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Fault detection in finite frequency domain for constrained networked systems under multi-packet transmission

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Abstract

In this paper, the fault detection problem is studied in finite frequency domain for constrained networked systems under multi-packet transmission. The considered transmission mechanism is that only one packet including parts of the measured information can be transmitted through the communication channel and their accessing is scheduled by a designed stochastic protocol. Then by virtues of the introduced performance indices in finite frequency domain, a novel effective fault detection scheme is presented, in which the fault detection filters completing the task with partially available measurements are designed to make sure that the residual is sensitive to the reference input and the fault in faulty cases and robust to the reference input in fault-free case. Further, convex conditions in terms of time-domain inequalities are developed to handle the proposed fault detection scheme. The theoretical results are validated by the simulation to detect the sensor fault on a lateral-directional aerodynamic model.

1. Introduction

The rapid advances in computer and communication technologies revolutionized the scale of the control systems. A class of control systems termed as networked control systems (NCSs), in which large spatially distributed components such as plants, controllers, sensors and actuators can be connected together [1–4], has gained a great deal of research attention because

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of their growing applications in practical areas such as aircrafts, ventilation, automobiles etc. Although the NCSs introduced many advantages such as reduction of system wiring, simple system diagnosis and low cost they also bring some new phenomena including networked-induced delay, packet losses, quantization and communication constraint, one can see [5,6] for more details.

Fault detection (FD) problem has been another challenging and active field of research due to the increasing demands on safety, higher performance and reliability in industrial process. Consequently, a great deal of efforts have been paid to this issue, and the results are mainly divided into two categories. One is the model-based methods, see e.g. [7,8] and the other is data-based methods, see e.g. [9,10]. For more details, one can see [11] for a survey. However, among these FD methods [12], the celebrated frequency domain approach is accepted as a significant one because the signals of the practical systems are often in certain frequency domain, see e.g., the finite frequency FD method have been developed for linear uncertain discrete-time systems in [13] and for linear parameter-varying systems in [14], respectively, with the aid of the generalized Kalman–Yakubovich–Popov (GKYP) lemma. Further, a FD scheme based on the steady-state method has been proposed in finite frequency domain in [15] for linear output feedback control systems. Though the mentioned methods were proven to be effective to detect certain types of faults, they were proposed for linear systems. In recent years, some finite frequency FD method have been carried out for nonlinear systems, i.e. [12] for T-S fuzzy systems and [16] for multi-delay uncertain systems, etc.. However, the FD method for stochastic systems has not been mature.

Due to the wide utilization of NCSs, it is naturally to study the FD methods for this class of systems. And thus a lot of researches have been carried out, i.e., FD method which is robust to the network-induced time delay has been developed in [18–20] and to packet dropouts in [21–23]. However, it should be noticed in above literatures and most other existing results concerned with the FD problem for NCSs, that the system data are assumed to be delivered in one packet. Nevertheless, the outputs of the system are often measured by multiple and distributed sensors, and thus the sampled data cannot be transmitted by one packet. In such cases, the mentioned FD methods will be invalid. Furthermore, as mentioned in [24,25], one of the communication constraints called medium access constraint, which is coming after the insert of the networks, also degrades the performance of the FD system. Under such constraint, not all the transmission nodes are allowed to transmitted through the communication channel simultaneously. Consequently, it is nature and important to study the FD approach for the NCSs under multi-packet transmission and such constraint. Long and Yang [26] have proposed a FD scheme for NCSs subject to time-varying transmission intervals and delays, packet dropouts, and communication constraints in the framework of switched stochastic parameter systems, but the frequency of the signals has not been considered yet.

Motivated by the above statements, the FD problem in finite frequency domain for NCSs with communication constraints under multi-packet transmission is addressed in this paper against to sensor failures. Specifically, the main contributions of this manuscript are lied in the following aspects: (i) the communication constraint, that is only one network node can access the communication channel, and a novel sensor fault model are considered. The whole FD system is modeled as multiple Markovian jump systems, and sufficient conditions guaranteeing the whole system with desired performances in finite frequency domain are derived. (ii) A new FD scheme, which is effective to detect the sensor faults with either large or small magnitudes, is proposed by making the generated residuals sensitive to both reference inputs and fault signals in faulty cases while robust to the reference inputs in fault-free case.

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