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New delay-dependent non-fragile H_∞ observer-based control for continuous time-delay systems

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ABSTRACT

The problem of the delay-dependent non-fragile H_∞ observer-based control for a class of continuous time-delay systems is investigated in this paper. The additive gain variations under consideration are contained in both the controller gain and observer gain. Delay-dependent criteria are derived to guarantee the stability of the non-fragile H_∞ observer-based control system using the Lyapunov functional approach. The controller and observer gains are given from the LMI feasible solutions. Based on the result of this paper, the constraint of matrix equality is not necessary for designing the non-fragile H_∞ observer-based controls. Computer software *Matlab* can be applied to solve all the proposed results. Finally, a numerical example is illustrated to show the improvement of this paper.

1. Introduction

Time-delay phenomena are often encountered in various practical systems, such as AIDS epidemic, aircraft stabilization, chemical engineering systems, distributed networks, inferred grinding model, manual control, microwave oscillator, neural network, nuclear reactor, population dynamic model, rolling mill, ship stabilization, and systems with lossless transmission lines [8,11]. In practical systems, analysis of a mathematical model is usually an important work for a control engineer as to control a system. However, the mathematical model always contains some uncertain elements. Therefore, under such imperfect knowledge of the mathematical model, seeking to design a robust control such that the system responses can meet desired properties is an important topic in system theory. Hence robust stability and robust stabilization problems for time-delay system have received some attenuation [7,10,14,15].

In the many real-world systems, state feedback control will fail to guarantee the stabilizability when some of system states are not measurable. In the observer-based control, output dynamic feedback control is provided and the system state can be estimated from the process. The observer-based controls are often be utilized to stabilize unstable systems or improve the system performance. Hence, the observer-based control for systems has been an interesting topic in control theory [6,12,13,16,19,21]. Lyapunov stability theory is used to design the nonlinear state observers for linear time-varying systems [19]. In [6,12,13,16], the LMI approach is introduced to design the observer-based controls for uncertain systems. In [21], a Razumikhin-type theorem is used to design the observer-based control for uncertain time-delay system and algebraic stabilizability conditions are provided.

In the recent years, the non-fragile control problem has been an attractive topic in theory analysis and practical implement. The non-fragile control concept is proposed to this new problem: how to design a feedback control that will be

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Nomenclature

$\Re^n$	n-dimensional real space
$\Re^{m\times n}$	set of all real m by n matrices
$L_2[0,\infty)$	space of square integrable functions on $[0,\infty)$
A^T (resp. x^T)	transpose of matrix A (resp., vector x)
$\lVert x\rVert$	Euclidean norm of vector x
$\lVert A\rVert$	spectral norm of matrix A
$\lVert f\rVert_2$	$\sqrt{\int_0^\infty \lVert f(t)\rVert^2 \mathrm{d}t}, f(t)\in L_2[0,\infty)$
rank(A)	rank of matrix A
$A\leqslant B$	$B-A$ is a positive semi-definite symmetric matrix
$P>0$	P is a positive definite symmetric matrix
$P<0$	P is a negative definite symmetric matrix
diag$Q_1\cdots Q_m$	block-diagonal matrix with $Q_1,\ldots,Q_m$ as the diagonal elements
$\begin{bmatrix} A & B \\ * & C \end{bmatrix}$	* represents the symmetric form of matrix; i.e., $^* = B^T$
I	unit matrix

insensitive to some error in gains of feedback control [3]. Design of non-fragile PID control for a given interval plant had been considered in [10]. Non-fragile guaranteed cost control for large-scale time-delay systems had been developed in [17]. In [23], non-fragile positive real control for a class of uncertain linear neutral time-delay systems had been proposed. Non-fragile guaranteed cost control problem for discrete linear systems had been studied in [25]. In [26], design of non-fragile guaranteed cost control for uncertain descriptor systems with time-varying state and input delays had been provided.

On the other hand, the H_∞ control concept was proposed to reduce the effect of the disturbance input on the regulated output to within a prescribed level [2,4,18,20,22]. The state feedback H_∞ controls for uncertain time-delay systems had been considered in [2,4,20,22]. The output H_∞ filtering design for neutral system without uncertainties had been proposed in [18]. However, the robust non-fragile H_∞ observer-based control for time-delay systems has never been considered in my best knowledge. This has motivated my study.

In this paper, we will adopt this useful methodology to the design of the robust non-fragile H_∞ observer-based controls for a class of continuous time-delay systems. The three classes of H_∞ observer-based controls with known and unknown time-delay values will be considered. Moreover, the H_∞-norm bound for the observer-based controls are provided.

2. Problem formulation and preliminaries

Consider the following continuous system with time delay:

$$\dot{x}(t) = A_0x(t) + A_1x(t-H) + Bu(t) + B_w w(t), \tag{1a}$$
$$y(t) = C_1x(t) + D_1u(t), \tag{1b}$$
$$z(t) = C_2x(t) + C_3x(t-H) + D_2u(t) + D_3w(t), \tag{1c}$$
$$x(t) = \phi(t), \quad t\in[-H,0], \tag{1d}$$

where $x\in\Re^n$, x_t is the state at time t defined by $x_t(s) := x(t+s)\ \forall s\in[-H,0]$, $u\in\Re^m$ is the input, $w\in\Re^l$ is the disturbance input, $y\in\Re^p$ is the measured output, $z\in\Re^q$ is the controlled output, $A_0,A_1\in\Re^{n\times n}, B\in\Re^{n\times m}, B_w\in\Re^{n\times l}, C_1\in\Re^{p\times n}$, $D_1\in\Re^{p\times m}, C_2\in\Re^{q\times n}, D_2\in\Re^{q\times m}$, and $D_3\in\Re^{q\times l}$ are constant matrices. The following modified observer-based control with the known time-delay value H is used to stabilize the system (1):

$$\dot{\hat{x}}(t) = A_0\hat{x}(t) + A_1\hat{x}(t-H) + Bu(t) + L[y(t)-\hat{y}(t)], \tag{2a}$$
$$\hat{y}(t) = C_1\hat{x}(t) + D_1u(t), \tag{2b}$$
$$u(t) = K\hat{x}(t), \tag{2c}$$

where $\hat{x}\in\Re^n$ is the estimation of x, $\hat{y}\in\Re^p$ is the observer output, $K\in\Re^{m\times n}$ is the controller gain, $L\in\Re^{n\times p}$ is the observer gain.

Here, the non-fragile observer-based control for the actual implement is considered:

$$\dot{\hat{x}}(t) = A_0\hat{x}(t) + A_1\hat{x}(t-H) + Bu(t) + (L+\Delta L)[y(t)-\hat{y}(t)], \tag{3a}$$
$$\hat{y}(t) = C_1\hat{x}(t) + D_1u(t), \tag{3b}$$
$$u(t) = (K+\Delta K)\hat{x}(t), \tag{3c}$$