Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Fuzzy Sets and Systems 153 (2005) 447–458
FUZZY sets and systems
www.elsevier.com/locate/fss

Adaptive fuzzy control for uncertain interconnected time-delay systems[☆]

Changchun Hua[a], Xinping Guan[a,*], Peng Shi[b,1]

[a]*Institute of Electrical Engineering, Yanshan University, Qinghuangdao 066004, China*
[b]*School of Technology, University of Glamorgan, Pontypridd, Wales, CF37 1DL, UK*

Received 18 August 2003; received in revised form 6 December 2004; accepted 10 January 2005
Available online 29 January 2005

Abstract

In this paper, the problem of control for a class of uncertain interconnected time-delay systems is studied. The interconnections of the system possess time-varying delay characteristics, and the bounds of uncertainties are not precisely known. A decentralized adaptive feedback controller is designed, which is independent of the delays. Lyapunov–Krasovskii approach is employed to show that the corresponding closed-loop system is asymptotically stable. A simulation example is given to demonstrate the potential of the proposed techniques.

Keywords: Adaptive fuzzy control; Interconnected systems; Time delays; Uncertainties

1. Introduction

Various engineering systems, such as electrical networks, turbojet engines, microwave oscillators, nuclear reactors, and hydraulic systems have the characteristics of time-delay. Due to the effect of time delay, these systems may possess instability, and the control performance of these systems are hardly

☆ This work is supported by the Science Foundation of Yanshan University for the Excellent Ph.D. Students and the National Nature Science Foundation of China (NO. 60274023 and NO. 60404022).
* Corresponding author. Tel.: +86 0335 8057041; fax: +86 0335 8051148.
E-mail addresses: cch@ysu.edu.cn (C. Hua), xpguan@ysu.edu.cn (X. Guan).
1 He was with Weapons Systems Division, Defense Science and Technology Organization, Department of Defence, PO Box 1500, Edinburgh 5111 SA, Australia.

0165-0114/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.fss.2005.01.002

assured. In the past 20 years, a great amount of effort has been devoted to the problems of stability analysis and robust control for time-delay systems, see for example, [1–5,8,9,11,12] and references therein.

On another research front line, many practical systems are found to be large-scale systems that are composed of a set of interconnected subsystems, such as power systems, digital communication networks, economic systems and urban traffic networks. Robust control for large-scale time-delay systems have been one of the hot study topics in the past years, and a lot of achievements have been made, see for example [6,7,10,13,14,17–19]. In [7], the problem of robust control for a class of interconnected systems with bounded uncertainties was considered. The same system was further discussed by using the decentralized sliding mode control method in [6]. The problem of stabilization of large-scale stochastic systems with time delay was studied in [19], while stabilization of a class of time-varying large scale systems subject to multiple time-varying delays in the interconnections was investigated in [10]. In the work of [18], the robust control problem was investigated by using a linear function as a bound for the uncertain interconnections.

In this paper, we will consider the control problem of a class of nonlinear interconnected time-delay systems, the uncertain interconnections of which are bounded by nonlinear functions. Motivated by the results in [17], from which, the adaptive fuzzy logic system can approximate the nonlinear functions to arbitrary precision, we employ fuzzy approach to approximate the bounds of interconnections in this paper, which has more advantages over the methods developed in [15,16]. Then a decentralized feedback controller independent of time delays is designed. Based on Lyapunov–Krasovskii function, we show that the resulting closed-loop control system is asymptotically stable. Finally, a simulation example is employed to verify the effect of the proposed techniques.

2. System formulation

Consider a class of interconnected time-delay systems whose ith ($i = 1, 2, \ldots, N$) subsystem is described by

$$\dot{x}_i = A_i x_i + B_i u_i + \sum_{j=1}^{N} H_{ij}\left(x_j, x_j\left(t - d_{ij}(t)\right)\right), \tag{1}$$

where $x_i \in R^{n_i}$ and $u_i \in R^{m_i}$ represent the state and control vectors, respectively, of the subsystem. A_i and B_i are constant matrices with compatible dimensions. $H_{ij}\left(x_j, x_j\left(t - d_{ij}(t)\right), t\right)$ are uncertain nonlinear interconnections, which indicate the interconnections among the current states and the delayed states of subsystems S_i and S_j, while $d_{ij}(t)$ are bounded time-varying delays and differentiable satisfying

$$0 \leqslant d_{ij}(t) \leqslant d_{ij} < \infty, \quad \dot{d}_{ij}(t) \leqslant d_{ij}^* < 1, \tag{2}$$

where d_{ij}, d_{ij}^* are positive scalars, and initial conditions are given as follows:

$$x_i(t) = \Omega_i(t), \quad t \in \left[t_0 - d_{ij}, t_0\right], \ \ i = 1, 2, \ldots, N,$$

where $\Omega_i(t)$ are continuous functions.

For system (1), we introduce the following assumptions.