2017 复杂曲面智能制造研讨会

中南大学 CENTRAL SOUTH UNIVERSITY | 广州番禺节能科技园 TIANAN HI-TECH ECOLOGICAL PARK

中国 · 番禺

2017/12月06-08日
广州天安番禺节能科技园科技交流中心首层

主办单位：中南大学数学与统计学院 广州天安番禺节能科技园
承办单位：中南大学工程建模与科学计算研究所 中南大学高性能复杂制造国家重点实验室 番禺区厂商会
协办单位：广州市天安孵化器运营有限公司 东环街商会

邀请报告人

Yusuf Altintas，教授，英属哥伦比亚大学, 加拿大，

陈　勇(Yong Chen)，副教授，南加州大学，美国

瞿志行(Chih-Hsing Chu)，教授，台湾国立清华大学

汤　凯（Kai Tang），教授，香港科技大学

王昌凌（Charlie C.L. Wang），教授，Delft理工大学，荷兰，ASME会士

李友福（Youfu Li），教授，香港城市大学

孙玉文， 教授，大连理工大学，教育部“长江学者奖励计划”特聘教授，国家杰出青年科学基金获得者

周元生， 助理教授，中南大学

研讨会组委

王昌凌 教授
荷兰Delft理工大学设计工程系

唐进元 教授
中南大学高性能复杂制造国家重点实验室

刘圣军 教授
中南大学数学与统计学院

刘倬 投资发展部总监
广州天安番禺节能科技园

联系人

位文言

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2017复杂曲面智能制造研讨会

会议通知

由中南大学数学与统计学院和广州天安番禺节能科技园联合主办，中南大学工程建模与科学计算研究所、高性能复杂制造国家重点实验室和番禺区厂商会联合承办的2017复杂曲面智能制造研讨会，将于2017年12月6-8日在广州天安番禺节能科技园召开。

研讨会邀请了海内外数字化制造领域中的杰出专家学者做学术报告，并就国内外最新研究进展、新理论/思路/方法、未来发展方向等多方面，进行学术讨论和交流，提出未来研究计划和合作方向。

研讨会主题

复杂曲面先进制造技术理论与应用。

会议时间

2017年12月6-8日

会议地点

广州天安番禺节能科技园科技交流中心

组委会

王昌凌 教授，荷兰Delft理工大学

唐进元 教授，中南大学

刘圣军 教授，中南大学

刘倬 投资发展部总监， 广州天安番禺节能科技园

主办单位

中南大学-数学与统计学院

广州天安番禺节能科技园

承办单位

中南大学工程建模与科学计算研究所

中南大学高性能复杂制造国家重点实验室

番禺区厂商会

研讨会费用

研讨会不收取参会人员任何费用，食宿与差旅费自理。请有意向参加研讨会的人员，请统一填写《报名回执》，并于 2017 年 12 月 01 日前发送到指定邮箱 zndxwwy082@163.com。

附件：《报名回执》

联系人：

位文言 17375896001 zndxwwy082@163.com

2017年复杂曲面智能制造研讨会报名回执

姓　　名	单　　　　位				
职务（职称）		联系电话		邮箱	
到会时间		离会时间		是否需要安排住宿	

备注：请于12月01日前发送至邮箱zndxwwy082@163.com，谢谢！

Workshop on Complex Surfaces Intelligent Manufacturing 2017
(复杂曲面智能制造研讨会 2017)
6-8 December 2017, Guangzhou, Guangdong, China
(中国广东广州，2017 年 12 月 6-8 日)
PROGRAM
(程序册)

Wednesday, December 6th (星期三，12 月 6 日)	
14:00-20:00	Registration (报到注册)
17:30	Dinner (晚餐)

Thursday, December 7th (星期四，12 月 7 日)		
Time (时间)	Speaker (报告人)	Title (题目)
9:00-10:00	Opening Remarks (开幕式)	
Session Chair (分会场主持人):		
10:00-10:30	Prof. Yusuf Altintas	Digital Machining (数字化加工)
10:30-11:00	Prof. Kai Tang (汤凯教授)	Energy-efficient five-axis machining of free-form surfaces (自由曲面的高效能五轴加工)
11:00-11:15	Coffee Break (中场休息)	

11:15-11:45	Prof. Yuwen Sun (孙玉文教授)	Multiple vector fields based five-axis toolpath planning for the machining of sculptured surfaces (雕刻曲面加工中基于多向量场的五轴刀具路径规划)
12:00	Lunch	
Session Chair (分会场主持人):		
14:30-15:00	Prof. Chih-Hsing Chu (瞿志行教授)	Continuity-Preserving Tool Path Planning in 5-Axis Flank Milling of Complex Geometries (复杂几何五轴侧铣中连续性保持的刀具路径规划)
15:00-15:30	Dr. Yuansheng Zhou (周元生博士)	A short report about some advanced technologies of gears manufacturing (齿轮制造的先进技术)
15:30-15:45	Coffee Break (中场休息)	
15:45-16:15	Prof. Youfu Li (李友福教授)	3D vision and its application in robotics (3D 视觉及其在机器人技术中的应用)
16:15-16:45	Prof. Yong Chen (陈勇教授)	Additive Manufacturing of Bio-inspired Complex Surfaces via Nanocomposite 3D Printing

		(基于纳米复合 3D 打印技术的仿生复杂曲面增材制造)
16:45-17:15	Prof. Charlie C.L. Wang (王昌凌教授)	Geometric Computing for Multi-Axis Additive Manufacturing (多轴增材制造中的几何计算)
17:15-17:45	Interactive session (互动问答环节)	
17:45	Dinner (晚餐)	

Friday, December 8th (星期五，12 月 8 日)

Session Chair (分会主持人):	
9:00	Visiting enterprises (企业参观)
12:00	Lunch (中餐)
14:30	Visiting enterprises (企业参观)
17:30	Dinner (晚餐)
Manage yourself (会议结束，自由安排)	

1. Yusuf Altintas 教授，加拿大英属哥伦比亚大学

Biography Yusuf Altintas is a Professor in Department of mechanical Engineering at university of British Columbia. Additionally, he is Ph.D. (McMaster)，Hon. Dr. Ing. (Stuttgart), NSERC–P&WC Industrial Research Chair, Coordinator of Mechatronics Option at UBC, Fellow of RSC, ASME, CIRP, SME, AvH, CAE, ISNM, and P&WC.

URL:http://mech.ubc.ca/yusuf-altintas/

Title Virtual High Performance Machining

Abstract The aim of our research is to develop mathematical models of metal cutting operations, machine tool vibrations and control. The science based digital models allow the virtual design of machine tools, and testing and optimization of machining operations.

The model predicts the cutting forces, torque and power consumed in machining parts by considering material properties, cutter geometry, structural flexibilities, and cutting conditions along the tool path. The structural dynamics of the machine tool can either be imported from Finite Element analysis if the machine tool is at the design stage, or from the experimental modal measurements if the machine is already built. The simulation system predicts chatter free cutting conditions within the work volume of the machine tool, or detects the presence of chatter vibrations along the tool path. The dynamics of servo drive control systems, and trajectory generation as a function of jerk, acceleration and velocity profiles of machine tools are considered in simulating the machine tool behavior. An in-house developed virtual and real time CNC system allows the design and analysis of any five axis machine tool controller.

The algorithms are published in open literature (Google Scholar h-77 with over 21600 citations), and packaged in industrial software tool box which can be used as a process planning tool by production engineers or as an analysis module by machine tool builders (over 250 companies and research centers world-wide). We are currently developing a controller for a 9 axis precision micro machine built in our laboratory, investigating damping of machine tool vibrations, and the stability of turning, drilling, boring, micro-cutting, threading of pipes and mill turn operations.

2. Kai Tang (汤凯) 教授，香港科技大学

Biography 汤凯教授，男，1959 年 4 月出生。1984 年由教育部公派到美国密执安大学（Ann Arbor）留学，1990 年获计算机工程博士。其后十年，任职于美国 Schlumberger CAD/CAM（后并入 UniGraphics），专门负责多轴复杂曲面加工道具路线生成商用软件的研发。2001 年受香港科技大学招聘，任教于该校机械及航天航空系，现为该系正教授。主要研究领域为计算机辅助设计及制造的基础算法；在复杂曲面加工道具路线生成方面，其发表的成果具有一定的影响力并且被数家商用软件采用。在 2001-2014 期间，作为单人首席科学家，共获得总额超过两千六百万港币的香港政府自然基金（General Research Fund）和创新基金（Innovative Technology Fund）研究项目。现任多家国际杂志编辑委员会委员，如 Journal of CAD, Journal of Computational Design and Engineering。

URL: http://ihome.ust.hk/~mektang/

Title 基于能效优化的复杂曲面五轴加工的规划策略

Abstract 针对大型零部件的五轴加工，尤其是在批量化大规模生产过程中，能量消耗问题不容忽视。有效的降低单位工件的加工能耗将显著的控制成本，减轻碳排放量，是工业界乃至学术界一贯追求的目标。本研究以此为出发点，从加工过程中的两个层面提出了针对复杂曲面的五轴加工规划策略，即刀具路径的优化和工件摆放姿态的优化。

在给定加工参数以及不影响加工表面质量的前提下，加工能耗通常由三大因素决定：加工时间，切削力，以及转台运动能耗。在五轴刀具路径的规划过程中，本研究通过计算结合以上三大能耗因素，提出了能量密度的概念，即切削单位体积材料所需能耗。通过有限采样曲面上不同刀触点沿不同进给方向的能量密度，提出了针对任意自由曲面的能量密度势能场。利用该势能场同时结合等残高路径规划策略，本研究完成了基于能效优化的刀具路径生成，通过对比传统加工模式可有效降低能耗 20-30%。

从另一角度出发，对于某些特定的复杂曲面，例如叶轮叶片，其加工路径受到其他因素的制约往往很难进一步优化。在给定了加工刀路的前提下，不同的工件摆放姿态会导致机床的转台呈现不同的运动方式，从而影响最终的加工效率。本研究通过优化工件摆放位置和姿态的六个参数，提出了能耗最优的工件摆放策略，相比传统的工件摆放有 40-50%的能效提升。

3. Yuwen Sun（孙玉文）教授，大连理工大学

Biography 孙玉文教授，博士生导师，国家杰出青年基金获得者，长江学者特聘教授。1994 年于西安交通大学机械制造工艺及设备专业获工学学士学位，2000 年于大连理工大学机械制造及其自动化专业直读博士毕业。2003 年初中国科学院沈阳自动化研究所博士后出站，2004 年起先后为澳大利亚昆士兰理工大学和新南威尔士大学访问学者，2005 年返校后聘为副教授，2007 年增列为博士生导师，2008 年入选教育部新世纪优秀人才支持计划，2009 年晋升为教授。主要从事数字化制造与数控加工技术，加工制造过程建模、仿真与优化，精密与特种加工技术，精密复杂曲面设计、加工与再制造工程等方面的研究工作。工作以来，负责和参与国家杰出青年科学基金项目、国家 973 计划项目课题、GF973 子课题、国家自然科学基金重大项目课题、重点和面上项目，数控重大专项子课题和国家 863 计划项目等科研项目 20 余项，著作权、授权及公开发明专利 10 余项，作为主要完成人获国家技术发明二等奖等国家和省部级奖励 3 项。

URL: http://faculty.dlut.edu.cn/sunyuwen/zh_CN/index.htm

Title Multiple vector fields based five-axis tool path planning for the machining of sculptured surfaces

Abstract The vector field based tool path method can conveniently generate the desired tool paths according to the preferred feed directions which reflect the machining intent of the designers at CC (cutter contact)points, thus recently, it has become the focus of interests. But, the current methods are still limited to the single surface machining. When machining the compound surface patch by patch, it has to plan additional tool path to machine the blending areas of the adjacent patches, and more importantly, the solutions of the key issue, i.e. tool path construction over the vector field, are still heuristic due to the high computational complexity. To solve the problems, a tool path method is developed, based on the multiple feed vector fields, for the 5-axis machining of a compound surface with the torus-end cutter. In this method, the feed vector field in the parametric domain is first constructed in form of stream function which is used to generate the candidate streamlines for tool path generation, and then a G^1 blending algorithm is presented to blend the vector fields in the adjacent parameter domains, ensuring the smooth transition of the cross-border streamline. On basis of this, the path lines with the reasonable side steps, which are corresponding to the streamlines, are selected as the desirable tool paths. Along the calculated tool path, the optimal tool orientation is further investigated so that at each cutter contact (CC) point, the torus-end cutter can touch the surface closely without gouging. Finally, examples are given to validate the proposed method.

4. Chih-Hsing Chu(瞿志行) 教授，台湾国立清华大学

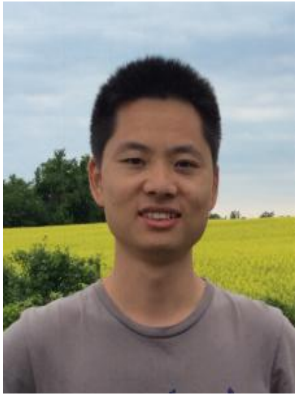
Biography Chih-Hsing Chu is a Professor in Department of Industrial Engineering and Engineering Management, National TsingHua University, Taiwan. He attended National Taiwan University and received his B.S. and M.S. degrees from Department of Mechanical Engineering. He received his Ph.D. degree in mechanical engineering from University of California at Berkeley, USA. His past work experiences include Web Applications engineer at Red Spark, an Autodesk Venture, USA, Daimler Benz AG, Germany, and a visiting researcher at the Laboratory for Machine Tools and Production Engineering (WZL), RWTH Aachen, Germany. Prior to joining National TsingHua University in 2002, he was an Assistant Professor in Industrial and Systems Engineering Department, Virginia Tech, USA. He was an invited scholar at CREDITS Center, Sungkunkwan University, Korea, during the summer of 2005. His research interests include digital manufacturing, CAD/CAM, augmented reality, and collaborative engineering. He is a member of IEEE, ASME, and SME.

URL:http://prl.ie.nthu.edu.tw/Member.html

Title Continuity-Preserving Tool Path Planning in 5-Axis Flank Milling of Complex Geometries

Abstract Five-axis flank milling has been widely used to produce high-value parts in the aerospace, automobile, mold, and energy industries because of its superior productivity and shaping capability. Tool-path planning in this milling operation is a challenging task with one major difficulty in precise control of geometrical errors on the machined surface. Previous optimization-driven tool-path planning methods provide a feasible approach to machining error control in five-axis flank milling of ruled surfaces. However, uneven modifications of the tool motion often result in poor surface quality on the finished part. This research proposes a new planning method for solving this problem. The proposed method generates a continuity-preserving tool path that not only produces minimized geometrical deviations but also maintains satisfactory surface quality. The tool path is described in the form of spline curves during its optimization-driven modification process. Instead of adjusting individual cutter locations, optimization algorithms are applied to determine the coefficients of the curve equations by minimizing accumulated errors on the machined surface. According to experimental data, the new method generates a tool path that yields superior results in both geometrical errors and surface roughness compared with traditional methods. This study provides an effective approach for intelligent tool-path planning in five-axis flank milling that considers multiple objectives in machining.

5. 周元生 博士， 中南大学



Biography 周元生，湖南祁阳人，本、硕、博分别在 08 年、11 年及 15 年毕业于哈尔滨工程大学，湖南大学，Concordia University (Montreal, Canada)，16 年加入中南大学，在机电工程学院车辆工程系，目前任职讲师，并在唐进元教授团队从事科学研究，主要研究方向为齿轮设计、制造及分析；复杂曲面智能制造；数控加工；CAD/CAM/CAE。强调科学技术与工业界的结合，进行解决实际工业问题与产出高质量的学术成果的科学研究。与工业界有十分紧密的合作，主持及参与了航空、汽车传动系统的多项相关项目，并在 Computer-Aided Design, ASME, International Journal of Machine Tools and Manufacture, Mechanism and Machine Theory 等期刊发表多篇高水平的学术论文。

URL: http://cmee.csu.edu.cn/bk/?id=zhouyuansheng

Title A short report about some advanced technologies of gears manufacturing

Abstract 针对当前的工业需求，中国齿轮行业在对高精度、高性能的需求越来越显著，急需新的技术来指导齿轮的设计、加工，从而满足齿轮的性能需求。在此背景下，我们将简单介绍我们课题组，即中南大学机电工程学院及高性能复杂制造国家重点实验室的齿轮研究课题组，在利用 CAD/CAM/CAE/CAO（计算机辅助设计、制造、分析及优化）等相关技术在齿轮研究所做的工作，相应的研究齿轮对象包过：直齿轮，斜齿轮、人字齿、锥齿轮、面齿轮等。

6. Youfu Li(李友福) 教授，香港城市大学

Biography 李教授在哈尔滨工业大学电子工程专业获得学士和硕士学位。1993 年在牛津大学工程科学系机器人技术研究组获博士学位。1993 年至 1995 年，在英国计算机科学系从事博士后研究工作。目前，他是香港城市大学机械与生物医学工程系的教授。他的研究兴趣包括机器人感知，机器人视觉，3D 视觉，可视跟踪，传感器导向控制，机电一体化和自动化。他曾任国际期刊 IEEE Transactions on Automation Science and Engineering (T-ASE) 副主编，现任国际杂志 IEEE Robotics and Automation Magazine (RAM)的副主编，和 IEEE 机器人自动化协会的会议编辑委员会编辑。

URL: http://www.cityu.edu.hk/mbe/meyfli/

Title 3Dvision and its applications in robotics

Abstract 3D vision is important to many engineering applications including robotics. In this talk, I will present our research in visual sensing for automated 3D measurements in general and for motion tracking for robotics in particular. Different approaches in our investigation in 3D vision research will be reported. These include an active vision approach to 3D visual sensing. With the auto-recalibration method developed, the vision system parameters can be recalibrated automatically, allowing the 3D sensing to be performed online without interruption. For motion tracking applications in robotics, at rajectory description based approach will be presented for motion trajectory description and recognition.

7. Yong Chen (陈勇) 副教授，美国南加利福尼亚大学

Biography Dr. Yong Chen is an associate professor in Epstein Department of Industrial and Systems Engineering and Department of Aerospace and Mechanical Engineering (courtesy) at *University of Southern California* (USC). He received his Ph.D. degree in Mechanical Engineering from *Georgia Institute of Technology* in 2001. Prior to joining USC in 2006, he was a senior Research and Development (R&D)engineer in *3D Systems Inc*, the pioneer and world leader in 3D Printing industry. Dr. Chen's research focuses on additive manufacturing (3Dprinting) in micro- and meso-scales, especially modeling, analyzing, synthesizing, and optimizing digital design and manufacturing. Among his published publications, he received more than ten *Best/Outstanding Paper Awards* in major design and manufacturing journals and conferences. Other major awards he received include the National Science Foundation *Faculty Early Career Development (CAREER) Award*, the *Outstanding Young Manufacturing Engineer Award* from the Society of Manufacturing Engineers (SME), and a *Leadership and Service Award* from the ASME CIE division. He was cited as one of the top young engineers(ages of 30-45) in USA through the invitation to the National Academy of Engineering (NAE) *Frontiers of Engineering Symposium*.
URL: http://www-bcf.usc.edu/~yongchen/

Title Additive Manufacturing of Bio-inspired Complex Surfaces via Nanocomposite 3D Printing

Abstract Many natural structures out-perform the conventional synthetic counterparts due to the specially evolved multi-scale and multi-material architectures. However, the majority of current 3D printing systems are designed to fabricate parts using a single material in a single scale mainly for structural purpose. Such complex yet beautiful designs existing in natural structures are far beyond the fabrication capability of current 3D printing systems. This talk will report our recent work on developing new multi-scale and multi-material additive manufacturing processes to fabricate bio-inspired complex surfaces including the eggbeater structure of the Salvinia Molesta leaves to create super hydrophobic structures. After a brief overview of current 3D printing technology, an additive manufacturing process named Immersed Surface Accumulation to fabricate complex micro-scale structures on an object surface will be presented. Such AM process enables one to reproduce biomimetic functional surfaces to achieve interesting properties such as hydrophobilicity and petal effect. Some promising applications enabled by the 3D-printed complex surfaces will be demonstrated and discussed. The talk will conclude with remarks and thoughts on future 3D printing developments and potential opportunities for intelligent manufacturing.

8. Charlie C.L. Wang(王昌凌) 教授，荷兰 Delft 理工大学

Biography Prof. Charlie C. L. Wang is a Fellow of American Society of Mechanical Engineers (ASME) with expertise in geometric computing, design and manufacturing. He received his Ph.D. in Mechanical Engineering from HKUST in 2002. After that, he joined Chinese University of Hong Kong in 2003. Starting from January 2016, he joined Delft University of Technology (TU Delft) as Professor, Chair of Advanced Manufacturing. His research interests include geometric computing, computer-aided design, advanced manufacturing and computational physics. Prof. Wang received a few awards from professional societies including the ASME CIE Excellence in Research Award (2016), the ASME CIE Young Engineer Award (2009), the CUHK Young Researcher Award (2009), the Best Paper Awards of ASME CIE Conferences (in 2008 and 2001), the Prakash Krishnaswami CAPPD Best Paper Award of ASME CIE Conference in 2011, and the NAMRI/SME Outstanding Paper Award in 2013. He serves on the editorial board of a few journals including Computer-Aided Design, IEEE Transactions on Automation Science and Engineering, ASME Journal of Computing and Information Science in Engineering, and International Journal of Precision Engineering and Manufacturing.

URL: http://homepage.tudelft.nl/h05k3/

Title Geometric Computing for Multi-Axis Additive Manufacturing

Abstract This talk consists of two recent research works conducted in my research group towards the direction of adding more degree-of-freedom motion in the process of additive manufacturing therefore further enhance the flexibility of fabrication. In the first work, a robotic system - RoboFDM is presented. The fabrication of 3D models in this system follows the principle of fused decomposition modeling (FDM). Different from conventional FDM, an input model fabricated by RoboFDM is printed along different directions at different places. A new algorithm is developed to decompose models into support-free parts that can be printed one by one in a collision-free sequence. In the second work, we do not limit material accumulation on a planar surface anymore. An input solid model is decomposed into a sequence of curved layers that can be fabricated by using multi-axis additive manufacturing. Both approaches have been tested on a hardware platform equipped with a 6DOF robotic arm.