CONTROL OF A CART-BALL SYSTEM; COMPARISON BETWEEN STATE-FEEDBACK CONTROLLER AND FUZZY LOGIC CONTROLLER

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Special dedicated to my beloved parents, family and fellow friends, who had strongly encouraged and supported me in my entire journey of learning…

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ABSTRACT

A cart-ball system is present as inverted pendulum problem which consist some basic concepts such as nonlinear, multivariable and non-minimum phase behavior system. This thesis is concerned to introduce a modern controller and intelligent controller. Besides that, it is related with the problem of modeling and control of a cart-ball system such that to balance the ball on the top of the arc and at the same time to place the cart at a desired position. The controllers that involve with the purpose of controlling the system are State-Feedback Controller and Fuzzy Logic Controller. Developing of mathematical modeling of a cart-ball system is the first task before the linearization technique is applied to the nonlinear model to design the State-Feedback Controller. After State-Feedback Controller is accomplished, designing of Fuzzy Logic Controller is continued to control the cart-ball system. Then, the simulation work of both controllers is done so that the comparisons between controllers can be established. Finally the animation of the cart-ball will be accomplished using the software. The simulation work is done using a MATLAB/SIMULINK platform.

ABSTRAK

Sistem kereta-bola mewakili masalah bandul terbalik yang memiliki sifat-sifat tidak linear, mempunyai banyak pembolehubah dan memiliki fasa yang tidak minimum. Tesis ini menumpukan untuk memperkenalkan pengawal moden dan pengawal pintar. Selain itu, ia mengandungi reka bentuk model matematik dan juga merekabentuk sistem kawalan kepada sistem kereta-bola ini bagi memastikan keseimbangan bola di atas kereta dan pada masa yang sama memastikan kereta berhenti pada jarak yang ditetapkan. Pengawal yang terlibat untuk mengawal sistem ini adalah Pengawal Suap-Balik Keadaan dan Pengawal Fuzzy Logik. Pembangunan model matematik dilakukan dahulu sebelum teknik penglinearan diaplikasikan pada model matematik yang tidak linear untuk membolehkan Pengawal Suap-Balik Keadaan di rekabentuk. Selepas Pengawal Suap-Balik Keadaan di rekabentuk, perekabentukan Pengawal Fuzzy Logik diteruskan untuk mengawal sistem kereta-bola. Kemudian kedua-dua pegawal ini akan dibandingkan untuk mendapat pengawal yang terbaik dalam mengawal system ini. Akhir sekali animasi untuk system kereta-bola akan dilaksanakan menggunakan perisian. Segala kerja simulasi dijalankan dengan menggunakan perisian MATLAB/SIMULINK.

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LIST OF ABBREVIATIONS

SISO	-	Single Input Single Output
MIMO	-	Multiple Input Multiple Output
SFC	-	State-Feedback Controller
FLC	-	Fuzzy Logic Controller
MF	-	Membership Function

CHAPTER I

INTRODUCTION

1.1 Overview

The cart-ball system, demonstrates some basic concepts in control being nonlinear, multivariable, and non-minimum phase. It is basically an inverted pendulum problem, which is a much used as a benchmark problem. In the Cart-Ball System, the control objective is to balance the ball on the top of the arc and at the same time place the cart in a desired position.

The project is deal with the nonlinear system of A Cart-Ball System. The State-Feedback Controller and Fuzzy Logic Controller will be designed in order to control the system. The comparison between State-Feedback Controller and Fuzzy Logic Controller will be determined in this system.

The task is literature study, nonlinear mathematical modeling, controller designing and simulation study. The simulation is using the Matlab/Simulink software.

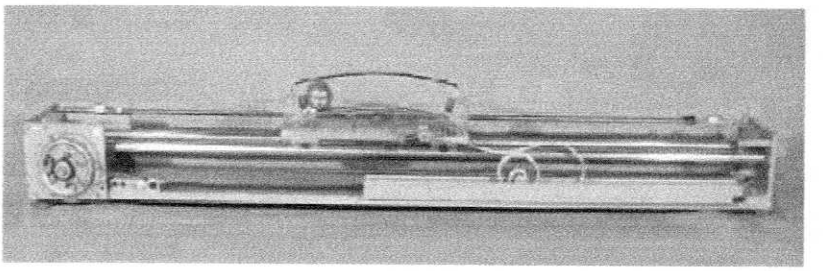

Figure 1.1 Example of a laboratory cart-ball system [Jantzen, 1999]

The ball-balancing system consists of a cart with an arc made of two parallel pipes on which an arc made of two parallel pipes and which a steel ball rolls. The cart moves on a pair of tracks horizontally mounted on a heavy support.

The control objective is to balance the ball on the top of the arc and the same time place the cart in a desired position.

The cart-ball system was built for teaching electrical engineers about automatic control, originally with a focus on state-space control theory. It is educational, because the laboratory rig is sufficiently slow for visual inspection of different control strategies and the mathematical model is sufficiently complex to be challenging.

This project will study the cart-ball system without the disturbance. Thus, the effect of the disturbance to the system will not be studied.

1.2 Objectives

The objectives of this research are as follows:

a. To familiar with the Matlab/Simulink software environment.

b. To design state-feedback controller to control the system.

c. To design fuzzy logic controller to control the system.

d. Comparison between both controllers will be established.

e. Animation of a cart-ball system will be established.

1.3 Problem Statements

A cart-ball system is challenging system from the engineering point of view. This is because the nonlinearities, multivariable and no-minimum phase.

The problems that include in this project are:

a. To balance the ball on the top of the arc.

b. To place the cart in a desired position.

1.4 Scope of Works

The scopes of work for this project are:

a. Design mathematical model of a cart-ball system.

b. Design state-feedback controller to control this system.

c. Design fuzzy logic controller to control this system.

d. Compare the performance of state-feedback controller and fuzzy logic controller, in order to determine the best controller to apply to the system using animation and graph.

1.5 Research Methodology

This thesis includes five chapters. In chapters 2, the research background is discussed. Here the important thing is the overall literature view that will produce the concept that correlative with the project research.

Chapter 3 presents the project methodology. In this chapter the procedure to done this project will be explain.

Chapter 4 is discussion about designing a cart-ball system using state feedback controller.

Chapter 5 is regarding to design a cart-ball system using fuzzy logic controller.

Chapter 6 is about the simulation results and the discussion about it. The performance of the plant for open loop is evaluated by simulation study using Matlab/Simulink.

Chapter 7 is concern about the conclusion of this project. Recommendations for future work of this project are presented at the end of this chapter.

CHAPTER II

RESEARCH BACKGROUND

2.1 Literature Review

The cart-ball system is a challenging problem in term of controlling a system. This is due to the nonlinearities, multivariable and non-minimum phase characteristic presented by a cart-ball system. The control objectives of a cart-ball system are to balance the ball on the top of the arc and at the same time place the cart at a desired position. The cart ball system was built for teaching electrical engineers about automatic control, originally with a focus on state-space control theory.

The laboratory rig for a cart-ball system is done for the educational purpose because the laboratory rig is sufficiently slow for visual inspection of different control strategies and mathematical model is sufficiently complex to be challenging. The approach is to develop the mathematical model from *first principles*, i.e., the basic laws of physics. After that the linearization was applied to the model in order to make it easier to discuss possible controller configurations [Jantzen, 1999].

Many researches were carried out researches to control an inverted pendulum system. Various control strategies have been proposed by numerous researchers for controlling the inverted pendulum such that the system is stable as well as the cart is move to the desired position. The approaches varied from the classical control to the advanced control. PID controller was design to control the inverted pendulum problem [Jantzen, 1999]. The drawback of the PID controller is it only can control for a Single-Input-Single-Output (SISO) system. It means that the PID controller only can control either for the position of the cart or angle of the ball at a one time [Jantzen, 1999]

The State-feedback Controller was use to control the system because it has capability to control the Multiple-Input-Multiple-Output (MIMO) system [Jantzen, 1999]. The disadvantage of using the SFC is a steady-state error is considerably big. So, to overcome this problem an integral control was introduce to the SFC [Nise, 2004]

CHAPTER III

RESEARCH METHODOLOGY

3.1 Methodology

Figure 3.1 shows the block diagram of the methodology that taken to complete the task. Firstly the mathematical model of a cart ball system must be derived. The model needs to linearize before the designing of controller start. Mathematical modeling is needed in order to design the controller and to get the equation for the plant (cart-ball). The plant equation must be as closed as the actual plant (nonlinear).

After getting the mathematical model and that model has been linearized, the next step is to design the state-feedback controller. The controller is designed so that the stable system can be achieved.

The next method is to design fuzzy logic controller to control the system. The comparison between FLC with SFC is done in order to determine the best controller to their system.