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Basis-dependent and delay-dependent results on robust L_1 filtering for networked control systems

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Abstract

Persistent and amplitude-bounded disturbances are nowadays considered for various engineering applications. Whereas the traditional H_∞ and L_2–L_∞ filtering methods under the energy-bounded external disturbances assumption cannot receive good noise suppression effect. To effectively reflect the capability of disturbances suppression, this paper proposes a robust L_1 filtering approach for a class of nonlinear networked control systems (NNCSs) described by Takagi–Sugeno (T–S) fuzzy model. According to the analysis of the typical time-delay issue induced by communication network and the parallel distributed compensation (PDC) technique, a fuzzy filtering error system is established. Attention is focused on designing the robust L_1 filter that guarantees the fuzzy filtering error system to be asymptotically stable and to have a prescribed L_1 noise attenuation level γ with respect to all persistent and amplitude-bounded disturbances. In particular, we concentrate on the delay-dependent case, using a basis-dependent Lyapunov–Krasovskii functional which refers to reducing the conservatism, the peak-to-peak performance criterion is first proposed. The integral inequality method and linear matrix inequality (LMI) technique are adopted during the process of robust L_1 stability analysis. Finally, two numerical examples are presented to demonstrate the effectiveness of the proposed method.

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1. Introduction

The filtering problem, which is recently one of the important research issues in control and signal processing fields, is to design a state estimator according to the measurable output signal in the case of noise interference. Currently, Kalman filtering and robust filtering are two main common used methods. The difference between them is that the former is based on the precise mathematical model and requires the noise inputs to be strict Gaussian process, while the latter does not have to acquire the noise statistics characteristics and has good robustness to the uncertainty in the signal model. As the in-depth study of the stability and performance analysis problem, some robust filter design methodologies are proposed by introducing different performance indexes (such as H_∞, L_2–L_∞, etc.). Generally speaking, H_∞ filtering is achieved by making the energy-to-energy gain from disturbances to filtering error outputs minimized and guaranteed to be less a given index, which is most commonly used [1,2]. L_2–L_∞ filtering minimizes the worst energy-to-peak gain from the disturbances to filtering error outputs [3,4]. It is noted that both the H_∞ and L_2–L_∞ filtering methods are limited by an implicit assumption that the external disturbances must be energy-bounded. However, when the disturbances of actual systems are persistent and amplitude-bounded signals, such as wind shear stress imposed upon aircraft wings, sea wave clutter interference signals on offshore platform, and so on, the above filtering methods are no longer suitable. In such cases, the study on robust L_1 filtering has received increasing attention, for example [5–7] and the references therein. To mention a few, the literature [5] investigates the problem of L_1 filtering for linear parameter-varying (LPV) systems with time-varying parameter matrices and delay, and furthermore, the literature [6] extends the method to the case of L_1 fixed-order filtering for switched LPV systems. The existing research results show that robust L_1 filtering can better satisfy a worst case peak-to-peak performance constraint for all persistent and amplitude-bounded disturbances (sinusoidal interference signal, unit step signal, etc.), and has important theoretical guidance significance and wide engineering application prospect.

Recent years, along with the common existence of nonlinearity in complex industrial systems, more and more attention has been paid to the fuzzy control and filtering problem of nonlinear systems [8–11]. Particularly, the T–S fuzzy model is intensively chosen due to the effectively approximation to actual nonlinear systems [12,13]. In a fuzzy model, a set of simple linear subsystems that represent the nonlinear plant in different regions of the state-space are obtained, and then are smoothly blended together through membership functions [14]. Motivated by such an idea, the literature [15] proposes a new Hankel norm filtering method for the stochastic time-delay systems via T–S fuzzy model approximation, while the literature [16] concerns with the H_∞ filtering problem for nonlinear stochastic T–S fuzzy systems. Corresponding to the above continuous-time systems, the discrete-time case is also studied [17,18], in which the literature [17] gives an H_∞ filter design approach for discrete-time T–S fuzzy systems. Nevertheless, compared with the aforementioned nonlinear systems, the analysis of NNCSs is more complex owing to the introduction of communication network. It is well known that the signals of NNCSs are transferred in network environment and some issues (such as time-delay, packet dropout, etc.) may arise [19,20], which will lead to instability, oscillation and poor system performance. Therefore, it is necessary to study the NNCSs and the filtering problem of NNCSs based on the T–S fuzzy model has emerged as a topic of considerable interest [21–23]. It can be seen from