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Short communication

Stability of Markovian jump systems with generally uncertain transition rates☆

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Abstract

This paper is concerned with exploring stability analysis for a class of Markovian jump systems (MJSs) with generally uncertain transition rates (GUTRs). In the GUTR model, each transition rate can be completely unknown or only its estimate value is known. This new uncertain model is more general than the existing ones and can be applicable to more practical situations. The stability criterion for such a class of uncertain MJSs is derived in terms of linear matrix inequalities (LMIs). Finally, a numerical example is given to illustrate the effectiveness and applicability of the proposed method.

1. Introduction

Over the past few decades, Markov jump systems (MJSs) have been an active area of research. It switches from one mode to another in a random way. The switching between the modes is governed by a Markovian process with discrete and finite state space. These models serve as convenient tools for analyzing plants that are subjected to random abrupt changes, which may result from random component failures, abrupt environment changes, disturbance, changes in the interconnections of subsystems, etc. [4].

As a dominant factor, the transition rates (TRs) in the jumping process determine the system behavior to a large extent, and so far, many analysis and synthesis results have been reported,

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assuming the complete knowledge of the transition rates (see, for example, [6,1,15,7,11,23,24]). In practice, it is difficult to precisely estimate the TRs. Therefore, developing the analysis and synthesis method for MJS with uncertain TRs receives the attention of researchers.

One type of the descriptions for the uncertain TRs is bounded uncertain TRs (BUTRs). In this description, the precise value of the TRs does not require to be known, but their bounds (upper bounds and lower bounds) are known (see, for example, [10,3,9,13,2,12]). However, in some practical cases, to obtain the bound of every TR is difficult or even impossible. Zhang et al. [20] proposed another description for the uncertain TRs, which is partly unknown TRs (PUTRs). In this description, some of the TRs can be unknown. This model also simulates researchers' interests (see, for example, [16–19,22,14,5]). Unfortunately, in this model every TR is either exactly known or completely unknown which maybe too restrictive in many practical situations. As aforementioned, it is hard to precisely estimate the TRs in practice. Therefore, a more practical situation is that the TR can be completely unknown or its bound is known.

The contributions of this paper are twofold. First, a new description for the uncertain TRs is proposed. This new model is named as general uncertain TR (GUTR). In this model each transition rate can be completely unknown or only its estimate is known. Such feature makes this model more flexible than that of both BUTR and PUTR. In fact, both BUTR and PUTR are the special cases of GUTR model. Therefore, this model can be applied to more practical situations. Second, a stability criterion is proposed for the MJSs with GUTRs. The derived criterion is in terms of linear matrix inequalities, and hence it can be easily checked. Moreover, the proposed criterion can also be applied to MJS with either BUTRs or PUTRs since both models are the special cases of GUTR model.

There are some possible directions to extend the proposed model and method. Filtering and fault-tolerant control are two important research areas due to their wide application in the practical systems. Liu et al. [8] investigated the fault-tolerant control for MJSs via proportional and derivative sliding mode observer technique. Zhang et al. [21] considered the problem asynchronous filtering of discrete-time switched linear systems with average dwell time. However, for the filtering and fault-tolerant control, no research has focused on the case of general uncertain transition rates. Therefore, it is worth further extending the proposed method to deal with these problems.

The remainder of the paper is organized as follows. In Section 2, the considered systems are formulated and the purposes of the paper are stated. In Section 3, the stability conditions for the underlying systems are derived via linear matrix inequalities. A numerical example is provided to illustrate the validity and applicability of the developed results in Section 4. Section 5 concludes the paper.

Notation: In this paper, $\mathbb{R}^n$ and $\mathbb{R}^{n\times m}$ denote the n-dimensional Euclidean space and the set of all $n\times m$ real matrices respectively. $\mathbb{N}^+$ represents the set of positive integers. The notation $P>0$ ($P\geq 0$) means that P is a real symmetric and positive definite (semi-positive-definite) matrix. For notation $(\Omega,\mathcal{F},P)$, Ω represents the space, $\mathcal{F}$ is the $\sigma-$algebra of subsets of the sample space and P is the probability measure on $\mathcal{F}$. $E\{\cdot\}$ stands for the mathematical expectation. Matrices, if their dimensions are not explicitly stated, are assumed to be compatible for algebraic operations.

2. Problem formulation

Consider the following stochastic system with Markovian jump parameters, defined on a complete probability space $(\Omega,\mathcal{F},P)$:

$$\dot{x}(t)=A(r_t)x(t),\quad t\geq 0, \tag{1}$$