

# GUOXIANG ZHAO

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## EDUCATION

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### Pennsylvania State University

Ph.D. in Electrical Engineering

GPA: 3.78/4

Dissertation title: Multi-robot optimal motion planning

*University Park, PA*

May 2022

### Purdue University

Master of Science in Mechanical Engineering

GPA: 3.81/4

*West Lafayette, IN*

May 2015

### Shanghai Jiao Tong University

Bachelor of Engineering in Mechanical Engineering & Automation

GPA: 87.4/100

*Shanghai, China*

June 2014

## RESEARCH INTERESTS

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Multi-robot systems, motion planning, distributed control, optimal control, artificial intelligence, deep learning

## RESEARCH EXPERIENCES

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### 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 is designed to navigate a large fleet of unicycle robots with a **limited communication/sensing range** 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.

- 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

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### • 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. (2021). Pareto optimal multi-robot motion planning.** *IEEE Transactions on Automatic Control*, vol. 66, no. 9, pp. 3984-3999, Sept. 2021. <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 algorithms 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. (2021). Distributed optimal motion planning with dependent goals.**

## WORK EXPERIENCES

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### TuSimple, Inc.

*Software Engineer*

January 2022 - Present

*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 **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 wide.
- 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  
Field Engineer Intern

July 2014 - August 2014  
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.

## COMPUTER SKILLS

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

## COURSEWORK

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

## ACADEMIC SERVICE

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### 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 Engineering, 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

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<b>EE 350 Continuous-Time Linear Systems</b>	August 2020 - May 2021
<i>Teaching Assistant</i>	<i>University Park, PA</i>

- 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.

<b>ME 355 Dynamic Systems Laboratory</b>	August 2015 - May 2016
<i>Teaching Assistant</i>	<i>University Park, PA</i>

- 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

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

## LEADERSHIP & SOCIAL SERVICES

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**Student Affairs Center, Shanghai Jiao Tong University**

*University Representative of National Student Loan Affairs*

April, 2011 - December, 2012

*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

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Chinese (native), English (professional proficiency)