GUOXIANG ZHAO

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EDUCATION

Pennsylvania State University *University Park, PA*
Ph.D. in Electrical Engineering May 2022
GPA: 3.78/4
Dissertation title: Multi-robot optimal motion planning

Purdue University *West Lafayette, IN*
Master of Science in Mechanical Engineering May 2015
GPA: 3.81/4

Shanghai Jiao Tong University *Shanghai, China*
Bachelor of Engineering in Mechanical Engineering & Automation June 2014
GPA: 87.4/100

RESEARCH INTERESTS

Multi-robot systems, motion planning, distributed control, optimal control, hybrid control, machine learning

RESEARCH EXPERIENCES

Distributed optimal motion planning with dependent goals March 2019 - Present

- A distributed algorithm is proposed to command robots in a **constrained and continuous state space** to goals with **minimal customized cost** subject to **a class of general nonlinear dynamics**;
- Asynchronous policy iterations are executed where robots only share value functions and policies without disclosing local information and **convergence to safe optimal policy** in the continuous state space is formally guaranteed;
- The distributed update fashion relieves the algorithm's dependency of computational complexity on robot number, reduces communication loads and makes it more flexible about robot dynamics and objectives.

Distributed safe reinforcement learning for multi-robot motion planning August 2020 - March 2021

- A **distributed reinforcement learning** algorithm is proposed to coordinate multiple mobile robots;
- A neural network is used to approximate both value and policy function and a **novel gradient-based optimizer with momentum** is proposed to tune weights;
- **Anytime collision avoidance**, uniform and ultimate boundedness of system states and **convergence of neural network controller weights** are formally guaranteed via Lyapunov analysis;
- Simulations show both 10 single integrators and unicycle robots can safely arrive at goal regions.

Distributed multi-robot near-optimal motion planning March 2018 - February 2019

- A scalable algorithm based on a hybrid control scheme is designed to navigate a large fleet of unicycle robots with a **limited communication/sensing rage** to goal regions in **cluttered environment** without causing any collisions;
- Computational complexity is **independent of robot number** and all robots are guaranteed to **reach their destinations within finite time** and **maintain a safe distance** between any two robots and robot-obstacle pairs;
- Simulations demonstrate the scalability of the algorithm using **25** unicycle robots and irregularly-shaped obstacles and also show **minor optimality losses** compared to globally optimal solutions.

Anytime multi-robot optimal motion planning June 2016 - February 2018

- A numerical algorithm is proposed to guide a team of mobile robots in **unstructured and cluttered environment** subject to **general nonlinear dynamics** arrive at their respective goal sets without causing any collisions;
- Via set-valued analysis, each robot's **safe arrival** at goal set with **minimal traveling time** is guaranteed;
- Computer simulations and real-world experiments with **Khepera III robots** and **Vicon system** on a four-way intersection show that the numerical algorithm has anytime property;
- Extensions to high-dimensional nonlinear systems with state constraints are available with minor revisions.

Functional printing control January 2014 - May 2015

· A printing motion control interface EZPrinting is developed to synthesize a HP Thermal Inkjet Printing System with its motion platform for large size printing tasks;
· It automatically calibrates printing motion platform for user specified missions and evaluates printing quality;
· EZPrinting facilitates inkjet surface-functionalized printing technologies and successfully produces test strips for detecting food-borne pathogens.

PUBLICATIONS

- **Journal papers**

  [J2] **Zhao, G.** & Zhu, M. (2022). **Scalable distributed algorithms for multi-robot near-optimal motion planning**. *Automatica*, vol. 140, Article 108637, June 2022. https://doi.org/10.1016/j.automatica.2022.110241

  [J1] **Zhao, G.** & Zhu, M. (2020). **Pareto optimal multi-robot motion planning.** *IEEE Transactions on Automatic Control*, vol. 66, no. 9, pp. 3984-3999, Sept. 2020. https://ieeexplore.ieee.org/document/9204457

- **Conference papers**

  [C3] Lu, Y., Guo, Y., **Zhao, G.** & Zhu, M. (2021). **Distributed safe reinforcement learning for multi-robot motion planning**. In *29th Mediterranean Conference on Control and Automation*, 1209-1214, Bari, Italy.

  [C2] **Zhao, G.** & Zhu, M. (2019). **Scalable distributed algo-rithms for multi-robot near-optimal motion planning.** In *58th IEEE Conference on Decision and Control*, 226–231, Nice, France.

  [C1] **Zhao, G.** & Zhu, M. (2018). **Pareto optimal multi-robot motion planning.** *2018 American Control Conference*, 4020-4025, Milwaukee, WI.

- **Working papers**

  [W1] **Zhao, G.**, Lu, Y., & Zhu, M. **Distributed optimal motion planning with dependent goals**.

- **Patent**

  [P1] Hung, W.-T., Wang, A., Xu, K., **Zhao, G.**, Zhang, B., Yu, N. (2023). **Systems and methods of maintaining map for autonomous driving**, U.S. Patent and Trademark Office. Submitted.

COMPUTER SKILLS

Languages & Packages	Linux Shell, Python, MATLAB, C++, JavaScript, Java, PyTorch/Tensorflow, ROS
Development Tools	Docker, Git, Jenkins, AWS suites (CLI/S3/RDS/DynamoDB/EC2/Lambda/Sagemaker), MongoDB, PostgreSQL, Jira, Confluence, Slack

COURSEWORK

Control & Optimization	Linear Control Systems, Dynamical Systems and Control, Nonlinear Systems, Adaptive and Learning Systems, System Identification, Convex Optimization, Stochastic Optimization
Mechatronics & Robotics	Microprocessing Electromechanical Systems, Electromechanical Motion Devices, Robotic Kinetics and Dynamics, Human Motion Kinetics, Functional Printing
Machine Learning	Pattern Recognition and Machine Learning, Introduction to Reinforcement Learning, Introduction to Deep Learning, Neural Networks
Math	Real Analysis, Stochastic Process, Linear Algebra, Numerical Analysis

ACADEMIC SERVICE

Journal Review

· IEEE Transactions on Automatic Control, IEEE Transactions on Systems, Man and Cybernetics: Systems, IEEE Control Systems Letters, IEEE Open Journal of Control Systems, IET Cyber-Systems and Robotics, International Journal of Aerospace Enginering, Scientific Report - Nature

Conference Review

· CDC 2017, ACC 2018, CDC 2018, ICCA 2018, CDC, 2019, ACC 2020, CDC 2020, ACC 2021, CDC 2021, MED 2021, CDC 2022, ICCA 2022, MECC 2022

TEACHING EXPERIENCE

EE 350 Continuous-Time Linear Systems August 2020 - May 2021
Teaching Assistant *University Park, PA*

· Instructed approximately 20 students weekly to solve recitation exercises and finish MATLAB assignments;
· Designed, proctored and graded monthly exams, held office hours and graded homework.

ME 355 Dynamic Systems Laboratory August 2015 - May 2016
Teaching Assistant *University Park, PA*

· Instructed over 50 students to finish 7 control experiments including robotic arms, magnetic force control and gyroscopes;
· Maintained 8 sets of laboratory apparatus and revised corresponding laboratory manuals.

HONORS AND AWARDS

- Dean's List and Semester Honors, College of Engineering
  Purdue University 2014
- Sun Hung Kai Scholarship
  Shanghai Jiao Tong University 2011-2014
- Timken Scholarship
  Shanghai Jiao Tong University 2012
- B-Level Merit Scholarship Award Top 5%
  Shanghai Jiao Tong University 2013

WORK EXPERIENCES

TuSimple, Inc. January 2022 - January 2023
Software Engineer *San Diego, CA*

· Worked in **Map Platform Team** to develop and maintain tools and services to produce high-definition maps. Supported all Map Ecosystem partners from fixing operational issues to improving user experiences/production efficiencies. Developed new features and optimized applications/infrastructures in catering to needs from map users.
· Designed and developed **Map Renovation Detector** that checks live **visual/LiDAR videos** of operational vehicles, integrated with **GPS/IMU** readings, to identify road condition changes in an event-driven and stream-processing fashion, visualizes changes on UI and requests users to verify if maps need updates. Developed video projector using **C++** to extract and mark changes of each frame and visualize results on UI. Developed **CNN-based** road marker detectors to identify road changes. Developed pipeline filter to eliminate redundant examinations and reduced computations and cost by **40%**. Led **a team of 4** to migrate deployments to AWS EC2 using **Kubernetes**, refactored backend and reduced pipeline cost **from ∼$800/wk to <$60/wk** and UI's response time **from ∼20s to <1s**. Refactored the whole platform to execute examination in a **real-time fashion**.
· Developed **Map Production UI** that visualizes routes on **Mapbox**, allows users to copy/partition/append/merge desired routes collected from operational vehicles, manages and monitors map production pipelines that merge edits into released maps. Refactored UI to support **2 more times** route types and reduced redundant steps by **80%** to improve user experience. Supplied **>30** map specialists with **3 more** GPS-based interactions to increase input efficiency and they dominated all others. Maintained different versions in **>20** environments in catering to more than **4 teams'** development/research needs. Migrated from monolithic server-based application to **cloud-based microservices** that speed up development and deployment.
· Developed **Assignment Management Platform** that dispatches event-triggered tasks to assignees with email/Slack messages, tracks task progress and controls access of different roles. Leveraged **OpenAPI** to support frontend/third-party queries and **PostgreSQL** to manage data. Integrated within **all map services** used by **>40 colleagues** and is being promoted company wise.
· Developed **Business Analytics Services** that collects production statistics/service deployments/git commits using **Java** for company-wise repositories. The Services stores data in **PostgreSQL** and visualizes statistics of service developments and deployments using **Looker**. Integrated with production platform/GitHub/CICD platform to periodically extract service production/development progress and operational health. Established a scalable framework providing **>10 families of tailored metrics** with potential expansions to more criteria.

Shanghai FANUC Robotics, Co., Ltd July 2014 - August 2014
Field Engineer Intern *Shanghai, China*

· Installed robot operation systems and programmed computer vision module of industrial robotic arms;
· Commissioned material handling robotic arms to finish a loading-inspecting-unloading procedure.

LEADERSHIP & SOCIAL SERVICES

Student Affairs Center, Shanghai Jiao Tong University April, 2011 - December, 2012
University Representative of National Student Loan Affairs *Shanghai, China*

· Supervised a team of over 30 members in organizing student loan signing ceremonies semesterly;
· Collaborated with bank representatives on verifying applicants' identities;
· Processed over 1600 student loan applications with a total value over RMB 10M (US$1.6M).

LANGUAGES

Chinese (native), English (professional proficiency)