International Journal of
Information Technology & Computer Engineering

ISSN 2347–3657

Volume 4, Issue 3, July 2016

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 4, Issue 3, July 2016

Design of a Non Fragile Optimal Control Based Realization in Comparison between LQR and Observer Based Controller for Magnetic Levitation System

Haseebi Ahmaid Khai, Aneeis Ur Rehimani,

ABSTRACT

In this study, we examine the magnet-based rail steering technology known as Magnetic Levitation. The primary goal is to determine which of two types of controllers, Linear Quadratic Regulators (LQR) and an Observer-based controller, can correctly suspend and push a train down a guide track composed of magnets. A state space model of a Magnetic Levitation system is developed so that it can carry out the required operation. MATLAB/SIMULINK is used to model the system's reaction. Unexpected behavior in the open loop demonstrated the instability of the developed model. Closed-loop analysis is performed using the results from the Linear Quadratic Regulator (LQR) and the Observer based Controller. For a variety of magnetic tracks, both controllers performed well. Compared to the Linear Quadratic Regulator (LQR) controller, the reaction time of the observer-based controller is much shorter. Observer based controller and Linear Quadratic Regulator (LQR) models are developed in Simulink. Furthermore, we examine several realization strategies for least fragility in controller implementation, including minimal realization, balanced realization, modal realization, and observer canonical realization. An ideal non-fragile controller design has been developed after a thorough analysis of the discrepancies between the various realization controllers in terms of rounding off error or truncation error. The computer-generated model was subjected to a variety of perturbations. Both open and closed loops are used to examine the data. The train was effectively suspended and pushed along the track, as shown by the closed-loop reaction.

Keywords: *Optimal Control, Realization, Non-fragile, LQR, Observer Based.*

1. INTRODUCTION

There is a wide range of applications for magnetic levitation systems. the levitation of molten metal in induction furnaces and the levitation of metal slabs during production (Laithwaite 1965, Jayawant and Rea 1965) [1]. frictionless bearings, high-speed maglev passenger trains, levitation of wind tunnel models, vibration isolation of sensitive gear. Here, we want to see which of two controllers—the Linear Quadratic Regulator (LQR) or the Observer Base Controller—is better at keeping the Maglev train suspended and moving down the track. The movement of a maglev train is regulated by three distinct systems. Three distinct but interrelated systems [2]: guidance, propulsion, and levitation. To drive the train down the track, a guidance system is used to provide the necessary side force. High-speed Maglev trains favor a propulsion method that employs an electrically driven motor embedded in the track itself. The train is held in the air by a levitation technology that uses magnetic fields to counteract the effects of gravity. To stabilize the open-loop response of these systems, a feedback route was included. The closed-loop response of the system was stabilized using both controllers [3]. In order to linearize the obtained nonlinear model, Valer and Lia suggest the systems linearization concept (the expansion in Fourier series and the preservation of the first order components) [4-5]. In order to achieve our goal of creating a non-fragile optimum controller, we first developed linear controllers to ensure the safety and comfort of train passengers. The state space model of a Magnetic Levitation train is simulated in MATLAB / SIMULINK [6] after a

Sarhad University of Science & Information Technology, Peshawar, Pakistan

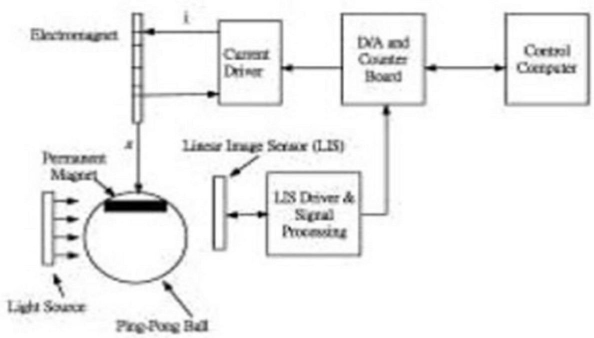

Fig. 1. Block Diagram of Magnetic Levitation System

2. MATHEMATICAL MODEL OF MAGNETIC LEVITATION SYSTEM

State space model of Magnetic Levitation is derived as given in [4]

$$v = \frac{dx}{dt} \text{------------}(1)$$

$$u = Ri + \frac{dL(x)i}{dt} \text{--------}(2)$$

$$m\ddot{x} = mg - C\left(\frac{i}{x}\right)^2 \text{------}(3)$$

Equation (2) indicates that L(x) is a nonlinear function. Various approximate values are used to determine the value of inductance for the Magnetic Levitation. If we take the assumption that the inductance of the system varies with the inverse of the ball position

$$L(x) = L + \frac{L_0 x_0}{x} \text{--------}(4)$$

Where L is the constant Inductance of the coil in the absence of the ball, L0 is the additional inductance contributed by the presence of the ball

$$u(t) = iR + \frac{d}{dt}\left(L_c + \frac{L_0 x_0}{x}\right)i$$

$$u(t) = iR + L\frac{di}{dt} - \left(\frac{L_0 x_0 i}{x^2}\right)\frac{dx}{dt}$$

Substituting L0 x0 =2C [4], we get

$$u(t) = iR + L\frac{di}{dt} - C\left(\frac{i}{x^2}\right)\frac{dx}{dt} \text{----}(5)$$

Linear Model of the System is

$$A = \begin{bmatrix} 0 & 1 & 0 \\ \frac{Cx_{03}^2}{mx_{01}^3} & 0 & -2\frac{Cx_{03}}{mx_{01}^2} \\ 0 & 2\frac{Cx_{03}}{Lx_{01}^2} & -\frac{R}{L} \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 0 \\ \frac{1}{L} \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$$

3. METHODOLOGY

The output response of both controllers i.e. LQR (Linear Quadratic Regulator) and Observer Based Controller was compared that which controller response can perfectly overcome the disturbance effect and overcome the disturbing effect and to improve the performance parameter and make the close loop response of the system stable. Different realization techniques are used to obtain a reduced and non-fragile model [3].

Realization Techniques

In order to obtain a reduced and non-fragile optimal controller different realization techniques are used. Minimal realization (The realization is known as "minimal" as it defines the system with least number of states). Balanced realization, Modal realization and Observer based canonical realization are the other different techniques used to obtained a reduced and non-fragile model.

4. RESULTS AND CONCLUSION

This work was carried out on considering a Magnetic Levitation System. The mathematical derivations were done in state space form. For simulation MATLAB software was used. Several road disturbances were being injected to the system. The open loop response in MATLAB shows oscillations, large overshoot and required large settling time to damp. Different controllers/compensators were designed to obtain the desired response. LQR controller improved the performance of the system. The results obtained were satisfactory. Then observer based controller was designed. After adding the observer gain to observer based controller the performance of the system was improved significantly as compared to LQR. Different realization techniques were then used, by applying these techniques the controllers action was made more efficient and the system was made highly stable and non-fragile.

International Journal of Information Technology & Computer Engineering
SSN 2347–3657
Volume 4, Issue 3, July 2016

Comparison between LQR Controller and Observer Based Controller

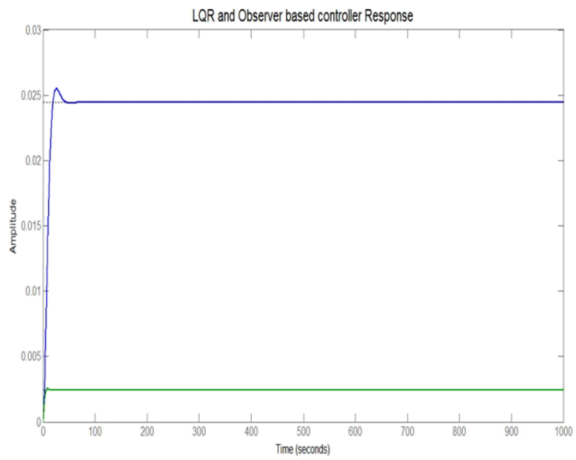

Fig. 2. Comparison between the LQR and Observer Based controllers

From the above plot it was very clear that the observer based controller has much better response as compared to the LQR controller. The overshoot and the settling time have been reduced up to a great level.

Minimal Realization

For LQR controller no state has been reduced, while in Observer Based controller three states have been removed .The controlled response has three states and after minimal realization the states remain the same in LQR controller and for observer based controller three states have been reduced, the controlled response has six states and after minimal realization the states were reduced to three. Difference between the LQR controller, Observer based and minimal realization response was plotted as shown in the figure.

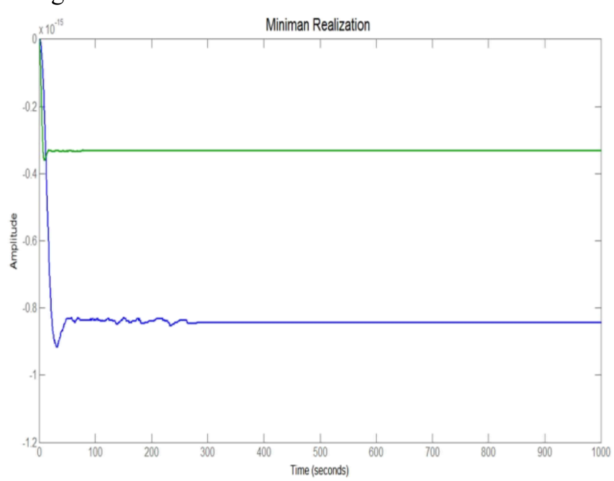

Fig. 3. Minimal Realization

Balanced Realization

Difference between the LQR controller, Observer based controller and balanced realization response was plotted as shown in the figure

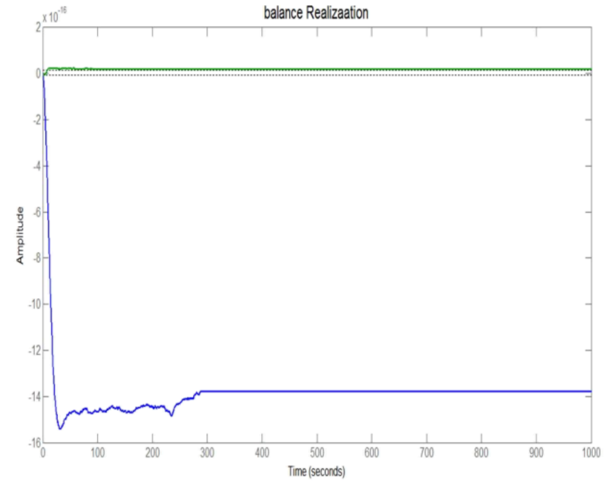

Fig. 4. Balance Realization

Model realization

Difference between the LQR controller, Observer based controller and model realization response was plotted as shown in Figure

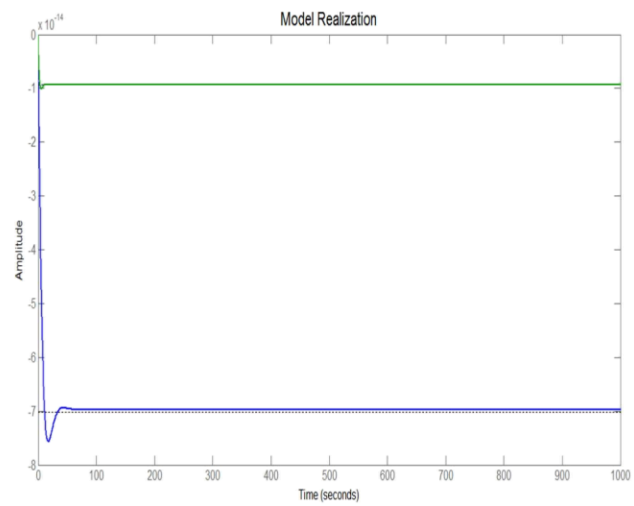

Fig. 5. Model Realization

Observer Canonical Realization

Difference between the LQR controller, Observer based controller and Observer Canonical realized response was plotted as shown in Figure

International Journal of Information Technology & Computer Engineering
SSN 2347–3657
Volume 4, Issue 3, July 2016

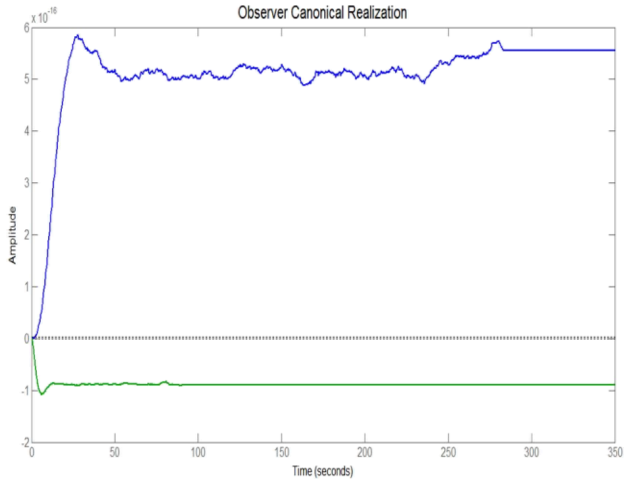

Fig. 6. Observer Canonical Realization

A brief summary of all types of realization techniques was given below in table 1. This table shows that observer canonical realization on LQR and balanced Realization in Observer based controller gives the least error to controller which represents the most optimal and most non-fragile optimal controller technique.

Table 1: Realization analysis for different controllers

Realization type	LQR controller	Observer Based Controller
Minimal Realization	10-15	10-16
Balanced Realization	10-15	10-17
Modal Realization	10-14	10-14
Observer canonical Realization	10-16	10-16

For different input disturbances the Observer based controller shows better response. The Observer based controller settles the oscillations more quickly, reducing the oscillation and overshoot. The designed Observer based controller provides better handling ability for wide range of disturbances and provides better ride comfort for passengers.

Hence it was very clear from results that the observer based controller shows better response as compared to LQR controller.

Also minimal realization gives the least error to controller which represents the most optimal and most non-fragile optimal controller technique.

REFERENCES

[1] The following is a quote from "Linear and Non Linear State space controller for magnetic levitation" by Walter Bariet and John Chiassont, published in the 1996 issue of the International Journal of System Sciences.

[2] Based on the research of the NASA Florida Space Institute, "Magnetic Levitation Space Propulsion" [2].

[3] [3] M.Abid Saeed, Niaz Ali, Muhammad Waqas, and Anees ur rehman, "Design of a Non Fragile Optimal Controller Realization for Vehicle Suspension Systems for Different Road Profiles", Sarhad University of Science and Information Technology Peshawar, Pakistan, and National Power control center NPCC, Pakistan, IOSR Journal of Electronics and Communication Engineering, February 2014.

[4] In 2010, during the International Conference on Signal Processing, Robotics, and Automation, Ishtiaq Ahmad and Muhammad Akram Javaid presented "Nonlinear Model & Controller Design for Magnetic Levitation System" from the University of Engineering and Technology in Taxila, Pakistan.

[5] Dolgas, Valer and Lia Research Article Title: "Modeling and Simulation of a Magnetic Levitation System" ORADEA UNIVERSITY ANNALS. Technical and Management Fascicles, Volume 6 (XVI), 2007.

[6] University of Michigan (1997), "Control Tutorial for Mat lab" (by Carnegie Mellon).