IEEE ICMA 2024 Conference Workshop

World Premium Workshops on Robotics

Sunday, August 4, 2024
13:30 - 15:00
Conference Room 1, 1F
Tianjin Shangri-La Hotel, Tianjin, China

Physical Human-Robot-Environment Interaction

Venue: Conference Room 1, 1F
Tianjin Shangri-La Hotel, Tianjin
Date and Time: 13:30 - 15:00, August 4, 2024

Organizers:

Prof. Xuping Zhang, Head of Section for Mechatronics and Dynamics, Department of Mechanical and Production Engineering, Aarhus University, Denmark
Prof. Huapeng Wu, Department of Mechanical Engineering, School of Energy Systems, Lappeenranta University of Technology, Finland

About the workshop: The motivation behind Physical Human-Robot-Environment Interaction stems from the growing need for robots to seamlessly integrate into human-centric environments, enhancing efficiency, and safety. This field has its roots in robotics, human-computer interaction, and environmental sensing, aiming to create systems that can intuitively collaborate with humans and adapt to dynamic surroundings. Key challenges include developing robust perception and decision-making algorithms and ensuring reliable and safe physical interactions. This workshop will feature keynote presentations from leading experts and in-depth discussions designed to foster collaboration and knowledge sharing. Attendees will gain insights into the latest research developments, practical applications, and emerging trends in this vital area of robotics. The workshop is structured to encourage active participation and networking, providing a platform for researchers, practitioners, and industry professionals to collaborate and push the boundaries of what is possible in physical human-robot-environment interactions.

List of Speakers and Schedule

Time	Topics	Speaker List
13:25-13:30	Welcome speech	Prof. Xuping Zhang Head of Section for Mechatronics and Dynamics, Department of Mechanical and Production Engineering, Aarhus University, Denmark
13:30-13:50	Sustainable and Resilient SME Production Powered by Cobots	Prof. Xuping Zhang Robotics Lab Department of Mechanical and Production Engineering Aarhus University, Denmark
13:50-14:10	Contact-Rich Manipulation of a Collaborative Industrial Mobile Manipulator: Variable Impedance Control with Imitation Learning	Dr. Zhengxue Zhou, Cooper Group Department of Chemistry University of Liverpool, UK
14:10-14:30	Augmenting Variable Admittance Control with Impedance Observer and Input Shaping for Collaborative Robots	Dr. Xingyu Yang, Robotics Lab Department of Mechanical and Production Engineering Aarhus University, Denmark
14:30-14:50	Active 3D Perception for Cobots	Leihui Li (PhD Student) Robotics Lab Department of Mechanical and Production Engineering Aarhus University, Denmark
14:50-15:00	Discussion and Connection	

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Workshop Talk 1

Sustainable and Resilient SME Production

Powered by Cobots

Xuping Zhang

Head of Section for Mechatronics and Dynamics, Associate Professor, Department of Mechanical and Production Engineering, Aarhus University, Denmark

E-mail: xuzh@mpe.au.dk

Abstract

In the rapidly evolving landscape of modern industry, the transition from Industry 4.0 to Industry 5.0 presents significant advancements and challenges for small and medium-sized enterprises (SMEs). This talk will delve into the background and motivation behind these industrial revolutions, highlighting the unique challenges and opportunities that SMEs face in adapting to these changes.

I will explore the increasing demands for advanced robotic research and development in SME production, focusing on how collaborative robots (cobots) can drive sustainable and resilient production processes. The discussion will include an in-depth look at our innovative cobot solutions and the overarching vision guiding our work.

Drawing from the extensive experience and expertise of the AU Robotics team, I will showcase our research interests and selected industrial projects that exemplify the practical application and benefits of cobots in SME environments. Attendees will gain

valuable insights into how cobots can enhance productivity, sustainability, and resilience in SME production, paving the way for a more integrated and efficient future in industrial operations.

Dr. Xuping Zhang is currently working with Aarhus University as an associate professor and the head of section for Mechatronics and Dynamics. His efforts at Aarhus University focus on establishing the education and research program in robotics. In research, he has built up close and extensive collaborations with the leading collaborative robot manufacturer Universal Robots A/S (Odens, Denmark), the leading wind energy company Vestas Wind Systems A/S (Aarhus, Denmark), and more than 10 manufacturing industries. Dr. Zhang received his Ph.D. in Mechanical Engineering from the University of Toronto in 2009 while studying at the Laboratory for Nonlinear Control. He worked with the Advanced Micro and Nano Systems at the University of Toronto as postdoctoral research associate from 2009 to 2011. He also Worked on dynamics of aircraft as an engineer with Pratt & Whitney Canada from 2011-2012. His research and teaching interest focuses on Design, Modelling, and Control of Robot Systems powered by Machine Learning and Digital Twin Technologies with applications to Robotic Rehabilitation, Robotic Inspection and Maintenance, Robotic Industrial Manufacturing and Production, and Robotic Single-Cell Handling. Dr. Zhang is the author of over 100 papers and has one filed patent. His work in robotic ICSI won the Best Automation Paper Award at the IEEE International Conference on Robotics and Automation 2011, and the Best Conference Paper Award at the IEEE International Conference on Mechatronics and Automation 2019.

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Workshop Talk 2

Contact-Rich Manipulation of a Collaborative Industrial Mobile Manipulator: Variable Impedance Control with Imitation Learning

Zhengxue Zhou,
Cooper Group
Department of Chemistry
University of Liverpool, UK
Email: Z.Z.Zhou@liverpool.ac.uk

Abstract

Variable impedance control (VIC) endows robots with the ability to adjust their compliance, enhancing safety and adaptability in contact-rich tasks. However, determining suitable variable impedance parameters for specific tasks remains challenging. To address this challenge, this research talk presents an imitation learning-based VIC policy that employs sensor fusion observations integrated with RGBD and force/torque (F/T) data enabling a collaborative mobile manipulator to execute contact-rich tasks by learning from human demonstrations. The VIC policy is learned through training the robot in a customized simulation environment, utilizing an inverse reinforcement learning (IRL) algorithm. High-dimensional demonstration data is represented by integrating a 16-layer convolution neural network (CNN) into the IRL environment. To minimize the sim2real Sim-to-Real gap, contact dynamic parameters in the training environment are calibrated. Then, the learning-based VIC policy is comprehensively trained in the customized environment and its transferability is validated through an industrial production case involving a high precision peg-in-hole task using a collaborative mobile manipulator. The training and testing results indicate that the

proposed imitation learning-based VIC policy ensures robust performance for contact-rich tasks.

Dr. Zhengxue Zhou is working as a postdoctoral research associate in the Autonomous Chemistry Laboratory under the Department of Chemistry at University of Liverpool (UK). His current research interest focuses on utilizing AI-powered mobile robot chemists for the discovery of new materials. Prior to joining the Cooper Group, he attained his PhD in robotics from the department of mechanical and production engineering at Aarhus University in Denmark. During his doctoral studies, he developed an industrial mobile manipulator that incorporated learning-based detection and interaction algorithms for the automation of production tasks in small and medium-sized enterprises. Additionally, he collaborated extensively with local companies such as Jydsk Emblem Fabrik, Vestas Aircoil, and NIZE equipment, participating in the development of automation systems and conducting on-site testing of robotic systems.

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Workshop Talk 3

Augmenting Variable Admittance Control with Impedance Observer and Input Shaping for Collaborative Robots

Xingyu Yang

Robotics Group

Department of Mechanical and Production Engineering

Aarhus University, Denmark; E-mail: xingyu_yang@mpe.au.dk

Abstract

The impedance/admittance control has undergone extensive investigation in physical Human-Robot Interaction. However, it remains an open-loop controlled system concerning robot impedance, as impedance lacks direct measurability. Moreover, robot impedance is too abstract and requires a more comprehensive and accurate assessment beyond force/trajectory errors. This talk presents a framework for controlling robot impedance in a closed-loop manner, employing a classical variable admittance controller augmented with an observer to provide feedback on the robot's actual impedance. A mobility-based evaluation approach is proposed for a more rigorous and comprehensive assessment of robot impedance, considering the synthetic effect of impedance parameters and the frequency of input force. Inverse dynamics model-based input shaping is implemented for a more precise trajectory execution. Both indirect and direct approaches for closed-loop controlling robot impedance are proposed. Experimental validations are conducted to evaluate the framework's performance. Results demonstrate the functionality of the impedance observer and input shaping. Both indirect and direct approaches exhibit significant effects on tracking constant impedance. Moreover, the direct approach showcases reductions of 50.79% and 34.73% in magnitude and phase

errors for tracking variable damping. The proposed framework has great potential for facilitating interaction control for contact-rich manipulations with complex variable impedance laws.

Dr. XingyuYang is currently working as a postdoctoral research fellow with Robotics Group, Department of Mechanical and Production Engineering, Aarhus University in Denmark. He received his Ph.D. degree in the Department of Mechanical and Production Engineering at Aarhus University in 2024. He received his B.S. degree in Mechanical Design, Manufacturing, and Automation from Chongqing University in 2017. While studying at the State Key Laboratory of Mechanical Transmissions, he was awarded the China National Scholarship for Postgraduate Students in 2019 and received his M.S. degree in Mechanical Engineering from Chongqing University in 2020. His research interests encompass a wide range of topics, including precision gear transmission, complex gear tooth surface design for spatial gear transmission, hypoid gear design with a low shaft angle, collaborative robot joint dynamics, physical Human-Robot Interaction, computer vision, machine learning, and nonlinear control.

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Workshop Talk 4
Active 3D Perception for Cobots

Leihui Li

Robotics Group

Department of Mechanical and Production Engineering

Aarhus University, Denmark; E-mail: leihui@mpe.au.dk

Abstract:

In this talk consists of two parts. The first part presents Look at Robot Base Once (LRBO), a novel methodology that addresses the hand-eye calibration problem without external calibration objects or human support. This method exploits learning-based 3D detection and registration algorithms to estimate the location and orientation of the robot base. The robustness and accuracy of the method are quantified by ground-truth-based evaluation, and the accuracy result is compared with other 3D vision-based calibration methods. Thence, the second part of this talk presents a no-reference PCQA method that recognizes sparse regions during 3D scanning, providing both local and overall quality scores. The proposed method utilizes geometric information from surfaces fitted to points, mapping to a 2D plane based on specified distance and angle, to analyze points distribution. The experiments on various datasets, including both synthetic and public datasets, are conducted to evaluate the accuracy and robustness of our method. The results show that the method can represent the density on surface more accurate and robust than traditional density calculation method.

Leihui Li is currently a PhD student with Robotics Group, Department of Mechanical and Production Engineering, Aarhus University in Denmark. He received his B.S. degree and M.S. degree in Computer Technology, School of Computer Science and Engineering, Tianjin University of Technology. His research interests lie on 3D Computer Vision, Physical Human-Robot Interaction, machine learning.