Quantized H_∞ Filtering for Discrete-Time Markovian-Jump T-S Fuzzy Systems with Time-Varying Delays via Event-Trigger Mechanism

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Abstract. The H_∞ filter design for delayed discrete-time Markovian-jump T-S fuzzy systems with quantized output measurement is the primary focus of this paper. To reach our notified goal, the event-trigger mechanism is designed so that the occupancy of the communication network resources is reduced. By manipulating the fuzzified Lyapunov-Krasovskii functional (LKF), sufficient conditions are derived by explicit expression of linear matrix inequalities (LMIs) which ensure the desired system is stochastically stable. Eventually, the proposed H_∞ filter design is validated by the implementation of the T-S fuzzy model of the tunnel diode circuit.

Introduction

The qualitative analysis of nonlinear systems is imperative so that the numerous practical systems show non-linearity when analyzing their dynamics. It is well known that T-S fuzzy models are capable of modelling nonlinear behaviour, by approximating any smooth nonlinear systems to any special accuracy within any compact set. Forever, it is quite common for network communication to have an information latching problem, which can be handled by extracting finite-state representations (modes) from Markovian-jump models. To be specific, discrete-time systems play a very vital role in digital signal analysis and processing. In place of it, the logarithmic quantizer is used to reduce the data-transmission rate in network communication. Additionally, energy consumption is reduced by the event-triggered transmission strategy and the lifetimes of the services are extended. On the other hand, the H_∞ filtering has been extensively studied to guarantee a bound of the worst-case estimation error where the statistics information on the disturbances is not required. Unfortunately, when it comes to the event-triggered scenario, the H_∞ filtering problem with quantization effects has not yet gained adequate research attention. Therefore, it is of significance to consider the event-triggered H_∞ filtering for nonlinear systems with quantization effects.

Results and discussion

In this paper, let us considered the following discrete-time T-S fuzzy Markovian-jump system:

IF θ_{1k} is M_{i1} and θ_{pk} is M_{ip} THEN $\quad x(k+1) = A_{hr(k)}x(k) + A_{dhr(k)}x(k-\tau_{r(k)}(k)) + B_{hr(k)}w(k)$

with the output measurement $y(k) = C_{hr(k)}x(k) + D_{hr(k)}v(k)$ and the estimated signal $z(k) = E_{hr(k)}x(k)$, where M_{ij} is a fuzzy set and θ_{jk} is the premise variable, $i \in \{1, 2, \cdots, r\}$ and $j \in \{1, 2, \cdots, p\}$, r is the number of IF-THEN rules; r, p are positive integers; $x(k) \in \mathbb{R}^n$ is the state; $v(k) \in \mathbb{R}^l, w(k) \in \mathbb{R}^n$ is the disturbance that belongs to $l_2[0,\infty)$; $A_{hr(k)}, B_{hr(k)}, C_{hr(k)}, D_{hr(k)}$, and $E_{hr(k)}$ are known matrices of appropriate dimensions; $\tau_{r(k)}(k) \in [\tau^m_{r(k)}, \tau^M_{r(k)}]$ is time-varying delay factor; The Markov-jump variable $\{r(k), k \in \mathbb{Z}_+\}$ is used to represent a mode of the subsystems. Further, the transmission instants sequence $\{k_s\}_{s\geq 0}$ with $k_0 = 0$ is generalized by the event-trigger instant $k_{s+1} = \min_{k>k_s}\{k/[y(k)-y(k_s)]^T\phi[y(k)-y(k_s)] \geq \sigma y^T(k_s)\phi y(k_s)\}$, where matrices $\phi > 0$ and $\sigma > 0$ are two event-triggered parameters to be designed properly.

From the input $\bar{y}(k)$, the filter has been estimated as

$$\hat{x}(k+1) = \hat{A}_{hr(k)}\hat{x}(k) + \hat{A}_{dhr(k)}\hat{x}(k-\tau_l(k)) + \hat{B}_{hr(k)}\bar{y}(k)$$

with estimation $\hat{z}(k) = \hat{E}_{hl}x(k)$, where $\hat{A}_{hl}, \hat{A}_{dhl}, \hat{B}_{hl}, \hat{C}_{hl}$ are filter parameters to be derived. The measured output is assumed to be quantized by the quantizer $q(y) = [q_1(y_1), q_2(y_2), \cdots, q_l(y_l)]^T$. Based on filtering error analysis, we have estimated the error dynamics $\xi(k)$ and its stability has been confirmed by Theorem 1.

Theorem 1. For a given $\gamma > 0$,, the filtering error system is stochastically stable, if there exists positive definite matrices P_{hl}, P_{h^+}, Q_1, Q_2, Q_3, R_1, R_2, and M_1, along with the scalar $\epsilon > 0$, for $h \in \rho$, $h^+ = (h_1(\theta(k+1)), h_2(\theta(k+1)), \cdots, h_r(\theta(k+1)))) \in \rho$ and $l \in \mathcal{S}$, which satisfies the LMI $[\phi_{nm}]_{5\times 5} < 0$ such that $\phi_{11} = -P_{h^+}$, $\phi_{13} = P_{h^+}[\mathcal{A}_{ijl}, \mathcal{A}_{dijl}, 0, 0, 0, 0, 0, \mathcal{B}'_{ijl}, \mathcal{D}_{ijl}]$, $\phi_{14} = P_{h^+}[\mathcal{B}_{ijl}, 0, 0, 0, 0, 0, 0,\ \mathcal{B}_{ijl},\ \mathcal{B}_{ijl}]$, $\phi_{15} = [\mathcal{C}^T_{ijl}, 0, 0, 0, 0, 0, 0, I, D'^T_{ijl}]$, $\phi_{22} = -I$, $\phi_{23} = [\mathcal{E}_{ijl}, 0, 0, 0, 0, 0, 0, 0, 0]$, $\phi_{33} = [\phi^{ij}_{33}]_{9\times 9}$, $\phi^{11}_{33} = -P_{hl} + Q_1 + Q_2 + Q_3 + \tau_l^2 R_1 + \tau_l^{m^2} R_2$, $\phi^{22}_{33} = -Q_3$, $\phi^{33}_{33} = -Q_1$, $\phi^{44}_{33} = -Q_2$, $\phi^{55}_{33} = -R_1$, $\phi^{56}_{33} = -M_1$, $\phi^{66}_{33} = -R_1$, $\phi^{77}_{33} = -R_2$, $\phi^{88}_{33} = -\phi(1-\sigma)$, $\phi^{99}_{33} = -\gamma^2 I$, $\phi_{44} = -\epsilon I$, $\phi_{55} = -\epsilon I$, and the remaining terms ϕ_{nm} are zero.

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