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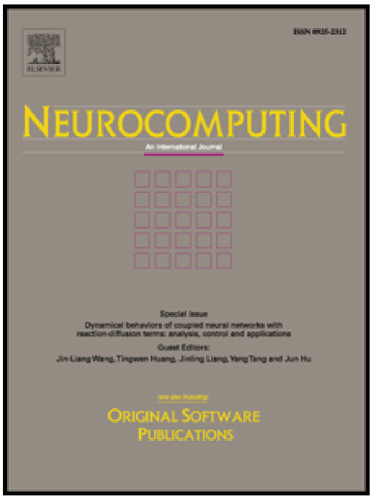

Sampled-data static output-feedback control for nonlinear systems in T–S form via descriptor redundancy

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Sampled-data static output-feedback control for nonlinear systems in T–S form via descriptor redundancy

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Abstract

This paper deals with a static output-feedback stabilization problem within a sampled-data framework for nonlinear systems in Takagi–Sugeno form. We investigate this problem on the basis of the descriptor-redundancy scheme. The resulting features are that: i) the sampled-data synthesis does not involve (even approximate) discrete-time models of nonlinear systems; ii) the sampled-data stability is analyzed in the continuous-time Lyapunov sense; and iii) the design algorithm consists of a single-stage linear matrix inequality problem without linear matrix equality constraints.

Keywords: Takagi–Sugeno fuzzy model; sampled-data control; static output feedback; descriptor redundancy.

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1. Introduction

From the viewpoint of feedback control, a typical foible of Takagi–Sugeno (T–S) fuzzy methodologies is that time-continuous measurements of a state are sometimes onerous in practical applications [1]. An immediate substitute can be to take measurements in a sampling manner, which yields time-hybrid closed-loop systems. The model is converted into a time-homogeneous one to design a controller in the discrete-time or continuous-time domain. For the former, the direct discrete-time design—to determine a discrete-time controller for the (approximate) discrete-time model of a continuous-time plant, and then to emulate it—can be utilized [2, 3]. Although this technique is promising, since the discrete-time modeling of nonlinear systems is necessarily only approximate, further consideration is required to guarantee the sampled-data closed-loop stability [4–6]. For the latter, the sampled-data dynamics is transformed into a continuous-time model with input delay, by which a sampled-data fuzzy tracking controller was derived [7]. It was extended to the robustification against time delays and uncertainties [8], the fuzzy sampled-data filtering [9], and the robust finite-time non-fragile stabilization against stochastic actuator faults [10].

Another vulnerability in feedback control is that it is not that common for all state variables to be measurable. The static output feedback (SOF) as an alternative of state feedback is known to be a fascinating yet challenging strategy in T–S fuzzy model-based design. The fundamental burden on the fuzzy SOF problem is caused by the fact that the Lyapunov inequality formulated in terms of linear matrix inequalities (LMI) is non-convex. Solutions to this difficulty mainly fall into two categories: the multiple-stage LMI-based method [11] and the single-stage method entailing additional constraints [12–16].

We note that extensive efforts have been researched for the single-stage method. In [12], the Lyapunov inequality is convexified by similarity-transforming the output matrices, as long as they are common and have no uncertainties. In [13], LMI conditions are proposed for the SOF problem with fuzzy measured outputs without uncertainties, based on the "P-problem" (or "W-problem") of [17]. In [14], it is addressed that the work in [13] implicitly requires common output matrices and no uncertainties therein. It is worthwhile to mention that [15] reveals that the P-problem-based approach may admit distinct output matrices. The uncertain fuzzy output case is analyzed in [16]. Recently, a novel SOF synthesis was proposed in [18], where the design is accomplished in a single LMI step excluding the linear matrix equality (LME) constraint.

This paper continues efforts to investigate the SOF fuzzy controller design problem, especially in the sampled-data framework that few SOF studies have focused on. We pay attention to the descriptor redundancy as a new tool for the concerned problem in that it can simultaneously represent a combined set of differential (i.e., plant) and algebraic (i.e., SOF and sampled-data) equations into a single model [19], thereby reducing the excessive design involved in existing methods [20]. The contributions of this paper are that: i) differing from the previous works, this sampled-data design does not require approximate [4] nor exact [6] discrete-time models of T–S fuzzy systems; ii) the sampled-data stability is analyzed in the continuous-time Lyapunov sense, while the input delay does not appear; and iii) the design conditions are derived in the format of a single-stage LMI problem without accompanying LME constraints.

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