UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SELF-ELECTED INVERTED PENDULUM BY HIGH PERFORMANCE CONTROL TECHNIQUE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Electrical Engineering Technology (Industrial Automation & Robotic) (Hons.)

by

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910710-05-5384

FACULTY OF ENGINEERING TECHNOLOGY

2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **SELF-ELECTED INVERTED PENDULUM BY HIGH PERFROMANCE CONTROL TECHNIQUE**

SESI PENGAJIAN: **2014/15 Semester 2**

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I hereby, declared this report entitled “Self-Elected Inverted Pendulum by High Performance Control Technique” is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Automation & Robotic) (Hons.). The member of the supervisory is as follow:

……

(Project Supervisor)

ABSTRAK

Bandul terbalik ialah satu sistem yang selalu digunakan untuk mengkaji atau memantau keupayaan teknik kawalan untuk sistem tidak linear.Dengan menggunakan peralatan OPENLABBOX siri model bandul terbalik, teknik kawalan yang akan digunakan di dalam sistem bandul terbalik dapat dikaji keberkesanannya.Teknik kawalan ini akan diaplikasikan untuk mereka sistem kawalan tidak linear bandul terbalik.Sistem tidak linear ini diambil kira untuk membina model yang kompleks.Model ini kemudiannya digunakan untuk demostrate teknik kawalan untuk sistem tidak linear.Sistem bandul terbalik ini disimulasi menggunakan Matlab seterusnya menggunakan ScicosLab untuk diaplikasikan ke dalam OPENLABBOX siri bandul terbalik.Oleh itu,respon teknik kawalan ini akan diukur melalui kebolehan sistem ini apabila rod bandul terbalik tidak dalam keadaan yang sesuai.

ABSTRACT

The Inverted pendulum is one of the most common plant that always been used to evaluate performance of control technique for non-linear system. By using OPENLABBOX series rotary inverted pendulum control plant, a control technique will be used and evaluated.The control technique method applied to the design of the control system of non-linear self-elected inverted pendulum.The non-linear inverted pendulum are considered in the modeling of the plant. The Proportional Integral Derivative and Fuzzy Logic Controller are tried on Rotary Inverted Pendulum as a controller for the system.The rotary inverted pendulum model are stimulated by using matlab then scicoslab as a result implemented on OPENLABBOX Series Inverted Pendulum.Thus, the performance and robustness of applied control technique will be evaluated base on it capability to self-elected with fastest reaction.

DEDICATION

To my beloved parents

ACKNOWLEDGEMENT

First of all, I would like to express my grateful to Allah S.W.T because of goodness that gives a way and strength in order to complete my project for Final Year Project. I have done my Final Year Project even though I faced a problem during the completing this Final Year Project. I would like to say special thanks to everyone that help me by giving advising and motivation.

Furthermore, I would like to thank and sincerest appreciation to my supervisor, Mr.Mohd Hanif Bin Che Hasan for his advice and valuable guidance. His guides, comments and suggestion are really useful for me in completing this Final Year Project. My appreciation also goes to my Final Year Project panels, Mr.Khalil Azha Bin Mohd Annuar and Mr.Mohd Razali Bin Sapiee for the good cooperation for my project.

My thank also goes to all my friend for giving me support and share the knowledge and information relate to my project. All of the idea and opinion was very useful in completing this project. Lastly, I also dedicate my appreciation to my family who give me strength and moral support until this semester. Thanks a lot to those individuals who have involve directly or indirectly in this project.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

PID	-	Proportional Integral Derivative
FLC	-	Fuzzy Logic Controller
RIP	-	Rotary Inverted Pendulum

CHAPTER 1
INTRODUCTION

This section basically gives a view for this project. The objectives and scope of work also be listed and explain in this section.

1.1 Overview of project

The inverted pendulum system is an example commonly found in control system and most difficult system to control in the field of control system engineering. Inverted pendulum is one of the most common plant that always been used to evaluate performance of control technique for nonlinear system. There are a few types of inverted pendulum but the Furuta pendulum, or rotational inverted pendulum, is a system found in many control laboratory. Since this inverted pendulum impressive platform for control it cans development of nonlinear control laws. This make the inverted pendulum is benchmark for the evaluating, designing, testing and comparing in various type of control technique.

However, stability of the system is depending on the applied control technique. These control techniques are important in control system. In real application, inverted pendulum system can be found in robotic field because it behaves very much like inverted pendulum. The dynamic of inverted pendulum simulates the dynamics of robot arm in the condition when the centre of pressure lies below the center of the gravity for the arm so that the system also unstable. Its popularity derives in part from the fact that it is unstable without control that is the pendulum

will simply fall over if the disturbance was occur in sensitivity to parameter variations.

In this project, a control technique method will be used and applied to design of the control system of non-linear self-elected rotary inverted pendulum. The Non-linear inverted pendulum is considered in the modeling of the rotary inverted pendulum plant which it is complex model. The control system is obtained based on the dynamic models of the system. This dynamic model is used to determine control technique to achieve the desired system performance and robustness. The control technique can be used to stability and in system robustness which is the controller needed to be design such that the inverted pendulum can be steadily balanced or self-elected after some disturbance.

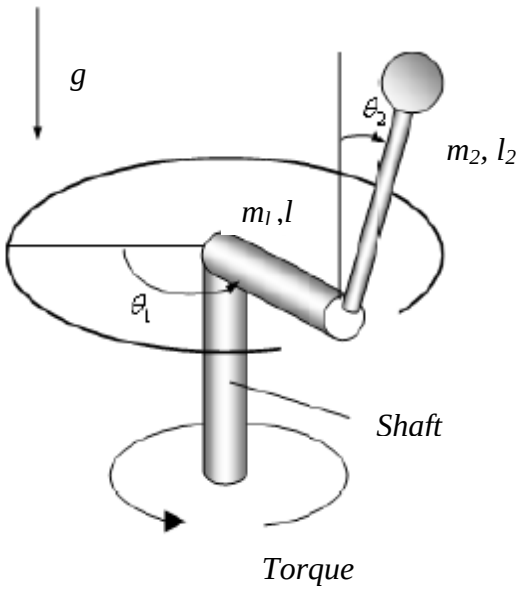

Figure 1.1: Rotational inverted pendulum

The figure above show the parameter considered in design of rotary inverted pendulum mathematical equation system and from that equation the state space representation can be derived. Then, the rotary inverted pendulum dynamic model is stimulated by using Matlab Simulink and Scicos as a result implemented on OPENLABBOX Series Rotary Inverted Pendulum. Thus, the performance and

robustness of applied control technique will be evaluated and able to control and self-elected with fastest reaction when disturbance is injected in the system. The overall results of simulation are compared with Proportional Derivative-controller (PID) method for evaluation purpose.

1.2 Problem Statement

The Rotary inverted pendulum system is an example of plant that commonly used in control system. Since the inverted pendulum is the most control problem in control system engineering, it became important plant in testing, designing, evaluating and comparing the new control technique method. These control methods are necessary to stability and balance in the robotic field or robotic application. In robotics, they faced the problem in stability the arm robot which it is unstable when it centre of pressure lies below the gravity. The fact that it is the pendulum will simply fall over if the disturbance was occurring in sensitivity to parameter variations. Thus, the control algorithm method are purpose to design a non-linear self-elected inverted pendulum with high performance algorithm.

1.3 Project Objective

The main purpose for this project is to design a self-elected inverted pendulum with high performance control technique. This project aims to achieve the following objectives:

1. To model non- linear inverted pendulum.
2. To simulate the Self-elected Inverted Pendulum system by high performance control technique.
3. To apply simulated design on real inverted pendulum system.
4. To evaluate performance of inverted pendulum system with PID method.

The objective of this project is to model non-linear Inverted Pendulum in order to testing or designing a high performance control technique and demonstrate the inverted pendulum system using Multipurpose Control Engineering. The performance of control system is evaluated with PID method to get a better result of the system.

1.4 Scope of work

The scope of work for this project to achieved the objective above:

1. Modeling non- linear inverted pendulum using Multipurpose control.
2. Simulating the inverted pendulum model with control technique by using Matlab
3. Applying the simulated design of inverted pendulum with high performance control technique on RIP by OPENLAB BOX
4. Evaluating performance of inverted pendulum system with PID method.

Evaluating performance of control system with PID method in term of stability, transient response and disturbance. This scope of work explained a modeling non-linear pendulum using Multipurpose Control Engineering plant OPENLAB BOX by Trity Technology. The inverted pendulum used is Rotary Inverted Pendulum. Then the model was simulating with high performance control technique by using Scicoslab. The performance of Inverted Pendulum is evaluated with PID method in term of stability, disturbance and transient response.

CHAPTER 2

LITERATURE REVIEW

This chapter introduces and explains the source of idea for design and modelling that are related to the project. It is found based on the research in form of previous similar concept, design model for a various type of control technique method in non-linear Inverted Pendulum system in previous papers or thesis. Inverted pendulum is one of the most common plant that often used to analyse the performance and effectiveness of a new control technique for non-linear system. A non-linear system is defined as one which does not satisfy the superposition property. Thus, the linear analysis approach start with considering the general non-linear form for a dynamic system and seeking to transform this system into linear system for the purpose of analysis and controller design.

The challenge in control system is to obtain the dynamic model which this model will be used to design or to determine suitable controller. This controller had control the system with desired system response and performance. Otherwise, a control algorithm will give a good stability and robustness. Recently, a lot of studies on the inverted pendulum have been done with various types of control techniques such as Proportional-Integral-Derivative (PID) controller, Fuzzy Logic controller (FLC), State Feedback controller, Fault Tolerant Controller (FTC) and Linear Quadratic Regulator (LQR) method.

(Yadav et al. 2011) did a study on various control technique for inverted pendulum. These researchers used the Proportional-Integral-Derivative (PID) controller and fuzzy logic controller to be applied in the system. This PID controller are capable of controlling the system in steady and close to normal

condition but incapable of controlling the system when there are abnormal condition or sudden changes in parameter occur. Since this system are unstable, (Chun-e et al. 2011) introduced four type of controller which is PID controller are one of the controller designed where the rest of the controller will be explain in the other paragraph. This PID controller is good controller toward robustness of inverted pendulum. The PID controller can control completely the angle and position of inverted pendulum even the disturbance occur.

(Prasad et al. 2012) did a study on optimal control of nonlinear inverted pendulum system using PID controller And Linear Quadratic Regulator (LQR) controller. This research paper used several PID controller methods in separate control schemes which it is combination of PID with LQR. This control technique are very complicated to be implemented but had an excellent performance when both of the PID + LQR controller are applied in the system than PID control method. This controller had smooth and fast performance and effective in robust. Since this method is complicated, many of researchers used the simplest controller that has the same result of performance and robustness.

(Hoseini & Poshtan 2007) applied a Fault Tolerant Control on an Inverted Pendulum. The controller applied on the system take a few second back into normal condition after had disturbance in the internal and external parameter. (Chun-e et al. 2011) designed a Tolerant Controller as forth controller. This controller gives an excellent performance and robustness but faced same problem as state feedback controller during the simulation process. All this control technique is conventional controllers that give satisfied performance. However, there are alternative methods of control technique which are present in the literatures for linear and non-linear system. Artificial Intelligence is an optimization and optimal control technique which is Fuzzy Logic controller and evolutionary computational such as genetic algorithm (GA) and particle swarm optimization (PSO) are the most applied in the present system. This intelligence computational technique given superior performance to the various systems.

From the past decade before, (Wei & Fang n.d.) did a design of basic fuzzy logic controller. This research made a comparison between the fuzzy logic with conventional controller. Theoretically, the fuzzy logic controller is implemented first by Mamdani and Assilian based on the Zadeh set theory. The fuzzy logic controller did not required mathematical modelling and complex computation. In conventional controller of inverted pendulum, the linearization of non-linear dynamic and PID control are designed for the system. The parameter is considered for the performance. However, the fuzzy logic controller is not good idea to be used if the conventional controller can get the satisfied result.

The improvement of fuzzy logic controller control technique are continuously be studied by researchers. (Chun-e et al. 2011) also introduced fuzzy logic controller in the system as the second controller. In this paper research, the researchers implement fuzzy logic controller as a second controller since the PID controller are less effective toward the performance and robustness. The two fuzzy logic controllers give the angle and position of the inverted pendulum completed control in seconds. (Yadav et al. 2011) proposed a design of a fuzzy logic as another controller to make the system more stable and robust. The developing several combination of fuzzy logic PD and PID give the better result in performance and robust of inverted pendulum than the two fuzzy logic controller. The result is considered in term of maximum overshoot, settling time and steady state error.

(Kuo et al. 2013) used genetic algorithm (GA) for optimized input members function fuzzy logic controller in rotary inverted pendulum control system. The GA fuzzy logic controller given an effective performance with robust stabilization capability for rotary inverted pendulum control system.(Rani et al. 2011), on the other hand, argues that the solution in GA have better control performance. This GA is capable in tuning the PID controller gains to balance the rotary inverted pendulum. A.Rahimi investigated a Particle swarm optimization algorithm with combined of PID and state feedback controller in rotary inverted pendulum system. These control method would result in effectiveness stability of rotary inverted pendulum system.

Unfortunately, the previous researchers shows that state feedback controller give less performance and robustness. Khizir Mahmud (n.d) design a state feedback controller to illustrated the fundamental ideas to control the inverted pendulum system. The state feedback controller is designed in two methods. The method are Pole Placement Method and Linear Quadratic Regulator (LQR).The performance and robustness of this controller give the higher overshoot which is less satisfied compare to the state feedback controller proposed by (Chun-e et al. 2011).Besides PID and fuzzy logic controller, state feedback controller as third controller is introduced to compare it robustness and performance with this two controller. Although the performance and robustness of fuzzy PD + PID are better than state feedback controller, it can give satisfied efficiency in short time. However, this controller had a problem with it initial value is far from the linearized value of the system during the simulation process.

From the current researches, matlab, cart inverted pendulum and rotary inverted pendulum are the most platform to evaluate the performance of non-linear inverted pendulum system. There are many literatures present used various type of control technique to control the system of non-linear Inverted Pendulum. The proposed of self-elected Inverted Pendulum with high performance control technique use a fuzzy logic controller to achieve the better performance and robustness. This kind of controller is suitable for non-linear system because it not require complicated calculation than other conventional controller and other intelligence controller.

CHAPTER 3
METHODOLOGY

This chapter will explain the methodology to complete this project which involves the steps of procedures or method that is taken from start until final stage of this project. This project methodology is important to ensure the project runs effectively and systematically. The process flow chart used to describe the whole methodology for the project development. This flow chart will explained in the sections of this chapter.

3.1 Process Flow Chart

The process flow chart in Figure 3.1 shows that the project start with literature review on inverted pendulum as non-linear system and control method that has fastest response and robustness. This review and research has been conducted after the project objectives and scope of work is clearly understood as the result of discussion session with supervisor. The literature review was obtained by searching and gathering any information that related with this project.

Next, the project was continued by getting the model of inverted pendulum. This model was taken in Multipurpose Control Engineering plant Instructor's Manual Laboratory OPENLAB BOX by Trity Technologies. After that, the model were tested and simulated by Scicoslab to verify the model toward real-plant response. At this stage, the re-model and modify process were taken to corrective action for the

model if the simulation fail to verify the plant against the real-plant response. The response of the model should have a similar to the physical responses.

After the verification model, the control technique for inverted pendulum was decided based on a control technique with high performance. In these stages, a control technique used is considered in term of performance and robustness based on the literature review. Then, this control technique will apply on the inverted pendulum to get the desired output with real-plant response. The control technique should have high performance and robustness in system. The performance and robustness was measures in term of stability, transient response and steady state response. The simulation process is use to get the desired system response. At this stage, the corrective action was taken if the simulation is failed to get the desired system response. This project finishes with evaluation or analysis process with PID method.

Figure 3.1 shows the step that will be implementing in this project start from the beginning until end of the project. The brief explanation will be given about three steps in methodology flowchart. The detail about the processes will be explained in the next proceeding section.