南通大学

专业技术五级及以下岗位申报表

申报人姓名：邱爱兵

申报岗位等级：专业技术五级

所在一级学科：控制科学与工程

现聘岗位等级：专业技术七级

填表时间：2019年5月4日

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6. 所在一级学科参照2018年4月国务院学位委员会、教育部印发的《学位授予和人才培养学科目录》填写。

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申报人签名：

2019年 5月5 日

一、 基本情况

姓名	邱爱兵	性别	男	民族	汉	籍贯	江苏海安
出生年月	1982.9	政治面貌	致公党		来校工作年月	2010.12	
健康状况	良好	联系电话	18251301948		邮箱	aibqiu@ntu.edu.cn	
所在一级学科	控制科学与工程				申报专业技术岗位等级	五	
现聘专业技术职务及聘任时间（转评专业技术职务分行填写）	副教授，2014.7						
是否遵纪守法，具有良好的品行和职业道德，具有良好的学术声誉、学术道德和合作精神	是						

二、 年度考核情况

任现职以来，各年度综合考核是否均为合格及以上			是
近三年年度考核情况	2016年	2017	2018年
	合格	合格	优秀

三、教学工作情况 2017

1.任现职以来，年度教学质量考核优秀次数（注明年份）			4次
2.近三年教学质量考核情况	2016年	2017年	2018年
	优秀	未考核（境外研修）	优秀

四、任现职以来业绩

1. 教师荣誉（申报条件附表条款1）

获得时间	称号名称	授予部门

2.人才称号（申报条件附表条款 2）

获得时间	称号名称	授予部门

3.团队建设（申报条件附表条款 3）

获得时间	团队名称	本人角色	批准部门

4.教学平台、公共服务平台负责人（申报条件附表条款 4）

获得时间	平台名称	本人角色	批准部门

5.专业建设负责人（申报条件附表条款 5）

获得时间	专业建设名称	本人角色	批准部门

6.学科、科研平台负责人（申报条件附表条款 6）

获得时间	平台名称	本人角色	批准部门

7.教学成果奖（申报条件附表条款 7）

获得时间	奖项级别	奖项等级	本人排名	评奖部门

8.自然科研成果奖（申报条件附表条款 8）

获得时间	奖项名称	奖项等级	本人排名	评奖部门
2018	面向节能降耗的超高效电机及其拖动系统成套装备的研制与产业化	中国产学研合作创新成果奖，一等奖	6 ✓	中国产学研合作促进会
2015	基于智能测控的超高效电机转子设计与制造的研究	教育科学技术进步奖，二等奖	5 ✓	教育部

9.专利奖（申报条件附表条款 9）

获得时间	奖项名称	奖项等级	本人排名	评奖部门

10.指导学生（申报条件附表条款 10）

获得时间	奖项名称	奖项等级	本人排名	评奖部门

11.科研项目（申报条件附表条款 11）

起止时间	项目名称	立项单位	项目级别	本人角色
1	闭环不确定系统基于反馈控制的故障诊断方法研究 2015/1-2018/12	国家自然科学基金委	国家级	主持人
2	采样数据系统的故障诊断与容错控制一体化设计 2015/1-2018/12	国家自然科学基金委	国家级	主持人
3	基于多约束条件和广义系统理论的复杂设备故障诊断方法 2014/1-2017/12	国家自然科学基金委	国家级	合作单位负责人

12.教学项目（申报条件附表条款 12 内容）

起止时间	项目名称	立项单位	项目级别	本人角色
				主持人

13.论文、论著、专利类（申报条件附表条款 13）

论文题目	发表刊物（卷/期）	本人角色	期刊级别（或分区）
Self-triggered fault estimation and fault tolerant control for networked control systems	Neurocomputing,2018, 272: 629-637	1	SCI/EI，二区
Event-triggered sampling and fault tolerant control co-design based on fault diagnosis observer	Journal of System Electronics and Engineering 2018, 29(1):176-186	1	SCI/EI，四区
An uncertainty-based approach to discrete-time fault estimation observer design for nonuniformly sampled systems	International Journal of Control, Automation, and Systems. 2017, 15(4):1651-1660	1	SCI/EI，四区
Fault estimation and accommodation for networked control systems with nonuniform sampling periods. International Journal of Adaptive Control and Signal Processing	International Journal of Adaptive Control and Signal Processing. 2015,29:427-442	1	SCI/EI，三区

基于事件触发的故障诊断与动态调节集成设计.	控制理论与应用. 2018, 35(8): 1159-1166	1	EI
非均匀采样数据系统时变故障估计与调节最优集成设计	自动化学报. 2014. 40(7):1493-1504	4	EI

专著名称	出版社	字数（本人撰写字数）	出版时间	折算论文篇数

发明专利授权名称（转让情况）	本人角色	授权时间（转让时间）	折算论文篇数

合计论文篇数（含折算）：__6__篇
自然科学论文__6__篇（其中中科院 JCR 三区及以上论文__2__篇；人文社科论文___篇;期刊级别按附表条件表述，如 SCI、EI、三区；CSSCI、SSCI、《高等学校文科学术文摘》转载等；ESI 学科排名前 1%或学科潜力值超过 0.5%的主要贡献者情况说明：_____

14.课程资源建设（申报条件附表条款 14）

获得时间	课程资源建设名称	本人角色	批准部门

15.标准制定（申报条件附表条款 15）

颁布时间	制定标准名称	本人角色	标准颁布主体

五、符合申报岗位条件情况

对照《南通大学电气工程学院2019年基础岗位新增聘用办法》，本人认为符合条件为：

聘任副高（副高、中级）专业技术职务满4年，具备附表2中所列的第8、11、13、___、___项条件，以及附表___中所列的第___、___、___、___、___项条件。

六、学院意见

经评审，　　同志拟聘为专业技术　　级岗位。

电气工程学院岗位聘用工作小组组长签字：

年　月　日

为表彰在促进科学技术进步工作中做出重大贡献，特颁发此证书。

获奖项目：基于智能测控的超高效电机转子设计与制造的研究

获 奖 者：邱爱兵(第5完成人)

奖励等级：科学技术进步奖二等奖

奖励日期：2016年2月

证 书 号：2015-276

中华人民共和国教育部

二〇一六年二月二十六日

国科奖社证字第0191号

2018年中国产学研合作创新成果奖

获奖证书

为表彰在产学研合作中取得的重要创新成果，特颁发此证书。

项目名称：面向节能降耗的超高效电机及其拖动系统成套装备的研制与产业化

奖项等级：一等奖

完成单位：南通大学、
南通大学技术转移中心、
江苏通达动力科技股份有限公司、
南通威尔电机有限公司、
江苏金通灵流体机械科技股份有限公司

主要完成人：顾菊平、华　亮、羌予践、王　岳、李俊红、邹爱兵、堵　俊、张迎梅、罗来武、季立新

证书号：20189033

中国产学研合作促进会

2018年12月

22600101-1266

国家自然科学基金

资助项目准予结题通知

邱爱兵　同志：

您承担的国家自然科学基金项目：(采样数据系统的故障诊断与容错控制一体化设计)，批准号：(61104028)按有关规定已审核完毕，准予结题。

与本项目资助有关的后续成果，请您继续及时报送。

祝您在研究工作中取得更好的成绩！

国家自然科学基金委员会

信息科学部

2015年4月24日

国家自然科学基金项目（No.61374136）合作协议书

甲方（项目主持方）：上海电机学院 文传博课题组 （负责人：文传博）
乙方（合作方）：南通大学 邱爱兵课题组 （负责人：邱爱兵）

2013年，甲乙双方以甲方所在的上海电机学院为依托单位合作申报了该年度的国家自然科学基金面上项目，并获得国家自然科学基金委的资助（项目名称：基于多约束条件和广义系统理论的复杂设备故障诊断方法；批准编号：61374136，项目经费：81万元）。为了保证合作研究的顺利开展，经双方友好协商达成以下协议：

一、经费分配

项目总经费为81万元，上海电机学院课题组负责其中的61万元；南通大学课题组负责其中的20万元（拨付明细见附件）。乙方承诺将严格按照经费预算花销。

二、任务分配

该项目申请总任务是：发表论文20-25篇，其中SCI收入6-8篇，申请发明专利4-7项。任务分配如下：

1）上海电机学院课题组的任务：抓总，并负责实验平台的建设工作，负责获取实验数据，协调两个单位具体工作，发表和录用15-18篇高水平的论文，其中SCI收录论文4-6篇，申请发明专利3-5项。

2）南通大学课题组的任务：发表和录用5-10篇高水平学术论文，其中SCI收录论文2-3篇，申请发明专利1-2项。

上述研究成果均需标注有国家自然科学基金项目资助编号。

未尽事宜，由双方友好协商后再确定。

项目负责人：文传博　　合作方负责人：邱爱兵

上海电机学院　　南通大学

年　月　日　　年　月　日

22600101-1266

国家自然科学基金

资助项目准予结题通知

邱爱兵　同志：

您承担的国家自然科学基金项目：(闭环不确定系统基于反馈控制的故障诊断方法研究)，批准号：(61473159)按有关规定已审核完毕，准予结题。

与本项目资助有关的后续成果，请您继续及时报送。

祝您在研究工作中取得更好的成绩！

国家自然科学基金委员会

信息科学部

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Self-triggered fault estimation and fault tolerant control for networked control systems☆

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ABSTRACT

A framework of self-triggered fault diagnosis (FD) and fault tolerant control (FTC) for networked control systems (NCSs) is presented in this paper. The self-triggered scheduler is implemented in a smart sensor node. By means of uncertain polytopic theory, we first design a fault diagnosis observer, which has a similar structure with Kalman filter, to simultaneously estimate the fault and state using the self-triggered nonuniform sampled outputs. Then, based on the obtained fault and state information, an active fault tolerant controller with a state-estimate-dependent self-triggered scheduler is provided. We prove that the closed-loop faulty system is input-to-state stable (ISS) under the proposed self-triggered sampling mechanism. Finally, simulation results are provided to verify that the proposed self-triggered FD and FTC scheme can significantly reduce the sampling cost while preserving the desired fault estimation and FTC performance.

1. Introduction

Due to the widespread use of embedded microprocessor in relevant application domains such as networked control systems (NCSs) and wireless sensor network, some nonuniform sampling techniques, especially event-triggered and self-triggered sampling techniques, have regained interests during the last decade [1–5]. Taking event-triggered sampling as an example, the state or the output of the plant is no longer periodically transmitted to the monitoring center. Instead, the sampling instants are determined by some events which are usually related to the current state or the output of the plant. Compared with the traditional periodic sampling counterpart, the event-triggered sampling can not only reduce the communication costs and energy consumptions in NCSs [6,7], but also improve the system performance or sensor precision [8–10]. However, in event-triggered sampling scheme, a dedicated hardware is usually required to constantly monitor or rapidly sample the state of system [2,11,12]. This disadvantage therefore promotes the development of self-triggered sampling scheme, in which, the next sampling instant depends on the current state. Since the self-triggered scheme relaxes the requirement of continuously testing event-triggering condition, it is more promising than the event-triggered one in the implementation aspect. A series of research results on self-triggered control have been achieved [13–24]. In [13], the benefit of self-triggered sampling technique is verified on two classes of nonlinear systems. Two self-triggered control schemes are proposed to ensure the $\mathcal{L}_2$ stability for the systems with state-dependent disturbance and state-independent disturbance in [14] and [15], respectively. In [16], a self-triggered implementation of linear controller is presented to retain the input-to-state stability (ISS) of the closed-loop system. Recently, various self-triggered sampling schemes are extended to different complex systems, including NCSs with packet dropout and communication delay [17–20] and multi-agent systems [21,22], which strongly pushed for the rapid development in this field. However, the above mentioned self-triggered conditions are generally defined with respect to the state, which requires that the state is always available. The requirement sometimes is not realistic in practice. Few works focus on the output based self-triggered control scheme. In [23], a self-triggered output feedback controller of linear plants is designed by use of a state observer. The gain of the observer is time-varying and needs to be computed online, which results in heavy calculation burden. In [24], an observer-based self-triggered output feedback control is developed for a

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Event-triggered sampling and fault-tolerant control co-design based on fault diagnosis observer

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2. School of Automation, Nanjing University of Science and Technology, Nanjing 210094, China;
3. College of Automation Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China

Abstract: A co-design scheme of event-triggered sampling mechanism and active fault tolerant control (FTC) is developed. Firstly, a fault diagnosis observer is designed to estimate both the fault and the state simultaneously by using the event-triggered sampled output. Some H_∞ constraints between the estimation errors and the event-triggered sampling mechanism are established to ensure the estimation accuracy. Then, based on the constraints and the obtained fault information, an event-triggered detector and a static fault tolerant controller are co-designed to guarantee the stability of the faulty system and to reduce the sensor communication cost. Furthermore, the problem of the event detector and dynamic FTC co-design is also investigated. Simulation results of an unstable batch reactor are finally provided to illustrate the effectiveness of the proposed method.

Keywords: event-triggered sampling, fault estimation, active fault tolerant control (FTC), co-design.

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1. Introduction

With the rapid development of digital technology, particularly when various kinds of embedded microprocessors are widely used in industry, it is popular to monitor and control continuous-time plant in discrete-time domain. In these types of systems, system outputs are generally periodically sampled. The periodic sampling pattern can simplify system analysis and synthesis, but it ignores the inter-sample behavior of the system [1] and always leads to a heavy consumption of energy, computation resource, or communication bandwidth [2]. To overcome the drawbacks of periodic sampling, some event-triggered sampling strategies have been proposed recently. The event-triggered sampling means that the sensor performs the sampling action only if the system state or output satisfies some pre-specified conditions [3]. Compared with periodic sampling, the event-triggered sampling can not only reduce the computation complexity, communication cost, or energy consumptions, but also improve the sensor precision [4] and the control performances [5]. The prior event-triggered sampling strategies are generally defined in terms of the system state [6–8], which assumes that all state information is always available. This assumption is not realistic in practice. The extension of state-based event-triggered sampling to output-based one has been investigated. The primary difficulty of the extension lies in how to determine a lower bound of the inter-event times. A mixed event-triggered sampling mechanism was developed in [9] and a lower bound related to the initial state and disturbance is derived by using the hybrid system approach. It is worth pointing out that all the above mentioned event-triggered sampling mechanisms require monitoring the system state or the output constantly. To avoid the continuous detection, self-triggered sampling [10–12] and sampled-data event-triggered sampling strategies have been proposed [13]. The sampled-data event triggered sampling is also called periodic event-triggered sampling [14–15], in which the event-triggering condition is periodically verified. The period can be regarded as the lower bound of inter-event times. Comparing with self-triggered one, the periodic event-triggered sampling can usually obtain larger sampling intervals. In [13], the event-triggered technique was applied to both sensor and controller nodes to reduce the transmission rates among the sensor, controller, and actuator, and a co-design scheme of the event detector and controller is developed. An observer-based sampled-data event-triggered sampling mechanism was proposed in [14]. Both the observer and the predictor are designed in sensor nodes to determine the transmission instant of state

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An Uncertainty-based Approach to Discrete-time Fault Estimation Observer Design for Nonuniformly Sampled Systems

Aibing Qiu*, Jing Zhang, and Juping Gu

Abstract: This paper considers the fault estimation problem of nonuniformly sampled system in which sensor sampling is performed at aperiodic interval. After being discretized at sampling instant, the nonuniformly sampled system is modeled as an equivalent polytopic system with norm bounded uncertainties. A discrete-time time-varying fault estimation observer with multiple design freedom is then constructed, and a sufficient condition given in linear matrix inequality (LMI) is provided to obtain the constant filter gain and ensure not only the asymptotic stability of fault estimation error but also the robustness of uncertainties. Compared with the existing observer designed based on continuous-time delay approach, the proposed one has a better estimation accuracy and less conservatism and is easy for digital implementation. A numerical simulation and a quadruple-tank benchmark are used to demonstrate the effectiveness and superiority of the proposed method.

Keywords: Discrete-time observer, fault estimation, nonuniform sampling, polytopic uncertainty.

1. INTRODUCTION

Due to great advantages of PLC, DSP and many other digital technologies, most continuous-time systems of industrial process are monitored and controlled in discrete-time domain. In these types of systems, the output is usually obtained by periodic sampling of sensors. The sampling period can be determined in different ways such as the classical Nyquist-Shannon sampling theorem or the maximum allowable transfer interval technique [1]. Although the periodic sampling pattern can simplify system analysis and synthesis, it completely ignores the inter-sample behavior of the system [2] and always leads to more consumption of communication bandwidth and computation resources [3]. Besides, on account of a number of reasons including sensor characteristic, packet loss and delay in network, and laboratory analysis, the sensor sampling is frequently performed at nonuniformly spaced time instants [4]. The nonuniform sampling pattern has several advantages over the periodic sampling. For instance, it can preserve controllability and observability in discretization [5], improve control performance [6], and increase sensor precision [7]. Furthermore, one of the most reliable and efficient way to reduce communication and computation burden in cyber-physical systems is to actively adjust sampling period online. Some active nonuniform sampling schemes such as self-triggered and event triggered sampling have been proposed and the research in this field has attracted considerable attentions in the past few years [8, 9].

On the other hand, with the increasing hugeness and complexity of modern engineering system, a small fault occurred in any component of a system probably can propagate from one point to another and may further lead to a total breakdown of the whole system. To guarantee the safety and reliability of a system, fault diagnosis techniques for dynamic systems have been extensively developed during the last half-century [10, 11]. Take periodic sampled system as an example, the Kalman filter based and parity relation based residual generators were developed for the fault diagnosis of the periodic sampled systems as early as the 1970s and 1980s [12, 13]. However, these classical works did not consider inter-sample behavior which may lead to poor performance of the diagnosis system. Based on continuous lifting technique, the so-called norm invariant transform is proposed to handle the inter-sample problem in periodic sampled-data fault detection [14]. The transform, however, requires the periodic sampled system to be strictly proper. A hybrid system approach is then introduced in [15] to tackle this requirement. It is verified that the hybrid system approach is more efficient than the continuous lifting technique for

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Fault estimation and accommodation for networked control systems with nonuniform sampling periods

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SUMMARY

This paper deals with the problem of fault estimation and accommodation for a class of networked control systems with nonuniform uncertain sampling periods. Firstly, the reason why the adaptive fault diagnosis observer cannot be applied to networked control systems is analyzed. Based on this analysis, a novel robust fault estimation observer is constructed to estimate both continuous-time fault and system states by using nonuniformly discrete-time sampled outputs. Furthermore, using the obtained states and fault information, a nonuniformly sampled-data fault tolerant control law is designed to preserve the stability of the closed-loop system. The proposed scheme can not only guarantee the impact of continuous-time uncertainties and discrete-time sampled estimation errors on the faulty system to satisfy a H_∞ performance index but also repress the negative effect of the unknown intersample behavior of continuous-time fault by use of an inequality technique. Finally, simulation results are included to demonstrate the feasibility of the proposed method. Copyright © 2014 John Wiley & Sons, Ltd.

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KEY WORDS: fault accommodation; nonuniform sampling; networked control systems; adaptive observer

1. INTRODUCTION

Owing to numerous advantages offered by communication, control and computer technologies, networked control systems (NCSs) have been extensively used in many engineering areas such as automatic manufacturing, aircraft, chemical and petroleum. In these types of systems, the communications between sensors, actuators, controllers and plants are established through a shared band-limited digital network, which leads to some new problems and challenges, for example, network-induced delay, quantization, packet dropout and variation of sampling period. The topics on analysis and design of NCSs have received considerable attentions, and fruitful results have been obtained, see for example [1–3] and the references therein. Furthermore, NCSs are usually affected by various kinds of faults as many other control systems, which may degrade system performance or even cause a total breakdown of systems. So it is important to detect faults and apply appropriate remedies as soon as possible. Recently, there are increasing interests on fault detection and isolation (FDI) and fault tolerant control (FTC) for NCSs [4–16].

Compared with FDI for NCSs, research works on FTC for NCSs are relatively few. However, in some safety-critical NCSs such as aircraft flight control systems, only FDI is far from enough to guarantee the safety and reliability of system. It is required to maintain the performance objectives under the faulty case, or if that turns out to be impossible, to assign new achievable objectives so

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基于事件触发的故障诊断与动态调节集成设计

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摘要: 本文发展了一种事件触发采样与更新检测机制、故障诊断及调节的集成设计框架. 事件触发技术不仅用于传感器端, 同时也用于容错控制器端. 所设计的故障诊断观测器能够应用基于事件触发的非均匀采样输出同时估计故障和系统状态, 基于所获得的状态和估计信息, 构造事件触发更新检测器和动态容错控制器, 进而借助于增广系统方法来集成设计两个事件触发检测器、故障诊断观测器和容错控制器, 以保证故障系统的性能, 同时尽可能的降低传感器、控制器、执行器三者之间的信息传输频率. 仿真实例验证了所提方法的可行性和优越性.

关键词: 故障调节; 事件触发; 故障估计; 集成设计

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An integrated design of event-triggered fault diagnosis and dynamic fault accommodation

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Abstract: An integrated design framework of event-triggered sampling and updating mechanism, fault diagnosis and fault accommodation is developed in this paper. The event-triggered technique is applied to both sensor node and fault tolerant controller node. A fault diagnosis observer is firstly designed to estimate the fault and the state simultaneously using the event-triggered nonuniform sampled output. Based on the obtained fault and state information, an event-triggered updating detector and a dynamic fault tolerant controller are then constructed. The augmented system approach is further employed to design the two detectors, the fault diagnosis observer and fault tolerant controller simultaneously, not only to guarantee the performance of the faulty system, but also to reduce the information transfer frequency among the sensor, controller and actuator. Simulation results are finally provided to illustrate the effectiveness and superiority of the proposed approach.

Key words: fault accommodation; event-triggered; fault estimation; integrated design

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1 引言(Introduction)

鉴于安全性与可靠性在现代工程系统中的重要地位, 故障诊断与容错控制技术在过去半个世纪内得到了学术界和工业界的持续关注[1–2]. 特别的, 随着网络通信技术在工业过程中的普及, 大量信息的远距离传输降低了通信的可靠性, 进而影响系统性能并增加了故障发生的可能, 为此, 研究人员开展了以网络化系统为对象的故障诊断与容错控制研究, 主要针对数据延迟、无序和丢包等典型网络传输现象进行了相应故障诊断与容错控制设计, 取得了大量理论和应用成果[3–5].

进一步的, 工业过程常通过周期性地采样与传输信息来监控系统, 然而这种传统的周期采样技术不仅会增加通信消耗, 同时也会导致计算和能量资源的浪费. 在此背景下, 事件触发技术被提出作为周期采样的替代和补充, 所谓的事件触发是指传感或通信设备

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非均匀采样数据系统时变故障估计与调节最优集成设计

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摘 要 针对一类发生连续时变故障的非均匀采样数据系统, 建立了一套主动容错控制最优设计方案. 首先, 为了实现基于非均匀离散采样输出对连续故障的估计, 同时鉴于现有自适应故障诊断方法无法直接推广于非均匀采样数据系统, 提出一种连续时间增广观测器最优设计方法, 既能保证故障估计误差快速收敛同时又对外界干扰鲁棒; 并且提出一个迭代算法对故障估计延迟与系统鲁棒性进行权衡; 进一步地, 基于所获得的故障信息, 并考虑估计误差和时变故障内采样特性对容错控制带来的不利因素, 设计基于状态反馈的非均匀采样容错控制器来快速恢复故障系统性能; 最后, 通过对四容水箱基准实例的仿真来验证所提方法的有效性.

关键词 时变故障调节, 非均匀采样, 采样容错控制, 性能权衡

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Optimal Integrated Design of Time-varying Fault Estimation and Accommodation for Nonuniformly Sampled Data Systems

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Abstract In this paper, an active fault tolerant control design scheme is presented for a class of nonuniformly sampled data systems with continuous time-varying fault. Since the adaptive fault diagnosis technique can not be directly extended to such systems, an optimal continuous augmented observer is firstly designed to estimate the fault by use of nonuniform discrete output. The observer can not only guarantee fast convergence of estimation errors but also be robust to external disturbance. Then, an iterative algorithm is proposed to make a tradeoff between estimation delay and system robustness. Furthermore, with the obtained fault information, a nonuniformly sampled data fault tolerant controller based on state feedback is designed to recover the performance of the faulty system in consideration of the adverse impact of estimation errors and inter-sample behavior of continuous fault. Finally, the simulation results of an quadruple-tank example are included to illustrate the effectiveness of the proposed method.

Key words Time-varying fault accommodation, nonuniform sampling, sampled-data fault tolerant control, performance trade-off

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随着现代工业系统向复杂化和大型化发展, 对其安全性和可靠性的要求也越来越高, 特别是在一些安全至上的装置如飞行器和化工设备中, 要求系统在发生故障的情况下仍能实现预指定的性能目标, 或者至少保持系统稳定以避免灾难性的后果. 在此背景下, 故障诊断特别是容错控制在过去数十年中得以广泛关注和快速发展[1−3]. 一般而言, 容错控制可分为被动和主动两种形式, 相比于前者, 主动容错是在对系统进行故障诊断的基础上, 主动调整控制策略, 因而能更有针对性地设计容错控制器, 效果更佳. 故障调节是实现主动容错最有效的方法之一, 其基本思路是在判断故障发生后对其进行辨识和估计, 然后再通过修正或附加控制率来补偿故障带来的影响, 使系统尽量保持无故障时的性能[3−4]. 文献 [5] 基于多模型估计法对故障进行检测和诊断, 在获得故障信息的基础上, 利用特征匹配法设计重构控制率. 文献 [6] 利用神经网络方法来在线估计故障的信息, 在此基础上利用附加控制率的方法以保证故障系统稳定. 针对多输入多输出离散时间系统, 文献 [7] 应用系统分解和 Kalman 滤波方法对执行器故障进行估计, 然后通过重构控制器的期望输出来补

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