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Journal of the Franklin Institute 000 (2017) 1–24
www.elsevier.com/locate/jfranklin

Co-design of event generator and quantized fault detection for time-delayed networked systems with sensor saturations

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Received 16 December 2016; received in revised form 12 June 2017; accepted 5 August 2017
Available online xxx

Abstract

This paper investigates the problem of fault detection for the time-delayed networked systems. Different from the traditional fault detection systems, the considered system has the following feature: (i) the measured output of system is subject to sensor saturations; (ii) the system considers the influence of transmission delay and disturbance, which are two common phenomenon under the network environment; (iii) an output-dependent triggered scheme and measurement quantization are introduced in order to reduce the network bandwidth burden and improve communication efficiency. Considering aforementioned characteristics, a new type of fault detection filter model is builded. By constructing a Lyapunov functional, some new sufficient conditions for both the existence of above filter and the mean square stability of networked systems are obtained in terms of linear matrix inequalities (LMIs). Moreover, the suitable fault detection filter and the event generator can be co-designed simultaneously. Finally, a simulation example and an industrial continuous stirred tank reactor system are employed to verify the effectiveness and usefulness of the proposed method.

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http://dx.doi.org/10.1016/j.jfranklin.2017.08.002

1. Introduction

With the increasing complexity and safety demand of dynamic systems, fault detection (FD) and fault tolerant control problems have been an active field of research over the past decades, and some model-based FD approaches have been studied [1–5]. Because of the inevitable exist of external disturbance, the FD method must have the ability to distinguish faults from external unknown inputs. If the fault of systems can not be detected immediately, the system could not work properly or even collapse. Therefore, the study of fault detection problem has important practical significance and theoretical value. Different from the problem of system control, the aim of fault detection is to construct a properly designed FD filter which could generate residual signal so as to efficiently detect abnormal changes in the systems. Generally, the main step of FD is the generation of a residual, which can be compared with a prescribed threshold. When the residual has a value larger than the threshold, an alarm is generated and the fault is detected. Recently, model–based approaches for FD has been devoted in many systems, such as linear uncertain systems, fuzzy systems, switched systems, Markovian jump linear systems, and networked systems [5–14]. For example, the authors in [7] studied the problem of fault detection filter (FDF) design for discrete-time switched systems with interval time-varying delays. The authors in [9] addressed the fault detection problem for discrete-time Markovian jump systems with incomplete knowledge of transition probabilities, randomly varying nonlinearities and sensor saturations. The authors in [13] investigated fault detection for Takagi–Sugeno fuzzy systems with time-varying delays via operator approach. The authors in [14] explored the problems of fault detection and control co-design for fuzzy networked control systems with quantization and multiple packet dropouts.

In recent years, networked control systems (NCSs) have received much attention because of there advantages such as low cost, simple installation and maintenance, and some important results have been reported on this issue. It is worth noting that many of the aforementioned results are concerned with networked control systems [10–14]. In NCSs, it is clear that a large amount of data information is to be transferred due to the rapid development of network technologies and the complexity of the reality system. However, the introduction of networks results some new problems and challenges such as missing measurements and communication delay which could degrade system performances or even cause fault. Meanwhile, the limited communication capacity of networks is one of the main sources of the system performance degradation in NCSs. Therefore, there exists an urgent need to develop new FD methodologies in the networked environment. As to the limited network bandwidth, there are two methods to be used to reduce the network bandwidth load. The first is measurement quantization to reduce the size of the data [15–19]. The second method is an even-triggered scheme which can reduce the quantity of the released data. In recent years, the even-triggered method has received increasing interest since it provides an effective way of reducing the burden of the computation and communication, thus significant considerations have been focused on the event-triggered control for some networked systems [20–26]. Besides, the event-triggered method has been applied to FD, and some nice results have also been achieved [27–32]. Particularly, in [27], the authors explored the problem of event-triggered fault detection and isolation for discrete-time linear time invariant systems. In [28], the authors investigate event-triggered FD for a class of discrete-time linear systems using interval observers. In [29–31], the authors studied the problem of FD for NCSs using Lyapunov functional stability analysis, polynomial fuzzy model and subspace identification, respectively. Recently, adaptively adjusted event-triggering method is presented in NCSs [33]. Compared with the above mentioned researches proposed by the same