Chapter 13
Recurrent Higher Order Neural Network Control for Output Trajectory Tracking with Neural Observers and Constrained Inputs

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ABSTRACT
This Chapter presents the design of an adaptive recurrent neural observer-controller scheme for nonlinear systems whose model is assumed to be unknown and with constrained inputs. The control scheme is composed of a neural observer based on Recurrent High Order Neural Networks which builds the state vector of the unknown plant dynamics and a learning adaptation law for the neural network weights for both the observer and identifier. These laws are obtained via control Lyapunov functions. Then, a control law, which stabilizes the tracking error dynamics is developed using the Lyapunov and the inverse optimal control methodologies. Tracking error boundedness is established as a function of design parameters.

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1. INTRODUCTION

Over the past decade, adaptive neural control schemes have received an increasing attention for applications on nonlinear systems control. Mainly due to the seminal paper (Narendra & Parthasarathy, 1990), there has been continuously increasing interest in applying neural networks to identification and control of nonlinear systems. Lately, the use of recurrent neural networks is being developed, which allows more efficient modeling of the underlying dynamical systems (Poznyak et al.). Three representative books (Suykens et al., 1996), (Rovitahkis & Christodoulou, 2000) and (Poznyak et al., 2000) have reviewed the application of recurrent neural networks for nonlinear system identification and control. In particular, (Suykens et al., 1996) uses off-line learning, while (Rovitahkis & Christodoulou, 2000) analyzes adaptive identification and control by means of on-line learning, where stability of the closed-loop system is established based on the Lyapunov function method. In (Rovitahkis & Christodoulou, 2000), the trajectory tracking problem is reduced to a linear model following problem, with application to DC electric motors. In (Poznyak et al., 2000), analysis of Recurrent Neural Networks for identification, estimation and control are developed, with applications on chaos control, robotics and chemical processes. One recent publication (Sanchez et al., 2008), explores the application of Recurrent Higher Order Neural Networks (RHONN) for trajectory tracking control schemes using the Kalman filtering training with real time applications to electrical machines.

In many control applications, the process presents highly nonlinear behaviour, uncertainties, unknown disturbances and bounded inputs. All these phenomena are required to be considered for control analysis and synthesis. The problem of designing robust controllers for nonlinear systems with uncertainties, which guarantee stability and trajectory tracking, has received an increasing attention lately. The presence of constrained inputs limits the ability to compensate the effects of unmodeled dynamics and external disturbances. These effects impact on the loss of stability, undesired oscillations and other adverse effects. There are several results on linear control systems with input constraints, (Hu & Lin, 2001). For nonlinear systems, control with constrained inputs is restricted by requiring to know the system model. Some algorithms allow the presence of uncertainties satisfying the matching condition (El-Farra & Christofides, 2001). In (El-Farra & Christofides, 2001), a control law, based on the Sontag formula with constrained inputs, is developed and applied to a chemical reactor. To relax the restriction of requiring knowledge of the system model, identification via recurrent neural networks arises as a potential solution (Hokimyan, et. al., 2001). Most of the control algorithms for nonlinear systems use the assumption that all the states are available for measurement, which is a condition seldom satisfied. The nonlinear observers arise as a solution, and have received much attention lately. For linear unknown systems, the observer design has been widely investigated. For nonlinear systems, the results are too restrictive according to the nonlinearity and system structure. In (Marino, 1990), an adaptive observer for nonlinear systems is proposed, where the uncertainties are assumed to be linear and the nonlinearities are functions of the output. In (Kim, et al., 1996), a nonlinear observer based on neural networks is developed. The nonlinearities are not required to depend on the system output only, but having some restrictions on the structure of the dynamical system. Robust observers have a good performance even in presence of modelling errors and disturbance uncertainties, but their design process is too complex. Although most of the approaches need the previous knowledge of the plant dynamics, recently, neural observers has emerged for unknown plant dynamics and have proven their ability of dealing with the presence of simultaneous external and internal uncertainties (Sanchez et al., 2007).
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