Chapter 14
Design of a Hybrid Adaptive Neuro Fuzzy Inference System (ANFIS) Controller for Position and Angle Control of Inverted Pendulum (IP) Systems

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ABSTRACT

This paper illustrates a comparison study of Fuzzy and ANFIS Controller for Inverted Pendulum systems. IP belongs to a class of highly non-linear, unstable and multi-variable systems which act as a testing bed for many complex systems. Initially, a Matlab-Simulink model of IP system was proposed. Secondly, a Fuzzy logic controller was designed using Mamdani inference system for control of proposed model. The data sets from fuzzy controller was used for development of a Hybrid Sugeno ANFIS controller. The results shows that ANFIS controller provides better results in terms of Performance parameters including Settling time(sec), maximum overshoot(degree) and steady state error.

1. INTRODUCTION TO IP SYSTEMS

The control of IP has been an interesting control problem since 1950s (Astrom & Furuta, 2000). It comprises of a rigid (Srivastava, 2009) or elastic (Dadios, 1997) pole mounted on a cart which is free to move in horizontal direction. A view of IP system is shown in Figure 1. It consist of cart driven by electric motor and a pendulum freely pivoted above it, along with sensors and electronic circuits.

IP systems provides a testing bed for various control techniques (Prasad et al., 2011) like feedback stabilization, variable structure control, passivity based control, non-linear observer, friction compensation, task oriented control, hybrid systems control (Maravall., 2005), chaotic system control etc. (Krishnan, 2012). The dynamics of IP is similar to two wheeled robots (Shiroma et al., 1996; Shimada

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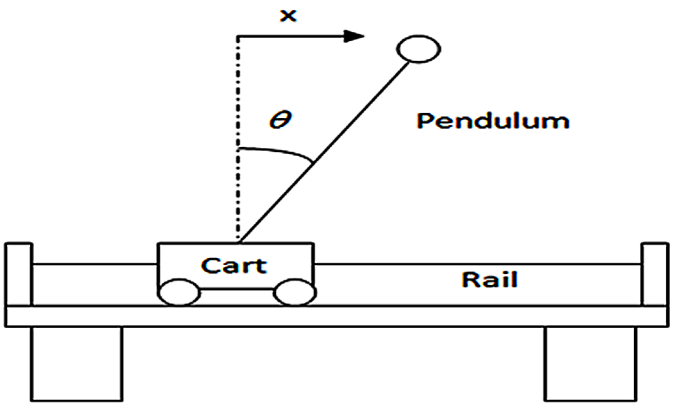
Figure 1. A view of complete IP system



& Hatakeyama, 2007), flexile robotic links (Zveu et al, 2004), biped robots (Kuo, 2007; Vanderborght et al., 2008), missile stability controllers (Hauser et al., 2005) etc. IP consist of two equilibrium position i.e. stable and unstable. The stable equilibrium is the position in which pendulum is pointing downwards and unstable equilibrium corresponds to the position when pendulum points directly upwards. To maintain pendulum in upward position a control force is required which is provided by Fuzzy or ANFIS controllers.

2. FREE BODY DIAGRAM (FBD) AND MATHEMATICAL MODELING OF IP SYSTEMS

The IP system comprises of mainly two sub-systems i.e. Cart and Pendulum (Kharola & Gupta, 2013) as shown in Figure 2. A pendulum of mass (m), hinged by an angle (θ) from vertical axis and mounted on a cart of mass (M). This cart is free to move in horizontal direction with the help of Force (F). The Coefficient of friction acting between cart and ground (b), length of pendulum (L) and Inertia of Pendulum (I).

A view of forces acting on Cart and Pendulum are shown with the help of free body diagrams (FBD) as shown in Figure 3 and Figure 4. The FBD are further used for developing governing mathematical equations for IP system.

Figure 2. A view of IP sub-systems