Journal of Nonlinear Systems and Applications (2018) 37–41
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STABILIZATION OF NONLINEAR DISCRETE-TIME FUZZY SYSTEMS WITH SATURATING ACTUATORS

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Abstract. This investigation considers sufficient conditions for the stabilization of discrete-time fuzzy systems subject to actuator saturation. The domain of attraction resulting from a priori designed state feedback law is analyzed by using the Lyapunov-Krasovskii functional approach. Then, the Lyapunov-Krasovskii and slack-variables functional approaches are applied to establish sufficient conditions that ensure convergence of admissible initial states within the domain of attraction. These conditions are formulated in linear matrix inequalities. Finally, numerical example illustrates the application of the proposed results.

Keywords. Discrete-time systems, LMI, Takagi-Sugeno fussy systems, domain of attraction, saturated control.

1 Introduction

In this paper, nonlinear systems represented by Takagi-Sugeno (T-S) fuzzy models with actuator saturation constraint are considered. The Takagi-Sugeno (T-S) fuzzy system [1],[2] is one of the most popular fuzzy system model in the model-based fuzzy control [3], [4]. Actuator saturation or control input saturation is probably one of the most usual nonlinearity encountered in control engineering due to the physical impossibility of applying unlimited control signals and/or safety constraints. In the existing literature, several approaches have been proposed to deal with the saturation problem [5]-[23], [31] References [14],[15], [16] have treated this problem and obtained saturating control laws that govern the system stability when the initial state belongs to an estimated domain. Based on the results of [14]-[19], the domain of attraction has been introduced to resolve the local stabilization problem. The domain discussed therein is a region in which the admissible initial states converge asymptotically to the origin in the context of input saturation. Therefore, the design objective of our study is to determine or estimate the maximum size of the domain of attraction as large as possible. Consequently, many algorithms have been presented to predict a system's performance by applying linear state feedback laws [14], [19] or linear output feedback laws [23]. Recently, in [24],[25], the relaxed stability and stabilizability conditions for fuzzy control systems were reported to release the conservatism of the conventional conditions by considering the interactions among the fuzzy subsystems. The relaxed conditions offer more freedom in guaranteeing the stability of the fuzzy control systems and were found to be very valuable in designing the fuzzy controller, especially when the design problem involves not only stability, but also the other performance requirements such as the speed of response, constraints on control input and output, and so on. However, the relaxed conditions in [24] and [25] took into account the interactions among the fuzzy subsystems in an analytical manner by using the property of the quadratic form [24], which lead to conservatism. To the best of our knowledge, the problem of stabilization of nonlinear discrete-time fuzzy systems with saturating actuators has not been fully investigated yet. More research in this area should be carried out because of its importance and usefulness for researchers and designers in this filed. These facts motivated us to conduct this work. This paper addresses the problem of nonlinear T-S discrete-time systems with actuator saturation. We are interested in obtaining the largest stability domain using the relaxed stability and stabilization conditions and the Lyapunov-Krasovskii functional. Based on the Lyapunov-Krasovskii, the slack variables and the relaxed conditions, the problem of estimating the domain of attraction of the T-S fuzzy system is formulated and solved as linear matrix inequalities (LMI). The next section gives some preliminary results. Section 3 presents the problem statements and section 4 demonstrates the main results of our study. Meanwhile, section 5 presents a numerical example to show the effectiveness of our results whereas the last section concludes our work.

2 Preliminaries

This section presents some preliminary results on which our work is based. Define the following subsets of $\mathbb{R}^n$:

$$\Omega(P,\rho) = \{x \in \mathbb{R}^n | x^T P x \le \rho, \rho > 0\}, \qquad (1)$$

$$\mathfrak{L}(F) = \{x \in \mathbb{R}^n || f_j x| \le 1, j \in [1,m]\}, \qquad (2)$$

with P a positive definite matrix and $F \in \mathbb{R}^{n\times n}$ and f_j

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†Manuscript received May 2017; revised February 2018.