J. Math. Anal. Appl. 446 (2017) 886–907

Contents lists available at ScienceDirect

Journal of Mathematical Analysis and Applications

www.elsevier.com/locate/jmaa

H_∞ control for Markovian jump systems with partially unknown transition rates via an adaptive method

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A R T I C L E   I N F O

Article history:
Received 30 December 2015
Available online 14 September 2016
Submitted by H. Zwart

Keywords:
H_∞ control
Markovian jump systems
Partially unknown transition rates
Linear matrix inequality
Adaptive method

A B S T R A C T

This paper investigates the problem of the H_∞ control for a class of continuous-time Markovian jump systems with partially unknown transition rates. An adaptive H_∞ performance index is defined to describe the disturbance attenuation performance of Markovian jump systems. By combining the linear matrix inequality (LMI) approach for designing H_∞ controllers and the adaptive method for estimating the unknown terms, a new method for designing the H_∞ controllers is proposed, where an estimation of the transition rate matrix is given and the controller parameter matrices are dependent on the known transition rates and the estimations of the unknown terms. The sufficient conditions for the existence of the adaptive state feedback controller and the adaptive dynamic output feedback controller are proposed and the estimations of the unknown transition rates are obtained from the adaptive laws. It is shown that the proposed adaptive controllers provide better performance than the traditional fixed gain controllers. A practical example is provided to illustrate the effectiveness and advantage of the proposed method.

1. Introduction

Markov jump system is a class of multi-modal systems in which the transitions among different modes are governed by a Markov chain. Markov jump systems can better describe the systems subject to abrupt variation in their structures or parameters induced by external causes, such as, sudden environmental changes, changing subsystem interconnections, and component failures [13,14,16,22]. Besides, motivated by the powerful modeling capability of Markov chains in practical applications, which cover diverse fields including target tracking problems, manufactory processes, aerospace systems, networked control systems and economic problems, for example [4,7,9,38] and the references therein, many useful results have been obtained. For instance, the mean square stochastic stability of the Markovian jump systems was invested

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http://dx.doi.org/10.1016/j.jmaa.2016.09.027

in [2,3], the stability and stabilization problems in the presence of uncertain parameters were addressed in [10,17,21,31] and the H_∞ filtering for Markovian jump systems was studied in [27,42].

On the one hand, the control of Markovian jump systems has been extensively studied, such as controllability analysis [18,39], optimal control [6,39], finite-time control [5,40], sliding-mode control [26] and H_∞ control [40,43]. In particular, H_∞ control is one of the hottest research areas because disturbance attenuation is an important system requirement. As is well known, state feedback controller is one of the most important controllers and many results on this issue have been reported [15,37]. Although, the state feedback H_∞ controller can provide a better performance than other controllers, the state information of the original system is necessary. Therefore, output feedback control is also one of the hottest problem where only the measured output is required, and there are several kinds of output feedback controllers, such as static output feedback controller [22], observer-based controller [1] and dynamic output feedback controller [15,25]. Especially, for the fact that the static output feedback controller leads to more conservatism and for observer-based controller the systems should be observable, the dynamic output feedback controller is more effective than the other two output controllers.

On the other hand, for the fact that the Markovian jump system is governed by a Markov chain, the ideal knowledge on the transition rates are definitely expected to simplify the system analysis and design. Therefore in most of the studies, complete knowledge of the mode transitions is required as a prerequisite for analysis and synthesis of Markovian jump systems which means that the information on transition rates of the underlying Markov chain is completely known. However, the likelihood of obtaining such available knowledge is actually questionable. In practice, incomplete transition rates are often encountered especially if adequate samples of the transitions are costly or time-consuming to obtain [36]. Examples with such difficulties can be found in many fields, such as networked control system with packet dropouts and channel delays [33], biochemical systems with diverse changes of environmental conditions, temperature, humidity. To relax the assumption that all the transition rates are known, a new concept for Markovian jump systems with uncertain or partially unknown transition rates is proposed [23,32,35] which has emerged as a topic of significant interest and a series of studies have been carried out [20,36]. The proposed systems are more general, by which much more complex switching phenomena can be modeled. However, to the best of authors' knowledge, for Markovian jump systems with partially unknown transition rates, there are few results on estimating the unknown transition rates.

Motivated by the aforementioned, in this paper, the problem of state feedback and dynamic output feedback H_∞ control for a class of continuous-time Markovian jump systems with partially unknown transition rates is investigated. The linear matrix inequality (LMI) approach [30,36] and adaptive method [12,34,41] are combined to solve this problem and an adaptive H_∞ performance index is defined to describe the disturbance attenuation performance of Markovian jump systems. One of the contributions of this paper is that the adaptive method is used to obtain the estimations of the unknown transition rates. Besides, a new form of controllers which is dependent on the transition rate matrix and the estimations is proposed. And the sufficient conditions for the existence of the adaptive state feedback controller and the adaptive dynamic output feedback controller are obtained and the adaptive laws are given. It is shown that the design conditions for the newly proposed adaptive controllers are more relaxed than the pure LMI-based design method from [30,36] for the traditional controller without adaptive mechanism. Third, for dynamic output feedback control, the non-convex matrix conditions in [30] which is solved by using the cone complementarity linearization (CCL) method [11] are transformed into LMIs by using Projection lemma and to obtain more effective adaptive laws, the unknown state is divided into known part and unknown part based on the measured output. Finally, a practical example is illustrated to show the effectiveness of the proposed method.

The article unfolds as follows. Section 2 presents the preliminaries. The state feedback H_∞ control is studied in Subsection 3.1 and the dynamic output feedback H_∞ control is studied in Subsection 3.2. A practical example is given in Section 4. Section 5 concludes this paper.