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H_∞ guaranteed cost control for uncertain Markovian jump systems with mode-dependent distributed delays and input delays

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Abstract

This paper investigates the H_∞ guaranteed cost control problem for mode-dependent time-delay jump systems with norm-bounded uncertain parameters. Both distributed delays and input delays appear in the system model. Based on a matrix inequality, a sufficient condition for the existence of robust H_∞ guaranteed cost controller is derived, which stabilizes the considered system and guarantees that both the H_∞ performance level and a cost function have upper bounds for all admissible uncertainties. By the cone complementary linearization approach, the desired state-feedback controller can be constructed. A numerical example is provided to show the effectiveness of the proposed theoretical results.

Keywords: Markovian jump systems; Guaranteed cost control; Robust H_∞ control; Distributed delay; Input delay; Linear matrix inequality

1. Introduction

Guaranteed cost control has been one of the fundamental issues in control area since it was first introduced by Chang and Peng [1]. In the past decades, many significant works

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about this topic have been addressed for both continuous-time systems [2,3] and discrete-time systems [4,5]. In [2], the robust guaranteed cost control problem for a class of uncertain Markovian jump systems with mode-dependent delays was solved. For the discrete-time case, the delay-dependent output feedback guaranteed cost control problem was considered in [6], where an iterative algorithm involving convex optimizations was developed to design the desired controllers. Recently, some researchers presented results on H_∞ guaranteed cost control [7] and H_2 guaranteed cost control [8]. More literatures about guaranteed cost control can be referred to [9,10], and the references therein.

Since time-delays and parametric uncertainty are often the sources of instability and poor performance in many engineering systems, considerable attention has been devoted to the problem of stability analysis and controller synthesis for uncertain time-delay systems [11,12]. Furthermore, in practical applications it is desirable to extend the system model to include distributed delays. A practical application, modeled by systems with distributed delays, can be found in [13]. Robust H_∞ output feedback control for uncertain distributed delay systems was presented in [14], while in [15] the robust H_∞ filtering problem was solved via an LMI approach. It is worth pointing out that the systems in the above literature do not include the control input delays. In practice, control input delays are often imposed by process-design demands, so it is necessary to study uncertain systems with both state and input delays. Guaranteed cost control and robust H_∞ control for this class of systems were investigated in [16,17]. On the other hand, Markov process has been widely used to describe some physical systems, such as power systems, economic systems and failure prone manufacturing systems, and many results have been reported in the literature; see, e.g., [18,19] and the references therein. However, to the best of authors' knowledge, the robust H_∞ guaranteed cost control for uncertain Markovian jump systems with both distributed delays and input delays has not been considered in the literature.

In this paper, we solve the robust H_∞ guaranteed cost control problem for a class of uncertain Markovian jump systems with both input delays and distributed delays. Here, it is considered that all matrices, namely, the state, control input and disturbance input matrices, are time-varying but norm-bounded. The time delay depends on the system mode which is a Markov process taking value in a finite set. Attention is focused on the design of robust H_∞ guaranteed cost control law. An LMI-based optimization procedure is developed to compute the controller gain and the upper bound of guaranteed cost function. The results are delay-dependent, which in a certain degree reduce the conservatism.

Notation: Throughout this paper, for real symmetric matrices X and Y, the notation $X \geq Y$ (respectively, $X > Y$) means that the matrix $X-Y$ is positive semi-definite (respectively, positive definite); I is the identity matrix with appropriate dimension; the superscript "T" represents the transpose; $tr(M)$ stands for the trace of matrix M; $\lambda_{\min}(M)$ denotes the minimum eigenvalue of the symmetric matrix M; $\varepsilon\{\cdot\}$ denotes the expectation operator; $C[-\tau,0]$ refers to the family of continuous functions from $[-\tau,0]$ to $\mathbb{R}^n$; $L_2[0,\infty]$ is the space of square-integrable vector functions over $[0,\infty)$; $\|\cdot\|_2$ stands for the usual $L_2[0,\infty)$ norm; $|\cdot|$ is the standard Euclidean vector norm; the symbol $*$ is used to denote the transposed elements in the symmetric positions of a matrix. Matrices, if not explicitly stated, are assumed to have compatible dimensions.