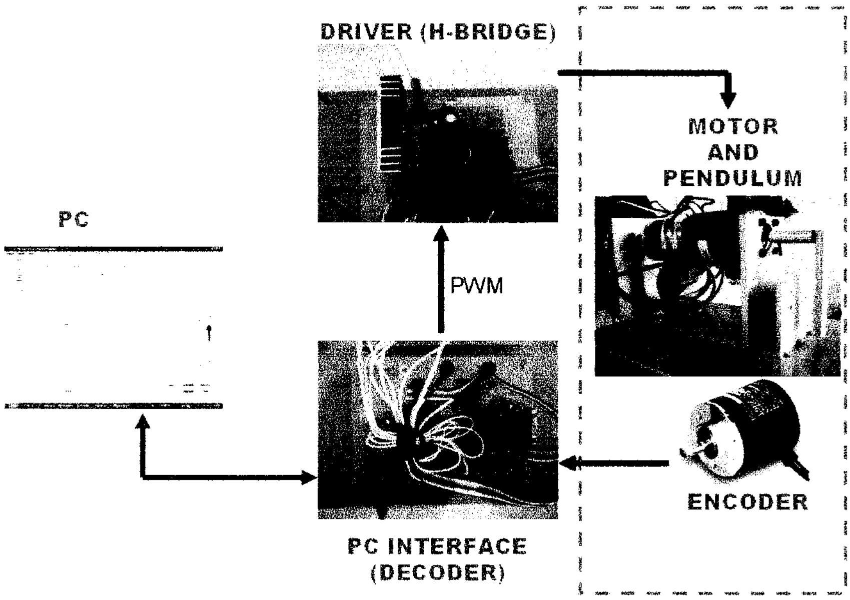

Figure 1.0: Inverted pendulum architecture

Figure 1.0 shows the architecture of this inverted pendulum system. Motor and encoder are coupled together. Mechanical structure which is the pendulum pole is mounted directly to the motor shaft. Interface is consisted of electronic circuit in which will responsible to pass data between pc, encoder and motor driver. Data will be received at pc side and it will be process to determine what kind of response the actuator should be exhibited.

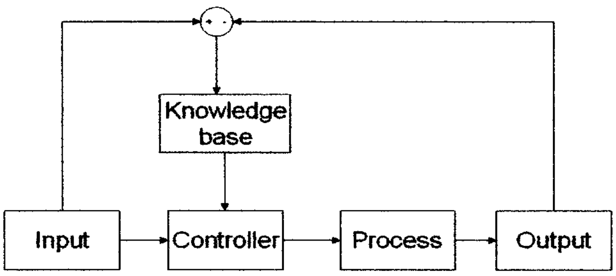

Figure 1.1: C# platform structure

C# platform structure is shown in Figure. Input is the setpoint and output is the angle. Flow 'Input to output' and flow 'Input & Output to Knowledge Base' are operating separately and independently. Using this approach, processing time is reduced compared to the conventional method where the data collection, signal processing and actuator driving happen serially.

1.3 Problem Statement

First challenge of an inverted pendulum system is the balance the pole. It is instable for the system to maintain the pole in a perpendicular position relative to the surface. The system pole initially pointing downward, then rotate upward to balance it. Another problem is the closed loop system (feedback). It is unable to produce good results in term of balancing. Even if it able to balance the pole, there may be some unwanted effect such as long settling time, overshoot, steady state error and etcetera may occur and this will affect the quality of the system. After initial balancing, there is another challenge which is the system resistance towards disturbance. Disturbance may cause the system to instability.