CONTROL OF PRACTICAL INVERTED PENDULUM USING STATE-FEEDBACK CONTROL SCHEME

MOHD ZAINI BIN MOHD GHAZALI

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Faculty of Electronic and Computer Engineering
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.....

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(COP DAN TANDATANGAN PENYELIA)
SHARATUL IZAH BT SAMSUDIN
Pensyarah
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
Karung Berkunci No 1752
Pejabat Pos Durian Tunggal
76109 Durian Tunggal, Melaka

Tarikh: 30 APRIL 2009

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

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Date : 30 APRIL 2009

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Supervisor's Name: MRS. SHARATUL IZAH BINTI SAMSUDIN

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To my beloved parents

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ABSTRACT

The inverted pendulum controlling system consists of three main problems that always appear in control applications which are nonlinear system, unstable and non minimum behavior phase system. The objective of this project is to design and applied a State-Feedback Controller on practical based inverted pendulum. Here, the pole-placement approach which is able in stabilizing the practical based inverted pendulum at vertical position and at the same time placing a cart at desired position will be designed. This controller will be implemented using Real-Time Windows Target application. Firstly, the mathematical model of an inverted pendulum system is synthesized. Then, the linearization technique will be applied to the nonlinear model so that the design of the State-Feedback Controller can be accomplished. The second stage involves analysis of simulation work and results. The final stage is implementing the controller to the practical based inverted pendulum. The performance test results is then presented and compared with simulation results which will verify the successful design and implementation of the controller. The simulation work is done using a MATLAB/SIMULINK platform and the Advantech PCI-1711 card is used as I/O devices to enable the interface with the practical based inverted pendulum system.

ABSTRAK

Pengawal sistem bandul terbalik mempunyai tiga masalah utama yang selalu ada dalam setiap aplikasi pengawal iaitu sistem tidak linear, tidak stabil dan memiliki fasa yang tidak minimum. Tujuan projek ini adalah untuk merekabentuk dan mengaplikasikan Pegawal Suap-Balik Keadaan pada model bandul terbalik sebenar menggunakan kaedah penempatan kutub yang berkemampuan mengimbangkan bandul terbalik pada kedudukan menegak dan pada masa yang sama berkeupayaan memastikan kereta berhenti pada jarak yang ditetapkan. Pengawal ini akan di aplikasikan menggunakan *Real-Time Windows Target.* Projek ini, pertamanya model matematik disentisis berdasarkan kepada teori ruang-keadaan. Selepas itu, teknik penglinearan dijalanan ke atas model tidak linear ini bagi membolehkan Pengawal Suap-Balik Keadaan di rekabentuk. Peringkat kedua, melibatkan analisis hasil simulasi. Sistem pengawal yang direkabentuk akan diuji pada model sebenar bandul terbalik pada peringkat akhir. Selepas itu,hasil ujian yang dicapai akan dipersembahkan dan dibandingkan dengan hasil ujian simulasi untuk memastikan kejayaan rekabentuk serta pelaksanaan sistem pengawal ini. Kerja simulasi dijalankan menggunakan perisian MATLAB/SIMULINK dan kad Advantech PCI-1711 digunakan sebagai alat masukan dan keluaran bagi membolehkan model bandul terbalik sebenar berfungsi dengan sistem pengawal yang direkabentuk.

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A/D	-	Analog/Digital
ADC	-	Analog-to-digital converter
ANG	-	Analog
COM	-	Common
CPU	-	Central Processing Unit
CW/CCW	-	Clockwise/Counter Clockwise
D/A	-	Digital/Analog
DAQ	-	Data Acquisition
DC	-	Direct Current
DIN	-	Deutsches Institut für Normung
I/O	-	Input/Output
PC	-	Personal Computer
PCI	-	Peripheral Component Interact
RTW	-	Real-Time Workshop
RTWT	-	Real Time Windows Target
SCSI	-	Small Computer System Interface
SFC	-	Statefeedback Controller
VR	-	Variable Resistor

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CHAPTER I

INTRODUCTION

The inverted pendulum offers a very good example for control engineers to verify a modern control theory. This can be explained by the facts that inverted pendulum is marginally stable, in control sense, has distinctive time variant mathematical model. The control objectives are to balance the pendulum on the upright position and at the same time place the cart at the desired position. Thus, an extremely good control strategy is needed in order to achieve the objective target.

This project will study the inverted pendulum system with the disturbance (horizontal force applied to the ball). The effect of the disturbance to the system will be studied in order to design a good controller. A good controller must be designed such that it can compensate the existence of the disturbance to the system and can control the system well. Thus, with the existence of the disturbance will make the controller design is tougher.

This project also study about the prospect of the designing controller to implement on the practical inverted pendulum model. The controller will be implementing using a Real-Time Windows Target application which is a MATLAB application. The data acquisition (DAQ) card is used as I/O devices to enable the interface with the practical inverted pendulum model. The Advantech PCI-1711 were chose as data acquisition (DAQ) card for this project

The reports will verify the modeling and control of the practical inverted pendulum. The hardware was designed based on a single inverted pendulum placed on the moving cart. The DC motors was used to drive the cart through a belt mechanism and control by power supply unit housed. The controller was implemented digitally using MATLAB software, and it stabilized the rod of an inverted pendulum in the upward vertical position, while at the same time, keeping the cart in the middle of the track. This project involved the design of a controller to stabilize an inherently unstable inverted pendulum. The system model used State-Feedback Controller based on pole-placement method. Modeling was performed in MATLAB software and then using SIMULINK application, a control system was developed.

1.1 Objectives

The objectives to be achieved in this project are:

i. To synthesis the mathematical model of the Inverted Pendulum based on the modeling of inverted pendulum by K.Ogata (1978).
ii. To design a state feedback pole placement control techniques controller which able to control the cart's position and the rod's angle of the inverted pendulum
iii. To fulfill the simulation works for the controllers in MATLAB before applied to the real system.
iv. To interface the controller from MATLAB to the physical inverted pendulum using Data Acquisition Card based on Real Windows Target Application.
v. To compare the simulation result and practical result

1.2 Problem Statement

The Inverted pendulum controlling system consist of 3 main problems that almost appears in control application which are nonlinear system, unstable and has no minimum behavior phase system. These problems can be solved by design the controller that can stabilize the real inverted pendulum at vertical position and at the same time place a cart at desired position. In this project the controller is designed based on state feedback scheme.

1.3 Scope of Works

The scope of work of this cover the development of the controller which is able to stabilize the practical based of inverted pendulum at vertical position and at the same time places a cart at desired position.

The scopes of works of this project are:

i. Understand the modeling of the Inverted pendulum.
ii. Synthesis mathematical model of a inverted pendulum system Synthesis the by K.Ogata(1978).
iii. Design a state feedback controller based on the pole placement method controller to control the Inverted Pendulum.
iv. Implement and simulate the designed controller in MATLAB.
v. Make adjustment to designed controller as to solve the problems during simulation.
vi. Interface between hardware and software using Real-Time Windows Target application. The Advantech PCI-1711 card will be used as the I/O devices to enable the interfacing.
vii. Compare the result between the simulation and the practical result.

This project will be implemented in MATLAB/SIMULINK.

1.4 Research Methodology

Figure 1.1 shows the block diagram of the methodology taken in order to accomplish the task. Firstly the mathematical model of an inverted pendulum system is synthesized. The mathematical model is based on the state space theory. Mathematical modeling is needed in designing the controller and as to obtain the equation for the plant (inverted pendulum). The plant equation must be as close as the actual plant (nonlinear). After that, the equations must be linearised around the origin as to design the State-Feedback Controller (SFC). The model based on State-Feedback controller will be studied and the designing controller will be simulated using MATLAB. The result will be analyzed. After that, the controller will be interfaced with the practical based of an inverted pendulum model using Real-Time Windows Target application and using Advantech PCI-1711 card. Lastly, the result between the simulation and the practical result will be compared.

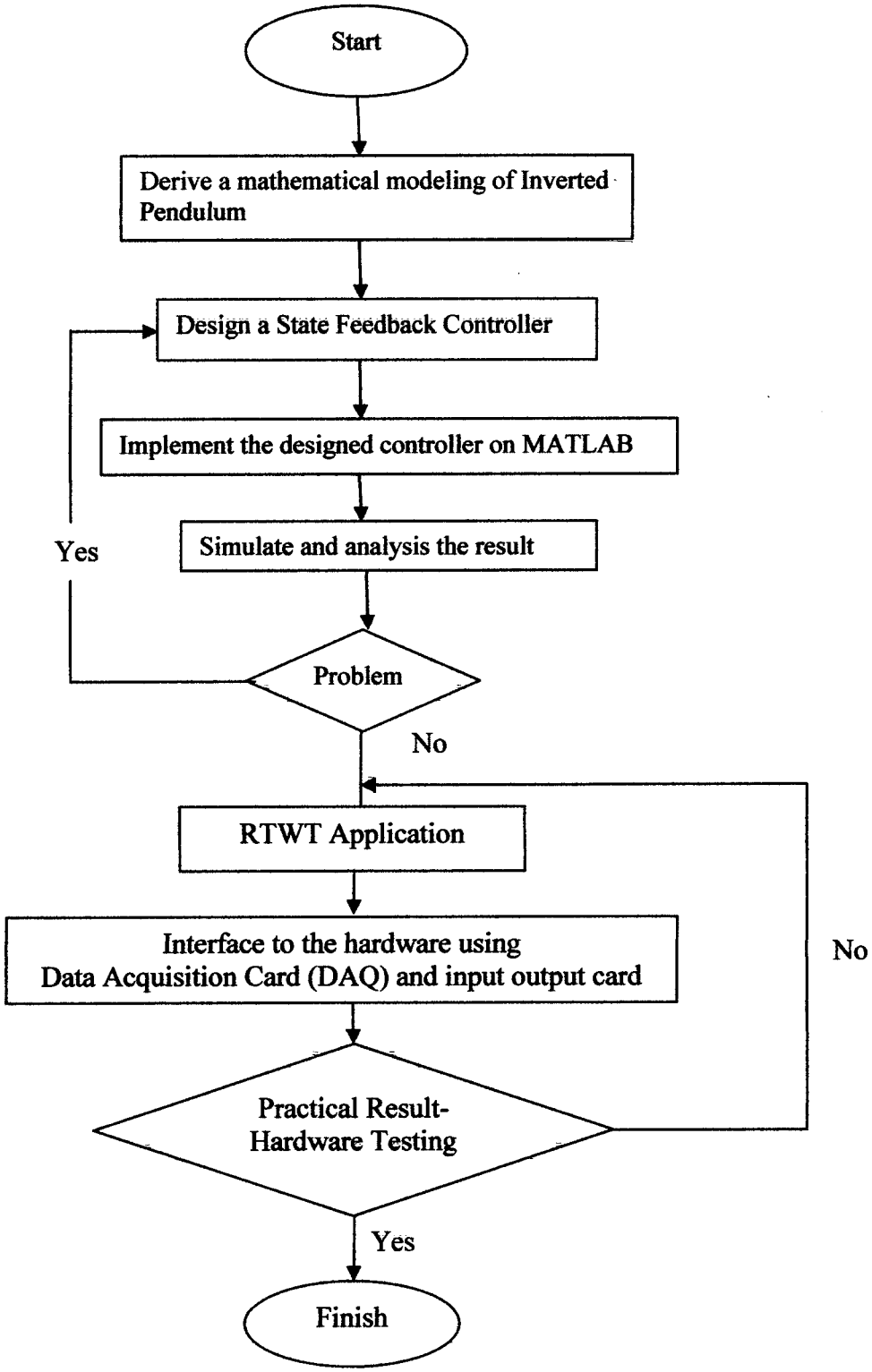

Figure 1.1 Flowchart shows the methodology of the research.