



# Event-based fault detection for networked systems with communication delay and nonlinear perturbation

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Received 7 July 2012; received in revised form 28 May 2013; accepted 27 June 2013

Available online 12 July 2013

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## Abstract

This paper is concerned with the event-based fault detection for the networked systems with communication delay and nonlinear perturbation. We propose an event-triggered scheme, which has some advantages over existing ones. The sensor data is transmitted only when the specified event condition involving the sampled measurements of the plant is violated. An event-based fault detection model is firstly constructed by taking the effect of event-triggered scheme and the network transmission delay into consideration. The main purpose of this paper is to design an event-based fault detection filter such that, for all unknown input, communication delay and nonlinear perturbation, the error between the residual signal and the fault signal is made as small as possible. Sufficient conditions for the existence of the desired fault detection filter are established in terms of linear matrix inequalities. Based on these conditions, the explicit expression is given for the designed fault detection filter parameters. A numerical example is employed to illustrate the advantage of the introduced event-triggered scheme and the effectiveness of the proposed method.

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## 1. Introduction

Fault detection and isolation (FDI) has been an active field of research over the past decades, in response to an increasing demand for higher performance, higher safety and reliability standards of modern dynamic systems. In general, the aim of FDI is to construct a residual signal

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and compare it with a predefined threshold. When the residual signal exceeds the threshold, an alarm is generated. Recently, the model-based approaches to FDI problems for dynamic systems have received more and more attention, as it makes use of the mathematical model for designing a fault detection filter/observer to detect the fault signal. So far, FDI problems have been widely investigated and lots of outstanding results have been made [1–5]. For example, in [1], the authors investigated the robust fault detection problem for a class of discrete-time networked systems with unknown input and multiple state delays. The authors in [2] are concerned with the fault detection problem for a class of discrete-time systems with randomly occurring nonlinearities, mixed stochastic time-delays as well as measurement quantization. In [3], the robust fault detection filter (RFDF) was designed for a class of linear systems with some nonlinear perturbations and mixed neutral and discrete time-varying delays. Different from robust control, the goal of robust fault detection is to make the error between the residual and the fault signal as small as possible.

On the other hand, networked control systems (NCSs) have received a great deal of research attention, which have many advantages such as low cost, reduced weight and power requirements, simple installation and maintenance, and high reliability. However, the insertion of network in the control systems can also bring about new interesting and challenging issues as to the limited capacity of the network cable, for example, the transmission delay, packet dropout, signal quantization, scheduling confusion, etc. Recently, many efforts have been made on NCSs. Due to the output signal of the plant is often measured at sampled points in many practical situations, most of the available results use a periodic triggered method (also called a time-triggered control). However, this might be a conservative choice. For example, the issues of limited resource and insufficient communication bandwidth and the case of inadequate computation power for fast systems are problems that often have to be dealt with. It is therefore of great need to build mechanisms for sampling that do not rely on periodicity or time-triggering techniques. Recently, event-triggered method, advocating the use of action only when some function of the system exceeds a threshold, has received considerable attention. Event-triggered method provides a useful way to determine when the sampling action is carried out. Compared with time-triggered method, it has the following advantages: (1) it only samples when necessary; (2) the burden of the network communication is reduced; (3) the computation cost of the controller and the occupation of the sensor and actuator are reduced. So far, many outstanding results under event-triggered method have been reported. In [6], the authors proposed an event-triggered control for linear systems with an external disturbance and derived the criteria to guarantee the uniform boundedness of the system. The authors in [7] proposed event-triggered strategies for control of discrete-time systems, in which the plant was assumed input-to-state stable with respect to measurement errors and the control law was updated once a triggering condition involving the norm of a measurement error was violated. The methods for design or implementation of controllers in the event-triggered form based on dissipation inequalities were proposed for both linear and nonlinear systems in [8]. In [9], the authors were concerned with the problem of event-based  $H_\infty$  filtering for networked systems with communication delay under a novel event-triggered scheme upon which the sensor data transmitted only when the specified event condition involving the sampled measurements of the plant was violated. Up to now, to the best of the authors' knowledge, little attention has been paid to the FDI problem for networked control system under event-triggered scheme. This situation has motivated our current investigation with the hope to shorten such a gap by addressing the fault detection with transmission delay under the event-triggered scheme.

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