Robust Stabilization of Large-Scale Time-Delay Systems with Estimated State Feedback

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Abstract. This paper proposes a class of observers and uses the estimated state feedback to stabilize a perturbed large-scale time-delay system in which the state is unmeasurable. An inequality representing the relationship among the perturbation bounds, interconnection magnitudes, and gains of observers and controllers is derived to ensure that the system is stabilized and the state is estimated. Moreover, this inequality does not need the solution of a Lyapunov equation or Riccati equation and is independent of time delays.

Key Words. Robust stabilization, time-delay systems, large-scale systems, observers.

1. Introduction

Time-delays exist always in practical control systems due to the action speed limitation of mechanism and/or electronics. Hence, the stability of time-delay system is worth investigating in control system analysis and design. Mori et al. (Ref. 1), Xu (Ref. 2), Hmamed (Ref. 3), and Su and Huang (Ref. 4) have derived many stability or robust stability criteria for single time-delay systems. For multiple time-delay systems, Chiasson et al. (Ref. 5), Wang et al. (Ref. 6), Walton and Marshall (Ref. 7), Chiasson

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(Ref. 8), and Lu and Chen (Ref. 9) proposed several stability or robust stability results. For large-scale systems with time delay, there are stability criteria and stabilization methods being developed by Mori et al. (Ref. 10), Suh and Bien (Ref. 11), Hmamed (Ref. 12), Lee and Radovic (Refs. 13–14), Wang and Song (Ref. 15), etc. However, there has been few works that study the control problem for large-scale delay systems whose state cannot be measured completely.

Recently, Wang et al. (Ref. 16) studied the problem of estimation and stabilization for perturbed large-scale systems with time delays. They proposed a technique to determine the gains of controllers and observers and the tolerable perturbation bound in large-scale time-delay systems. However, in that paper, the controller and observer gains are determined by two inequalities; at the same time, the perturbation bound is obtained from a complicated form. In this paper, we use a more systematic method to find the relationship among the controller gain, observer gain, and allowable perturbation bound so that the states of each subsystem are asymptotically estimated and the whole system is asymptotically stable. The relationship is expressed by a simple inequality without solving a Lyapunov equation or invoking complicated computations.

Let $\mathbb{R}^n$ and $\mathbb{R}^{n \times m}$ denote the real vector space of dimension $n$ and linear matrix operator from $\mathbb{R}^m$ to $\mathbb{R}^n$, respectively. $A^T$ denotes transpose of the matrix $A$; $\|x\|$ means the Euclidean norm of the vector $x$, and $\|A\|$ means the spectral norm of the matrix $A$; moreover, the matrix measure is defined as

$$\mu(A) := (1/2)\lambda_{\text{max}}(A^T + A).$$

2. System Description and Problem Formulation

Consider the following perturbed large-scale time-delay system which consists of $N$ interconnected subsystems:

$$\dot{x}_i(t) = A_ix_i(t) + B_iu_i(t) + \sum_{j=1}^{N} A_{ij}x_j(t-d_{ij}) + f_i(x_i(t), t),$$

$$y_i(t) = C_ix_i(t),$$

$$x_i(t) = x_{0i}(t), \quad t \in [-d_i, 0], \quad i = 1, 2, \ldots, N,$$

where $t \in \mathbb{R}_+$ is the time, $x_i(t) \in \mathbb{R}^{n_i}$, $u_i(t) \in \mathbb{R}^{m_i}$, $y_i(t) \in \mathbb{R}^{p_i}$, represent the state, input, and output vectors of each subsystem, respectively. The matrices $A_i$, $B_i$, $C_i$ are constant matrices with appropriate dimensions; $d_{ij} \in \mathbb{R}_+$ and...