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Non-fragile guaranteed cost control for uncertain stochastic nonlinear time-delay systems ☆

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Abstract

This paper deals with the problem of non-fragile guaranteed cost control for a class of uncertain stochastic nonlinear time-delay systems. The parametric uncertainties are assumed to be time-varying and norm bounded. The time-delay factors are unknown and time-varying with known bounds. The aim of this paper is to design a memoryless non-fragile state feedback control law such that the closed-loop system is stochastically asymptotically stable in the mean square for all admissible parameter uncertainties and the closed-loop cost function value is not more than a specified upper bound. A new sufficient condition for the existence of such controllers is presented based on the linear matrix inequality (LMI) approach. Then, a convex optimization problem is formulated to select the optimal guaranteed cost controller which minimizes the upper bound of the closed-loop cost function. Numerical example is given to illustrate the effectiveness of the developed techniques.

Keywords: Stochastic systems; Time-varying delays; Guaranteed cost control; Linear matrix inequalities (LMIs); Norm-bounded uncertainty

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1. Introduction

Time delay as a source of instability and poor performance often appears in many dynamic systems, for example, biological systems, chemical systems, metallurgical processing systems, nuclear reactor, long-transmission lines in pneumatic, hydraulic systems and electrical networks. The stability analysis and control of the system with time delay has been widely studied in the past several years, see for example [1–4] and the references therein. Recently, more and more attention has been paid on the problems of the robust stability analysis and robust controller synthesis for uncertain stochastic time-delay systems, see for example [5–13], and the references therein. However, when controlling a real plant, it is also desirable to design a control systems which is not only asymptotically stable but also guarantees an adequate level of performance. One approach to this problem is the so-called guaranteed cost control approach firstly introduced in [14]. The approach has the advantage of providing an upper bound on a given performance index and thus the system performance degradation incurred by uncertainty and time delay is guaranteed to be less than this bound. Based on this idea, there have been some efforts to tackle the guaranteed cost controller design problem, see [17,19–22]. Moreover, the problem of non-fragile control has been an attractive topic in theory analysis and practical implement, which is to design a feedback control that will be insensitive to some error in gains of feedback control [15]. Following this idea, there have been some results on this general topic, see for example [11,16–19]. The problem of non-fragile stabilization and $\mathscr{H}_\infty$ control design for uncertain stochastic time-delay systems was investigated in [11]. In [16], design of non-fragile PID control for a given interval plant had been considered, while in [17], non-fragile state feedback control had been investigated for a class of uncertain neutral systems with time-varying delays both in state and control input. In [18], non-fragile positive real control for a class of uncertain linear neutral time-delay systems had been proposed. In [19], design of non-fragile guaranteed cost control for uncertain descriptor systems with time-varyingstate and input delays had been provided. However, to the best of our knowledge, the non-fragile guaranteed cost control problem for uncertain stochastic nonlinear systems with time-varying delays has not been fully investigated yet. This motivates the research in this paper.

In this paper, the problem of non-fragile guaranteed cost control for uncertain stochastic nonlinear systems with time-varying delays under controller gain perturbations is studied. Based on Lyapunov functional technique combined with the linear matrix inequality (LMI) technique, we develop a robust non-fragile guaranteed cost control for this system, which guarantees the robustly stochastically asymptotic stability of the resulting closed-loop system in the mean square for all admissible parameter uncertainties, time delays and controller gain variations and guarantees an adequate level of performance index. A new sufficient condition for the existence of the non-fragile guaranteed cost controller is derived in terms of LMIs, and their solutions provide a parameterized representation of the controller. The LMIs can be easily solved by various efficient convex optimization algorithms [24]. A numerical example is given to illustrate the feasibility and effectiveness of the proposed techniques.

Notations: The notation in this paper is quite standard. The superscript "T" stands for the transpose of a matrix; $\mathbf{R}^n$ and $\mathbf{R}^{n\times n}$ denote the n-dimensional Euclidean space and the