Lei Zheng

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Research Interests

- Robotics; autonomous vehicles; safety-critical control; motion planning; nonparametric Bayesian learning

Education

- **The Hong Kong University of Science and Technology** — Hong Kong SAR, China
  Ph.D. in Robotics & Autonomous Systems, Systems Hub — Sep. 2022 – Oct. 2025
  Robot Motion Planning and Control Lab — Supervisor: Prof. Jun Ma & Prof. Michael Yu WANG
- **The Hong Kong University of Science and Technology** (CWB) — Hong Kong SAR, China
  Ph.D. in Robotics & Autonomous Systems, Department of Electronic & Computer Engineering — Aug. 2023 – Aug. 2024
  Robotics Institute — Supervisor: Prof. Jun Ma & Prof. Shaojie Shen
- **Sun Yat-sen University** — Guangzhou, China
  M.Eng. in Pattern Recognition and Intelligent Systems — Sep. 2018 – Jul. 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 — Sep. 2014 – Jul. 2018
  Outstanding Graduates — Comprehensive Ranking: 1/119

Academic Appointments

- **National University of Singapore**, — Singapore
  Research Fellow, Department of Electrical and Computer Engineering — Jan. 2026 - Present
  Project: "Safe Learning Using Probabilistic Machine Learning" — Supervisor:Prof. Armin Lederer
- **Carnegie Mellon University,** — Pittsburgh, United States
  Visiting Scholar — Feb. 2025 – Aug. 2025
  Intelligent Control Lab, Robotics Institute, School of Computer Science — Supervisor: Prof. Changliu Liu

Work Experience

- **XAG - Advancing Agriculture, Senior Robotics Engineer** — Jul. 2021 – Jul. 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

- **Carnegie Mellon University** Supervisor: Prof. Changliu Liu
  - **Whole-Body Control and Contingency Planning for Safety Under Uncertainty** Feb. 2025 – Aug. 2025
    - Implemented whole-body control strategies for humanoid robots to ensure operational safety under uncertainties.
    - Applied the projected safe set algorithm for safe manipulation in cluttered environments, resolving conflicting constraints to minimize safety violations.
    - Deployed contingency planning approaches for safety-critical autonomous vehicles under uncertainties.

- **The Hong Kong University of Science and Technology** Supervisor: Prof. Jun Ma & Prof. Michael Yu WANG
  - **Safe Generative Planning via Reachability-Guided Diffusion** Oct. 2024 – Present
    - 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** Mar. 2024 – Oct. 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** Oct. 2023 – Mar. 2024
    - Introduced a learning-based controller to guide nonlinear autonomous systems back to a predefined safe state asymptotically, while upholding task efficiency in the presence of external disturbances.
    - Developed a stochastic fail-operational barrier by utilizing the control barrier function in conjunction with the estimated environmental disturbances obtained through the incremental learning process.
    - Conducted theoretical analyses to ensure probabilistic asymptotic stability, thereby converging the unsafe ego agent back to a defined safe set under external disturbances.
  - **Homotopic parallel trajectory optimization** Sep. 2023 – Present
    - We leveraged optimal control theories to design a real-time parallel trajectory optimization algorithm for autonomous driving in congested traffic using an iterative parallel method based on C++ multi-threading techniques.
    - 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** Sep. 2022 – Aug. 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
    - We have programmed 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 predictive path following control** Jul. 2020 – Jun. 2021
    - Developed a learning-based MPFC control paradigm for nonlinear systems under uncertain disturbances, which leveraging a high-level model predictive contouring controller for proactivity with a low-level Bayesian learning-based feedback linearization controller for adaptivity and real-time computation consideration.
    - The designed algorithm enabled nonlinear systems to rapidly and safely rejoin their reference trajectory after experiencing non-stationary wind disturbances with stability guarantees.
    - The algorithm was implemented on a quadrotor, and demonstrated excellent predictive, safety, and high-accuracy control performance in the presence of aerodynamic disturbances.
  - **Safe incremental Bayesian learning for uncertain airflow estimation and adaptation** Jul. 2020 – Mar. 2021
    - Designed efficient incremental Gaussian processes accounting for airflow uncertainties.
    - Estimated wind disturbances caused by external environments to enhance flight safety and maintain control stability in cluttered areas. Utilized these estimates to compensate for related control errors, ensuring reliable navigation.
  - **Learning-based safety-critical control** Mar. 2018 – Jul. 2020
    - Designed an online learning safety-critical control algorithm in QP form for high relative degree nonlinear systems under uncertainties, integrating learning-based control Lyapunov functions and control barrier functions. Achieved safe and accurate control performance with theoretical stability and safety guarantees.
    - Realized safe connected cruise control and tracking control for autonomous vehicles and quadrotors under external disturbances.

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
- Top grade scholarship, Nanchang University 2016 - 2018

Professional Services

- Academic Consultant
  - U.S. News & World Report Best Colleges Ranking (US News Ranking), Reputation Expert (Asian area)
- Technical Reviewer
  - IEEE Transactions on Cybernetics (TCYB)
  - Engineering Applications of Artificial Intelligence (EAAI)
  - Robotics and Autonomous Systems (RAS)
  - IEEE Robotics and Automation Letters (RA-L)
  - IEEE Control Systems Letters (L-CSS)
  - 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**, 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 Review in Control*], Jan. 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*, accepted, 2025.

[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," [under review at *Engineering Applications of Artificial Intelligence*], Oct. 2025.

[4] 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," [under review at *IEEE Transactions on Control Systems Technology*], June 2025.

[5] **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*, accepted, 2025.

[6] 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.

[7] 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.

[8] **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.

[9] Zengqi Peng, Yubin Wang, Xu Han, **Lei Zheng**, and Jun Ma*, "LearningFlow: Automated Policy Learning Workflow for Urban Driving With Large Language Models," *arXiv preprint arXiv:2501.05057* [under review at *IEEE Transactions on Artificial Intelligence*], Jan. 2025.

[10] **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.

[11] **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.

[12] 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.

[13] 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] 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 *IFAC World Congress*], Oct. 2025.

[2] Minzhe Zheng†, **Lei Zheng**†, Lei Zhu, and Jun Ma*, "Occlusion-Aware Consistent Model Predictive Control for Robot Navigation in Occluded Obstacle-Dense Environments," *arXiv preprint arXiv:2503.04563* [under review at *IEEE International Conference on Robotics and Automation*], Sep. 2025.

[3] **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.

[4] 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.

[5] **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.

[6] **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.

[7] 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.

[8] **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.

[9] **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:**
  - C++, Python, MATLAB, LaTex.
- **Language Proficiency:**
  - English: C1 CEFR level.
  - Chinese: Native speaker.