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Design of observer-based event-driven controllers for a class of state-dependent nonlinear systems

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Abstract

The design problems of the observer-based event-driven controllers are investigated for the state-dependent nonlinear systems in this paper. An event-driven criterion is proposed to determine whether the newly sampled states of the designed state-dependent observer should be sent out to the controller. As a result, the communication resources can be saved significantly while the burden of the network communication can be reduced. Influenced by the event-driven controller, the closed-loop system is rewritten as the delayed system. The state-dependent integral function is introduced to be the Lyapunov function candidate to obtain less conservative asymptotic stability conditions and preserve the desired H_∞ performance for the closed-loop system. The observer gain matrix, the controller gain matrix and the event-driven parameters are co-designed and co-obtained in terms of solution to a set of linear matrix inequalities (LMIs). Finally, the effectiveness of the proposed method in this paper is illustrated by the numerical examples and the tunnel diode circuit systems.
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1. Introduction

In practical systems, state-dependent nonlinearities often appear due to unavoidable parameter variations, disturbances, and so on. The class of state-dependent nonlinear systems covers a wider class of nonlinear systems and exists widespread in actual systems, such as the tunnel diode circuit [1,2], the inverted pendulum [3], and the truck trailer [3]. So it is of practical

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significance to research on the stability analysis and controller synthesis for the state-dependent nonlinear system. In the field of control, it is well known that state feedback control is one of the most commonly methods of control. But because of the difficulty of measurement or the limitation of measuring equipment on the economy and usability in the actual systems, it is difficult for state feedback control. To the best of authors knowledge, state observer is an effective way to estimate the states of the system to complete state feedback control. The classic state observer has been designed and proved to be an efficient tool for state estimation in [4]. The state feedback controller based on the state-dependent observer is designed for the state-dependent nonlinear system in this paper. In order to prove that the closed system with the designed controller is asymptotically stable, the integral function [5] with states and estimated states is introduced to be the Lyapunov function.

In actual industrial systems, system components are connected through common digital communication network medium. Because of the limited network bandwidth, some uncertainties often happen [6–12], which bring greatly impacts on systems, such as performance degradation, instability, and failures of control. To counteract or to relieve the impacts on systems, event generators are placed into systems to reduce the occupancy bandwidth of network. Compared with periodic sampling mechanism, event-driven mechanism can reduce the release time of the sensor. As a result, communication resources can be saved. In recent years, event-driven methods have been paid more attention [13–26]. For the continuous-time linear system, the observer-based event-driven control problem has been proposed in [24], both continuous- and discrete-time event generators have been designed. Notice that send-on-delta sampling [27–30] allows reduction of event rates and better resource utilization in the networked control systems. But when the system is quasi-stationary, the number of events is quite high by send-on-delta approached (without taking into account noise effects). In this paper, the event-driven criterion is given in the form of energy, which is described by relative increment ratio of energy between the energy increment at current time and the energy at last release time. Only when the ratio is over the threshold, the state is sent out to the controller. Consequently, the burden of the network communication is reduced and the communication bandwidth is saved. To the best of our knowledge, little work has been considered on observer-based event-driven control for the state-dependent nonlinear systems. It motivates authors to research on this issue.

In this paper, the event-driven state feedback controller and the robust event-driven state feedback controller are designed for the state-dependent nonlinear systems, respectively. Assume that the system can be controlled through a network medium and only network transmission delays can be considered. The main works of this paper are highlighted as follows:

1. For the state-dependent nonlinear system, based on the designed state-dependent observer, the event-driven criterion is proposed in the form of energy, which can be described by relative increment ratio of energy between the energy increment at current time and the energy at last release time. As a result, the transmission frequency of sampling signals can be significantly reduced, and the burden of the network communication can be reduced.
2. The closed-loop system with the observer and the controller is modeled as the time-varying delayed system. The state-dependent integral function is chosen to be the Lyapunov function candidate to prove that the system is asymptotically stable with the desired H_∞ performance.
3. The observer gain, the controller gain and the event-driven parameters are co-designed and co-obtained in terms of solution to a set of LMIs.

At last, the effectiveness of the proposed method is illustrated by the numerical examples and the tunnel diode circuit systems.

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