南通大学

专业技术五级及以下岗位申报表

申报人姓名：商亮亮

申报岗位等级：专业技术九级

所在一级学科：控制科学与工程

现聘岗位等级：专业技术十级

填表时间：2019年 5月 4日

填表说明

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2．本表第一至第五项内容由本人填写，并附证明材料。

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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。

申报人承诺：

本表所填信息属实，所有申报材料均为任现专业技术职务以来的新增业绩。本人对本表所填写内容的真实性负全部责任。

申报人签名：

2019年 5月6 日

一、 基本情况

姓名	商亮亮	性别	男	民族	汉	籍贯	山东淄博
出生年月	1981 年 11 月	政治面貌	群众		来校工作年月	2016 年 7 月	
健康状况	良好	联系电话	18260597642		邮箱	shangliangliang@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	九	
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）	讲师，2016 年 10 月						
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_年	_2018_年
	合格 √	合格 √	合格 √

三、教学工作情况

1.任现职以来，年度教学质量考核优秀次数（注明年份）			
2.近三年教学质量考核情况	_2016_年	_2017_年	_2018_年
	~~优秀~~ 良好	~~优秀~~ 良好	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

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
2017/12-2018/12	基于规范变量分析的多模态化工过程故障监测与诊断	南通市科技局	市级	主持人
2017/09-2019/08	基于递推子空间辨识的多模态过程建模	江苏省教育厅	厅级	主持人
2017/05-2019/05	数据驱动建模与故障监测和诊断系统开发	校教务处	省级指导	指导老师
2017	基于子空间辨识的多模态化工过程故障监测与诊断	南通大学	校级	主持人

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
2018/10-2019/10	基于 MATLAB 的《信号与系统引论》课程改革研究	教务处	校级	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）
Efficient recursive kernel canonical variate analysis for monitoring nonlinear time - varying processes	Canadian Journal of Chemical Engineering, 2017. 3.	第一作者	SCI 4 区
基于改进 PCA 的空调系统传感器故障监测与诊断	控制工程(已录用)	通讯作者	核心
Efficient recursive kernel principal component analysis for nonlinear time-varying processes monitoring	Chinese Control and Decision Conference. (已录用)	第一作者	EI 检索

Efficient recursive canonical variate analysis approach for monitoring time - varying processes	Journal of Chemometrics, 2017, 31.	第一作者	SCI 4 区
Recursive Fault Detection and Identification for Time-Varying Processes	Industrial & Engineering Chemistry Research, 2016, 55(46)	第一作者	SCI 2 区
基于递推规范变量分析的时变过程故障检测	东北大学学报(自然科学版) 2016, 37(12):	第一作者	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__1__篇；人文社科论文__0__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：__化学化工潜力超过 0.5%的 ESI 学科__

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 中级 （副高、中级）专业技术职务满 1 年，具备附表 3 中所列的第 5、7 项条件，以及附表___中所列的第___、___、___、___、___项条件。

六、学院意见

经评审， 商亮亮 同志拟聘为专业技术 九 级岗位。

电气工程学院岗位聘用工作小组组长签字：

年 月 日

南通大学 财务处
综合信息门户

https://vpn.ntu.edu.cn/

网上查询

项目成组查询

查询功能 南通大学项目成组查询 · 查询年份 2019年 · 过滤全零项目 是 · 否 合并子项目 · 是 否

项目成组查询

项目代码	项目名称	负责人	控制余额	可用余额
0308[illegible]060	人才引进项目：基于[illegible]的多模态化工过程故障监测与诊断	[illegible]	29,484.00	29,484.00
[illegible]603CC4[illegible]	[illegible]项目：基于[illegible]的多模态过程建模	[illegible]	0.00	0.00
[illegible]303[illegible]52[illegible]	[illegible]：基于[illegible]分析的多模态化工过程故障监测与诊断	[illegible]	1,401.72	1,401.72
13053039	课程教学改革研究课题：基于MATLAB的《信号与系统》[illegible]课程改革研究	[illegible]	3,000.00	3,000.00
合计			33,885.72	33,885.72

南通大学教学改革研究课题合同书

课题名称：基于 MATLAB 的《信号与系统引论》课程改革研究　　课题编号：2018B39

课题来源：学校教务处　　审批经费：3,000

委托部门：学校教务处　　配套经费：0

课题负责人：商亮亮　　承担部门：电气工程学院

课题组成员：杨奕，瞿逊春，邱爱兵，李俊红，杨赛

根据《南通大学教学改革研究课题管理办法》签订本合同。

一、研究内容和目标，以及主要技术经济指标

基于 Matlab 的《信号与系统引论》课堂教学内容改革主要包括如下两个方面：

1）课堂教学内容改革；精心挑选重点难点内容，借助 MATLAB 软件完成习题演算和波形绘制。依据《信号与系统引论》的各章节主要内容，将以下 6 部分内容：a) 常用基本信号的 MATLAB 表示和运算；b) 连续时间信号与系统的时域分析；c) 连续时间信号与系统的频域分析；d) 连续时间信号与系统的复频域分析；e) 离散时间信号与系统的 Z 域分析，用 MATLAB 编程实现运算和分析，进一步加深学生对概念和分析原理的理解。

2）如何提高课堂教学效率。《信号与系统》授课过程中，往往需要画图来表示各种信号曲线，单纯的绘图方面就需要大量时间。然而，MATLAB 强大的绘图和计算能力，不仅能轻而易举的绘制出这些曲线，而且能动态的演示曲线的生成，可以给学生留下深刻的印象，使课堂教学的效率得到很大提高，提升学生的听课效果。

目标：主要围绕基于 MATLAB 的《信号与系统》课堂教学内容改革、对当前教学模式进行研究和改革，并修订原有的课程教学大纲。针对时域和频域分析部分的重点内容，结合实际工程例子，利用 MATLAB 软件编程实现可视化的理论教学内容呈现。

二、提交成果的形式、数量、使用范围以及效益分析等

1) 2018.10-12　通过查阅文献、调查研究，撰写修订方案，教师定期研讨；学生座谈及反馈信息记录；

2) 2019.01-04　实施研究方案，实现基于 MATLAB 的时域和频域分析的程序编写和说明手册，完成课堂教学验证的反馈信息收集；

3) 2019.05-06　实现基于 MATLAB 的复频域和 Z 域分析的程序编写和说明手册，进一步优化相关程序代码；

4) 2019.07-08　分析整理研究资料，在省级及以上期刊上发表 1～2 篇与课题相关的教研论文。

三、经费概算及分年度使用计划

合计费用：3,000

其中：

项目 / 年度	图书资料费	调研费	版面费	上机费	成果打印费	小型会议费	文具费	其它费用
2018	200	0	0	0	300	0	0	0
2019	0	0	2,500	0	0	0	0	0

四、课题起止时间及年度计划内容

1 2018.10-2018.11

研究内容：将本学院《信号与系统》任课教师组成教学团队，定期研讨的交互式学习、取长补短、共同提高。展开课题调研，并广泛搜集和整理相关资料；

2 2018.11-2018.12

研究内容：规划需要改革的授课内容，进行教学内容调整和教学大纲的修订；

3 2019.01-2019.02

研究内容：基于 MATLAB 的时域部分程序编写；

连续时间信号与系统的时域分析；连续时间系统零状态响应的数值计算；连续时间系统冲激响应和阶跃响应的求解；用 MATLAB 实现连续时间信号的卷积；利用 MATLAB 中的 Simulink 进行系统时域特性仿真

4 2019.03-2019.04

研究内容：连续时间信号与系统的频域分析

傅里叶变换的 MATLAB 求解；用 MATLAB 分析 LTI 系统的频率特性；用 MATLAB 分析 LTI 系统的输出响应

5 2019.05-2019.06

研究内容：连续时间信号与系统的复频域分析

用 MATLAB 进行部分分式展开；用 MATLAB 分析 LTI 系统的特性；用 MATLAB 进行 Laplace 正、反变换；离散时间信号与系统的 Z 域分析；用 MATLAB 画离散系统零极点图；用 MATLAB 分析离散系统的频率特性。

6 2019.07-2019.08

研究内容：整理所有教改内容，实现所有程序代码的验证，以及 MATLAB 编程操作参考手册的编写。

五、课题负责人必须按要求向教务处提交中期研究进展情况报告。

六、课题完成后，课题负责人必须到教务处办理有关结题手续，及时提交结题申请书、课题研究报告、课题成果鉴定书及合同规定的研究成果。

七、由于各种原因课题不能继续进行时，课题负责人应向教务处提出报告，说明原因，终止该课题，并办理有关手续。

八、本项目的其他管理按《南通大学教学改革研究课题管理办法》执行。

九、本合同一式三份，委托部门、承担部门、课题负责人各执一份。

委托部门：（签章）
负责人（签字）

承担部门：（签章）
负责人（签字）

课题负责人：（签字）

2018年11月14日

EFFICIENT RECURSIVE KERNEL CANONICAL VARIATE ANALYSIS FOR MONITORING NONLINEAR TIME-VARYING PROCESSES

Liangliang Shang,[1,2] Jianchang Liu[2,3] and Yingwei Zhang[2,3*]

1. School of Electrical Engineering, Nantong University, Nantong, Jiangsu 226019, P. R. China
2. College of Information Science and Engineering, Northeastern University, Shenyang, Liaoning 110819, P. R. China
3. State Key Laboratory of Synthetical Automation for Process Industries, Northeastern University, Shenyang, Liaoning 110819, P. R. China

Kernel canonical variate analysis (KCVA) cannot be adopted for monitoring nonlinear time-varying processes because of changes in variance, mean, and correlation between variables. Efficient recursive kernel canonical variate analysis (ERKCVA) is thus proposed to monitor the nonlinear time-varying processes. In a high-dimensional feature space, the covariance matrix can be updated recursively by the exponentially weighted moving average approach. The first-order perturbation theory is introduced to obtain the recursive singular value decomposition of the Hankel matrix, which can significantly reduce the computational cost of the proposed method. Prediction errors and state variables are non-Gaussian; thus, upper control limits can be derived from the estimated probability density function by kernel density estimation. The proposed method is demonstrated by simulating a continuous stirred tank reactor. Simulation results indicate that ERKCVA could efficiently capture the predefined normal and natural changes in nonlinear time-varying processes. In addition, ERKCVA can also identify 4 types of sensor faults.

Keywords: kernel canonical variate analysis, first-order perturbation theory, nonlinear time-varying processes, monitoring

INTRODUCTION

To ensure safe operation and production efficiency in modern industrial processes, process monitoring has been widely studied over the recent decades. Approaches to process monitoring are categorized as knowledge-based, model-based, and data-driven.[1] The disadvantage of the knowledge-based approach is that it requires a large amount of knowledge that is practically difficult to obtain. The data-driven approaches such as principal component analysis (PCA) and partial least squares (PLS) drew significant interest. More recently, subspace identification methods (SIMs) have attracted significant attention for industrial process monitoring,[2,3] which include numerical algorithms for subspace state space system identification (N4SID), canonical variate analysis (CVA), and multi-variable output-error state space (MOESP).[4] However, both statistical process monitoring techniques and subspace identification based detection methods are based on assumptions of linear variable relationships, thereby limiting their application in many practical situations if these relationships are nonlinear.

Nonlinear characteristics among different process variables are commonly observed in many complex process industries. A typical linear correlation and a nonlinear correlation between 2 variables are shown in Ge et al.,[5] in which the change in variable 1 is not proportional to the change in variable 2. Linear relationships are easy to capture using the traditional multivariate statistical process control method but not nonlinear ones. Different processes may show different nonlinear relationships among process variables. Auto-associative neural networks[6,7] and kernel function are the commonly adopted nonlinear extension methods. A review reference[8] suggests that an artificial neural network cannot be a general nonlinear extension, unlike the kernel function method. Kernel principal component analysis (KPCA) is one of the most widely used nonlinear PCA extensions.[9–12] Its core idea is to first map the data space into a high-dimensional feature space by a kernel function and then perform corresponding computation in the linear feature space. CVA combined with the kernel method has rarely been studied.[13] Regardless, the kernel extension of canonical correlation analysis (CCA) is widely known particularly in machine learning and pattern recognition.[14–16] Samuel and Cao[17] proposed a novel kernel canonical variate analysis (KCVA) technique for nonlinear dynamic process monitoring in which the traditional CVA is performed in the kernel space generated from kernel PCA. Ciabattoni et al.[18] proposed a KCVA-based nonlinear monitoring and diagnostic system for detecting faults and bad occupant behaviours in a residential microgrid. Huang et al.[19] proposed quality-relevant nonlinear process monitoring based on kernel input-output canonical variate analysis (KIOCVA); the technique can evaluate whether the fault in the process affects product quality. To meet the diverse requirements of the market, processes have to experience predefined normal changes, such as set point changes, input feed to a chemical reactor, and so on.[20,21,5] Apart from the predefined normal changes, natural changes, such as slow parameter variation, sensor drift, and precision degradation, also exist in many industrial processes. The time-varying characteristics of the process are usually reflected in changes in variance, mean, correlation, and order of the system.[22] Process monitoring based on time-invariant KCVA may result in a large number of false alarms. Thus, a KCVA-based

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《控制工程》论文录用证明书

单彪;堵俊;商亮亮 同志：您好！
您撰写的论文《基于改进PCA的空调系统传感器故障检测与诊断》，稿件编号：170900，经专家评审和编委会审核，决定作为论文被我刊正式录用。
特此证明！
《控制工程》编辑部
2018-08-29

Dear Author(s):

This letter is to notice you that the following paper, submitted to the The 31st Chinese Control and Derison Conference, is received.

Paper Information

Paper ID: 1316

Language: English

Submission Type: Regular Paper

Area: A23 Data-driven control

Code:

Title: Efficient recursive kernel principal component analysis for nonlinear time-varying processes monitoring

Corresponding author: Liangliang Shang (10251)

Authors with PINs: Liangliang Shang (10251), Yan Ze (53912), Aibing Qiu (16548), Fei Li (91485), Zhou Xinyi (45730)

Abstract:
Due to the nonlinear time-varying characteristics of industrial processes, the kernel principal component analysis (KPCA) without updating statistics would result in a much higher false alarm rate. To monitor nonlinear time-varying processes more effectively, an efficient recursive kernel principal component analysis (ERKPCA) is proposed based on recursive eigenvalue decomposition with less complexity. First, the new observations data are projected into a high-dimensional linear feature space using a nonlinear mapping method. In the linear feature space, the first order perturbation theory is introduced to update the eigenvalues and eigenvectors directly, which can reduce the computational cost to (O(m2)) compared with that of the traditional eigenvalue decomposition ((O(m3))). The distribution of the kernel principal components and residual in the feature space are non-Gaussian, thus upper control limits of statistics can be derived by kernel density estimation. With the simulation of the Tennessee Eastman chemical process, the monitoring results illustrate the validity of the proposed approach. It can not only accommodate the slow process drift under normal operation, but also identify the three types of process faults in nonlinear time-varying processes.

Keywords:
Kernel principal component analysis, the first order perturbation theory, nonlinear time-varying processes, monitoring

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WILEY CHEMOMETRICS

RESEARCH ARTICLE

Efficient recursive canonical variate analysis approach for monitoring time-varying processes

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[2]School of Electrical Engineering, Nantong University, Nantong, 226019, Jiangsu, PR China
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Email: zhangyingwei@mail.neu.edu.cn

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Canonical variate analysis (CVA) has been applied successfully in process monitoring. This paper proposes an efficient recursive CVA approach to monitor time-varying processes. The exponential weighted moving average approach has been adopted to update the covariance matrix of past observation vectors without the need for recalling past training data. The most important challenge faced by the recursive CVA algorithm is the high computation cost. To reduce the computation cost, the first order perturbation theory was introduced to update the singular value decomposition (SVD) of the Hankel matrix recursively. The computation cost of recursive SVD based on the first order perturbation theory is significantly less compared with conventional SVD. The proposed method is illustrated by the simulation of the continuous stirred tank reactor system. Simulation results indicate that not only can the proposed method effectively adapt to the natural changes of time-varying processes but also the proposed method can also identify two types of abrupt sensor faults.

KEYWORDS
Monitoring, recursive canonical variate analysis, the first order perturbation theory, time-varying processes

1 | INTRODUCTION

As the competition of the global market increases, modern industry must be more efficient and raise the quality of end products. To achieve those purposes, process monitoring has become highly important in recent years. There are three main approaches for process monitoring: the knowledge-based approach, the model-based approach, and the data-driven approach.[1] The disadvantage of the knowledge-based approach is that it needs a large amount of knowledge that, in practice, is not easy to obtain. Although the data-driven approach has been widely applied, subspace identification methods have attracted significant attention for process modeling and monitoring in the last two decades.[2–4] The conventional subspace identification methods include canonical variate analysis (CVA), numerical algorithms for subspace state space system identification (N4SID), and multi-variable output-error state space.[5] Juricek et al[6] demonstrated that the CVA model was more accurate than N4SID. Negiz and Cinar[7] reported that balanced realization and projections to latent structures (PLS) do not provide optimal orthogonal state variables, but canonical variate state space realization and orthogonal states PLS give minimal state variables that are orthogonal.

Canonical variate analysis was first developed by Hotelling[8] and was discussed in detail by Andeson.[9] Many successful examples for monitoring with the CVA approach have been already published. Negiz and Cinar[10] applied the canonical variate state space model to multivariable statistical monitoring and illustrated its performance in the milk pasteurization process. Russell et al[11] applied CVA to the Tennessee Eastman process simulator for fault detection. Juricek et al[2] applied CVA to monitor the process faults in a nonlinear continuous stirred tank reactor (CSTR) system. Stubbs et al[12] applied CVA to fault detection and diagnosis and used the Tennessee Eastman process simulator for case studies. Canonical variate analysis shows good monitoring performance for linear processes and stationary operating conditions. However, because of the fluctuations of raw materials, aging of the main components of the process,

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Recursive Fault Detection and Identification for Time-Varying Processes

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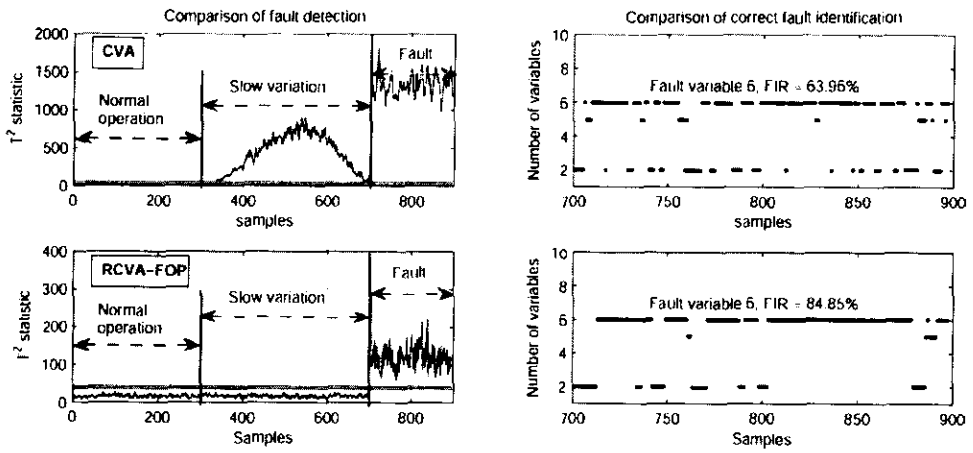

ABSTRACT: Canonical variate analysis (CVA) has been extensively applied in monitoring of different industrial processes. However, conventional CVA is unable to handle the characteristics of time-varying processes. It tends to interpret the natural changes of the process as faults, which would cause high false alarm rates. To solve this problem, a recursive canonical variate analysis based on the first order perturbation theory (RCVA-FOP) is proposed to detect faults in time-varying processes. Without recalling past training data, the covariance of past observation vectors is updated by the exponential weighted moving average (EWMA) method. Moreover, the first order perturbation theory is introduced to realize the recursive singular value decomposition (SVD) of the Hankel matrix, which can reduce computational time significantly compared with the conventional SVD. To identify the real reason for a fault, an EWMA contribution plot based on CVA is also proposed to enhance the fault identification rate. The proposed method is verified with simulations of the continuous stirred tank reactor. Simulation results indicate that the RCVA-FOP method not only can effectively adapt to the natural changes of time-varying processes but also can detect and identify three types of faults, which include sensor precision degradation, heat exchanger fouling fault, and sensor bias.

1. INTRODUCTION

As the competition of the global market becomes increasingly intense, modern industry has to be more efficient and raise the quality of end products. As an essential technique, process monitoring has already become more and more important in recent years. The main process monitoring approaches consist of three categories: the knowledge-based approach, the data-driven approach, and the model-based approach.[1] The disadvantage of the knowledge-based approach is that it needs a large amount of knowledge, which is not easy to obtain in practice. Although the data-driven approach has been widely applied, subspace identification methods (SIMs) have greatly attracted researchers' attention for monitoring and modeling in the last two decades.[2−4] Canonical variate analysis (CVA), multivariable output-error state space (MOESP), and numerical algorithms for subspace state space system identification (N4SID)[5] are the three conventional subspace identification methods. Juricek et al.[6] certified that the accuracy of CVA was higher than that of N4SID. Larimore[7] clarified that only the CVA procedure has been developed on the basis of optimal statistical inference principles, and as a result it achieves optimal statistical accuracy while the others can be considerably less accurate.

Many successful examples for fault detection and identification with the CVA approach have already been reported. Negiz and Cinar[8] applied the canonical variate state space (CVSS) model in milk pasteurization process monitoring.

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基于递推规范变量分析的时变过程故障检测

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摘 要: 由于规范变量分析(CVA)不适应过程的时变特性,容易把正常的过程改变识别为故障.因此,针对时变过程提出一种故障检测方法是十分必要的.采用指数权重滑动平均来更新过去观测矢量的协方差矩阵.递推CVA有较高的计算负荷是需要解决的关键问题.通过引入一阶干扰理论来递推更新Hankel矩阵的奇异值分解(SVD).与普通奇异值分解相比,显著降低了递推算法的计算负荷.将提出的基于一阶干扰理论的递推规范变量分析(RCVA-FOP)应用于田纳西伊斯曼化工过程中.仿真结果表明,所提出方法不仅能有效适应过程的时变特性,而且可以有效检测到两种类型的故障.

关 键 词: 一阶干扰理论;规范变量分析;时变过程;故障检测
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Recursive Canonical Variate Analysis for Fault Detection of Time-Varying Processes

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Abstract: Because CVA (canonical variate analysis) is unable to adapt the characteristics of time-varying processes, by which the normal changes of the process is easily identified as faults, it is very necessary to propose a monitoring approach for time-varying processes. The exponential weighted moving average approach was adopted to update the covariance of the past observation vectors. The most critical problem faced by recursive CVA algorithm is the high computation cost. To reduce the computation cost, the first order perturbation theory was introduced to update recursively the singular value decomposition (SVD) of the Hankel matrix. The computation cost of recursive SVD based on the first order perturbation theory is significantly less compared to the SVD. Recursive canonical variate analysis based on the first order perturbation (RCVA-FOP) was applied in the Tennessee Eastman chemical process. Simulation results indicate that the proposed method not only can effectively adapt to the normal change of time-varying processes, but also can detect two types of faults.

Key words: first order perturbation theory; CVA (canonical variate analysis); time-varying processes; fault detection

为了提高现代工业过程的生产效率,近年来故障检测越来越重要.故障检测有三种主要方法:基于知识的方法、基于模型的方法、基于数据驱动的方法[1].基于知识的方法的缺点是需要大量不容易获取的过程知识.尽管数据驱动方法已被广泛应用,但在过去的二十年中基于子空间辨识模型的方法吸引了过程建模和监控领域的学者和专家的关注.常规的子空间辨识方法包括规范变量

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