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Stabilization of Markovian jump systems with incomplete knowledge of transition probabilities and input quantization ☆

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Abstract

This paper introduces the stabilization condition for the Markovian jump systems (MJSs) with incomplete knowledge of transition probabilities and input quantization. To obtain the less conservative stabilization condition, an appropriate weighting method is proposed by using all possible slack variables from the relationship of the transition probabilities, which does lead to a form of linear matrix inequalities (LMIs). Further, a proposed controller not only stabilizes the MJS with incomplete knowledge of transition probabilities but also eliminates the effect of input quantization. Simulation examples report the effectiveness of the proposed criterion.
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1. Introduction

In the past decades, Markovian jump systems (MJSs) have attracted much attention because they are suitable to represent many dynamic systems subject to random abrupt variations [1–13]. Because of the property of the MJS by a Markov chain taking values in a finite set, such systems have been widely applied in many practical application, such as manufacturing systems [1], actuator saturation [2], and networked control systems (NCSs) [3]. For this research topic, many researchers have focused the analysis and the synthesis under the assumption that the exact values of transition probabilities are

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known [8,10,11,13]. However, because it is hard to obtain the complete knowledge of transition probabilities in real systems, another interesting topic has been studied in the MJSs with incomplete knowledge of transition probabilities [4–7]. For the stability analysis and synthesis of such systems, [4,5,7] employed the free-connection weighting method and designed the state feedback controller by using the linear matrix inequalities (LMIs). Recently, [6] introduced the robust stabilization condition for the MJS with transition probabilities taken to be known and incomplete with known bounds.

Furthermore, in modern engineering applications, the important issue is not only the model uncertainty such as incomplete knowledge of transition probability but also the uncertainty of data transmission. Among the above-mentioned literature, it has been assumed that the data transmission is perfect between the controller and the plant. That is, data missing is unrisen in the closed-loop system. However, there is not the case in practice. In modern control systems, especially NCSs, the plant and the controller are connected through a network. Such systems essentially require many kinds of data processing devices such as analog-to-digital and digital-to-analog converters or encoders and decoders, which has several advantages such as flexibility, easy installation and maintenance, low cost [14,15]. Even though these systems have many benefits, some new phenomena are always occurred with quantization, networked-induced delay, and packet dropout, which severely degrade the general performance of systems and sometimes lead to an unstable systems [16]. Among the above phenomena, the input quantization has significant impact on the performance of the systems. Recently, the stabilization problem of the systems with the type of the static quantizers has been studied extensively for NCSs [17,18] and for non-NCSs [19,20]. The main method used to handle the input quantization is the controller design that consists of a main control part to achieve stability and an extra control part to eliminate the effect of quantization [21,19]. To the best of the author's knowledge, until now intensive studies on the controller design of the MJSs with incomplete knowledge of transition probabilities and input quantization have not been carried our thus far.

Motivated by the above observations, this paper introduces the stabilization condition of the MJSs with incomplete knowledge of transition probabilities and input quantization and designs the state-feedback controller for input quantization. The main contributions of this paper can be emphasized as follows. First, to derive the less conservative stabilization conditions, the transition rates related with the transition probabilities are represented in terms of three relationships which do not require the lower and upper bounds of the transition rates, differently from other methods in the literature. The derived conditions are formulated into the second-order matrix polynomials of the unknown transition rates using an appropriate weighting method. And then, the LMI conditions for the controller design are obtained from the polynomials. Second, we design a state-feedback controller for the MJS with incomplete knowledge of transition probabilities and input quantization, where such systems with the static quantizer have not been proposed thus far. The effectiveness of the proposed method is verified by numerical examples and a practical example.

This paper is organized as follows. Section 2 presents a system description and some preliminary results. Section 3 provides a new stabilization condition for MJS with incomplete knowledge of transition probabilities and input quantization. Section 4 illustrates some simulation results for the proposed criterion. Finally, Section 5 concludes the paper with a summarization.

Notation: The notations $X \geq Y$ and $X > Y$ mean that $X - Y$ is positive semidefinite and positive definite, respectively. In symmetric block matrices, $(*)$ is used as an ellipsis for terms that are induced by symmetry. Furthermore, $\mathbf{Sym}(X) = X + X^T$ stands for any matrix X. The notation e_k indicates a unit vector with a single nonzero entry at the kth position, i.e. $e_k \triangleq [0\ldots \underbrace{1}_{k\text{th}} \ldots 0]^T$.

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