Decentralized Adaptive Robust State Feedback for Uncertain Large-Scale Interconnected Systems with Time Delays

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Abstract. The problem of the decentralized robust control is considered for a class of large-scale time-varying systems with delayed state perturbations and external disturbances in the interconnections. Here, the upper bounds of the delayed state perturbations and external disturbances in the interconnections are assumed to be unknown. Adaptation laws are proposed to estimate such unknown bounds; by making use of the updated values of the unknown bounds, decentralized linear and nonlinear memoryless robust state feedback controllers are constructed. Based on Lyapunov stability theory and Lyapunov–Krasovskii functionals, as well as employing the proposed decentralized nonlinear robust state feedback controllers, it is shown that the solutions of the resulting adaptive closed-loop large-scale time-delay system can be guaranteed to be uniformly bounded and that the states converge uniformly and asymptotically to zero. It is also shown that the proposed decentralized linear robust state feedback controllers can guarantee the uniform ultimate boundedness of the resulting adaptive closed-loop large-scale time-delay system. Finally, a numerical example is given to demonstrate the validity of the results.

Key Words. Large-scale systems, decentralized control, adaptive control, robust control, time-delay systems, Lyapunov–Krasovskii functionals.

1. Introduction

In general, a large-scale dynamical system is characterized by a large number of variables representing the system, a strong interaction between
The system variables, and a complex structure; see e.g. Refs. 1–2. In particular, a large-scale interconnected dynamical system can be considered as a networked system with nonlinear components. The advantage of this approach is to reduce the complexity of the system, making it feasible to implement a controller. Thus, the problem of decentralized control of large-scale interconnected dynamical systems has been studied widely; see e.g. Ref. 1 and the references therein.

It is well known that some degree of uncertainty is often included in practical control systems. Therefore, the problem of decentralized robust control of large-scale interconnected systems with significant uncertainties has received considerable attention by researchers and many approaches to designing decentralized robust state or output feedback controllers have been developed. For example, in Ref. 6 the decentralized state feedback controllers, proposed in Ref. 5 for linear time-varying interconnected systems, were extended to the decentralized state feedback problem of two classes of large-scale interconnected systems with nonlinear perturbations. In Ref. 7, decentralized linear and nonlinear state feedback controllers were proposed for a class of large-scale interconnected nonlinear systems with time-varying uncertainties.

In many practical control problems (chemical processes, hydraulic systems, rolling mill systems), there are delays due to measurement of system variables, physical properties of the equipment used in the system, signal transmission (transport delay), and so on. The existence of delay is frequently a source of instability; see e.g. Refs. 8–9. Therefore, the problem of decentralized stabilization for large-scale time-delay interconnected systems has received considerable attention and some results have been obtained. In Ref. 10, for example, the stabilization problem of a class of large-scale nonlinear systems with infinite delay was considered. It was shown that exponential stability can be achieved by a suitable choice of state feedback controllers for large-scale systems with infinite delay. In Refs. 11–12, the decentralized stabilization problem of linear time-invariant, large-scale multivariable systems with time-delay was considered and some sufficient conditions on decentralized local state feedback control were derived. In Ref. 13, based on the assumption that each isolated subsystem is strictly feedback positive real, a class of decentralized stabilizing output feedback controllers was proposed for large-scale systems with time-varying delays in the interconnections. In Ref. 14, the problem of decentralized stabilization of large-scale systems with time-varying delays in the interconnections was considered and some decentralized memoryless state feedback controllers were designed. The approach presented in Ref. 14 was based on the assumption that each isolated subsystem is strictly feedback positive real.