Lei Zheng

Robotics & Autonomous Systems Thrust
The Hong Kong University of Science and Technology (GZ Campus)
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Research Interests

- Robotics, autonomous driving, unmanned aerial vehicles, motion planning and control, nonparametric Bayesian learning

Education

- **The Hong Kong University of Science and Technology** (GZ Campus) Guangzhou, China
  Ph.D. in Robotics & Autonomous Systems, Systems Hub Sept. 2022– Present
  Robot Motion Planning and Control Lab Supervisor: Prof. Jun Ma & Prof. Michael Yu WANG
- **The Hong Kong University of Science and Technology** (CWB Campus) Hong Kong SAR, China
  Ph.D. in Robotics & Autonomous Systems, Department of Electronic & Computer Engineering Aug. 2023– Present
  Robotics Institute Supervisor: Prof. Jun Ma & Prof. Shaojie Shen
- **Sun Yat-sen University** Guangzhou, China
  M.Eng. in Pattern Recognition and Intelligent Systems Sept. 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 Sept. 2014 – Jul. 2018
  Outstanding Graduates Average Mark: 89.79/100, Comprehensive Ranking: 1/119

Work Experience

- **XAG - Advancing Agriculture, Senior Robotics Engineer** Jul. 2021 – Jul. 2022
  - **High-speed navigation for agricultural aerial vehicles**
    - **Robust real-time trajectory generation:** I 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 posed 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 (13.8m/s)**.
    - The associated smooth return and dynamic height adjustment function have been used in about **40 % of agricultural drones in China** in 2022.
    - The associated trajectory replanning algorithm has been used 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 multi-agent algorithms for motion planning.

Research Experience

- **The Hong Kong University of Science and Technology** Supervisor: Prof. Jun Ma & Prof. Michael Yu WANG
  - **Incremental Bayesian learning for fail-operational control in autonomous driving** Oct. 2023 – Present
    - This controller is designed to guide autonomous vehicles back to a predefined safe state asymptotically, while upholding task efficiency.
    - A stochastic fail-operational barrier is developed by utilizing control barrier function in conjunction with the estimated environmental disturbances obtained through the incremental learning process.
    - A rigorous theoretical analysis of probabilistic asymptotic stability is provided with the aim of converging the unsafe EV back to a defined safe set.
  - **Homotopic parallel trajectory optimization for autonomous driving** Sept. 2023 – Present

- We leverage 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.
- We propose a barrier-enhanced homotopic parallel trajectory optimization (BHPTO) approach with over-relaxed alternating direction method of multipliers (ADMM) for real-time integrated decision-making and planning.
- Through a series of experiments, the proposed development demonstrates improved task accuracy, stability, and consistency in various traffic scenarios using synthetic and real-world traffic datasets.

• Spatiotemporal receding horizon planning for autonomous driving Sept. 2022 – Aug. 2023
We developed safe and efficient motion planning strategies for autonomous vehicles to achieve high-task performance in dense traffic scenarios, where surrounding vehicles exhibit multi-modal behaviors. We leverage optimal control theories to design a real-time motion planning algorithm through constraint transformation and multiple shooting techniques. Furthermore, we have programmed the developed algorithms on an autonomous car to realize adaptive cruise driving, lane changing, overtaking, and racing tasks in a mixed dense traffic flow simulation environment based on C++ and ROS. 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

• Time reallocation for trajectory replanning 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.

• Uncertain airflow estimation and adaptation Jul. 2020 – Mar. 2021
Designed efficient incremental Gaussian Processes accounting for airflow uncertainties. The wind disturbance caused by the external environment is estimated to improve flight safety and control stability in cluttered environments. Following that, the estimated wind disturbance is used to compensate for the associated control error.

• Safe Learning-based Control Mar. 2019 – Jul. 2020
Designed efficient and elegant online-learning QP control algorithm for high relative degree nonlinear systems under uncertainties, integrating learning-based control Lyapunov functions and control barrier functions, which achieves safer and more accurate control performance with theoretical guarantees of stability and safety. Following that, we realized connected cruise control for autonomous vehicles in mixed traffic flow.

• Safe Reinforcement learning Mar. 2018 – Mar. 2019
Developed a safe reinforcement learning framework for quadrotors, which involved leveraging control barrier functions and ensemble learning to address uncertainties and achieve safe control performance.

Selected Honors and Awards

- **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, MathorCup Global Mathematical Modeling Challenge, China 2017
- Second Class Prize, National College Student Mathematical Contest in Password, Ministry of Education, China 2017
- Honorable Mention, The International Mathematical Contest in Modeling, United States 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)
  - IEEE Robotics and Automation Letters (RA-L)
  - IEEE International Conference on Robotics and Automation (ICRA)
  - IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)

◦ European Control Conference (ECC)
◦ IEEE International Conference on Intelligent Transportation Systems (ITSC)

Publications

- **International Refereed Journals** (*represents the corresponding author)

[1] **Lei Zheng,** Rui Yang, Michael Yu Wang, and Jun Ma*, "Barrier-Enhanced Homotopic Parallel Trajectory Optimization for Safety-Critical Autonomous Driving," arXiv preprint arXiv:2402.10441, 2024.

[2] **Lei Zheng,** Zengqi Peng, Rui Yang, Michael Yu Wang, and Jun Ma*, "Spatiotemporal Receding Horizon Control with Proactive Interaction Towards Autonomous Driving in Dense Traffic," arXiv preprint arXiv:2308.05929, 2023.

[3] **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 (EAAI),* vol. 110, Feb. 2022.

[4] 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 (RA-L) (Presentation at ICRA),* vol. 6, issue 2, pp. 2854-2861, April 2021.

[5] 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 (RA-L) (Presentation at ICRA),* vol. 7, no. 2, pp. 3286-3293, April 2022.

- **International Refereed Conference Proceedings**

[1] **Lei Zheng,** Rui Yang, Zengqi Peng, Wei Yan, Michael Yu Wang, and Jun Ma*, "Incremental Bayesian Learning for Fail-Operational Control in Autonomous Driving," submitted to *European Control Conference (ECC).*

[2] 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," submitted to *IEEE International Conference on Robotics and Automation (ICRA).*

[3] **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," accepted by *IEEE International Conference on Intelligent Transportation Systems (ITSC).*

[4] 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," accepted by *IEEE International Conference on Intelligent Transportation Systems (ITSC).*

[5] **Lei Zheng,** Rui Yang, Jiesen Pan, and Hui Cheng*, "Safe Learning-based Tracking Control for Quadrotors under Wind Disturbances," *Proceedings of American Control Conference (ACC),* pp. 3638-3643, May 2021.

[6] **Lei Zheng,** Rui Yang, Jiesen Pan, and Hui Cheng*, and Haifeng Hu, "Learning-Based Safety-Stability-Driven Control for Safety-Critical Systems under Model Uncertainties," *International Conference on Wireless Communications and Signal Processing (WCSP),* pp. 1112-1118, Oct. 2020.

Patents

- **Invention Patent**

[1] **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 issued Nov. 2022.

[2] 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.

[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] 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.

[5] 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.

[6] 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, **Lei Zheng,** "A peanut grading and shelling machine," C.N. Patent CN205902768U, filed May 2016, and granted Jan. 2017.

Skills

- **Programming Tools:**
  - C++, Python, MATLAB, Latex.
- **Language Proficiency:**
  - English: IELTS 7.0 (C1 CEFR level).
  - Chinese: Native speaker.