

# Robust Control of Inverted Pendulum using Fuzzy Logic Controller

Sandeep Kr. Tripathi Himanshu Pandey and Prema Gaur

**Abstract**—Robust Control has been used in various applications to improve the performance of the system. The inverted pendulum (also called “Cart-Pole” system) is a classical example of nonlinear and unstable control system. In This paper we present different design techniques of controller for stabilizing the inverted pendulum (cart system) problem and there comparative analysis of performance and reliability which is done through simulation on MATLAB-Simulink. Robust control (H<sub>∞</sub>) in association with fuzzy produce better response as compared to fuzzy controller.

**Index Terms**—Inverted Pendulum, H<sub>∞</sub>, Fuzzy Logic, Robust Control

## I. INTRODUCTION

A two dimensional inverted Pendulum consists of a freely hinged rod over a dynamic platform that can be driven by either belt-motor system or by cart system. It has inherently two states i.e. stable and the unstable. The stable state is undesirable state and the pendulum is downward oriented. In unstable state pendulum orient strictly upward and hence, requires a counter force to stay align to this position because disturbance will shifts the rod away from equilibrium. This problem has been addressed by testing and implementation of under-actuated mechatronical system and controlling of inherently open loop unstable with highly non-linear dynamics like robotics [1-3] and space rocket guidance systems.

Process model is that component of control system which manipulates the inputs to get the desired output, however due to unexpected disturbances, its output deviates. So, in order to sense and rectify these random deviations dynamically feedback with controller to make it a close-loop system has been proposed.

Initially upright position of the pendulum has been assumed due to disturbance un-compensated model of the system has tendency to move downward towards the stability. Our proposed Controller will try to compensate this disturbance and maintain its upward state. Numerous controlling techniques are available, ranging from conventional controller, artificial intelligence controllers [4]-[6] to recent robust controllers [7]-[13].

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In our design, Matlab/Simulink platform used for observing such compensating controller. The inverted pendulum problem is the classical problem of the control system. It is a highly non linear system. Such type of control problem needs very precise and robust control. The overshoot and the error, both play crucial role in the stability of Inverted

Pendulum (IP). The objective of the present work is to get the optimized and robust performance of a nonlinear system with the help of Robust (H<sub>∞</sub>) controller using Fuzzy Logic Algorithm.

## II. MATHEMATICAL ANALYSIS

In order to analyses the control system, mathematical model is established to predict the behavior before utilizing it into a real system. In this process, we rationalize differential and algebraic equations obtained from conservation laws and its characteristics to obtain transfer function of the process.

We have taken mathematical model of [1] for our work. The separate Free Body Diagram of the cart and pendulum as shown in figure 2.1 is used to obtain its mathematical model.

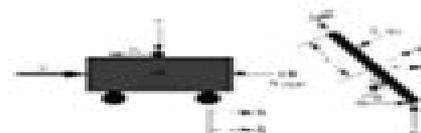


Figure 2.1 Free Body Diagram of the System

By applying Newton's 2nd law of motion to the cart system and assuming the (nonlinear) coulomb friction applied to the linear cart is assumed to be neglected. The force on the linear cart due to the pendulum's action has also been neglected in the presently developed model, the following dynamic equation in horizontal and vertical direction are:

*a) Horizontal direction:* Summing the forces in the Free Body Diagram of the cart in the horizontal direction, we get the following equation of motion:

$$M\ddot{x} = F - bc - N \quad \text{-----(2.1)}$$

The force exerted in the horizontal direction due to the moment on the pendulum is determined as follows:

$$N = m \frac{d^2}{dt^2} (x + l \sin \theta) \quad \text{-----(2.2)}$$

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