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Robust control for nonhomogeneous Markov jump processes: An application to DC motor device

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Abstract

This paper studies the problem of robust H_∞ controller design for a class of uncertain Markov jump systems with time-varying transition probabilities, which follows nonhomogeneous jump processes. The time varying transition probability matrix is described as a polytope set. By Lyapunov function approach, under the designed controller, a sufficient condition is presented to ensure that the resulting closed-loop system is stochastically stable and that a prescribed H_∞ performance index is satisfied. Finally, an application of a DC motor device is addressed to demonstrate the effectiveness of developed techniques.

1. Introduction

In many practical dynamical systems, such as aircraft landing, industrial heat-exchanger systems, economic systems and electrical power distribution systems [1], abrupt variation in structures or parameters occurs frequently. It is worth mentioning that Markov jump systems (MJSs), as a special kind of stochastic systems, are appropriate and reasonable to describe such kind of systems, which suffering component failures or repairs, sudden environmental disturbance, or operation in different points. In recent years, Markov jump systems have attracted much attention, and the existing results

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cover a large variety of problems such as stochastic stability and stabilization [2], control [3–11], forecasting, fault detection and filtering [12–18]. It is a well known fact that Markov jump transition probability plays an important role on system description and performance. However, the above-mentioned works are all under the assumption that one can completely access to the transition probabilities. Under the assumption that the transition probability of Markov jump may not be measurable exactly, or that may be only part of the transition probabilities are available, researchers have done some attempt work on MJSs with partially known transition probabilities [19–21] and some work has also been done on systems with uncertain transition probability (see, e.g., [22,23] and the references therein).

These earlier works all assume that the transition probabilities are time-invariant, however, this assumption is not realistic in many situations, one example is in networked systems: it is known that packet dropouts and network delays in such systems can be modeled by Markov processes, and the networked system is considered as a Markov jump system [24,25]. Meanwhile, we should note that such delays and packet dropouts are different in different periods [26], so the transition probabilities vary through the whole working region and will bring in uncertainties. Another example is in the helicopter system [27], where the airspeed variations in its system matrices are modeled as a time-invariant Markov process ideally, but such variation of these multiple airspeeds cannot be avoided when the weather changes. In such situations, it is reasonable to model the system by time-varying Markov jump process, that is, the transition probabilities are time varying. One feasible assumption is to use a polytope set [28] to describe this uncertainty characteristic caused by time-varying transition probabilities. The main reason is that although the transition probability of the Markov process is not exactly known, we can evaluate some values in some working points, so we can model these time-varying transition probabilities by a polytope, which belongs to a convex set. This motivated us to apply this kind of set to express time-varying transition probabilities in Markov jump systems.

In this paper, we will design a robust H_∞ controller for a class of MJSs with nonhomogeneous jump processes. This paper is organized as follows: problem statement and preliminaries of this paper are given in Section 2. In Section 3, stochastic stability analysis of the discrete-time system is addressed. In Section 4, a set of mode-dependent robust H_∞ controllers for such Markov jump systems are designed. A DC motor example is provided to show the effectiveness of our approach in Section 5. Finally, some concluding remarks are given in Section 6.

In the sequel, the notation $\mathbb{R}^n$ stands for an n-dimensional Euclidean space, the transpose of a matrix is denoted by A^{T}, $E\{\cdot\}$ denotes the mathematical statistical expectation of the stochastic process or vector, $L_2^n[0,\infty)$ stands for the space of n-dimensional square integrable function vector over $[0,\infty)$, a positive-definite matrix is denoted by $P>0$, I is the unit matrix with appropriate dimension, and $*$ means the symmetric term in a symmetric matrix.

2. Problem statement and preliminaries

Consider a probability space (M,Q,P), where M, Q and P represent, respectively, the sample space, the algebra of events and the probability measure, the following uncertain Markov jump system (MJS) is considered:

$$\begin{cases} x_{k+1} = A(r_k)x_k + C(r_k)w_k + g(x_k, r_k) \\ z_k = D(r_k)x_k + E(r_k)w_k \end{cases} \tag{2.1}$$

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