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Non-Linear Control Design of Ball and Beam System.

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BSTRACT

During the real-time design of a dynamic system, control system with advanced Control strategies to handle inherent nonlinearities and disturbances. The control of nonlinear system which has the dynamic changes in its characteristics requires the higher standard nonlinear controllers such as adaptive controllers, robust controllers. In the case of Ball and Beam system, the position of ball on beam at the desired location has the higher difficulties since it is nonlinear in nature. This process is done with the Model Reference Adaptive Control, Model Predictive Control, and results are compared for both the theoretical and in realtime.
Keywords: Ball and Beam system, Model Reference Adaptive Control, Model Predictive Control

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INTRODUCTION

Ball and beam system, is an open loop unstable system. As beam is restricted to certain horizontal level without feedback, the ball rolls over the path of beam moving from one end to the other. To stabilize the ball, control system measuring position of ball, beam adjustment is used. Due to non linearities and coupling effects in ball and beam system, the model is designed to control the position of ball. This research compares the performance of model based and non-model based control strategies [1]. Due to problems like variations in process dynamics, nonlinear actuators, changes in environmental conditions and variation in characters of disturbances. Designing of controllers like MRAC using MIT rule is carried out. Error is obtained between output of plant a reference model which is minimized by adjusting control parameters. This paper concludes that system becomes unstable if value of adaptation gain is large. To handle variations, algorithm uses MI rule [2]. Three controllers have been used traditional PID controller, pole placement controller and fuzzy logic. The design has been carried out by designing two loops, outer one for fuzzy logic and inner loop for PID controllers which helps us to compare the controller's performance and analyse which best provides steady state results [3]. This paper deals with both linear and nonlinear aspects of MPC. In linear model, steady state targets, resolving infeasibilities caused by constraints and state estimation. In nonlinear approach, paper briefs about what is desirable from theoretical perspective and difference observed when implementing in real time [4]. Real time experiments have been studied through control of ball and beam system. Position of ball is measured by various sensors and location of ball is changed by changing angle of beam by various motors [5].

BALL AND BEAM SYSTEM SETUP

The Ball and beam system is one of the most popular and laboratory models for teaching control systems in engineering. The ball and beam system is widely used and it covers various modern design methods. It is an open loop highly unstable system.

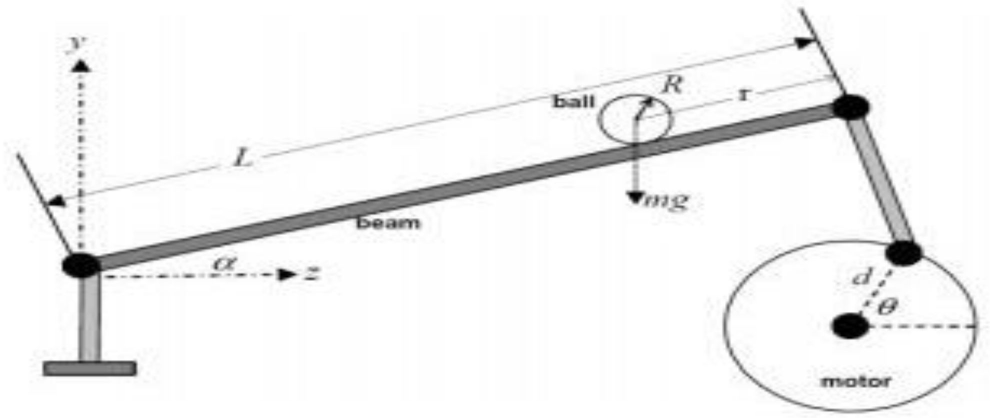

Figure 1: Ball and Beam system setup.

The system consists of a steel ball rolling on the top of a long beam. The beam is mounted on the output of the shaft of an electric motor. The beam can be tilted about its centre axis by applying an electrical control signal to the motor amplifier. The position of the ball on the beam can be measured using a special sensor. The figure 1 shows the simple ball and beam system. The control work is to regulate the ball position on the beam by changing the angle of the beam. This is a difficult control task because the ball does not stay in one place on the beam but moves with an acceleration which is directly proportional to the tilt of the beam. In control technology, the system is open loop unstable because the system output (the ball of the position) is proportional to the angle of the beam.The feedback control must be used to keep the ball at the desired set point on the beam.The control of unstable systems like chemical process industries where we have to stabilize the temperature of chemical reaction or in aerospace for controlling a rocket during vertical take-off where the angle of the thruster jets or diverters must be continually controlled to prevent rocket tumbling, is critically important to many of the most difficult control problems and must be brought into the laboratory. These unstable systems are usually risky and cannot be brought into the laboratory. The ball and beam system was developed to resolve these criteria. It is a simple, safe mechanism having the important dynamic features of an unstable system. The system used in this project is the Quanser servo plant (SRV02). The Quanser servo plant is a highly nonlinear and open-loop unstable system which depicts the conventional ball and beam system.

CONTROLLER DESIGN

PID CONTROLLER:

PID controller continuously calculates an error value from the difference between a desired set point and a measured process variable and applies correction based on proportional, integral, and derivative terms.PID is also used as a tuning method for integrating an unstable process. The open loop frequency response is the common characteristic with the controller in cascade form having a maximum phase. The controller parameters are adjusted corresponding to maximum peak resonance making the frequency response curve tangent to the specified ellipse to control the over shoot stability and dynamics of the system.PID tuning algorithm is used to analyse the accomplishment of PID controller.

MRAC CONTROLLER

Adaptive control is used to design advanced control systems for better performance and accuracy. Model Reference Adaptive Control (MRAC) is a modern adaptive strategy whose reference model is described by the behaviour of the plant and changes in control system is embedded within so that it could track the reference model. MRAC is characterized by adjusting parameters which is done by adjusting mechanisms which works on principle of minimizing error between output and reference model. The adjusting mechanism can be developed by using different types of mathematical approaches like MIT rule, Lyapunov theory and the theory of augmented error.

MPC CONTROLLER:

In MPC, the control input is calculated by solving an optimization problem on-line, and because of this, MPCs have been traditionally used for systems with relatively slow dynamics. MPC models forecasts the changes in the dependent variables of the modelled system that will be caused by changes in the independent variables. MPC predicts the future plant outputs, based on the future inputs and initial inputs. These predictions are used for the perfect modelling of the ball with low steady state errors and the settling time, as a result the system settles more faster. The MPC typically sends out only the first change in each independent variable which is to be implemented, and repeats the calculation when the next change is required.MPC doesn't require determination of control law making it more useful. The great advantage of MPC is that open loop optimal control problems can be solved rapidly enough, using standard mathematical programming algorithms, to permit use of MPC though the system is non linear. Even though the system is non linear, the hard constraints on states and controls must be satisfied with the help of this MPC controller. Thus MPC controller is an effective implementation of the dynamic programming solution.

SIMULATION RESULTS

PID CONTROLLER

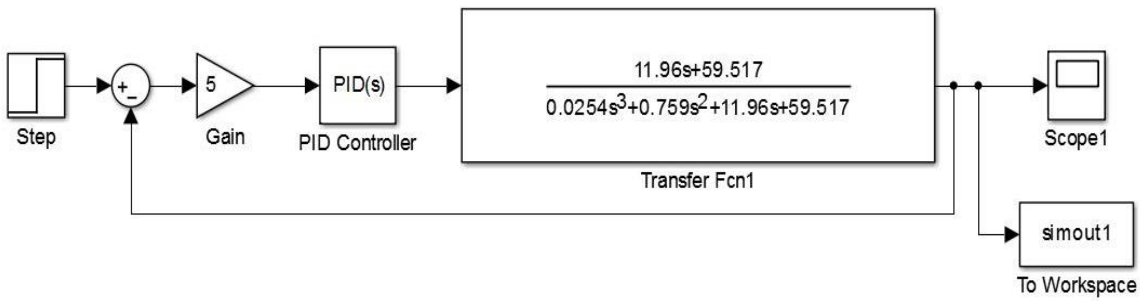

Figure :2 Simulink Diagram of PID Controller for Ball and Beam system

Table 1: Dynamic Behaviour of Ball and Beam system for PID Controller

Dynamic Behaviour	PID controller values
Peak time Tp(sec)	1.35
Settling time Ts(sec)	2.3

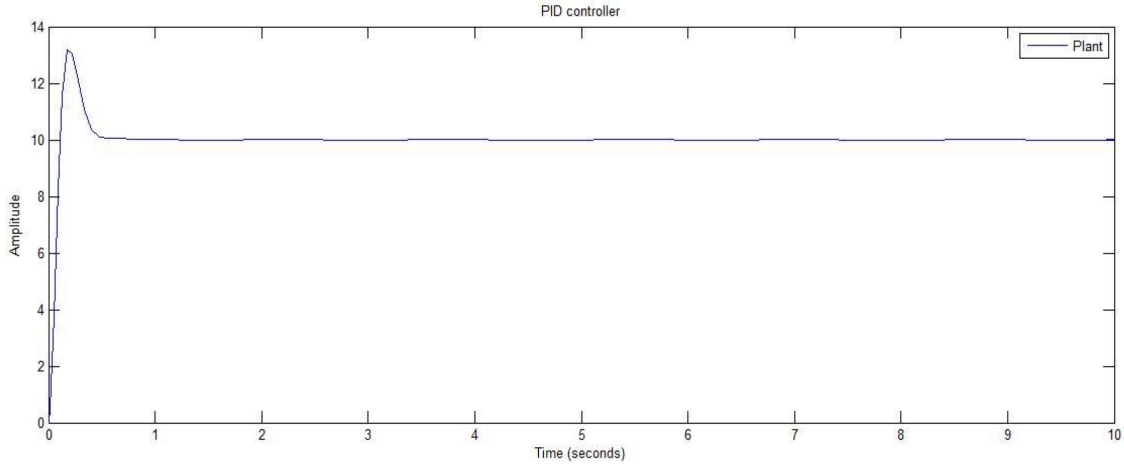

Figure :4 Simulink result of PID Controller for Ball and Beam system

MRAC CONTROLLER

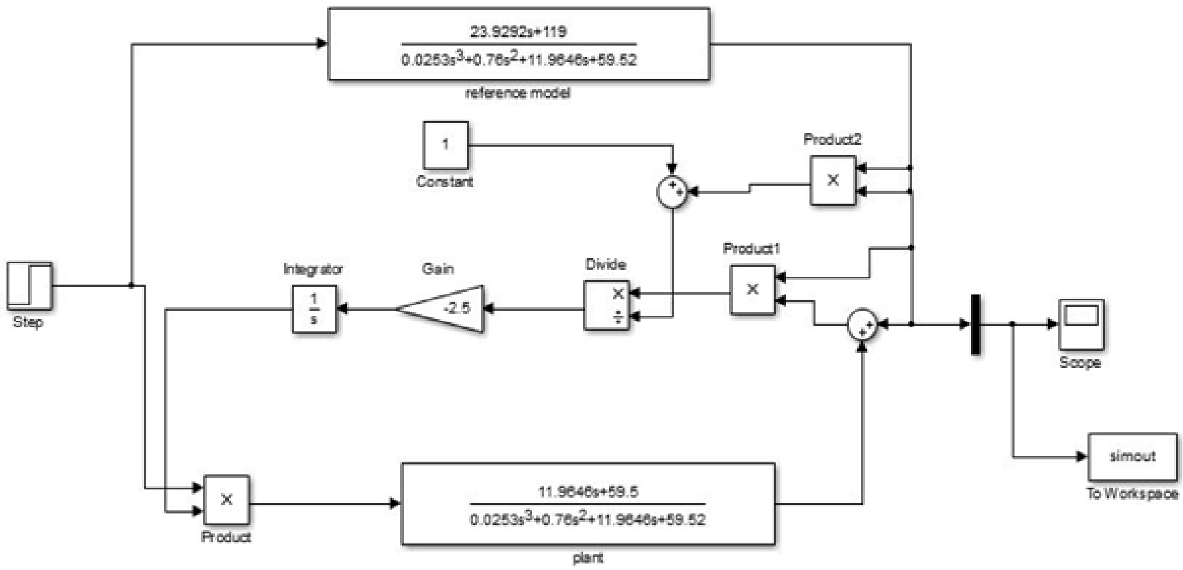

Figure 5: Simulink Diagram of MRAC with Modified MIT rule

Table 2: Dynamic Behaviour of Ball and Beam system for MRAC Controller

Dynamic Behaviour	MRAC Controller values
Peak time Tp(sec)	2.65
Settling time Ts(sec)	2.4

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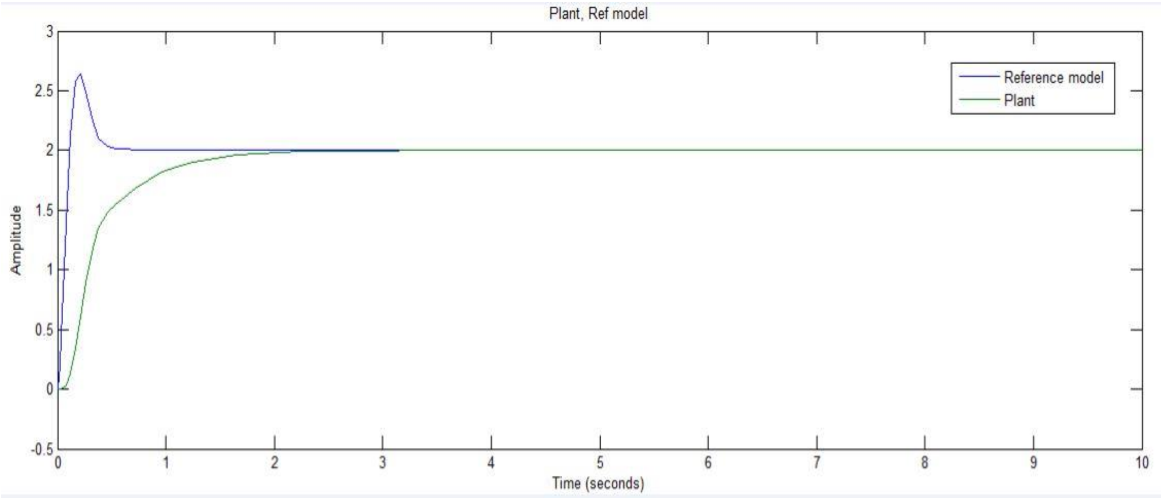

Figure 8: Simulink Result of MRAC With Modified MIT Rule for Ball and Beam system

MPC CONTROLLER:

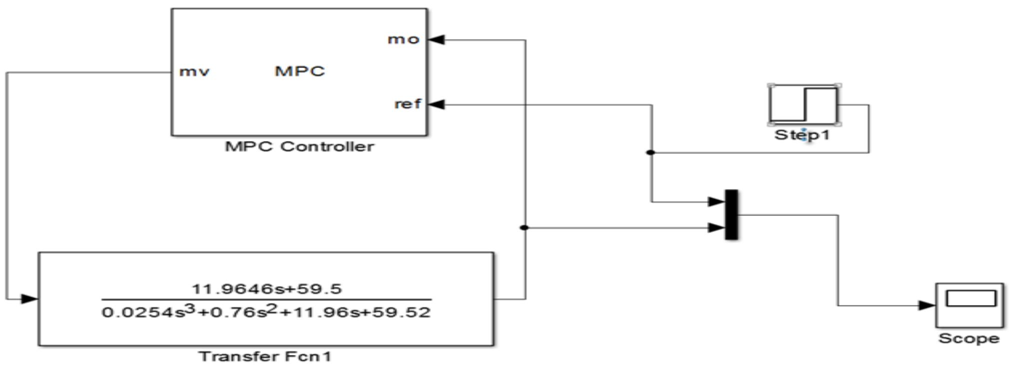

Figure 6:Simulink Diagram of Model Predictive Control

Table 3: Dynamic Behaviour of Ball and Beam system for Model Predictive Controller

Dynamic Behaviour	MPC controller values
Peak time Tp(sec)	1.31
Settling time Ts(sec)	1.45

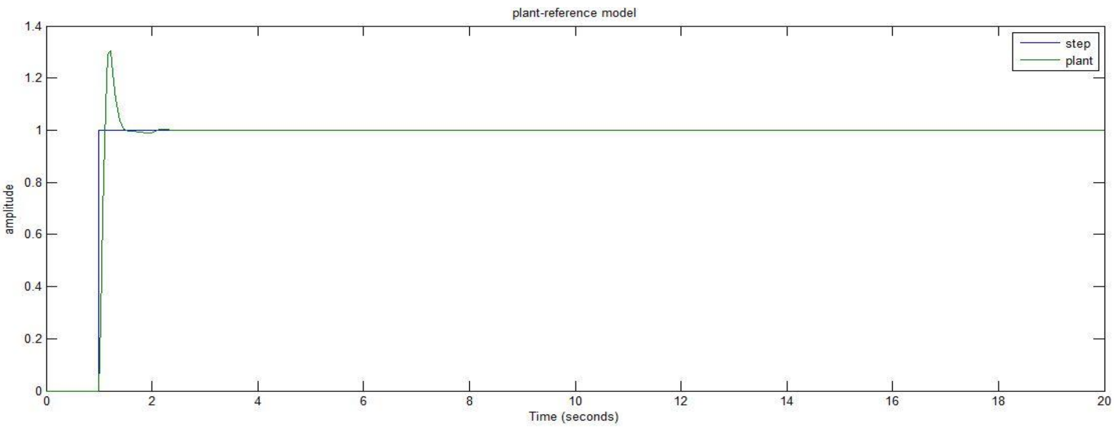

Figure 9: Simulink Result of Model Predictive Control for Ball and Beam system

COMPARISION OF PERFORMANCE WITH DIFFERENT CONTROLLERS FOR BALL AND BEAM SETUP

Table 4:Performance of different controllers with Ball and Beam setup

Controllers	Peak time Tp(sec)	Settling time Ts(sec)
MRAC	2.65	2.4
MPC	1.31	1.45
PID	1.35	2.3

CONCLUSION

The working of ball and beam system has the dynamic non linearities, hence the nonlinear adaptive controllers has the better results when operated for the nonlinear system. Our paper deals with the comparison of most efficient way of a controller to track the reference of the output model with same input.Basic PID Controller is taken as a reference model and comparison is carried keeping it in consideration.Use of MIT rule in MRAC system results in good performance of the overall closed loop system that can be seen by simulation results carried in this paper.In future, we can implement the ball and beam system with the Gain Scheduling.

REFERENCES

[1] Keshmiri, Jahromi, Mohebbi, Amoozgar and g Xie, Modeling and control of Ball and Beam system using model based and non-model based control approaches, International Journal on Smart Sensing and Intelligent Systems, 5, MARCH 2012, NO. 1.

[2] P. Swarnkar, S. K. Jain and R. K. Nema, Effect of adaptation gain on system performance for model reference adaptive control scheme using MIT rule, International Conference of World Academy of Science, Engineering and Technology, Paris, 2010, 70-75.

[3] Houshyar asadi, arash mohammadi, maysam oladazimi, Stabilization ball and beam by fuzzy logic control(FLC) strategy, The International Society for optical engineering 8349:115, 8349 83493, December 2011.

[4] James B. Rawlings, Tutorial: Model Predictive Control Technology. University of Wisconsin-Madison Madison, w1 53706-1691,June 1999.

[5] Sıtkı KOCAOĞLU,Hilmi KUŞÇU, Design and Control Of PID-Controlled Ball and Beam System,2013.

[6] P. Swarnkar, S. K. Jain and R. K. Nema, Comparative Analysis of MIT Rule and Lyapunov Rule in Model Reference Adaptive Control Scheme, Innovative Systems Design and Engineering,2, 4,2011, 154-162.

[7] W. Yu, Nonlinear PD Regulation for Ball and Beam System,International Journal of Electrical Engineering Education, 46,2009, 37–59,

[8] Adrian-Vasile Duka, Stelian Emilian Oltean, and Mircea Dulău, Model Reference Adaptive vs. Learning Control for the Inverted Pendulum, presented at the International Conference on Control Engineering and Applied Informatics (CEAI), 9, 2007, 67-75,

[9] P. Swarnkar, S. Jain, R. K. Nema, Application of Model Reference Adaptive Control Scheme to Second Order System Using MIT Rule, presented at International Conference on Electrical Power and Energy Systems ICEPES-2010, 2010, MANIT, Bhopal, India,.

[10] 10.Fuaad Rahmat M., Wahid H., Abdul Wahab N., Application of Intelligent Controller in A Ball and Beam Control System, International Journal on Smart Sensing And Intelligent Systems, 3, No. 1, MARCH 2010, 45-60.

[11] 11.Peter Well stead: control systems.co.uk. Ball and Beam 1: Basics.http://www.controlsystemsprinciples.co.uk/ whitepaperslball-and-beam.