OBSERVER-BASED ADAPTIVE FUZZY BACKSTEPPING CONTROL FOR STRICT-FEEDBACK NONLINEAR SYSTEMS WITH UNKNOWN TIME DELAYS

Shaocheng Tong, Ning Sheng and Yongming Li

Department of Basic Mathematics
Liaoning University of Technology
No. 169, Shiying Street, Guta Distinct, Jinzhou 121001, P. R. China
jztsc@sohu.com

Abstract. *In this paper, an adaptive fuzzy backstepping control approach is developed for a class of nonlinear systems with unknown time delays and unmeasured states. By using fuzzy logic systems to approximate the unknown nonlinear functions, a fuzzy adaptive state observer is designed for estimating the unmeasured states. By combining the adaptive backstepping technique with adaptive fuzzy control design, an adaptive fuzzy output feedback backstepping control approach is developed. It is mathematically proved that the proposed adaptive fuzzy control approach is able to guarantee that all the signals of the closed-loop system are semiglobally uniformly ultimately bounded (SUUB) and that the tracking error converges to a small neighborhood of the origin by appropriate choice of the design parameters. Simulation results are provided to show the effectiveness of the proposed approach.*
Keywords: Nonlinear time-delay systems, Fuzzy logic systems, State observer, Adaptive output feedback control, Backstepping design, Stability analysis

1. **Introduction.** In recent years, with the development of backstepping technique, fuzzy control theory and methods [1-3], many approximator-based adaptive fuzzy backstepping controllers have been developed for the nonlinear systems in strict-feedback form [4-12]. The adaptive fuzzy backstepping controllers can provide a systematic methodology of solving the tracking or regulation control problems, in which the fuzzy logic systems are used to approximate the nonlinear uncertainties, and adaptive fuzzy controllers are constructed recursively. The main features of these adaptive approaches can deal with those nonlinear systems without satisfying the matching conditions, and do not require that the nonlinear uncertainties must be linearly parameterized [4,9,10,12]. Therefore, approximator-based adaptive fuzzy backstepping control has become one of the most popular design approaches in fuzzy control community.

In view of time delay frequently occurring in real engineering systems, the stability analysis and robust control for nonlinear time-delay systems have attracted considerable attention in recent years. It is well known that time delays may destroy the stability or degrade the performance of the controlled systems. Therefore, the stability analysis and controller synthesis of nonlinear time-delay systems are important both in theory and applications. By using Lyapunov-Razumikhin functions or Lyapunov-Krasovskii functions, many adaptive backstepping stabilizing control schemes are developed in [13,14] for nonlinear time-delay systems with parametric uncertainties. To deal with completely unknown nonlinear systems with time delays, several approximation-based adaptive fuzzy controllers have been reported in [15,16]. The proposed adaptive control approaches can