SHAOCHENG LUO

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RESEARCH INTERESTS

I am fascinated by how a team of connected robots can collaborate in a distributed way and perform challenging tasks that are labor-intensive or prohibited to operators, such as aquatic environmental monitoring and operations, while under practical constraints such as connectivity maintenance, collision avoidance, and more. I also strive for solutions to multi-agent systems that are enhanced by collective perceptions for higher efficiency and operator safety protection, which are essential in autonomous driving.

EDUCATION

Postdoctoral Fellow, Department of Computing Science (Specialty: Collective Driving – Shared Perception to Improve Safety of Autonomous Vehicles) *Aug 2020 - present*
University of Alberta, Edmonton, Alberta, Canada
Advisor: Dr. Hong Zhang

Ph.D., Technology (Specialty: Computer and Information Technology) *Aug 2014 - May 2020*
Purdue University, West Lafayette, Indiana, USA
Dissertation: Multi-robot System in Coverage Control: Deployment, Coverage, and Rendezvous
Advisor: Dr. Byung-Cheol Min

M.S., Mechatronic Engineering (Specialty: Industrial Robots and Control) *Sept 2009 - Mar 2012*
Zhejiang University, Hangzhou, China
Thesis: Design of Multi-axis Motion Controller Based on Fieldbus Communications
Advisor: Dr. Shiqiang Zhu

B.S., Mechanical Engineering (Specialty: Automobile Engineering) *Aug 2005 - Jul 2009*
Harbin Institute of Technology, Weihai, China
Thesis: Design of a Steering System for Tracked Vehicles
Advisor: Dr. Binjiu Yang

PUBLICATIONS

Journal Papers:

[1] **Shaocheng Luo**, Jonghoek Kim, and Byung-Cheol Min, "Asymptotic Boundary Shrink Control with Multi-robot Systems", *IEEE Transactions on Systems, Man, and Cybernetics: Systems.* (Accepted)

[2] Tamzidul Mina, Shyam Sundar Kannan, Wonse Jo, **Shaocheng Luo**, Galen B. King, and Byung-Cheol Min, "Distributed Multi-robot Arbitrary Object Transportation with Pushing Surface Identification and Model-based Pushing Effort Regulation", *IEEE Transactions on Systems, Man and Cybernetics: Systems.* (Under review)

[3] Ramviyas Parasuraman, Jonghoek Kim, **Shaocheng Luo**, and Byung-Cheol Min, "Multi-Point Rendezvous in Multi-Robot Systems", *IEEE Transactions on Cybernetics,* Vol. 50 (1), pp. 310-323, 2020.

[4] **Shaocheng Luo**, Jonghoek Kim, Ramviyas Parasuraman, Jun Han Bae, Eric T Matson, and Byung-Cheol Min, "Multi-robot Rendezvous Based on Bearing-aided Hierarchical Tracking of Network Topology", *Ad Hoc Networks,* Vol 86, pp. 131-143, 2019.

[5] Xinglai Jin, Shiqiang Zhu, Wenxiang Wu, and **Shaocheng Luo**, "A Novel Robotic Motion Control Strategy Based on Improved Fuzzy PID and Feedforward Compensation", *Applied Mechanics and Materials,* Vol. 365-366, pp. 821-826, 2013.

[6] **Shaocheng Luo**, Shiqiang Zhu, and Huifang Wang, "Adaptive PID saturate output feedback control of robot manipulators", *Transducer and Microsystem Technologies (Chinese),* Vol. 31 (3), pp. 66-70, 2012.

Conference Papers:

[1] **Shaocheng Luo**, Yogang Singh, Hanyao Yang, Jun Han Bae, J. Eric Dietz, Xiumin Diao, and Byung-Cheol Min, "Image Processing and Model-Based Spill Coverage Path Planning for Unmanned Surface Vehicles", *2019 MTS/IEEE OCEANS,* Seattle, WA, USA, October 27-31, 2019.

[2] Jun Han Bae, **Shaocheng Luo**, Yogang Singh, Bumjoo Lee, Richard M. Voyles, Mauricio Postigo, Edgar Gonzales, Lizbeth Paredes Aguilar, and Byung-Cheol Min, "Development of an Unmanned Surface Vehicle for Remote Sediment Sampling with a *Van Veen* Grab Sampler", *2019 MTS/IEEE OCEANS,* Seattle, WA, USA, October 27-31, 2019.

[3] Manoj Penmetcha, **Shaocheng Luo**, Arabinda Samantaray, J. Eric Dietz, Baijian Yang, and Byung-Cheol Min, "Computer Vision-based Algae Removal Planner for Multi-robot Teams", *2019 IEEE International Conference on Systems, Man and Cybernetics (SMC),* Bari, Italy, October 6-9, 2019.

[4] **Shaocheng Luo**, Jun Han Bae, and Byung-Cheol Min, "Pivot-based Collective Coverage Control with a Multi-robot Team", *2018 IEEE International Conference on Robotics and Biomimetics (IEEE ROBIO 2018),* Kuala Lumpur, Malaysia, December 12-15, 2018.

[5] Walter D. Leon-Salas, Thomas Fischer, Xiaozhe Fan, Golsa Moayeri, and **Shaocheng Luo**, "A 64x64 Image Energy Harvesting Configurable Image Sensor", *IEEE International Symposium on Circuit and Systems (ISCAS 2016),* Montreal, Canada, May 22-25, 2016.

[6] **Shaocheng Luo** and Shiqiang Zhu, "Open Architecture Multi-Axis Motion Control System for Industrial Robot Based on CAN Bus", *Automatic Control and Artificial Intelligence (ACAI 2012),* Xiamen, China, March 24-26, 2012.

Reports and Presentations:

[1] Siqi Yan, Xiaolong Wang, **Shaocheng Luo**, and Hong Zhang, "Collective Driving with Shared Perception to Improve Driving Safety", *Autonomous Systems Initiative (ASI) Real-World Automated Transport Workshop*, University of Alberta, Edmonton, AB, Canada, October 2, 2020.

[2] **Shaocheng Luo**, "Coverage Control Using Multi-robot Systems and Its Applications in Environmental Monitoring and Operations", *Electrical and Computer Engineering Seminar*, University of Louisville, Louisville, KY, USA, March 6, 2020.

[3] **Shaocheng Luo**, "Multi-robot Systems and Their Applications for Greater Human Well-being", *Global Scientist Interdisciplinary Forum at Southern University of Science and Technology (SUSTech)*, Shenzhen, China, January 4, 2020.

[4] **Shaocheng Luo**, "Advances of Multi-robot Systems in Environmental Monitoring and Operations: Three Basic Collective Behaviors", *Shanghai University 2019 International Forum for Young Scholars on Intelligent Vehicle Science & Engineering*, Shanghai, China, November 12, 2019.

[5] **Shaocheng Luo**, Yogang Singh, Hanyao Yang, Junhan Bae, J. Eric Dietz, Xiumin Diao and Byung-Cheol Min, "Coverage Path Planning for Efficient Spill Cleaning in Maritime Environment", *6th Annual*

Environmental Community Mixer, Purdue Discovery Park Center for the Environment (C4E), Purdue University, West Lafayette, IN, USA, October 17, 2019.

[6] Yogang Singh, Junhan Bae, Shyam Sundar Kannan, **Shaocheng Luo**, Wonse Jo, Yuta Haoshi, Jose Garcia, Brittany Newell, Mauricio Postigo, Sara McMillan, Richard Voyles, Lisabeth Leonor Pardes Aguilar, Godofredo Pena, Edgar Gonzales Zenteno and Byung-Cheol Min, "Design and Development of Unmanned Robotic Water Quality Monitoring and Sediment Sampling Systems", *6th Annual Environmental Community Mixer, Purdue Discovery Park Center for the Environment (C4E)*, Purdue University, West Lafayette, IN, USA, October 17, 2019.

[7] **Shaocheng Luo**, "Multi-robot Systems with Applications in Water Environmental Monitoring and Operations", *Research Presentation in Senseable City Lab at MIT,* Cambridge, MA, USA, October 1, 2019.

[8] Junhan Bae, Yogang Singh, **Shaocheng Luo**, Wonse Jo, Yuta Haoshi, Jose Garcia, Brittany Newell, Mauricio Postigo, Sara McMillan, Richard Voyles, Lisabeth Leonor Pardes Aguilar, Godofredo Pena, Edgar Gonzales Zenteno and Byung-Cheol Min, "Robotic Water Quality Monitoring and Sediment Sampling: A Pilot Study", *2019 NEXUS Workshop Poster Presentation*, Purdue University, West Lafayette, IN, USA, July 25, 2019.

[9] **Shaocheng Luo**, Wonse Jo, Jun Han Bae, and Byung-Cheol Min, "A Systematic Solution for Autonomous Aquatic Spill Removal with a Multi-robot Team", *Fall 2018 Realizing the Digital Enterprise (RDE) Graduate Research Poster Session ,* West Lafayette, IN, USA, November 26, 2018.

[10] **Shaocheng Luo** and Byung-Cheol Min, "Algae Harvesting with a Multi-robot Team", *Purdue Dawn or Doom '18 Emerging Technology Conference*, West Lafayette, IN, USA, November 5-6, 2018.

[11] **Shaocheng Luo**, Jun Han Bae, and Byung-Cheol Min, "Oil Spill Cleanup with Multi-robot Systems", *5th Annual Environmental Community Mixer, Purdue Discovery Park Center for the Environment (C4E)*, West Lafayette, IN, USA, October 12, 2018.

[12] **Shaocheng Luo**, Ramviyas Parasuraman, Jun Han Bae, and Byung-Cheol Min, "Environmental Operations with Multi-robot Systems", *2018 Midwest Robotics Workshop (MWRW 2018),* Chicago, IL, USA, June 14-15, 2018.

[13] **Shaocheng Luo**, Tamzidul Mina, Ramviyas Parasuraman, Byung-Cheol Min, "Distributed Algorithms for Coordination of Multi-Robot Systems", *Polytechnic Faculty Convocation 14th Annual Poster Session,* West Lafayette, IN, USA, March 31, 2018.

[14] **Shaocheng Luo**, Ramviyas Parasuraman, Jun Han Bae, Jonghoek Kim, and Byung-Cheol Min, "Robust Multi-Robot Rendezvous Control in Cluttered and GPS-Denied Environments", *Cocktails & Collaboration with Northrop Grumman Poster Session,* West Lafayette, IN, USA, September 13, 2017.

[15] **Shaocheng Luo**, Ramviyas Parasuraman, Jun Han Bae, Sangjun Lee, Jonghoek Kim, and Byung-Cheol Min, "Multi-robot Rendezvous Control and Optimization", *2017 Midwest Robotics Workshop (MWRW 2017),* Chicago, IL, USA, May 18-19, 2017.

[16] **Shaocheng Luo**, Ramviyas Parasuraman, Jun Han Bae, Jonghoek Kim, and Byung-Cheol Min, "Time-Constraint Multi-Robot Rendezvous Control and Optimization", *2017 NSF I/UCRC: Center for Robots and Sensors for the Human Well-being (RoSe-HUB) IAB Meeting,* Minneapolis, MN, USA, April 26-28, 2017.

[17] **Shaocheng Luo**, Jun Han Bae, Ramviyas Parasuraman, Jonghoek Kim, and Byung-Cheol Min, "Bounded Distributed Rendezvous Control while Preserving Connectedness in Cluttered Environments", *2016 NSF I/UCRC: Center for Robots and Sensors for the Human Well-being (RoSe-HUB) IAB Meeting,* Charlotte, NC, USA, November 17-18, 2016.

[18] Jun Han Bae, **Shaocheng Luo**, Jee Hwan Park, Dong Hun Lee, and Byung-Cheol Min, "Water Quality Monitoring System Based on Robotics and Cyber-Physical Systems", *2016 NSF I/UCRC: Center for*

Robots and Sensors for the Human Well-being (RoSe-HUB) IAB Meeting, Charlotte, NC, USA, November 17-18, 2016.

SCHOLARSHIPS AND AWARDS

- Purdue Polytechnic Dean′s Graduate Student Travel Grant, *Oct 2019*. Amount: $300
- Purdue Computer and Information Technology Graduate Student Travel Grant, *Oct 2019*. Amount: $600
- International Travel Support Funds from Purdue Polytechnic Office of Globalization, *Oct 2019*. Amount: $600
- Purdue Graduate Student Government Travel Grant, *Dec 2018*. Amount: $500
- Purdue Polytechnic Dean′s Graduate Student Travel Grant, *Nov 2018*. Amount: $600
- Purdue Computer and Information Technology Graduate Student Travel Grant, *Oct 2018*. Amount: $600
- International Travel Support Funds from Purdue Polytechnic Office of Globalization, *Oct 2018*. Amount: $750
- 2018 Polytechnic Institute Summer Research Scholarship. Amount: $3,333 (Provided by the Graduate School during *May 1 - Aug 15, 2018*)
- 2016 Xinjiang Government Award for Outstanding Self Finance Students Abroad (Awarded by Education Office, Consulate-General of the P. R. China in Chicago), *May 2017*
- SMART Lab 2016 Yearly Most Valuable Person Award from lab director Dr. Byung-Cheol Min, *Jan 2017*
- Kaggle Competition: Shelter Animal Outcomes Prediction (Top 20%), May 2016 - June 2016
- Full Graduate Student Scholarship, Zhejiang University, *Sep 2009 - Mar 2012*
- Kindness Ambassador, Hangzhou Rehabilitation Center for Hearing-impaired Children (HRCHC), *2011*
- Merit Student of Zhejiang University, *2010*
- Provincial Excellent Graduate, Harbin Institute of Technology, *2009*
- Merit Student of Harbin Institute of Technology, *2007* and *2008*
- First Class the People′s Scholarship, Harbin Institute of Technology, *2007*

TEACHING

CNIT 161: Introduction to Programming and Data Management for Smart Manufacturing (Sole Instructor)
Spring 2020
Dept of Computer and Information Technology, Purdue, West Lafayette

- Python and SQL languages are introduced as a combination in this course, for the purpose of database operations.
- Methodologies such as data analysis and business status investigation are introduced and practiced in the scenario of manufacturing.

CNIT 105: Introduction to C Programming Language (Lab Instructor)
Fall 2019, Spring 2019, Fall 2018, Spring 2018, Fall 2017
Dept of Computer and Information Technology, Purdue, West Lafayette, Supervisor: Prof. Guity Ravai

- Average Course Evaluation: 4.6/5.0 (Department Average: 3.0/5.0); Sessions taught per semester: 4; Average number of students per session: 25.
- Designed inlabs, weekly assignments, and exams.

- Was the first one who introduced debugging exercise to students in lab sessions, and got tremendous positive feedback.
- Instructed 6 undergrad lab helpers, because we sometimes recruit a few lab helpers from previous students to provide more immediate response and assistance for new students.

STEM Academic Boot Camp: Introduction to Computer Programming (Sole Instructor)
Summer 2019
Polytechnic Institute, Purdue, West Lafayette, Coordinator: Ms. Antonia Munguia

- This is the course created in Purdue to support the education of first-year college students from underrepresented socioeconomic regions and communities and women in the STEM field. This course met every working day for 1.5 hours and lasted for five weeks. I designed the lectures, labs, and exams.

Introduction to Microprocessors (Sole Instructor)
Fall 2016
SMART Lab, Purdue, West Lafayette, Supervisor: Dr. Byung-Cheol Min

- This is a eight-week long seminar based course for SMART Lab members, including junior PhDs, Masters, and Undergrads, to help them gain knowledge in microprocessors and their applications in Robotics.
- I designed the course and labs, with a specific topic every week on structure of microprocessor, hardware utilities, communication mechanism and protocols, sensor reading, motion control, etc.

PROJECTS

Collective Driving with Shared Perception to Improve Safety in Autonomous Driving
University of Alberta, Edmonton, Supervisor: Dr. Hong Zhang *Aug 2020 - present*
Sponsor: Autonomous Systems Initiative – funded by the Government of Alberta - Economic Development, Trade and Tourism through the Major Innovation Fund (MIF)

- **Cooperative perception for 3D object localization in driving scenarios**
  - Propose a probabilistic Voxelnet that intakes point clouds and generates 3D bounding boxes with uncertainty for traffic participants;
  - Perform fusion by taking shared bounding boxes and their associated probabilities to increase the localization accuracy of the fused box while decreasing its uncertainty.
- **Traffic object association under large perspective changes**
  - Propose a solution to vehicle association between observers (e.g., vehicles or roadside cameras) that have significantly different perspectives;
  - Devise a network that learns the appearance of visually observed vehicles in the form of 3D structural key-points;
  - Perform vehicle association using a GNN (Graph Neural Network) where each node contains the learned structural features as well as the pose of the vehicle to the observers.

Multi-robot systems and control
SMART Lab, Purdue, West Lafayette, Supervisor: Dr. Byung-Cheol Min *Aug 2016 - May 2020*
Sponsor: NSF I/UCRC ROSE-HUB, NSF CAREER (#1846221)

- **Multi-robot coverage control**
  - The multi-robot coverage problem is considered as robots performing a complete coverage to multiple areas in the workspace in a collective manner, the research can be used in hazardous chemical spills cleaning and harmful algae blooms removal;
  - Realized multiple path planning strategies for a diversity of scenarios using geometric tessellation approaches;

  - Incorporated computer vision and deep learning technologies in path planning;
  - Designed a distributed control law that allows strong scalability, while no global coordinate or external localization system is needed.

- **Multi-robot rendezvous control**
  - The rendezvous problem is considered as robots arriving at the selected rendezvous location with minimum communication in unknown environments;
  - Devised a distributed control mechanism with bounded control inputs, and is capable of handling cluttered environment as well as obstacle avoidance dynamically;
  - Developed a multi-point rendezvous mechanism for multi-robot systems, which leverages both rendezvous efficiency and robustness;
  - Validated the efficacy through both simulations and field tests with multiple wirelessly networked robots.

- **Multi-robot task planning**
  - The task planning is essential for a number of discrete working areas which involves robot team partition;
  - Devised a robot team allocation strategy based on optimization and resource distribution;
  - Applied convolutional neural network (CNN) based machine learning techniques to recognize the working areas.

Water and sediment samplings with unmanned surface vehicles
SMART Lab, Purdue, West Lafayette, Supervisor: Dr. Byung-Cheol Min *Nov 2016 - May 2020*
Sponsors: UNSA NEXUS, NSF I/UCRC ROSE-HUB, Purdue Research Foundation (PRF)

- **Unmanned surface vehicle (USV) implementation**
  - We built underactuated USVs which can maneuver and visit decided waypoints to do water and sediment sampling;
  - Implemented two modes for the control of USV – teleoperation with a joystick and autonomous control, on NVIDIA Jetson Nano using ROS, peripherals including GPS sensors, electronic compass, joystick, and motor controllers;
  - Devised a robust navigation control law for the USV that is driven by two parallel propellers.

- **Water/sediment robotic sampler design**
  - Developed a protocol using Ethernet communication for remote control of robotic sampler, the network scalability leads to potentials of constructing a robotics-integrated cyber-physical system (CPS);
  - Designed a real-time monitoring system consisting of data visualization, control panel, Ethernet interfacing, and data storage functionalities using MATLAB graphic user interface (GUI) programming.

ZJU-Sanlian lower-limb robotic exoskeleton aiming at on-site rescue
ZJU Robotics Research Center, Zhejiang University, Supervisor: Dr. Shiqiang Zhu *Feb 2013 - Jul 2014*
Sponsor: Sanlian Co., Ltd.

- The proposed exoskeleton was to assist firefighters in urban search and rescue, which is powered by minimized hydraulic power system.
- Designed the electrical control system using National Instrument CompactRio chassis along with LabView programming; the system takes input of human intention by measuring human-machine interaction via force sensors, and generate output including the angular acceleration, velocity, and displacement of each joint;

- Implemented a Ring topology network for communication that connects different modules such as sensors, actuators, high level and low level controllers, etc.

Multi-axis motion controller (MAMC) tailored for "Qianjiang-I" 6-DOF arc-welding robot
ZJU Robotics Research Center, Zhejiang University, Supervisor: Dr. Shiqiang Zhu *Mar 2010 - Apr 2013*
Sponsor: Zhejiang Province Natural Science Foundation General Project

- Designed the MAMC v2.0, consisting of a Digital Signal Processor (DSP) for high-speed computation in robot control and a Complex Programmable Logic Device (CPLD) for multiple peripheral interfacing;
- Implemented the saturation input feedback control for each of the six joints driven by servo motor, and realized high tracking accuracy for the end effector;
- Realized a CAN fieldbus communication network that connects multiple MAMCs to enable multiple robot collaboration in a factory pipeline.

GRANT WRITING EXPERIENCES

External Research Grants

- **Awarded**
  - CAREER: Adaptive Human Multi-robot Systems, Sponsor: National Science Foundation, PI: Byung-Cheol Min, Amount: **$500,000**, *2019* (Assisted in writing)
  - UNSA NEXUS: Robotic Water Quality Monitoring and Distribution Systems: A Pilot Study, Sponsor: Universidad Nacional de San Agustin, PI: Byung-Cheol Min, Amount: **$365,439**, *2017* (Assisted in writing)
- **Not Awarded**
  - CPS: Medium: Multi-Robot Cyber-Physical Systems for Water Quality Monitoring, Sponsor: National Science Foundation, PI: Byung-Cheol Min, Amount: **$999,638**, *2017* (Assisted in writing)
  - NRI: FND: ARMOUR: Augmented Reality Modus Operandi for Multi-User, Multi-Robot Teams, Sponsor: National Science Foundation, PI: Byung-Cheol Min, Amount: **$686,049**, *2017* (Assisted in writing)

Internal Research Grants

- **Awarded**
  - Purdue Research Foundation (PRF) Summer Faculty Research Grant for 2017: CRAWLER: A Cyber-Physical System for Real-time Autonomous Water and Lakebed Environment Reporting, Sponsor: Purdue University, Sponsor: Purdue University, PI: Byung-Cheol Min, Amount: **$8,000**, *2017* (Assisted in writing)
- **Not Awarded**
  - Purdue Research Foundation (PRF) Summer Faculty Research Grant for 2016, PI: Byung-Cheol Min, Amount: **$8,000**, *2016* (Assisted in writing)

MENTORING EXPERIENCE

Graduate Student Mentoring

- **Siqi Yan** (Master's student with the Department of Computing Science at the University of Alberta, Canada) *Aug 2020 - present*

Undergrad Student Mentoring

- **Hanyao Yang** (Now a Senior Undergrad student in Huaqiao University, China) *July 2019 - Sept 2019*
- **Sangjun Eom** (Now a Master student in CRL, Purdue, West Lafayette) *Aug 2015 - Jan 2016*

- **Taa Soratana** (Now a PhD student in the University of Michigan (Ann Arbor)) *Aug 2015 - Jan 2016*

ACADEMIC SERVICES

Journal Referee

- IEEE Transactions on Systems, Man and Cybernetics: Systems
- IEEE/ASME Transactions on Mechatronics
- IEEE Robotics and Automation Letters (RA-L)
- Journal of Intelligent and Robotic Systems
- International Journal of Advanced Robotic Systems
- International Journal of Adaptive Control and Signal Processing (ACSP)
- Computers & Security (COSE)
- Optimization and Engineering (OPTE)
- International Journal of Adaptive Control and Signal Processing
- International Journal of Advanced Manufacturing Technology

Conference Referee

- IEEE International Conference on Robotics and Automation (ICRA), 2019, 2020 & 2021.
- IEEE International Conference on Robotic Computing (IRC), 2018, 2019 & 2020.
- International Conference on Practical Applications of Agents and Multi-Agent Systems (PAAMS), 2020.
- International Conference on Social Robotics (ICSR), 2016.

PROFESSIONAL ACTIVITIES

- **Program Committee Member**, IEEE International Conference on Robotics and Biomimetics (ROBIO), Dali, China, 2019.
- **Assisted in writing**, A Roadmap for US Robotics: From Internet to Robotics (2016 Edition), §*6.2.2. Environmental Monitoring*, 2016.

PROFESSIONAL MEMBERSHIPS

Institute for Electrical and Electronics Engineers (IEEE), Student Member **2014 - present**

- Technical Committee on Multi-Robot Systems (2019 - present)
- IEEE Robotics and Automation Society (2014 - present)