Chapter 17

Neural Network Control of a Laboratory Magnetic Levitator

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ABSTRACT

Magnetic levitation (maglev) systems are nowadays employed in applications ranging from non-contact bearings and vibration isolation of sensitive machinery to high-speed passenger trains. In this chapter a mathematical model of a laboratory maglev system was derived using the Lagrangian approach. A linear pole-placement controller was designed on the basis of specifications on peak overshoot and settling time. A 3-layer feed-forward Artificial Neural Network (ANN) controller comprising 3-input nodes, a 5-neuron hidden layer, and 1-neuron output layer was trained using the linear state feedback controller with a random reference signal. Simulations to investigate the robustness of the ANN control scheme with respect to parameter variations, reference step input magnitude variations, and sinusoidal input tracking were carried out using SIMULINK. The obtained simulation results show that the ANN controller is robust with respect to good positioning accuracy.

1. INTRODUCTION

Essentially magnetic levitation (maglev) is the use of controlled magnetic fields (or magnetic forces) to cause a magnetic object to float in air in defiance of gravity (Richard, 2004). Maglev systems are widely used in various fields, such as magnetic (non-contact) bearings (Hassan & Mohamed, 2001), high-speed maglev passenger trains (Murai & Tanaka, 2000) and vibration isolation of sensitive machinery (Shen, 2002). Most of the current maglev systems are of the electromagnetic suspension (EMS) type, whereby electric current variations control the attractive force of an electromagnet. The mathematical models of such systems are highly nonlinear and open-loop unstable (Yang, Miyazaki, Kanae & Wada, 2005). Hence it is not a trivial task to construct a high performance controller to accurately position the levitated object.

In recent years, many techniques have been reported in the technical literature for controlling maglev systems. Barrie and Chiasson (1996) as well as Joo and Seo (1997) employed feedback

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linearization techniques to design control laws for maglev systems. Al-Muthairi and Zbiri (2004) and Phuah, Lu and Yahagi (2005) applied the nonlinear sliding mode control technique to improve the positioning accuracy of maglev systems. Other types of controllers for maglev systems reported in the technical literature include: phase-lead compensation (Wong, 1986; Sani, 2004); fuzzy logic controllers (Golob, 2000; Tzes, Chen, & Peng, 1994) and artificial neural network controllers (Kemal, 2003).

Artificial neural networks (ANNs) have shown a great promise in identification and control of nonlinear systems. ANNs constitute a powerful data-modelling tool that is able to capture and represent complex input/output relationships. The motivation for the development of ANN technology stemmed from the desire to develop an artificial system that could perform "intelligent" tasks similar to those performed by the human brain (Hagan, M., Demuth, H., & De Jesus, 2002). ANNs are composed of simple elements operating in parallel. These elements were inspired by biological nervous systems. One can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements. ANNs have been trained to perform complex functions in various fields of application including pattern recognition, identification, classification, vision and automatic control.

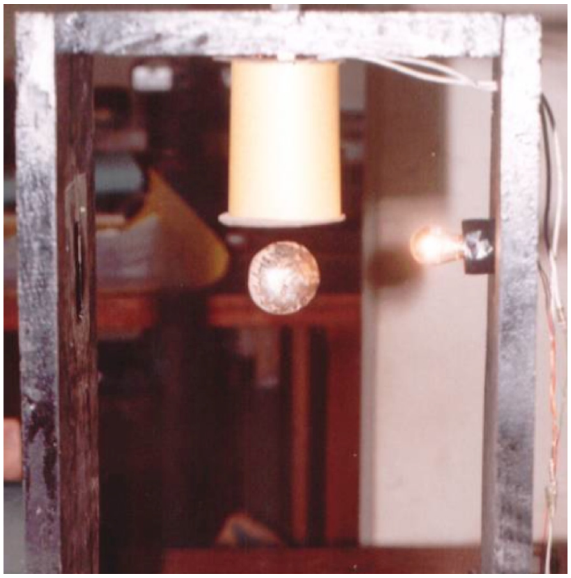
This work considers a laboratory maglev system that was implemented by Sani (2004) and controlled using a lead compensator. An artificial neural network controller for the system is proposed and simulated in the MATLAB/SIMULINK environment. The proposed controller is trained based on the performance of a linear state feedback controller, which was designed to satisfy a pair of dominant poles in the state-space. The rest of the chapter is organized as follows. Section 2 deals with the mathematical modelling of the maglev system. In Section 3 a linear state feedback controller for the maglev system is designed based on well-known engineering specifications of peak overshoot and settling time. Section 4 contains the design and training of an ANN controller for the maglev system. Section 5 presents and discusses simulation results of the proposed ANN controller. Conclusions drawn from the study are given in the last section.

2. MATHEMATICAL MODEL OF THE MAGLEV SYSTEM

The maglev system considered in this paper consists of ferromagnetic ball suspended in a magnetic field. Only the vertical motion is considered. The objective is to keep the ball at a prescribed reference level. The dynamical equations of the maglev system are derived using the Lagrange method.

Figure 1 shows a photograph of the maglev system while Figure 2 shows the corresponding schematic diagram, where: M is the levitated ball mass (kg); g is acceleration due to gravity (m/s^2); V is the voltage (V) applied to the electromagnet

Figure 1. Photograph of a laboratory magnetic levitation system



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