Shiyu Zhang

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E-mail: shiyu.zhang@oru.se
Address: Teknikhuset Room 2210, Fakultetsgatan 1, Örebro, Sweden

Research Interests

- Multi-robot coordination
- Human-robot interaction
- Real-time perception, planning and control under uncertainties
- Non-linear optimization
- Machine learning
- Modelling and computation methods for complex optimization problems in real-world applications

Education and work experience

Postdoctoral researcher, Aug. 2019-present

- Multi-Robot Planning and Control Lab, Center for Applied Autonomous Sensor Systems, School of Science and Technology, Örebro University, Örebro, Sweden
- Research and implementation on multi-arm motion coordination and task allocation
- PI: Prof. Federico Pecora

Ph.D. in *Navigation, Guidance and Control*, Sept. 2014-Jan. 2019

- State Key Laboratory of Virtual Reality Technology and Systems, Beihang University, Beijing, China
- Dissertation: Research on Servo-Serial-Manipulator-Based Haptic Interaction System in Virtual Cockpit
- Advisor: Prof. Shuling Dai, Prof. Rui Zhou

Visiting researcher, Apr. 2018-Jun. 2018

- Mechatronics and Robotics Laboratory for Innovation, Politecnico di Milano, Milan, Italy
- Human-robot interaction algorithm development and experiment
- Advisor: Prof. Andrea Zanchettin

B.S. in *Automation*, Sept. 2010-Jun. 2014

- School of Electrical Engineering and Automation, Hefei University of Technology, Hefei, China

Research Experience

- **Online and scalable multi-arm coordination, planning and control (postdoctoral project), Aug. 2019-present**

  I am the scientific and technical lead of the Vinnova project AutoBoomer - Automated Drill Planning for Multiple-Boom Rigs in Underground Mining and studying multi-arm coordination, planning and control under uncertainties. The objective is to **let multiple robot manipulators cooperatively complete a sequence of complex tasks without human assistance**, while guaranteeing safety, optimizing efficiency, being able to **react to online changes and uncertain factors**, and having good **scalability**. The key problem is multi-robot coordination in shared workspaces, including collision avoidance, task allocation, motion planning and control. With the collaboration with Epiroc and Zinkgruvan Mining, the developed technologies are employed in the problems involving **real boomers and mining tasks**.

  Coordination strategy, task allocation and motion planning methods are developed, which allows several

robot arms work safely in a shared workspace [J1, J8]. The methods can deal with uncertainties in task execution online, and the computation time scales linearly with the number of robots by exploiting parallel computation, which have been **verified by experiments with up to three 7-DOF robots and up to ten simulated robots**.

Currently, I continue to study task allocation and motion planning methods, studying planning and control based on reinforcement learning and game theory, model decoupling methods and efficient computation methods for complex problems to further optimize the overall performance.

- **Servo-serial-manipulator-based haptic interaction in virtual reality systems (Ph.D. dissertation), Sept. 2016-Dec. 2018**

  I was responsible for the new project in the lab, haptic interaction with a serial robot in virtual reality systems. The objective is to deal with the long-standing immature haptic interaction in virtual reality systems (especially in virtual cockpit systems).

  A novel haptic interaction scheme, which employs a mechanical system including a robot arm as the haptic feedback manipulator, was developed [P1,P2]. Key scientific problems were extracted and studied to make the initial concept work [J5-J7].

  Later the problem was extended to the general **human-robot interaction** problem and the core problem, **real-time planning and control under uncertainties**, was studied. Methods based on non-linear optimization and machine learning were developed to generate optimal motions for the robot according to the perception information in real-time, which greatly improved the computational efficiency and accuracy of the complex high-dimensional problems, and therefore promoted safe and natural human-robot interactions [J2-J4]. With the collaboration with Politecnico di Milano, the **haptic interaction experiments were performed with a 250Hz real-time system including a 6-DOF robot** [J2, J3].

  The dissertation has been awarded Excellent Doctoral Dissertation of School of Automation Science and Electrical Engineering in Beihang University (2019).

- **Physics-based skinning for the virtual hand, Jan. 2016-Aug. 2016**

  In order to balance the goals among real visual output, physically accurate deformation and real-time performance in virtual manipulation simulation, physics-based simulation methods for virtual hand deformation were developed, including the skeleton-skin hand modelling, the combination of the geometric skinning and physics-based skinning, the dynamics modelling of the skin based on energy optimization and the real-time solver based on the alternating optimization algorithm.

- **Virtual cockpit system construction, Sept. 2014-Dec. 2015**

  Experimental platform of the virtual cockpit system construction, including virtual manipulation based on the data glove, 3D scene construction based on Ogre/ Unity and Virtual scene display based on Oculus Rift.

Publications and Patents

- [J1] Zhang Shiyu, Pecora Federico. Online Sequential Task Assignment with Execution Uncertainties for Multiple Robot Manipulators. *IEEE Robotics and Automation Letters*, online available
- [J2] Zhang Shiyu, Dai Shuling, Zhao Yongjia. Continuous Trajectory Planning Based on Learning Optimization in High Dimensional Input Space for Serial Manipulators. *Engineering Optimization*, accepted
- [J3] Zhang Shiyu, Zanchettin Andrea Maria, Villa Renzo, Dai Shuling. "Real-time trajectory planning based on joint-decoupled optimization in human-robot interaction." *Mechanism and Machine Theory* 144 (2020): 103664.

- [J4] Zhang Shiyu, Dai Shuling, Zanchettin Andrea Maria, Villa Renzo. "Trajectory planning based on non-convex global optimization for serial manipulators." *Applied Mathematical Modelling* 84 (2020): 89-105.
- [J5] Zhang Shiyu, and Dai Shuling. "Real-time kinematical optimal trajectory planning for haptic feedback manipulators." *Simulation* 95.7 (2019): 621-635.
- [J6] Zhang Shiyu, and Dai Shuling. "Workspace analysis for haptic feedback manipulator in virtual cockpit system." *Virtual Reality* 22.4 (2018): 321-338.
- [J7] Zhang Shiyu, and Dai Shuling. "Real-time trajectory generation for haptic feedback manipulators in virtual cockpit systems." *Journal of Computing and Information Science in Engineering* 18.4 (2018): 041015.
- [J8] Zhang Shiyu, Pecora Federico. Loosely-Coupled Motion Coordination for MultipleRobot Manipulators in Shared Workspaces. *IEEE transactions on Robotics* (under second review)
- [P1] Zhang Shiyu, Dai Shuling. *Chinese invention patent*: A Virtual Cockpit System with Haptic Feedback (一种带有力/触觉反馈的虚拟现实飞机座舱系统). (Approved, publication number: CN107221223B)
- [P2] Zhang Shiyu, Dai Shuling. *Chinese invention patent*: A Haptic Feedback System Based on the Servo Manipulator (一种基于伺服机构的主动力触觉反馈系统及其工作方法). (Approved, publication number: CN107728778B)

Projects

- **AutoBoomer - Automated Drill Planning for Multiple-Boom Rigs in Underground Mining, 2019-2022, Vinnova (Sweden's Innovation Agency)**
  - Scientific and technical lead, responsible for theory development and system implementation
- **Learning for Dexterous and Accurate Manipulation of Autonomous Agents, 2019-2021, Key Project on New Generation of Artificial Intelligence (Ministry of Science and Technology of China)**
  - Leading member for proposal writing
- **Research on Haptic Interaction Based on Servo-Serial-Manipulator in Virtual Cockpit Systems, 2017-2019, Project of State Key Laboratory of Virtual Reality Technology and Systems, Beihang University**
  - Scientific and technical lead, responsible for proposal writing, theory development and system implementation

Talks

- **我从人工智能中了解到学习的意义**
  - TED Circles, TEDxShuguangLu, May 2021
- **Smarter Machines or Simpler World: Real-Time Planning and Control**
  - AASS (Center for Applied Autonomous Sensor Systems) Seminar, Örebro University, Sept. 2019
- **Real-time Trajectory Planning of Robots for Haptic Feedback in Virtual Cockpit Systems**
  - Mechatronics and Robotics Laboratory for Innovation, Politecnico di Milano, Apr. 2018
- **Real-time Kinematical Optimal Trajectory Planning for Haptic Feedback Manipulators**
  - 14th Academic Forum for Graduate Students at Beihang University, Dec. 2017

Review service

- IEEE/ASME Transactions on Mechatronics (2021)
- IROS - IEEE/RSJ International Conference on Intelligent Robots and Systems (2021)
- Mechanism and Machine Theory (2020)

- Autonomous Robots (2020)
- ICRA - International Conference on Robotics and Automation (2020)
- Expert Systems with Applications (2020)
- Robotica (2018, 2020)
- Applied Mathematical Modelling (2018)

Skills

- **Research experience** in human-robot interaction, real-time planning and control for robots under uncertainty, optimization, machine learning and computer graphics
- **Programming:** familiar with Matlab/ C/ C++, familiar with robotic planning and control algorithms
- **Robotic platform:** familiar with ROS, experience in ABB and Franka Emika robots development
- **English:** fluent in written and spoken English
- **Mathematics:** optimization theory, numerical analysis, matrix theory, mathematical statistics, control theory, functional analysis, etc

Awards

- Excellent Graduate of Beihang University, 2019
- Excellent Doctoral Dissertation of School of Automation Science and Electrical Engineering, Beihang University, 2019
- Scholarships in Beihang University for five consecutive years
- Second Prize of 4th International Contest of Applications in Nano-Micro Technology, 2013
- Special Prize of 6th Chinese Contest of Applications in Network of Things, 2012
- Scholarships in Hefei University of Technology for four consecutive years