

Lei Zheng

Address: 4 Engineering Drive 3, National University of Singapore, Singapore 117583.

Scopus Author ID: 57211810044 ORCID: 0000-0002-8603-0096

Email: zack.zheng@nus.edu.sg Personal Page: <https://zack4417.github.io/>

Research Interests

- Safe learning-based control; generative model; autonomous driving and embodied robot safety.

Academic Appointments

- **National University of Singapore,** Singapore
Research Fellow, Department of Electrical and Computer Engineering
Project: “Safe Learning Using Probabilistic Machine Learning”
2026 - Present
Supervisor: Prof. Armin Lederer
- **Carnegie Mellon University,** Pittsburgh, United States
Visiting Scholar
2025
Supervisor: Prof. Changliu Liu

Education

- **The Hong Kong University of Science and Technology** Hong Kong SAR, China
Ph.D. in Robotics & Autonomous Systems, Systems Hub
2022 – 2025
Robot Motion Planning and Control Lab
Supervisors: Prof. Jun Ma & Prof. Michael Yu WANG
• *Ph.D. Student*, Department of Electronic & Computer Engineering
2023 – 2024
Robotics Institute
Co-Supervisor: Prof. Shaojie Shen
- **Sun Yat-sen University** Guangzhou, China
M.Eng. in Pattern Recognition and Intelligent Systems
2018 – 2021
RAPID Lab, School of Computer Science and Engineering
Supervisor: Prof. Hui Cheng
- **Nanchang University** Nanchang, China
B.Eng. in Automation, School of Information Engineering
2014 – 2018
Outstanding Graduates
Comprehensive Ranking: 1/119

Work Experience

- **XAG - Advancing Agriculture, Senior Robotics Engineer** 2021 – 2022
 - **High-speed navigation for agricultural aerial vehicles**
 - **Robust real-time trajectory generation:** Developed robust real-time trajectory generation algorithms for agricultural aerial vehicles. This was essential to achieve safe and high-speed autonomous flight, and precise spraying in precision farming. Given the high navigation speed, short sensing range, and unknown environments, generating high-quality trajectories in real time poses a significant challenge. To address this, we developed memory-efficient real-time algorithms for trajectory re-planning, and integrated the software into agricultural aerial vehicles to realize **safe, smooth and high-speed navigation (13.8 m/s)**.
 - The associated smooth return and dynamic height adjustment functions have been deployed in about **40 % of agricultural drones in China** in 2022.
 - The associated trajectory replanning algorithm has been deployed in **over 50 countries and regions**.
 - **Backup policy for safety guarantees:** Developed a real-time collision detection algorithm and emergency braking strategy for unmanned vehicle systems.
 - **Simulation environment:** Developed an efficient simulation environment for mapping and planning algorithms based on Unreal Engine 4.
 - **Multi-agent system for precision farming:** Developed robust and real-time safety-critical navigation algorithms for multi-agent systems.

Research Experience

- **National University of Singapore** Supervisor: Prof. Armin Lederer
• **Real-Time Generative Robot Control via Learning-Based Policy Distillation** 2026 – Present
 - Developed a learning-based policy distillation framework that accelerates diffusion-based robot control from iterative sampling to single-pass inference for real-time closed-loop deployment.
 - Designed a Koopman-inspired latent transition module that preserves control-relevant trajectory structure while reducing diffusion-policy inference latency by orders of magnitude.
 - Validated the framework on D4RL MuJoCo locomotion benchmarks and a physical Kinova Gen3 manipulator, demonstrating millisecond-level inference, faster task execution, and reliable obstacle-aware control.
- **Safe Learning with Task-Adaptive Robustness for Humanoid Robot** 2026 – Present
 - Developed a task-adaptive safety filter framework for motion control that enables a legged robot to safely execute long-horizon control tasks in unstructured environments.
 - Aligned the safety filters’ task-dependent robustness with individual motion primitives using on-policy imitation learning and offline reinforcement learning to mitigate distribution shifts.
 - Integrated the safety filter primitives into a language-guided motion intelligence framework, enabling real-world demonstrations such as safely cooking a fried rice dish.
- **Carnegie Mellon University** Supervisor: Prof. Changliu Liu
• **Safety-Critical Whole-Body Control and Contingency Planning under Uncertainty** 2025
 - Investigated safety-critical whole-body control and projected-safe-set methods for humanoid manipulation in cluttered environments, with emphasis on resolving conflicting safety constraints.
 - Deployed contingency planning approaches for safety-critical autonomous vehicles under uncertain and partially observed environments..
- **The Hong Kong University of Science and Technology** Supervisor: Prof. Jun Ma & Prof. Michael Yu WANG
• **Safe Generative Planning via Reachability-Guided Diffusion** 2024 – 2025
 - Developed DualShield, a model predictive diffusion framework that unifies multimodal generative planning with formal safety guarantees for autonomous vehicles under uncertain interactions.
 - Introduced dual use of Hamilton-Jacobi reachability value functions: proactively guiding diffusion denoising toward safe regions, and reactively forming control barrier value functions as safety shields via real-time QP.
 - Designed safety-guided objective functions that steer trajectory generation away from high-risk regions while maintaining dynamic feasibility through model-based rollouts.
- **Barrier-enhanced contingency planning for mobile robots under uncertainties** 2024 – 2025
 - Introduced a consensus safety barrier module to ensure reliable safety coverage in trajectory space under perception uncertainties. This module allows each generated trajectory to share a common consensus segment while accounting for different scenarios, ensuring motion safety and consistency in dense obstacle environments.
 - The parallel consensus alternating direction method of multipliers (ADMM) iterations is leveraged to transform the non-convex NLP planning problem into a series of low-dimensional QP problems. This strategy ensures each generated feasible trajectory adheres to the same consensus segment while enabling large-scale optimization in real time.
 - Performed comprehensive experiments on various autonomous driving tasks utilizing C++ and ROS, showcasing enhanced safety, accuracy, and motion consistency of the proposed approach compared to state-of-the-art parallel trajectory optimization methods in complex obstacle environments.
 - Conducted hardware validation on Ackermann-steering platforms using C++ and ROS, demonstrating enhanced safety, task accuracy, and motion consistency of our approach under perception uncertainty. Experiments featured high-difficulty scenarios, including multi-robot interactive navigation and cluttered urban intersections with dynamic occlusions.
- **Incremental Bayesian learning for fail-operational control** 2023 – 2024
 - Developed an incremental Gaussian process learning framework to estimate unknown environmental disturbances and model residuals in disturbed nonlinear autonomous systems.
 - Integrated GP posterior mean and uncertainty estimates into stochastic fail-operational control barrier functions, enabling the ego system to recover toward a predefined safe state under external disturbances.
 - Derived probabilistic safety and asymptotic recovery guarantees by coupling Bayesian uncertainty quantification with control barrier and Lyapunov arguments.

- Validated the method on autonomous driving scenarios with safety-critical recovery requirements under uncertain interaction and disturbance conditions.

• **Homotopic parallel trajectory optimization** 2023 – 2024

- Leveraged optimal control theory to design a real-time parallel trajectory optimization algorithm for autonomous driving in congested traffic using C++ multi-threading.
- Proposed a barrier-enhanced homotopic parallel trajectory optimization (BHPTO) approach with over-relaxed ADMM for real-time integrated decision-making and planning.
- Conducted extensive experiments with synthetic and real-world datasets in autonomous driving, demonstrating significant improvements in task accuracy, stability, and consistency in various traffic scenarios.

• **Spatiotemporal receding horizon control for autonomous driving** 2022 – 2023

- Developed a computationally efficient safe motion planning scheme for autonomous driving, which leverages multiple shooting method to improve computational efficiency and numerical stability, enabling the accurate accomplishment of complex tasks in dense traffic scenarios in real time
- Deployed the developed algorithms on an autonomous vehicle to realize adaptive cruise driving, lane changing, overtaking, and racing tasks in a mixed dense traffic flow simulation environment based on C++ and ROS 2. In this simulation environment, the human-driven vehicles follow the synthetic intelligent driver model and the actual trajectories from the NGSIM datasets in the San Francisco Bay area.

• **Sun Yat-sen University, RAPID Lab, School of Computer Science and Engineering** Supervisor: Prof. Hui Cheng

• **Learning-Based Safety-Critical Feedback Control under Model Uncertainty** 2018 – 2021

- Developed incremental Gaussian-process models to estimate unknown disturbances and model residuals in nonlinear robotic systems, enabling online adaptation under nonstationary environmental uncertainties.
- Designed event-triggered model update mechanisms to reduce unnecessary GP updates while maintaining real-time uncertainty adaptation for closed-loop control.
- Integrated Bayesian learning with feedback linearization, model predictive control, and CLF/CBF-based safety-critical control to improve tracking performance while maintaining closed-loop stability and safety guarantees.
- Validated the framework on quadrotor trajectory tracking and connected-cruise-control tasks under wind disturbances and uncertain system dynamics.

Teaching

- Teaching Assistant, ROAS 5700, Robot Motion Planning and Control, HKUST (GZ) Spring 2024
- Teaching Assistant, PDEV 6800Y, Introduction to Teaching and Learning in Higher Education, HKUST (GZ) Fall 2024

Selected Honors and Awards

- The Overseas Research Award, HKUST 2025
- **Outstanding Paper Award**, National Postdoctoral Academic Forum on “Internet of Things and Wireless Communication Technology,” China 2020
- National Scholarship, Ministry of Education, China (**top 0.2%**) 2017
- Second Class Prize, National College Student Mathematical Contest in Password, Ministry of Education, China 2017
- Tellhow Scholarship, Nanchang University (**top 0.05%**) 2017
- Jiangling Scholarship, Nanchang University (**top 0.05%**) 2017
- First Class Prize, Asia and Pacific Mathematical Contest in Modeling, China 2016

Professional Services

- **Editorial Service**
 - Associate Editor, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2026
- **Professional Activities**
 - Co-organizer, Workshop on Learning and Formal Methods for Robotics (LAFR), IROS 2026, Pittsburgh, PA, USA

- **Technical Reviewer**

Journals:

- IEEE Transactions on Robotics (TRO)
- IEEE Transactions on Cybernetics (TCYB)
- IEEE Transactions on Industrial Informatics (TII)
- IEEE Transactions on Vehicular Technology (TVT)
- IEEE Robotics and Automation Letters (RA-L)
- Engineering Applications of Artificial Intelligence (EAAI)
- Robotics and Autonomous Systems (RAS)
- Control Engineering Practice (CEP)
- IEEE Control Systems Letters (L-CSS)
- European Journal of Control
- ASME Journal of Dynamic Systems, Measurement and Control

Conferences:

- IEEE International Conference on Robotics and Automation (ICRA)
- IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
- IEEE Conference on Decision and Control (CDC)
- American Control Conference (ACC)
- European Control Conference (ECC)
- IFAC World Congress
- IEEE International Conference on Intelligent Transportation Systems (ITSC)

Publications

- **International Refereed Journals** (*corresponding author, [†]equal contribution)

- [1] **Lei Zheng***, Peiqi Yu, Zengqi Peng, Changliu Liu, and Armin Lederer, “Dynamic Neural Koopman Distillation for Real-Time Robot Control Using Diffusion Models,” [under review at *IEEE Robotics and Automation Letters*], May 2026.
- [2] **Lei Zheng**, Rui Yang, Minzhe Zheng, Zengqi Peng, Michael Yu Wang, and Jun Ma*, “Occlusion-Aware Contingency Safety-Critical Planning for Autonomous Vehicles,” *IEEE Transactions on Cybernetics*, vol. 56, no. 5, pp. 2777 - 2790, May 2026.
- [3] **Lei Zheng**, Rui Yang, Minzhe Zheng, Michael Yu Wang, and Jun Ma*, “Safe and Real-Time Consistent Planning for Autonomous Vehicles in Partially Observed Environments via Parallel Consensus Optimization,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 27, no. 5, pp. 5174 - 5190, May 2026.
- [4] Zengqi Peng, Yubin Wang, Xu Han, **Lei Zheng**, and Jun Ma*, “LearningFlow: Automated Policy Learning Workflow for Urban Driving With Large Language Models,” *IEEE Transactions on Artificial Intelligence*, accepted, 2026.
- [5] Rui Yang, **Lei Zheng**, Shuzhi Sam Ge, and Jun Ma*, “Safe and Non-Conservative Contingency Planning for Autonomous Vehicles via Online Learning-Based Reachable Set Barriers,” *IEEE Transactions on Control Systems Technology*, accepted, 2026.
- [6] **Lei Zheng**, Luyao Zhang, Peiqi Yu, Yifan Sun, Sergio Grammatico, Jun Ma, and Changliu Liu*, “Contingency Planning for Safety-Critical Autonomous Vehicles: A Review and Perspectives,” [under review at *Annual Reviews in Control*], Jan. 2026.
- [7] Rui Yang, **Lei Zheng**, Shuzhi Sam Ge, and Jun Ma*, “Bayesian Learning-Based Safe Feedback Motion Planning for Disturbed Nonlinear Systems With Differential Flatness,” [under review at *Engineering Applications of Artificial Intelligence*], Oct. 2025
- [8] Zengqi Peng, Yubin Wang, **Lei Zheng**, and Jun Ma*, “Bilevel Multi-Armed Bandit-Based Hierarchical Reinforcement Learning for Interaction-Aware Self-Driving at Unsignalized Intersections,” *IEEE Transactions on Vehicular Technology*, vol. 74, no. 6, pp. 8824-8838, June 2025.
- [9] Wenru Liu, Haichao Liu, **Lei Zheng**, Zhenmin Huang, and Jun Ma*, “Synergizing Decision Making and Trajectory Planning Using Two-Stage Optimization for Autonomous Vehicles,” *IEEE Transactions on Vehicular Technology*, vol. 74, no. 4, pp. 5489-5503, April 2025.
- [10] **Lei Zheng**, Rui Yang, Michael Yu Wang, and Jun Ma*, “Barrier-Enhanced Parallel Homotopic Trajectory Optimization for Safety-Critical Autonomous Driving,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 26, no. 2, pp. 2169-2186, Feb. 2025.
- [11] **Lei Zheng**, Rui Yang, Zengqi Peng, Michael Yu Wang, and Jun Ma*, “Spatiotemporal Receding Horizon Control With Proactive Interaction Towards Autonomous Driving in Dense Traffic,” *IEEE Transactions on Intelligent Vehicles*, vol. 9, no. 11, pp. 6853-6868, Nov. 2024.

- [12] **Lei Zheng**, Rui Yang, Zhixuan Wu, Jiesen Pan, and Hui Cheng*, “Safe Learning-based Gradient-free Model Predictive Control Based on Cross-entropy Method,” *Engineering Applications of Artificial Intelligence*, vol. 110, p. 104731, Feb. 2022.
- [13] Zhixuan Wu, Rui Yang, **Lei Zheng**, and Hui Cheng*, “Safe Learning-Based Feedback Linearization Tracking Control for Nonlinear Systems With Event-Triggered Model Update,” *IEEE Robotics and Automation Letters* (Presented at IEEE International Conference on Robotics and Automation), vol. 7, no. 2, pp. 3286-3293, Apr. 2022.
- [14] Rui Yang, **Lei Zheng**, Jiesen Pan, and Hui Cheng*, “Learning-Based Predictive Path Following Control for Nonlinear Systems Under Uncertain Disturbances,” *IEEE Robotics and Automation Letters* (Presented at IEEE International Conference on Robotics and Automation), vol. 6, no. 2, pp. 2854-2861, Apr. 2021.

• **International Refereed Conference Proceedings**

- [1] Hailong Wen, **Lei Zheng**, and Armin Lederer*, “Safely Learning Gaussian Process Safety Filters via Event-Triggered Structured Exploration,” [under review at *Neural Information Processing Systems*], 2026.
- [2] Rui Yang, **Lei Zheng**, Ruoyu Yao, and Jun Ma*, “DualShield: Safe Model Predictive Diffusion via Reachability Analysis for Interactive Autonomous Driving,” *Proceedings of the IEEE International Conference on Intelligent Transportation Systems*, 2026.
- [3] Rui Yang, **Lei Zheng**, Shuzhi Sam Ge, and Jun Ma*, “Bayesian Learning-Based Safe Feedback Motion Planning for Disturbed Nonlinear Systems With Differential Flatness,” *IFAC World Congress*, 2026.
- [4] Minzhe Zheng[†], **Lei Zheng**[†], Lei Zhu, and Jun Ma*, “Occlusion-Aware Consistent Model Predictive Control for Robot Navigation in Occluded Obstacle-Dense Environments,” IEEE International Conference on Robotics and Automation, 2026.
- [5] **Lei Zheng**, “Towards Real-Time Safe Optimization for Autonomous Vehicles under Uncertainties,” *IEEE International Conference on Robotics and Automation Workshop on Robot Safety under Uncertainty from “Intangible” Specifications*, 2025.
- [6] Zengqi Peng, Xiao Zhou, **Lei Zheng**, Yubin Wang, Bo Yang, Jian Huang, and Jun Ma*, “Interaction-Aware Self-Driving at Unsignalized Intersections: A Reward-Driven Automated Curriculum Learning Approach,” *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 5088-5095, Oct. 2024.
- [7] **Lei Zheng**, Rui Yang, Zengqi Peng, Wei Yan, Michael Yu Wang, and Jun Ma*, “Incremental Bayesian Learning for Fail-Operational Control in Autonomous Driving,” *Proceedings of the European Control Conference*, pp. 3884-3891, Jul. 2024.
- [8] **Lei Zheng**, Rui Yang, Zengqi Peng, Haichao Liu, Michael Yu Wang, and Jun Ma*, “Real-Time Parallel Trajectory Optimization With Spatiotemporal Safety Constraints for Autonomous Driving in Congested Traffic,” *Proceedings of the IEEE International Conference on Intelligent Transportation Systems*, pp. 1186-1193, Sep. 2023.
- [9] Zengqi Peng, Xiao Zhou, Yubin Wang, **Lei Zheng**, Ming Liu, and Jun Ma*, “Curriculum Proximal Policy Optimization With Stage-Decaying Clipping for Self-Driving at Unsignalized Intersections,” *Proceedings of the IEEE International Conference on Intelligent Transportation Systems*, pp. 5027-5033, Sep. 2023.
- [10] **Lei Zheng**, Rui Yang, Jiesen Pan, and Hui Cheng*, “Safe Learning-based Tracking Control for Quadrotors under Wind Disturbances,” *Proceedings of the American Control Conference*, pp. 3638-3643, May 2021.
- [11] **Lei Zheng**, Rui Yang, Jiesen Pan, Hui Cheng*, and Haifeng Hu, “Learning-Based Safety-Stability-Driven Control for Safety-Critical Systems under Model Uncertainties,” *Proceedings of the International Conference on Wireless Communications and Signal Processing*, pp. 1112-1118, Oct. 2020.

Patents

• **Invention Patent**

- [1] **Lei Zheng**, Wei Yan, and Jun Ma, “A high-frequency adaptive connected cruise controller for dealing with lane-cutting behavior by surrounding vehicles under external environmental disturbances,” C.N. Patent CN118907092A, filed Jul. 2024, and granted Nov. 2025.
- [2] **Lei Zheng**, Zenghong Chen, and Zhaonian Liu, “Mobile device target point determination method, apparatus, device, and storage medium,” C.N. Patent CN115309149A, filed Jul. 2022, and granted Jul. 2025.
- [3] **Lei Zheng**, Rui Yang, and Hui Cheng, “A UAV safety trajectory tracking method based on predictive control and barrier function,” C.N. Patent CN112666975B, filed Dec. 2020, and granted Mar 2022.
- [4] Jiesen Pan, **Lei Zheng**, and Hui Cheng, “A robust control method based on reinforcement learning and Lyapunov function,” C.N. Patent CN110928189A, filed Dec. 2019, and granted Apr. 2022.
- [5] Rui Yang, **Lei Zheng**, and Hui Cheng, “A learning-based predictive path following control method for rotor UAV,” C.N. Patent CN112416021A, filed Nov. 2020, and granted Dec. 2021.

- [6] Rui Yang, **Lei Zheng**, and Hui Cheng, “A distributed safety learning control method for mobile robot clusters, invention patent,” C.N. Patent CN112506194B, filed Dec. 2020, and granted Mar 2022.
- [7] Xiaobing Li, Xu Wang, Huilong Zhou, **Lei Zheng**, and Hui Cheng, “A peanut grading and shelling machine,” C.N. Patent CN105852155A, filed May 2016, and granted Nov. 2017.

- **Utility Model Patent**

- [1] Xiaobing Li, Xu Wang, Huilong Zhou, and **Lei Zheng**, “A peanut grading and shelling machine,” C.N. Patent CN205902768U, filed May 2016, and granted Jan. 2017.

Invited Talks & Presentations

- [1] “Towards Real-time Safe Optimization for Autonomous Vehicles under Uncertainties,” Junior researcher talk, Atlanta, United States, 2025. *Invited by:* ICRA Workshop on Robot Safety under Uncertainty from “Intangible” Specifications.
- [2] “Real-Time Safe Autonomy: Barrier-Enhanced Control for Autonomous Vehicles under Uncertainty,” Carnegie Mellon University, Pittsburgh, United States, 2025. *Invited by:* Prof. Changliu Liu.
- [3] “Barrier-Enhanced Motion Planning and Control for Safety-Critical Mobile Robots,” KTH Royal Institute of Technology, Stockholm, Sweden, 2024. *Invited by:* Prof. Jana Tumova.
- [4] “Efficient Autonomous Driving in Congested Traffic,” Greater Bay Area Intelligent Connected Vehicles and Autonomous Systems Forum, Shenzhen, China, 2023. *Invited by:* HKUST Shenzhen-Hong Kong Collaborative Innovation Research Institute.

Skills

- **Programming Tools:**

- **Programming Tools:** C++, Python, MATLAB, LaTeX, PyTorch, ROS/ROS 2, Git.

- **Language Proficiency:**

- English: C1 CEFR level.
- Chinese: Native speaker.