CONTROL OF INVERTED PENDULUM-CART SYSTEM BASED ON FUZZY LOGIC APPROACH

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Especially for:

My parents and my wife, who offered me unconditional love, understanding and support throughout my life

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ABSTRACT

This project involves the design of software simulation to make the inverted pendulum to remain upright. The pendulum will depend on the cart so that it can oscillate in a clockwise and counter clockwise direction. Next the cart will be able to move along a straight line along the direction in which the pendulum swings. With the dynamic that drive the cart's motor along the track as the motion of the pendulum, the pendulum is actually will be prevented from falling from an upright position. Inverted pendulum control problem in this way is a classic way for the control system, because the system is inherently unstable. The pendulum will not remain upright without external force. This type of system is also very difficult to control manually, and thus it is requires the use of electronic controls. In this project, the control algorithms used are the fuzzy logic and PID which is an AI controller and classical controller respectively. Both algorithms will be implemented digitally using MATLAB Simulink software. Finally, this project will demonstrate the effectiveness of control system to stabilize the inverted pendulum quickly, and it will also show the stability control system to unexpected interruptions or disturbances.

ABSTRAK

Projek ini melibatkan reka bentuk similasi perisian untuk membuat “inverted pendulum” atau bandul songsang yang akan kekal tegak. Bandul tersebut bergantung kepada “cart” atau trolinya maka ia boleh berayun mengikut arah jam dan arah lawan jam. Troli tersebut seterusnya akan dapat bergerak di sepanjang satu garis lurus dalam arah bandul itu berayun. Kaedah dinamik untuk memandu motor ini yang menggerakkan troli di sepanjang trek tersebut dengan mengikut gerakan bandul, akan menghalang bandul daripada jatuh dari kedudukan tegaknya. Untuk mengawal bandul songsang,sebenarnya ianya adalah kaedah lama dalam sistem kawalan, kerana sistem ini pada asasnya tidak stabil. Bandul tidak akan kekal tegak tanpa adanya daya yang dikenakan. Sistem jenis ini juga amat sukar untuk dikawal secara manual, dan dengan itu ianya memerlukan penggunaan kawalan elektronik. Dalam projek ini, algoritma kawalan yang digunakan adalah fuzzy logic iaitu jenis kawalan AI dan PID jenis kawalan klasik. Kedua-dua algortima ini akan digunakan secara digital dengan menggunakan software MATLAB Simulink. Akhir sekali, projek ini akan menunjukkan keberkesanan sistem kawalan untuk menstabilkan bandul songsang dengan cepat. Ianya juga akan menunjukkan kemantapan sistem kawalan daripada gangguan luar yang tidak dijangka.

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LIST OF SYMBOLS

L	-	Length between axle centre and the centre of pendulum
F	-	Control force
x	-	Position of the cart
θ	-	Angle of the pendulum with respect to vertical axis
g	-	Gravity acceleration
M	-	Mass of cart
m	-	Mass of pendulum
b	-	Friction coefficient of cart
I	-	Inertia of pendulum

LIST OF ABBREVIATIONS

AI	Artificial Intelligent
BOA	Bisector of Area
CNS	Central Nervous System
COA	Centre of Area
FIS	Fuzzy Inference System
FLC	Fuzzy Logic Controller
FLO	Flex or Cross-Over
GA	Genetic Algorithm
IPC	Inverted Pendulum-Cart
LOM	Largest of Maximum
MF	Membership Function
MOM	Mean of Maximum
PID	Proportional, Integral and Derivative
SOM	Smallest of Maximum
UD	Universe of Discourse

CHAPTER 1

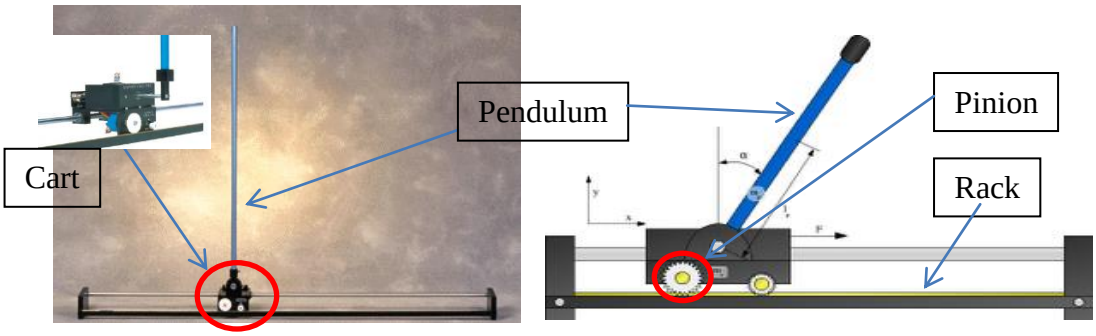
INTRODUCTION

1.1 Project Background

To balance such a broom-stick on our finger or the palm of our hand, therefore the position of our hand had to constantly adjust to keep the object remain upright. An Inverted Pendulum does basically the same thing. However, it's limited, which is, it only moves in one dimension, while our hand could move up, down, sideways, and etc.

The inverted pendulum system is a non-linear system. It is inherently unstable, fast reacting and high order system. It has been a very good experiment for a variety of control techniques and new control theory. Furthermore, the inverted pendulum system can simulate many phenomena like two legs walking robot, flying objects in space, missile navigation and others.

This thesis includes research in the problem of inverted pendulum system. Generally there are two types of inverted pendulum. A moving-cart (also referred to as moving-wagon) and the other is the type of rotation. Moving pendulum-cart upside down can only move clockwise and anti-clockwise in the direction along the track. This thesis, considered the inverted pendulum control problem of a moving-cart.



(a) (b)

Figure 1.1: Inverted Pendulum-Cart System

In conventional control theory, most of the control problem is usually solved by a mathematical tool based on the model system. But actually, there are a variety of systems with complex mathematical models are not available or difficult to generalize.

As an alternative, fuzzy control techniques can provide a good solution for this problem by introducing and using linguistic information. The most difficult aspect in the design of fuzzy controllers is the basic construction of the rule. Construction of fuzzy rules is based on the operator control based on their own experience. Also for tuning fuzzy membership functions, the rule is the most important thing in the design of fuzzy systems.

1.2 Problem Statement

1) To make the pendulum in the upright or upward unstable equilibrium position and to balance it if it's has a disturbance.
2) Therefore, there is a task to be solved which is stabilization.
3) There are various methods proposed in the literature but a non-linear mathematical model will be used to design a Simulink Model
4) Fuzzy logic and PID controller have been chosen and to be discussed as its controller.
5) To investigate a Fuzzy Inference System (FIS) algorithm that is include the Fuzzy rules and its Membership Function (MF).

1.3 Objectives

Following are the objectives to be achieved at the end of this project implementation. The objectives are:

1) To control and stabilize the inverted pendulum-cart systems in the limited cart track.
2) To design a fuzzy controller to be used in Simulink.
3) To compare the result obtained using Fuzzy Logic Controller with the PID controller.

1.4 Scope of Works

The particular literature reviews have been studied to make the decision on how to solve and what is the scope to be covered.

So, to accomplishing this research, a few scopes of works have been determined. The first scope of work is to design the Inverted Pendulum-Cart (IPC) System, based on the mathematical model obtained, using Simulink. The second step is to design the Fuzzy Logic Controller (FLC) and simulating it in MATLAB Simulink for proper tuning and verification. Then the results should be analyzed to make a comparison between FLC and a PID controller.

1.5 Thesis Outline

This report has a compilation of many chapters that will elaborate in stages the research work that have been carried out. As in general this report mainly consists of five main chapters which are an introduction, literature review, simulation using Fuzzy Logic Controller in MATLAB software, hardware application results analysis and conclusion.

Chapter 1

This chapter discusses the important aspect of the research work such as project background, objectives, scope of work, methodology as well as the thesis outline itself.

Chapter 2

This chapter is completely dedicated to literature review about the IPC system and its controller. This chapter will be showed about the discussion from other papers, journals and articles of an IPC system, its operation and its Simulink model. Furthermore, the controller algorithms will be discussed as well.

Chapter 3

This chapter discusses on how the circuit modeling being developed using MATLAB Simulink software. The model of IPC system will be developed first. Then the FLC and PID controller will be applied to the system to produce a stable result. Before that all the development of its controllers will be discuss.

Chapter 4

This chapter will discuss more on the results and analysis. The result will be analyzed in term of cart position and speed, pendulum angle and its speed, overshoot and settling time of the IPC system.

Chapter 5

This last chapter presents the conclusion and suggestion in improving this research work. A few recommendations and suggestions have been included for the future research.

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