

## 目 次

一种五自由度混联机器人运动学分析	高云峰, 吕明睿, 周 伦, 李瑞峰 ( 1 )
一种改进的分布式搜索引擎模型	钱立兵, 季振洲, 吴 昊 ( 8 )
导管螺旋桨不同桨叶的叶梢泄露涡分析	周军伟, 王大政 ( 14 )
电势对硅片摩擦电化学材料去除特性的影响	王金虎, 翟文杰 ( 20 )
正弦图合击-分进方法的线段检测技术	杨天博, 冯 星, 张永强, 程丹松, 石大明 ( 25 )
三角形微沟槽飞艇蒙皮表面的流场分析	谭惠丰, 康敬天, 卫剑征, 王长国 ( 32 )
管材弯曲回弹对内高压成形的影响及补偿方法	张伟玮, 韩 聪, 谢文才, 苑世剑 ( 36 )
四元数约束的容积卡尔曼滤波及其应用	钱华明, 黄 蔚, 孙 龙 ( 40 )
GPS/SINS 超紧组合导航系统自适应混合滤波算法	周卫东, 蔡佳楠, 孙 龙 ( 47 )
无人水面艇目标图像自适应分割算法	马忠丽, 梁秀梅, 文 杰 ( 53 )
小型航天器浸入与不变自适应反步姿态跟踪	张 超, 张胜修, 蔡光斌, 侯明哲 ( 60 )
增材制造椭圆锥齿轮的齿面与齿距误差分析	林 超, 樊 宇, 张正文, 才立忠, 李忠华 ( 69 )

声矢量阵快速子空间方位估计算法  
..... 梁国龙, 张 柯, 安少军, 范 展 ( 76 )

航行体出水空泡溃灭载荷特性研究  
..... 赵蛟龙, 孙龙泉, 张忠宇, 姚熊亮 ( 81 )

基于多特征在线模板更新的鲁棒目标跟踪算法  
..... 陈东岳, 陈宗文, 桑永嘉 ( 87 )

三维各向异性功能梯度材料的有限体积法  
..... 宣领宽, 明平剑, 龚京风, 张文平, 韩春旭 ( 95 )

具有状态依赖噪声的随机  $H_\infty$  预演控制  
..... 王宏霞, 张焕水, 陈 欣, 俞 立 (101)

极小 Cayley 图的确定性小世界网络模型  
..... 刘艳霞, 奚建清, 张 芩 (107)

自适应提升小波在干涉高光谱压缩中的应用  
..... 温 佳, 马彩文, 赵军锁, 王彩玲 (112)

脉冲参数主动匹配式 micro-EDM 脉冲电源  
..... 孙术发, 刘美爽, 狄士春 (118)

森林生境因子无线传感器网络采集系统  
..... 李 丹, 孙利新, 戴 巍, 王霓虹 (123)

CONTENTS

Analysis of kinematics of a five-axis hybrid manipulator  
..... GAO Yunfeng, LÜ Mingrui, ZHOU Lun, LI Ruifeng ( 1 )

An improved model of distributed search engine  
..... QIAN Libing, JI Zhenzhou, WU Hao ( 8 )

Analysis of tip leakage vortex of different blade in ducted propeller  
..... ZHOU Junwei, WANG Dazheng ( 14 )

Influence of polarization potential on tribo-electrochemical material removal properties of silicon wafer  
..... WANG Jinhu, ZHAI Wenjie ( 20 )

Line segment detection using sinogram unite-and-divide method  
..... YANG Tianbo, FENG Xing, ZHANG Yongqiang, CHENG Dansong, SHI Daming ( 25 )

Flow field analysis of Micro-V shape riblets airship surface  
..... TAN Huifeng, KANG Jingtian, WEI Jianzheng, WANG Changguo ( 32 )

The effect of springback of CNC bending on hydro-formed sub-frame and compensation methods  
..... ZHANG Weiwei, HAN Cong, XIE Wencai, YUAN Shijian ( 36 )

Cubature Kalman filter with quaternion constraint and its application  
..... QIAN Huaming, HUANG Wei, SUN Long ( 40 )

An adaptive revising filtering method for GPS/SINS ultra-tightly coupled system  
..... ZHOU Weidong, CAI Jianan, SUN Long ( 47 )

Image adaptive segmentation algorithm for unmanned surface vehicle targets  
..... MA Zhongli, LIANG Xiumei, WEN Jie ( 53 )

Immersion and invariance adaptive backstepping attitude tracking of micro-spacecraft  
..... ZHANG Chao, ZHANG Shengxiu, CAI Guangbin, HOU Mingzhe ( 60 )

Tooth surface and pitch error analysis of elliptical bevel gearing by additive manufacturing  
..... LIN Chao, FAN Yu, ZHANG Zhengwen, CAI Lizhong, LI Zhonghua ( 69 )

Fast subspace DOA estimation algorithm based on acoustic vector sensor array	.....	LIANG Guolong, ZHANG Ke, AN ShaoJun, FAN Zhan ( 76 )
Cavitation collapse load characteristic research in the out-of-water process of vehicle	.....	ZHAO Jiaolong, SUN Longquan, ZHANG Zhongyu, YAO Xiongliang ( 81 )
Robust object tracking based on online update of multi-feature template	.....	CHEN Dongyue, CHEN Zongwen, SANG Yongjia ( 87 )
Finite volume method for three-dimensional anisotropic functionally graded materials	.....	XUAN Lingkuan, MING Pingjian, GONG Jingfeng, ZHANG Wenping, HAN Chunxu ( 95 )
Stochastic $H_\infty$ preview control with state-dependent noise	.....	WANG Hongxia, ZHANG Huanshui, CHEN Xin, YU Li (101)
Deterministic small-world network model based on minimal Cayley graph	.....	LIU Yanxia, XI Jianqing, ZHANG Qin (107)
An adaptive wavelet transformation used on interference hyperspectral image compression	.....	WEN Jia, MA Caiwen, ZHAO Junsuo, WANG Cailing (112)
Research of active pulse parameters matching micro-EDM pulse power supply	.....	SUN Shufa, LIU Meishuang, DI Shichun (118)
Wireless sensor networks system of forest habitat factors collection	.....	LI Dan, SUN Lixin, DAI Wei, WANG Nihong (123)

# 《哈尔滨工业大学学报》

## 第十一届编辑委员会

顾问	杜善义	王仲奇	张杰	王子才	
主任委员	蔡鹤皋				
副主任委员	韩杰才	郭斌	谈和平	徐晓飞	
委员	王常虹	姚郁	沈毅	曹喜滨	崔乃刚
	赫晓东	孙毅	陈德应	张中兆	许荣庆
	史小平	宋申民	姚英学	付宜利	翟文杰
	吴伟国	郭茂祖	战德臣	张宏莉	谭久彬
	刘林华	孙东立	陈玉勇	魏俊杰	王勇
	孙秀冬	杨春晖	李钰	冯玉强	郑文忠
	李惠	王幼青	武振宇	于水利	赵庆良
	裴玉龙	邹广天	K.L.Teo		
主编	段广仁				

本刊被下列数据库列为刊源期刊

- 美国《工程索引》( Ei Compendex )

美国《化学文摘》( CA )

英国《科学文摘》( INSPEC )

日本《科技文献速报》( JICST )

俄罗斯《文摘杂志》( AJ )

美国《数学评论》( MR )

德国《数学文摘》( ZB1 MATH )
- 美国《剑桥科学文摘》( CSA )

美国《应用力学评论》( AMR )

美国《国际航空航天文摘》( IAA )

美国《现代数学出版物》( CMP )

中国科学引文数据库( CSCD )核心刊

中国科技论文统计分析数据库( CSTPCD )核心刊

中国学术期刊综合评价数据库( CAJCED )

哈 尔 滨 工 业 大 学 学 报  
Harbin Gongye Daxue Xuebao  
( 月 刊    1954 年 创 刊 )

第 46 卷    第 7 期    2014 年 7 月 30 日 出 版

Journal of Harbin Institute of Technology  
( Monthly , Started in 1954 )

Vol.46    No.7    2014-07-30

主管单位：中华人民共和国工业和信息化部  
主办单位：哈尔滨工业大学  
主    编：段广仁  
编辑出版：《哈尔滨工业大学学报》编辑部  
              哈尔滨市南岗区西大直街 92 号( 150001 )  
              电话：0451-86414260 , 86414135  
E-mail: hitxuebao@ hope.hit.edu.cn  
Http://hit.alljournals.cn  
印刷单位：哈尔滨工业大学印刷厂  
国内发行：哈尔滨市邮政局  
国外发行：中国国际图书贸易总公司  
              ( 北京 399 信箱 )

Supervised by: Ministry of Industry and Information Technology of the People's Republic of China  
Sponsored by    Harbin Institute of Technology  
Editor-in-Chief    DUAN Guangren  
Edited & Published by    Editorial Board of Journal of Harbin Institute of Technology  
Postcode: 150001        E-mail: hitxuebao@ hope.hit.edu.cn  
Http://hit.alljournals.cn  
Distributed by China International Book Trading Corporation  
                  ( P.O.Box 399, Beijing, China )

中国标准连续出版物号:ISSN 0367-6234  
CN 23-1235/T

邮发代号:国内 14-67  
国外 928 M

定 价:20.00 元/期  
240.00 元/年

哈  
尔  
滨  
工  
业  
大  
学  
学  
报

第  
四  
十  
六  
卷  
第  
七  
期  
二  
〇  
一  
四  
年  
七  
月

哈  
尔  
滨  
工  
业  
大  
学  
学  
报

第  
四  
十  
六  
卷  
第  
七  
期  
二  
〇  
一  
四  
年  
七  
月

哈  
尔  
滨  
工  
业  
大  
学  
学  
报

第  
四  
十  
六  
卷  
第  
七  
期  
二  
〇  
一  
四  
年  
七  
月

哈  
尔  
滨  
工  
业  
大  
学  
学  
报

第  
四  
十  
六  
卷  
第  
七  
期  
二  
〇  
一  
四  
年  
七  
月

# 《哈尔滨工业大学学报》征稿简则

《哈尔滨工业大学学报》主要报道自然科学领域的基础理论、工程技术与应用方面的最新研究成果,欢迎省(部)级以上政府基金资助项目(国家自然科学基金、863、973、博士点基金等)相关论文。报道方向包括航天、机械、能源、动力、材料、电气、电子、信息与控制、计算机、化工、生物工程、土木工程、市政环境、暖通空调、道路、桥梁、交通工程、工程力学及有关交叉性学科。

## 投稿要求

1. 原创性论文,有创新性,主题明确、结构完整、论据可靠、论证合理、层次分明、逻辑严密、文字精炼、可读性强。
2. 投稿具有合法性,不存在抄袭、剽窃、篡改等不良行为;来稿未在任何正式出版物上刊载过(网上可检索到全文的会议论文也包括其中),不允许一稿多投。
3. 请严格遵守国家有关保密规定,不泄漏国家机密。

## 写作要求

1. 稿件请用 Word 编辑排版,一般 6000 字左右。附英文题名,5~8 个中、英文关键词。中、英文摘要内容包括:研究目的、主要方法、结果、结论四要素。要求 200~300 字,内容应具体、准确,切忌空洞和主观评价。
2. 文中插图精绘,图中文字清楚,应有图序、图题和图注。表中栏目及图的标目应按标准方式标注。如:时间的标注方式应为  $t/s$  或  $t/min$  或  $t/h$ ,速度的标注方式应为  $v/(m \cdot s^{-1})$ 。
3. 第一作者后面的作者中如有博士生导师,请一并给予介绍(包括姓名、性别、出生年、职称、学位或学历、电话、E-mail);如获基金资助,请在文章首页地脚处标示出项目名称和编号,请标注和文章内容紧密相关的基金项目,不支持独立研究单位的多项基金标注;最下方请标注通信作者姓名及 E-mail 地址。
4. 参考文献必须是公开发表过的文献,按文中引用顺序编号。在文中标出文献序号,详细的文献信息附于文末,建议不少于 15 个文献,英文文献占 60% 左右。

请严格按照标准方式著录,各类文献著录方式如下:

- 1) 专著:[序号]作者姓名.书名[M].出版地:出版者,出版年:起页码-止页码。
- 2) 期刊:[序号]作者姓名.论文题目[J].期刊名,出版年,卷(期):起页码-止页码。
- 3) 会议论文集:[序号]作者姓名.论文题目[C]//论文集名.出版地:出版者,出版年:起页码-止页码。
- 4) 硕士及博士学位论文:[序号]作者姓名.论文题目[D].出版地:出版者,出版年。
- 5) 电子文献:[序号]主要责任者.电子文献题名[电子文献类型/电子文献载体].电子文献的出处或可获得地址,发表或更新日期/引用日期(任选)。

电子文献类型标志代码为:数据库 DB;计算机程序 CP;电子公告 EB.

电子文献载体标志代码为:磁带 MT;磁盘 DK;光盘 CD;联机网络 OL.

- 6) 专利:[序号]专利所有者.专利题名.专利国别:专利号[P],出版日期。

网站的"作者指南"栏上提供了样例,作者可参考进行撰写。

## 投稿方法

请通过哈尔滨工业大学学术期刊中心(<http://hit.alljournals.cn/>)进入《哈尔滨工业大学学报》网页([http://hit.alljournals.cn/hitxb\\_cn/ch/index.aspx](http://hit.alljournals.cn/hitxb_cn/ch/index.aspx)),于在线投稿系统的"作者登录"一栏进行投稿(首先需要注册)。本刊仅接受作者通过此系统提交的投稿;投稿前请认真阅读本刊网站中的"作者指南";若需查询稿件处理状况,请通过"作者登录"进行查询。同一篇稿件只需投稿一次,以免系统给出多个编号,如果要修改请和编辑部联系。



# 一种五自由度混联机器人运动学分析

高云峰, 吕明睿, 周 伦, 李瑞峰

(哈尔滨工业大学 机器人研究所, 150001 哈尔滨)

**摘 要:** 为了使工业机器人的位姿改变更加快速、灵巧,对一种五自由度混联机器人进行了结构分析.建立 D-H 坐标系求得末端执行器的位姿矩阵,提出一种基于 PAUL 逆变换法的串联机器人逆运动学封闭解的求解分析方法,求得该机器人的运动学逆解.计算机仿真结果验证了该算法的快速性和有效性.运用包络理论确定局部关节联动所形成的工作空间包络面,论证了该机器人作业姿态的灵巧性.利用几何叠加方法规划出机器人灵巧工作空间,为结构设计和运动控制提供了依据.

**关键词:** 混联机器人;运动学;运动学逆解;工作空间;灵巧性

**中图分类号:** TP242.2      **文献标志码:** A      **文章编号:** 0367-6234(2014)07-0001-07

## Analysis of kinematics of a five-axis hybrid manipulator

GAO Yunfeng, LÜ Mingrui, ZHOU Lun, LI Ruifeng

(1. State Key Laboratory of Robotics and System, Harbin Institute of Technology, 150000 Harbin, China)

**Abstract:** The structure of a novel 5-DOF industrial manipulator was analyzed. The homogeneous transformation matrix of the manipulator was obtained by establishing a series of D-H frames. Based on Paul's inverse transformation, an analytical method that could direct the solution of inverse kinematics problems of series manipulators was proposed, and the closed-form solution of inverse kinematics was derived. Computational simulation results indicated that the algorithm was efficient and real-time. The enveloping surface of the local joints' workspace was specified using envelop theory. Working dexterity of the manipulator was discussed. The dexterous workspace of the manipulator on which the structure design and motion control were based was established via geometrically overlaying the enveloping surfaces of local joints' workspace.

**Keywords:** hybrid manipulator; kinematics; inverse solution; workspace; dexterity

# 一种改进的分布式搜索引擎模型

钱立兵, 季振洲, 吴昊

(哈尔滨工业大学 计算机科学与技术学院, 150001 哈尔滨)

**摘要:** 为了解决传统分布式搜索引擎存在的搜索性能问题,从索引结构、查询算法方面改进了传统模型.提出了一种非集中的高并行化搜索模型,该模型按照文档主题对索引分类,对较长的倒排记录表采用位图结构,利用多线程技术对索引节点实现并行搜索算法(multi max score heap, MMSH).实验结果表明:改进模型中的索引分类方法与倒排表结构的位图策略,能够增强 Merge 层查询的针对性,降低 Merge 层节点的 CPU 和内存开销;在倒排表不能完全存入内存情况下, MMSH 算法能够实现高度并行化查询,其查询效率高于经典的 term-at-a-time 算法,缩短了平均查找时间,提高了系统吞吐量.索引分类、位图结构以及并行查询算法能够避免查询的盲目性,改善了分布式搜索引擎的性能.

**关键词:** 分布式引擎;索引分类;倒排结构;并行搜索

中图分类号: TP393

文献标志码: A

文章编号: 0367-6234(2014)07-0008-06

## An improved model of distributed search engine

QIAN Libing, JI Zhenzhou, WU Hao

(School of Computer Science and Technology, Harbin Institute of Technology, Harbin 150001, China)

**Abstract:** To solve the problem of search performance in traditional distributed search engine, a non-centralized high parallelization search model was proposed and the traditional model was improved in the index structure and search algorithm. In the model, the index was classified according to document theme, bitmap structure was employed for longer inverted record list, and parallel search algorithm (multi max score heap, MMSH) was achieved in index node by using multi-threading technology. Experimental results show that the improved search model with index classification and bitmap strategy of the inverted list structure can enhance the search pertinence in Merge layer, reduce CPU and memory cost. In the case that the inverted list can not be completely stored in memory, MMSH algorithm can implement highly parallel search and its query efficiency is higher than the classical term-at-a-time algorithm, which shortens the average search time and improves the system throughput. Index classification, bitmap structure and parallel query algorithm can avoid query blindness and improve the performance of distributed search engines.

**Keywords:** distributed indexing; index classification; inverted structure; parallel search

# 导管螺旋桨不同桨叶的叶梢泄露涡分析

周军伟, 王大政

(哈尔滨工业大学(威海) 船舶与海洋工程学院, 264209 山东 威海)

**摘要:** 为了深入探讨叶梢泄露涡的流动机理,研究了导管螺旋桨中桨叶螺距比与盘面比对叶梢泄露涡的影响,以及不同桨叶中叶梢泄露涡、叶梢负荷与叶梢泄露流三者之间的关联。采用数值方法对不同桨叶的导管螺旋桨流场进行了模拟分析。结果表明:当螺距比增大,叶梢泄露涡逐渐远离桨叶吸力面,涡核空化数降低;当盘面比增大,叶梢泄露涡的轨迹基本不变化,涡核空化数提高;叶梢泄露流通过与叶梢泄露涡之间的流动剪切作用影响叶梢泄露涡的发展;叶梢泄露流速受到叶梢负荷的影响,负荷越高的位置,叶梢泄露流的速度也越高。

**关键词:** 导管螺旋桨;叶梢泄露涡;螺距比;盘面比;涡核空化数

中图分类号: U661.31; U664.33

文献标志码: A

文章编号: 0367-6234(2014)07-0014-06

## Analysis of tip leakage vortex of different blade in ducted propeller

ZHOU Junwei, WANG Dazheng

(School of Naval Architecture and Ocean Engineering, Harbin Institute of Technology in Weihai,  
264209 Weihai, Shandong, China)

**Abstract:** The effects of pitch ratio and blade area ratio on the tip leakage vortex (TLV) were studied in a ducted propeller. Furthermore, the relationship among the TLV, tip loading and tip leakage flow (TLF) of different blades was discussed. The flow field of the ducted propeller with several different blades was numerically simulated and analyzed and the results showed that as the pitch ratio increased, the tip leakage vortex moved away from the suction side of the blade, and the core cavitation number decreased. As the blade area ratio grew, the vortex core trajectory did not alter, and the vortex core cavitation number rose. The TLV was influenced by TLF through flow shearing, while the TLF was controlled by the tip loading, the velocity of TLF at the position with heavier loading was higher.

**Keywords:** ducted propeller; tip leakage vortex; pitch ratio; blade area ratio; vortex core cavitation number

# 电势对硅片摩擦电化学材料去除特性的影响

王金虎, 翟文杰

(哈尔滨工业大学 机电工程学院, 150001 哈尔滨)

**摘要:** 为了提高硅片抛光效率,改善抛光表面质量,采用电化学交流阻抗谱法实验研究了极化电势对硅片表面钝化作用的影响规律,结合摩擦电化学实验探讨了极化电势对硅片表面摩擦系数及材料去除特性的影响.结果表明,在碱性  $\text{CeO}_2$  抛光液中,对硅片施加 1 V 阳极极化电势能够促进其表面形成抑制腐蚀的钝化层,极化电势过高会破坏表面钝化层,过低则抑制钝化层形成.良好的硅片表面钝化层能够有效增大其摩擦系数,提高摩擦电化学实验过程中的材料去除率.

**关键词:** 硅片;极化电势;钝化;摩擦电化学;材料去除

中图分类号: TH177.2      文献标志码: A      文章编号: 0367-6234(2014)07-0020-06

## Influence of polarization potential on tribo-electrochemical material removal properties of silicon wafer

WANG Jinhu, ZHAI Wenjie

(School of Mechatronics Engineering, Harbin Institute of Technology, 150001 Harbin, China)

**Abstract:** To increase polishing efficiency and improve surface quality of silicon, electrochemical measurements were used to study the influence of polarization potential on passivation of silicon wafer, based on which tribo-electrochemical tests were done to investigate the effect of polarization potential on friction and material removal. Results show that the passivation film with better corrosion inhibition effect can be obtained under anode polarization potential of 1 V in alkaline  $\text{CeO}_2$  polishing liquid. A higher polarization would destroy the passivation film, while a lower polarization would suppress the formation of it. Moreover, the passivation film on silicon wafer can increase surface friction coefficient as well as material removal rate.

**Keywords:** silicon wafer; polarization potential; passivation; tribo-electrochemical; material removal

# 正弦图合击-分进方法的线段检测技术

杨天博<sup>1</sup>, 冯 星<sup>2</sup>, 张永强<sup>3</sup>, 程丹松<sup>3</sup>, 石大明<sup>3</sup>

(1. 哈尔滨工业大学 航天学院, 150001 哈尔滨; 2. 光电控制技术重点实验室, 471009 河南 洛阳;  
3. 哈尔滨工业大学 计算机科学与技术学院, 150001 哈尔滨)

**摘要:** 为了提高图像处理中线段的检测精度和速度, 提出一种称为“合击-分进(UND)”的精确且快速的线段检测方法. 该方法包括频域的频谱合并和 Radon 空间的正弦图分解两个阶段. 在合击阶段, 原始图像经过二维并行多层傅里叶变换、直角坐标至极坐标映射、一维傅里叶逆变换等处理后得到它的正弦图; 在分进阶段, 检测 Radon 空间正弦图的各个峰值及其邻域内的蝶翼边缘, 每一邻域对应图像空间中的一个窗口, 并针对每个窗口正弦图的蝶型曲线进行边缘分析, 从而得到线段的端点. 实验结果表明: UND 方法在分割精度上优于 SHT、RHT 和 LSD 等经典线段分割方法, 检测速度上优于 SHT 和 LSD 方法. UND 算法不但能提高准确度, 还能降低计算成本, 增强对噪音干扰的鲁棒性.

**关键词:** 线段检测; Radon 变换; 傅里叶变换; 合击-分进

中图分类号: TP391      文献标志码: A      文章编号: 0367-6234(2014)07-0025-07

## Line segment detection using sinogram unite-and-divide method

YANG Tianbo<sup>1</sup>, FENG Xing<sup>2</sup>, ZHANG Yongqiang<sup>3</sup>, CHENG Dansong<sup>3</sup>, SHI Daming<sup>3</sup>

(1. School of Astronautics, Harbin Institute of Technology, 150001 Harbin, China;  
2. Science and Technology on Electro-Optical Equipment AVIC, 471009 Luoyang, Henan, China;  
3. School of Computer Science and Technology, Harbin Institute of Technology, 150001 Harbin, China)

**Abstract:** A fast line segment detection method, unite-and-divide (UND) approach, is investigated, which includes two phases, namely the union of spectra in the frequency domain and the division of the sinogram in Radon space respectively. In the union phase, for a given image, its sinogram is obtained by parallel 2D multilayer Fourier transform, Cartesian-to-polar mapping and 1D inverse Fourier transform. In the division phase, every peaks and edges of butterfly wings in its neighborhood in sinogram are firstly specified, with each neighborhood area corresponding to a window in image space, and then, by applying edge-analyzing to each sinogram of each windowed separately, the endpoints of line segments are extracted. Our experiments are conducted on benchmark images, the results reveal that the UND method yields high accuracy, low computational cost and is more robust to noise.

**Keywords:** line segment detection; radon transform; fourier transform; unite-and-divide(UND)

# 三角形微沟槽飞艇蒙皮表面的流场分析

谭惠丰, 康敬天, 卫剑征, 王长国

(哈尔滨工业大学 复合材料与结构研究所, 150001 哈尔滨)

**摘要:** 微米尺度的沟槽是临近空间飞艇大面积减阻的一种可行的减阻形式. 以临近空间飞艇减阻为研究背景, 通过采用  $k-\omega$  SST 湍流模式, 对微米尺度的三角形沟槽进行了流场分析, 得到了三角形沟槽壁面流的速度场和压力场. 通过计算不同尺寸三角形微沟槽的减阻率和沟槽内的流线形状, 分析了微米尺度沟槽的减阻机理和不同沟槽尺寸对减阻能力的影响. 研究表明, 沟槽内的流线形状对沟槽的减阻能力有重要影响, 尺寸合适的沟槽可以减小流体和壁面之间的切应力, 减小流动阻力, 对临近空间飞艇的蒙皮设计和减阻研究提供了一定参考.

**关键词:** 微沟槽; 临近空间飞艇; 减阻; 蒙皮

中图分类号: V214.8

文献标志码: A

文章编号: 0367-6234(2014)07-0032-04

## Flow field analysis of Micro-V shape riblets airship surface

TAN Huifeng, KANG Jingtian, WEI Jianzheng, WANG Changguo

(Center of Composite Material and Structure, Harbin Institute of Technology, 150001 Harbin, China)

**Abstract:** It is a viable form of drag reduction for airship to use airship envelope with micron-scale grooves. In this paper, the  $k-\omega$  SST turbulence model is used to analyze the V-shaped micro-riblets. The velocity and pressure field are obtained using this model. Both the drag reduction mechanism for micro-grooves and the influence of different groove size are analyzed by the streamline pattern and the drag reduction rate. The results show that the streamline pattern is an important reason for drag reduction ability, and the grooves with appropriate size can reduce the drag between fluid and wall.

**Keywords:** micro-riblets; airship; drag reduction; envelope

# 管材弯曲回弹对内高压成型的影响及补偿方法

张伟玮<sup>1</sup>, 韩 聪<sup>1</sup>, 谢文才<sup>2</sup>, 苑世剑<sup>1</sup>

(1.哈尔滨工业大学 材料科学与工程学院, 150090 哈尔滨; 2.一汽轿车股份有限公司, 130012 长春)

**摘 要:** 管材数控弯曲后的回弹严重影响试件成形精度, 容易导致弯曲管内高压成形过程起皱缺陷. 为了补偿回弹, 避免内高压成形过程的缺陷, 首先建立管材塑性弯曲理论模型以及材料的弹塑性线性强化模型, 通过理论解析得到弯曲回弹量表达式; 其次对实验过程中不同弯曲角度下的回弹量进行线性回归分析. 拟合结果表明: 理论上对于回弹角的预测是合理的; 同时将理论预测得到的回弹量补偿到管材数控弯曲过程, 消除弯曲管内高压成形过程起皱缺陷, 得到尺寸精度合格的试件.

**关键词:** 副车架; 内高压成形; 回弹量; 塑性弯曲

中图分类号: TP394

文献标志码: A

文章编号: 0367-6234(2014)07-0036-04

## The effect of springback of CNC bending on hydro-formed sub-frame and compensation methods

ZHANG Weiwei<sup>1</sup>, HAN Cong<sup>1</sup>, XIE Wencai<sup>2</sup>, YUAN Shijian<sup>1</sup>

(1.School of Materials Science and Engineering, Harbin Institute of Technology, 150001 Harbin, China;

2. FAW Car Co., Ltd., 130012 Changchun, China)

**Abstract:** The springback of CNC bending reduces accuracy of tube bending, which leads to the wrinkle during subsequent hydro-forming, and to avoid the defect during hydro-forming, springback compensation is necessary. In this paper, theoretical model of tube plastic bending and strain hardening model of materials were set up firstly, and then the value of springback angle was derived. Meanwhile, several groups of experiments were carried out, and linear fit formula between springback angle and bending angle based on mathematical statistics was also obtained. Finally, the hydro-forming experiments show that the wrinkle can be avoided by springback compensation during CNC bending, and the dimensional accuracy of hydro-formed sub-frame is acceptable.

**Keywords:** sub-frame; hydro-forming; springback; plastic bending

# 四元数约束的容积卡尔曼滤波及其应用

钱华明, 黄 蔚, 孙 龙

(哈尔滨工程大学 自动化学院, 150001 哈尔滨)

**摘 要:** 针对一些非线性系统状态变量中存在四元数约束的情况, 提出了一种四元数约束下的容积卡尔曼滤波 (quaternion constrained cubature kalman filter, QCCKF) 算法. 基于最小约束代价函数, 采用三阶球面-相径容积规则近似计算系统状态的后验均值和协方差, 给出了 QCCKF 滤波递推公式. 设计的 QCCKF 算法可以有效地对状态进行估计, 扩展了 CKF 的应用范围. 最后对飞行器姿态估计系统进行仿真, 仿真结果表明, 该算法估计精度优于常规 CKF 和无迹四元数估计法 (unscented quaternion estimator, USQUE), 并满足四元数约束条件, 较好地解决了非线性系统存在四元数约束的问题, 验证了算法的有效性.

**关键词:** 容积卡尔曼滤波; 四元数约束; 最小约束代价函数; 三阶球面-相径容积规则

**中图分类号:** U666. 12      **文献标志码:** A      **文章编号:** 0367-6234(2014)07-0040-07

## Cubature Kalman filter with quaternion constraint and its application

QIAN Huaming, HUANG Wei, SUN Long

(College of Automation, Harbin Engineering University, 150001 Harbin, China)

**Abstract:** Aiming at the case of the state vector with quaternion constraint in some nonlinear systems, a quaternion constrained cubature Kalman filter algorithm is presented. Based on a minimum constrained cost function, this algorithm uses three-degree spherical-radial cubature rule to approximate the posterior mean and covariance, and gives the QCCKF recursive formula. It can estimate the state effectively, and extends the applications of the cubature Kalman filter (CKF). By simulating for the spacecraft attitude estimation system, simulation results show that the proposed algorithm is superior to CKF and unscented quaternion estimator (USQUE) in precision, satisfies the quaternion constraint, and solves the problem that the nonlinear system has quaternion constraint, which show the validation of the proposed method.

**Keywords:** cubature Kalman filter; quaternion constraint; minimum constrained cost function; three-degree spherical-radial cubature rule



# GPS/SINS 超紧组合导航系统自适应混合滤波算法

周卫东, 蔡佳楠, 孙 龙

(哈尔滨工程大学 自动化学院, 150001 哈尔滨)

**摘 要:** 针对传统反馈校正滤波结构中, 由于不可观测状态的反馈导致系统滤波精度下降, 以及由于全球定位系统/捷联惯性导航系统 (GPS/SINS, global positioning system/strapdown inertial navigation system) 超紧组合导航系统量测方程的非线性导致滤波难度的增加等问题, 本文重新推导了线性的量测方程, 并将基于状态可观测性的混合校正滤波算法应用于该模型. 通过对比三种主流可观测性分析方法, 选用误差协方差阵的特征值和特征向量可观测性分析方法分析系统状态的可观测性. 最后根据可观测性分析的结果制定自适应的反馈因子, 从而对 SINS 和 GPS 接收机误差进行校正. 仿真结果显示, 该方法可以有效提高不完全可观测系统的估计精度.

**关键词:** 可观测性; GPS/SINS 超紧组合; 混合校正; 特征值; 特征向量

中图分类号: TN967.2      文献标志码: A      文章编号: 0367-6234(2014)07-0047-06

## An adaptive revising filtering method for GPS/SINS ultra-tightly coupled system

ZHOU Weidong, CAI Jianan, SUN Long

(College of Automation, Harbin Engineering University, 150001 Harbin, China)

**Abstract:** In conventional feedback filter, the feedback from some unobservable system states will lead to the divergence of navigation errors. Further the measurement equation of global positioning system/strapdown inertial navigation system (GPS/SINS) is nonlinear, and it increases the complexity of the filter. To solve these problems, a linear measurement equation was derived in this paper. As a complement to this measurement model, a composed adaptive revising filtering method based on the observability of states was presented as well. The eigenvalues and eigenvectors analysis method of error covariance matrix was chosen to analyze the observability of system states as a result of the comparison of three popular observability analysis methods. The feedback factors were thus designed according to the analyzed results. As a consequence, errors from the original data of SINS and GPS receiver can be corrected. Simulation results demonstrate that our proposed method is effective and can improve the estimate accuracy of the system in incomplete observable condition.

**Keywords:** observability; GPS/SINS ultra-tightly coupled system; composed revising; eigenvalue; eigenvector

# 无人水面艇目标图像自适应分割算法

马忠丽, 梁秀梅, 文 杰

(哈尔滨工程大学 自动化学院, 150001 哈尔滨)

**摘 要:** 针对水面目标与海天背景对比度变化大、景深差异明显的特点, 提出一种改进的自适应 Mean-Shift 图像分割算法. 首先通过估计参考点领域灰度值分布, 自适应地得到空间域带宽, 然后结合叶斯准则, 自适应计算空间窗内灰度域带宽, 实现目标与背景的自适应分割. 分别抽取水面艇视频图像中, 目标远、近距离以及清晰对比度不同的视频帧进行仿真测试, 与传统分割算法对比研究, 结果表明该算法可以有效实现水面目标图像分割.

**关键词:** 目标分割; 水面艇; 自适应 Mean-Shift; 带宽

**中图分类号:** TH133; TP183

**文献标志码:** A

**文章编号:** 0367-6234(2014)07-0053-07

## Image adaptive segmentation algorithm for unmanned surface vehicle targets

MA Zhongli, LIANG Xiumei, WEN Jie

(College of Automation, Harbin Engineering University, 150001 Harbin, China)

**Abstract:** Considering the large contrast changing of surface targets and sea-sky background and the obvious difference of field depth, an improved image segmentation algorithm based on self-adaptive Mean-Shift is proposed. Spatial bandwidths are adaptively computed according to the estimation of gray distribution around the reference point; then the gray-level bandwidths are adaptively computed with a novel Bayesian theory in the corresponding windows; and finally adaptive segmentation is obtained. In the experiment, both the close and distant target frames, as well as target frames of different contrast, are extracted respectively from the surface vehicle video sequence. Compared with the traditional segmentation algorithm, experimental results prove that the proposed algorithm can effectively complete segmentation of surface target images.

**Keywords:** target segmentation; surface vehicle; adaptive Mean-Shift; bandwidth

# 小型航天器浸入与不变自适应反步姿态跟踪

张超<sup>1</sup>, 张胜修<sup>1</sup>, 蔡光斌<sup>1</sup>, 侯明哲<sup>2</sup>

(1.第二炮兵工程大学 控制工程系,710025 西安; 2.哈尔滨工业大学 控制理论与制导技术研究中心,150001 哈尔滨)

**摘要:** 针对具有惯性张量不确定性、外干扰及饱和限制的小型航天器非线性姿态跟踪问题,将反步法和系统浸入与流形不变理论相结合,提出了分块自适应约束控制结构.航天器姿态模型由修正罗德里格参数进行全局非奇异描述.在设计反步控制器时,引入指令滤波器和修正跟踪误差信号以施加系统状态和执行器的饱和限制,同时较容易地获得虚拟控制导数.为提高反步控制器的鲁棒性和性能,利用基于不变流形的非线性观测器对时变的系统“总干扰”进行在线估计补偿.由于不变流形方法使得估计误差具有指定的一致稳定动态,因而该分块自适应控制器比传统的自适应反步控制器更容易调节,且性能不受未知的估计律动态的影响.李亚普诺夫直接方法证明了估计误差有界性和闭环系统输入状态稳定.数值仿真表明,与传统方法相比,所提出的控制器结构具有更高的姿态跟踪性能和干扰估计精度.

**关键词:** 姿态跟踪;修正罗德里格参数;自适应反步法;浸入与不变;饱和约束

中图分类号: V448

文献标志码: A

文章编号: 0367-6234(2014)07-0060-09

## Immersion and invariance adaptive backstepping attitude tracking of micro-spacecraft

ZHANG Chao<sup>1</sup>, ZHANG Shengxiu<sup>1</sup>, CAI Guangbin<sup>1</sup>, HOU Mingzhe<sup>2</sup>

(1. Dept. of Control Engineering, The Second Artillery Engineering University, 710025 Xi'an, China;

2. Center for Control Theory and Guidance Technology, Harbin Institute of Technology, 150001 Harbin, China)

**Abstract:** A modular adaptive controller is proposed for the nonlinear attitude tracking of micro-spacecraft in the presence of uncertain inertial tensor, external disturbances and saturation constraints, which combines the theory of system immersion and manifold invariance (I&I) and constrained backstepping. Firstly, the spacecraft attitude is globally represented by modified Rodrigues parameters. Then the backstepping controller is derived to implement any operating constraints and obtain the derivatives of virtual control easily by introducing command filters and modified tracking errors. To improve the robustness of baseline controller, the nonlinear estimator is constructed based on I&I to estimate and compensate the time-varying total disturbances on line. Because the I&I approach allows for prescribed uniformly stable dynamics to be assigned to the estimation error, the resulting modular adaptive controller is easier to tune compared to classical adaptive backstepping. And its performance does not suffer from unpredictable dynamical behavior of the estimation laws. The closed-loop input-to-state stability and boundedness of the estimation error are guaranteed by Lyapunov direct method. Comparative simulations state that the proposed controller is successful in achieving high attitude performance and precise estimation of disturbance.

**Keywords:** attitude tracking; modified Rodrigues parameters; adaptive backstepping; immersion and invariance; saturation constraint

# 增材制造椭圆锥齿轮的齿面与齿距误差分析

林 超, 樊 宇, 张正文, 才立忠, 李忠华

(重庆大学 机械传动国家重点实验室, 400030 重庆)

**摘 要:** 为提高椭圆锥齿轮增材制造的加工精度,减少其加工误差,对增材制造加工的椭圆锥齿轮进行误差测量,并分析误差产生的原因.运用齿轮啮合空间传动原理及增材制造的基本原理,建立了椭圆锥齿轮空间啮合坐标系、增材加工坐标系、分层模型、椭圆锥齿轮的理论误差模型和误差检测模型;对椭圆锥齿轮进行前处理分析,并对增材制造过程进行研究,获得该齿轮增材制造的加工方法;采用超景深三维显微系统和三坐标测量机对该齿轮进行检测,分析其表面误差精度与齿距误差.结果表明:利用增材制造法加工的椭圆锥齿轮误差偏大;优化 STL 模型,减小金属粉末直径,减少激光半径和热效应对加工层的影响,均有助于提高增材制造加工精度.

**关键词:** 齿轮;椭圆锥齿轮;误差分析;增材制造;加工精度

中图分类号: TH132. 424

文献标志码: A

文章编号: 0367-6234(2014)07-0069-07

## Tooth surface and pitch error analysis of elliptical bevel gearing by additive manufacturing

LIN Chao, FAN Yu, ZHANG Zhengwen, CAI Lizhong, LI Zhonghua

(The State Key Laboratory of Mechanical Transmission, Chongqing University, 400030 Chongqing, China)

**Abstract:** To improve accuracy and reduce processing error, the elliptical bevel gearing by additive manufacturing is measured, and the causes of error are analyzed. Space spherical coordinate system, additive manufacturing coordinate system, layers model, theoretical error model and error detection model of ellipse elliptical bevel gear are established by the meshing theory of space transmission and the theory of additive manufacturing. The pre-process of elliptical bevel gearing is analyzed, the process of additive manufacturing is researched and the additive manufacturing method of this gear is obtained. The gears are detected by digital microscope system and coordinate measuring machine, to analyze the surface precision and gear pitch error. The analysis results show that the error of ellipse bevel gear is a little big by the use of material manufacturing method. Optimizing STL model, reducing the diameter of metal powder, decreasing the effect on the processing layer by laser radius and thermal effect, will contribute to raise additive manufacturing precision.

**Keywords:** gear; elliptical bevel gear; error analysis; additive manufacturing; precision

# 声矢量阵快速子空间方位估计算法

梁国龙<sup>1,2</sup>, 张 柯<sup>1,2</sup>, 安少军<sup>1,2</sup>, 范 展<sup>1,2</sup>

(1.哈尔滨工程大学 水声技术重点实验室, 150001 哈尔滨; 2.哈尔滨工程大学 水声工程学院, 150001 哈尔滨)

**摘 要:** 针对声矢量阵高分辨方位估计算法运算量大的问题, 基于声压振速联合信息处理, 提出了一种快速的声矢量阵高分辨方位估计算法. 该算法选择参考阵元的电子旋转矢量作为期望信号, 运用多级维纳滤波器 (MSWF) 对信号子空间进行快速估计, 不需要计算声矢量阵的互协方差矩阵, 不用进行特征值分解, 从而大大缩减了计算量. 另外, 该算法基于矢量传感器声压与振速的相干性原理, 充分利用了声压振速组合抗干扰能力, 有效抑制了各向同性噪声. 理论分析和计算机仿真表明, 该算法在拥有良好 DOA 估计性能的同时, 大大减小计算量.

**关键词:** 声矢量阵; 联合处理; MSWF; 方位估计

中图分类号: TN911

文献标志码: A

文章编号: 0367-6234(2014)07-0076-05

## Fast subspace DOA estimation algorithm based on acoustic vector sensor array

LIANG Guolong<sup>1,2</sup>, ZHANG Ke<sup>1,2</sup>, AN ShaoJun<sup>1,2</sup>, FAN Zhan<sup>1,2</sup>

(1. Science and Technology on Underwater Acoustic Laboratory, Harbin Engineering University, 150001 Harbin, China;

2. College of Underwater Acoustic Engineering, Harbin Engineering University, 150001 Harbin, China)

**Abstract:** Against the problem of huge computation of high-resolution DOA estimation algorithm using acoustic vector sensor array, a fast high-resolution DOA estimation algorithm was proposed based on the combination processing of pressure and particle velocity. The algorithm selected the electronic rotation vector of the reference element as the desired signal and MSWF (multi-stage Wiener filter) was used to estimate the signal subspace, which greatly reduced the amount of computation because it did not need to calculate the cross-covariance matrix of acoustic vector sensor array and Eigen value decomposition. The algorithm is based on the principle of coherency between pressure and particle velocity, which can suppress interference well in isotropic noise field. Theoretical analysis and computer simulations show that the algorithm has good performance of DOA estimation while it greatly reduces the amount of computation.

**Keywords:** acoustic vector sensor array; combined processing; MSWF; DOA estimation

# 航行体出水空泡溃灭载荷特性研究

赵蛟龙, 孙龙泉, 张忠宇, 姚熊亮

(哈尔滨工程大学 船舶工程学院, 150001 哈尔滨)

**摘要:** 为计算出水过程中空泡溃灭载荷对航行体出水过程的影响,从空泡溃灭的物理现象入手,将空泡溃灭过程分为空泡运动阶段和空泡溃灭冲击阶段,在两个阶段分别用势流理论方法与双渐进方法进行计算,形成一套完整的空泡溃灭载荷计算方法. 在与相关试验值对比吻合较好,验证方法有效性的基础上,获得了空泡溃灭载荷及形态在整个出水过程中的变化规律. 最后研究了航行体弹性振动对航行体出水空泡溃灭载荷的影响,航行体弹性振动对溃灭冲击载荷的峰值及脉宽影响较小.

**关键词:** 肩空泡; 势流方法; 非线性双渐进法; 溃灭载荷

**中图分类号:** U661.1      **文献标志码:** A      **文章编号:** 0367-6234(2014)07-0081-06

## Cavitation collapse load characteristic research in the out-of-water process of vehicle

ZHAO Jiaolong, SUN Longquan, ZHANG Zhongyu, YAO Xiongliang

(College of Ship Engineering, Harbin Engineering University, 150001 Harbin, China)

**Abstract:** In this paper, the whole cavitation collapse process was divided into cavitation moving phase and cavitation collapse shock phase based on the physical phenomenon of cavitation collapse process, potential flow method and Nonlinear Doubly Asymptotic Approximation (NDAA) were respectively used to calculate the two stages to make a mechanical analysis of the whole process to study the effect of the load of cavitation collapse on the sailing body movement. A new method was established to calculate the load of cavitation collapse, and a whole calculation method on the load of cavitation collapse was established. By comparing the results of numerical calculation with the experiment, the reasonability of the method was validated. Based on it, the law of the load of the cavitation collapse and the shape of the cavitation were obtained. Finally, the effect of elastic vibration on the cavitation collapse was researched, and the elastic vibration had a little effect on the peak value and periods of the collapse load.

**Keywords:** shoulder cavitation; potential flow method; NDAA; cavitation collapse load

# 基于多特征在线模板更新的鲁棒目标跟踪算法

陈东岳, 陈宗文, 桑永嘉

(东北大学 信息科学与工程学院, 110136 沈阳)

**摘要:** 在 Mean-shift 算法框架下提出一种基于多特征在线模板更新策略的鲁棒目标跟踪算法. 首先, 针对目标与背景色彩相似引发的跟踪漂移现象, 提取照度不变性色彩特征与旋转不变性 LBP 纹理特征提取算法, 并通过引入 BWH 算法实现多特征融合; 其次, 在传统的 Mean-shift 算法收敛条件上增加了直方图相似度校验, 以避免陷入局部最优解. 此外, 还提出了基于直方图差异空间分布图的遮挡现象检测算法, 从而提升了模板在线更新算法的准确性. 实验结果表明, 本文方法对于复杂动态场景、遮挡现象以及目标自身形变具有较强的鲁棒性和较高的准确性.

**关键词:** 鲁棒目标跟踪; Mean-shift; 纹理特征提取; 模板更新; 特征融合

中图分类号: TP391

文献标志码: A

文章编号: 0367-6234(2014)07-0087-08

## Robust object tracking based on online update of multi-feature template

CHEN Dongyue, CHEN Zongwen, SANG Yongjia

(College of Information Science & Engineering, Northeastern University, 110136 Shenyang, China)

**Abstract:** This paper proposes a robust object tracking algorithm under the Mean-shift framework based on the online update strategy of multi-feature template. At first, to solve the drift problem caused by cluttered backgrounds, the illumination invariant color features and the rotation invariant LBP texture feature were extracted and were combined together with the BWH algorithm. Secondly, in addition to the traditional convergence condition of Mean-shift algorithm, a histogram similarity checking step was presented against the local optima problem. Besides, occlusion detection algorithm based on spatial distribution of the histogram difference was proposed to enhance the precision of the template update. Experimental results showed that the proposed tracking algorithm is robust and accurate against cluttered dynamical background, occlusion and the object deformation.

**Keywords:** robust object tracking; Mean-shift; texture feature extraction; template updating; feature extraction

# 三维各向异性功能梯度材料的有限体积法

宣领宽<sup>1,2</sup>, 明平剑<sup>1</sup>, 龚京风<sup>1</sup>, 张文平<sup>1</sup>, 韩春旭<sup>1</sup>

(1.哈尔滨工程大学 动力与能源工程学院, 150001 哈尔滨; 2.中国舰船研究设计中心, 430064 武汉)

**摘要:** 为了研究三维各向异性功能梯度材料的线弹性问题, 发展一种弹性结构的有限体积方法, 该方法采用四面体网格, 对不规则形状问题的适用性强. 空间上采用交错非结构有限体积法进行离散, 位移、速度、加速度定义在节点上, 应力、材料属性定义在单元中心上且在单元内均匀分布, 时间上采用欧拉格式进行离散. 数值结果表明, 本方法计算结果与其他数值方法结果吻合良好, 计算速度快且内存消耗少, 可以有效模拟三维各向异性功能梯度材料的弹性问题.

**关键词:** 各向异性; 功能梯度; 有限体积法; 弹性分析

**中图分类号:** O343.7

**文献标志码:** A

**文章编号:** 0367-6234(2014)07-0095-07

## Finite volume method for three-dimensional anisotropic functionally graded materials

XUAN Lingkuan<sup>1,2</sup>, MING Pingjian<sup>1</sup>, GONG Jingfeng<sup>1</sup>, ZHANG Wenping<sup>1</sup>, HAN Chunxu<sup>1</sup>

(1.College of Power and Energy Engineering, Harbin Engineering University, 150001 Harbin, China;

2.China Ship Development and Design Center, 430064 Wuhan, China)

**Abstract:** A finite volume method (FVM) is developed for elastic analysis of three-dimensional (3D) anisotropic linear elastic solids with continuously variable material properties. The method employs tetrahedral elements so that it owns adaptability to problems with irregular domain. A staggered unstructured FVM is used for spatial terms. The displacement, velocity and acceleration are defined on the cell vertex while the stress and material properties which are uniform in the cell are defined on the cell center. An Euler scheme is employed for time dependent terms. The numerical results of the FVM agree well with the results of other numerical methods, and the FVM consumes much less computational time and memory, which is able to predict the 3D anisotropic linear elastic problems accurately and efficiently.

**Keywords:** anisotropic; functionally graded; finite volume method; elastic analysis



# 具有状态依赖噪声的随机 $H_\infty$ 预演控制

王宏霞<sup>1</sup>, 张焕水<sup>2</sup>, 陈欣<sup>1</sup>, 俞立<sup>1</sup>

(1. 浙江工业大学 信息工程学院, 310023 杭州; 2. 山东大学 控制科学与工程学院, 250061 济南)

**摘要:** 为了改善一类系统的  $H_\infty$  控制性能, 采用对策论与动态规划相结合的方法, 研究具有依赖于状态的乘性噪声连续随机系统  $H_\infty$  预演控制问题, 提出了解耦耦合的微分及偏微分方程组的思路, 并利用特征线法求解, 给出了该问题可解的条件和显式预演控制器, 为解决随机时滞系统的控制问题提供新的思路.

**关键词:**  $H_\infty$  预演控制; Riccati 方程; 随机系统

中图分类号: TP13

文献标志码: A

文章编号: 0367-6234(2014)07-0101-06

## Stochastic $H_\infty$ preview control with state-dependent noise

WANG Hongxia, ZHANG Huanshui, CHEN Xin, YU Li

(1. School of Information Engineering, Zhejiang University of Technology, 310023 Hangzhou, China;

2. School of Control Science and Engineering, Shandong University, 250061 Jinan, China)

**Abstract:** The paper aims to improve the  $H_\infty$  control performance of a class of systems. It is concentrated on  $H_\infty$  preview control for stochastic Ito system with state-dependent noise. Associating game theory and dynamic programming, we present the solvable condition and explicit controller of the stochastic  $H_\infty$  preview control via decoupling the coupled ordinary and partial differential equations and utilizing the characteristic curve.

**Keywords:**  $H_\infty$  preview control; Riccati equation; stochastic system

# 极小 Cayley 图的确定性小世界网络模型

刘艳霞<sup>1,2</sup>, 奚建清<sup>1</sup>, 张 苓<sup>2</sup>

(1.华南理工大学 软件学院, 510006 广州; 2.华南理工大学 计算机科学与工程学院, 510006 广州)

**摘 要:** 小世界网络的确定性模型研究是复杂网络建模领域的重要分支,通过分析 Cayley 图的极小性与小世界特性的关联,提出一种基于极小 Cayley 图构造小世界网络的确定性模型.模型通过选择满足条件的极小 Cayley 图,恰当地扩展其生成集,构造出一类对称性强且结构规则的小世界网络.结果表明,和现有模型不同,该模型可根据需求构造常数度或非常数度网络,且生成网络不仅具有较高的聚集系数和低的网络直径,而且是节点对称的,在通信网络、结构化 P2P 覆盖网络等实际领域的拓扑结构设计中具有重要应用.

**关键词:** 复杂网络;小世界网络;确定性模型;Cayley 图

中图分类号: TP393.0      文献标志码: A      文章编号: 0367-6234(2014)07-0107-05

## Deterministic small-world network model based on minimal Cayley graph

LIU Yanxia<sup>1,2</sup>, XI Jianqing<sup>1</sup>, ZHANG Qin<sup>2</sup>

(1. School of Software Engineering, South China University of Technology, 510006 Guangzhou, China;

2. School of Computer Science and Engineering, South China University of Technology, 510006 Guangzhou, China)

**Abstract:** The research on deterministic small-world network model is an important branch of complex network modeling. This paper analyzes the small-world property of the minimal Cayley graph and proposes a deterministic small-world network model based on minimal Cayley graph. The model constructs a class of small-world networks with high symmetry by selecting a minimal Cayley graph, and appropriately expands its generating set. Compared with the existing models, this model can be used flexibly to get small-world networks with const degree or variable degree, which is adaptable for the design and analysis of the real networks such as communication network and P2P overlay network.

**Keywords:** complex network; small-world network; deterministic model; Cayley graph

# 自适应提升小波在干涉高光谱压缩中的应用

温 佳<sup>1,2</sup>, 马彩文<sup>2</sup>, 赵军锁<sup>1</sup>, 王彩玲<sup>3</sup>

(1.中国科学院 软件研究所天基综合信息系统重点实验室, 100190 北京;  
2.中国科学院 西安光学精密机械研究所, 710119 西安; 3.西安石油大学 计算机学院, 710065 西安)

**摘 要:** 为了更好地提高干涉高光谱图像的压缩性能,针对干涉成像光谱仪的成像原理,提出了一种自适应方向预测提升小波变换的方法,在帧序列方向的提升小波变换中,以自适应方向获得最佳预测值,并且改变传统三维提升小波的变换顺序,消除大部分干涉条纹冗余,大量实验证明本文方法得到的高频子带小波系数相对于传统方法在指定码率的情况下重构图像可以获得更高的信噪比,恢复的光谱曲线具有更小的均方误差。  
**关键词:** 干涉高光谱;LASIS;光谱压缩;提升小波变换  
**中图分类号:** TP731      **文献标志码:** A      **文章编号:** 0367-6234(2014)07-0112-06

## An adaptive wavelet transformation used on interference hyperspectral image compression

WEN Jia<sup>1,2</sup>, MA Caiwen<sup>2</sup>, ZHAO Junsuo<sup>1</sup>, WANG Cailing<sup>3</sup>

(1. Science and Technology on Integrated Information System Laboratory, Institute of Software, Chinese Academy of Sciences, 100190 Beijing, China; 2. Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences, 710119 Xi'an, China; 3. School of Computer Science, Xi'an Shiyou University, 710065 Xi'an, China)

**Abstract:** To get better performance of interference hyperspectral image compression, according to the imaging principle of interference hyperspectral image, we propose an adaptive direction prediction wavelet transform for LWT (Lifting Wavelet Transformation), to get the best predicted values through adaptive direction in the LWT on the frame direction, and change the order of the traditional wavelet transform. The experiment results prove that the proposed method can get higher SNR at the same bpppb compared with the traditional method, and can get smaller MSE in the recovered spectral curve.  
**Keywords:** interference hyperspectral image; LASIS; spectrum compression; lifting wavelet transformation

# 脉冲参数主动匹配式 micro-EDM 脉冲电源

孙术发<sup>1</sup>, 刘美爽<sup>1</sup>, 狄士春<sup>2</sup>

(1.东北林业大学 工程技术学院,150040 哈尔滨; 2.哈尔滨工业大学 机电工程学院,150001 哈尔滨)

**摘要:** 为了提高微细电火花加工(micro-EDM)效率,设计了一种脉冲参数主动匹配式 micro-EDM 脉冲电源.采用等能量加工的方法,对不同的脉冲匹配参数进行加工效率对比实验,设计了脉冲参数主动匹配式脉冲电源的结构、功能和控制策略,并进行了加工实验验证.结果表明:选定合适的脉宽和脉间参数,使极间电容单次充电和单次放电,可获得最高的加工效率;该电源脉冲参数可根据极间电压和极间电容的大小自动调整;进行微小孔加工,加工连续性较好,加工效率和加工质量较高.利用该电源可进行微细加工,加工效率较传统电源有显著的提升,并能保证较高的加工质量.

**关键词:** 主动匹配式;微细电火花加工;脉冲电源;脉冲参数;加工效率

中图分类号: V261.6      文献标志码: A      文章编号: 0367-6234(2014)07-0118-05

## Research of active pulse parameters matching micro-EDM pulse power supply

SUN Shufa<sup>1</sup>, LIU Meishuang<sup>1</sup>, DI Shichun<sup>2</sup>

(1. School of Engineering and Technology, Northeast Forestry University, 150040 Harbin, China;

2. School of Mechatronics Engineering, Harbin Institute of Technology, 150001 Harbin, China)

**Abstract:** To improve the efficiency of micro-EDM, we designed a pulse power supply which can actively match pulse parameters for micro-EDM. By using the processing method of equal energy, we conducted the comparison experiments of processing efficiency in different pulse parameters, designed the structure, function and control strategy of this pulse power supply, and carried out a machining experiment. The results show that the highest machining efficiency can be obtained by selecting the appropriate pulse width and pulse interval, making the electrode capacitance charge and discharge for only one time, and the pulse parameter of the pulse power supply can automatically adjust to electrode voltage and capacitance. When machining the micro holes, the power supply has good processing continuity, high processing efficiency and quality, and when used for micro machining, the power supply can obviously improve the processing efficiency and get good processing quality compared to the traditional power supply.

**Keywords:** active matching, micro-edm, pulse power, pulse parameters, machining efficiency

# 森林生境因子无线传感器网络采集系统

李 丹<sup>1</sup>, 孙利新<sup>2</sup>, 戴 巍<sup>1</sup>, 王霓虹<sup>1</sup>

(1.东北林业大学 信息与计算机工程学院,150040 哈尔滨; 2.哈尔滨工程大学 计算机科学与技术学院,150001 哈尔滨)

**摘 要:** 为了改善传统森林调查过程中,森林温度、湿度、光照强度等生境因子获取手段单一、动态变化不及时等缺陷,运用嵌入式技术和无线传感器网络技术,完成了森林生境因子自动采集系统.采用 LPC2148 为主控制芯片,以 MYSQL 作为系统数据库,AecGIS Server 为 GIS 平台,通过 BH1750FVI 光照传感器和 SHT11 温湿度传感器共同研制采集装置,将实时获取的森林生境因子数据经 nRF905 无线通信模块发回上位机入库,并由 WebGIS 实时显示生境因子的动态变化.实验结果表明,在传感器节点之间应用的通信协议中引入数据包编号机制和时间同步机制可以缓解网络阻塞,降低网络丢包率.当无线通信模块的发射频率设置为 433 MHz,传输速率和发射功率分别设置为 9 600 bps 和 10 dBm 时,传感器节点间通信半径设置在小于 50 m 范围之内可以有效地控制误帧率.

**关键词:** 生境因子;嵌入式;无线传感器网络;自动采集

**中图分类号:** TP391.4      **文献标志码:** A      **文章编号:** 0367-6234(2014)07-0123-06

## Wireless sensor networks system of forest habitat factors collection

LI Dan<sup>1</sup>, SUN Lixin<sup>2</sup>, DAI Wei<sup>1</sup>, WANG Nihong<sup>1</sup>

(1. School of Information & Computer Engineering, Northeast Forestry University,150040 Haerbin, China;

2. School of Computer Science & Technology, Harbin Engineering University,150001 Haerbin, China)

**Abstract:** To improve the method of collecting of forest habitat factors such as forest temperature, humidity and light intensity, an automatic collection system of forest habitat factors was completed with the use of embedded technology and wireless sensor network technology. This system used the LPC2148 embedded chip as main control chip, MySQL as the system database AecGIS Server as GIS platform, to obtain forest temperature, humidity and light intensity by the collection device composed of BH1750FVI light sensor and SHT11 temperature and humidity sensor, to establish communication with the host computer by nRF905 wireless communication module so as to store data and real-time display of the dynamic changes of the forest habitat factors in a web page. The test results showed that the data packet numbering mechanism and time synchronization mechanism used into the communication protocol of sensor nodes could alleviate network congestion and reduce the loss rate of the data packets. When the emission frequency of the wireless communication module was set to 433 MHz, the transmission rate and emission power were set to 9 600 bps and 10 dBm, the error rate of frames could be effectively controlled within the range of less than 50 meters.

**Keywords:** habitat factors; embedded; wireless sensor network; automatic collection