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A novel approach to stability and stabilization of fuzzy sampled-data Markovian chaotic systems

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Abstract

This paper studies the problems of stability and stabilization of a class of Markovian chaotic systems via fuzzy sampled-data control. Different from some existing results, the Markovian jumping with general uncertain transition rates is considered for such systems. A novel approach, i.e., input-delay-dependent vector approach, is proposed for the first time. Based on this approach, an input-delay-dependent Lyapunov–Krasovskii functional (LKF) with cubic function of input delay is successfully constructed, and the convex combination technique is used with ease to derive stability and stabilization criteria. Compared with some existing stability and stabilization criteria for chaotic systems, our results are not only less conservative but also with reduced calculation complexity. Finally, the superiorities of proposed results are illustrated by two numerical examples.

Keywords: Markovian chaotic systems; Fuzzy sampled-data control; Stability and stabilization; Input-delay-dependent vector approach; Generally uncertain transition rates

1. Introduction

Chaos is a natural nonlinear phenomenon that has great potential in many practical applications such as secure communication, information processing, pattern recognition, and chemical reactions [1–5]. Consequently, there has been increased attention to chaos related nonlinear dynamics in science and engineering. Due to the properties of initial-value-sensitivity, topological transitivity, pseudo random, and no periodicity, chaotic systems possess unpredictable and irregular behaviors, which may lead to undesirable performance-degraded situations or even instability

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of systems [6]. Thus, chaos control has become one of the most significant topics in a variety of areas. Up to now, various interesting control approaches have been proposed to analyze chaotic systems, such as sliding mode control [7], feedback control [8], adaptive control [9], and so on.

Meanwhile, Takagi–Sugeno (T–S) fuzzy model has gained growing research interest since it has excellent ability to approximate complex dynamical behaviors [10]. With a set of fuzzy IF–THEN rules, T–S fuzzy model can represent local linear input–output relations of a nonlinear system. Due to this feature, T–S fuzzy model is favorable to system analysis and controller design. Moreover, it has been shown that many chaotic systems including Rösler system [11], Lorenz system [12], and Chua's system [13], can be exactly represented by T–S fuzzy models. Consequently, T–S fuzzy control has been widely applied to chaotic systems [14–18].

As communication and digital technology have grown, sampled-data control is in the spotlight because of its low cost consumption, high reliability, and easy installation [19–23]. In the implementation of sampled-data control systems, only the sampled information at its sampling instants is transmitted to the controller, which can reduce the amount of transmitted information and effectively save the communication bandwidth. Hence, the investigation of sampled-data control of chaotic systems is of great importance. The investigation of sampled-data control systems has fallen into mainly three approaches, that is, discrete-time approach [24], impulsive model approach [25], and input delay approach [23]. The most popular approach is input delay approach, which is based on modeling the sample-and-hold with a delayed control input. Recently, based on input delay approach, many interesting results have been reported on stabilization of chaotic systems via fuzzy sampled-data control [6,10,26–31]. In [26–28], by designing fuzzy sampled-data control, the stabilization has been investigated for chaotic systems. In [29] and [30], by constructing input-delay-dependent LKFs, fewer constraint conditions have been obtained. In [6], by designing a memory fuzzy sampled-data controller, less conservative stabilization criteria have been proposed. Most recently, by constructing a new input-delay-dependent LKF, improved results have been established for chaotic systems in [10]. It is well known that the input-delay-dependent Lyapunov method is very effective for conservatism reducing, since it can fully capture the information about the actual sampling pattern. However, in the most existing works, input-delay-dependent Lyapunov terms are mainly constructed based on linear function of input delay. Input-delay-dependent Lyapunov terms with high order function of input delay are hard involved, since its derivation may be nonlinear of input delay. Then, the convex combination technique cannot be directly used. Therefore, it is still a challenging problem to construct input-delay-dependent LKFs with high order function of input delay to further improve the existing results for fuzzy sampled-data chaotic systems. This is the first motivation of the current work.

On the other hand, in [6,10,26–31], researchers focus only on reducing conservatism for chaotic systems, while the calculation complexity is neglected. In fact, during the application of LMI-based criteria to large-scale physical systems, the calculation complexity is a very important issue [32]. A criterion with too much complexity may be restrictive in many real applications. Therefore, it is important to establish stabilization criteria considering both the conservatism and calculation complexity for fuzzy sampled-data chaotic systems, which is the second motivation of the current work.

In addition, due to the limitations of equipment and the influence of uncertain factors, Markovian jumping is commonly encountered in chaotic systems, and the transition rates in some jumping processes are difficult to precisely estimate [33–38]. Thus, it is necessary to consider Markovian jumping with generally uncertain transition rates for chaotic systems. Unfortunately, up to now, few results have been established on stability and stabilization for fuzzy sampled-data Markovian chaotic systems with generally uncertain transition rates. Hence, the existing stability and stabilization criteria are not available anymore. Therefore, the analysis of stability and stabilization for fuzzy sampled-data Markovian chaotic systems with generally uncertain transition rates is of great importance, which is the third motivation of the current work.

Motivated by the aforementioned discussions, our objective in this paper is to establish new stability and stabilization criteria for Markovian chaotic systems with generally uncertain transition rates via fuzzy sampled-data control. The rest of this paper is organized as follows. We shall introduce some notations and formulate the problem in Section 2. Then in Section 3 we shall state and prove our main results, and give some illustrative examples in Section 4. Finally, we shall give a conclusion in Section 5.

The main contributions of our work are summarized as follows.

1) The stability and stabilization problems are considered for the first time for fuzzy sampled-data Markovian chaotic systems with generally uncertain transition rates. Compared with existing results in [6,10,26–31], our results are more applicable in practical situation.

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