Lei Zheng

Robotics & Autonomous Systems Thrust
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Research Interests

- Robotics, autonomous driving, unmanned aerial vehicles, multi-agent systems, motion planning and control

Academic Appointment

- **Sun Yat-sen University** Guangzhou, China
  Visiting Students Mar. 2018 – Sept. 2018
  RAPID Lab, School of Computer Science and Engineering Supervisor: Prof. Hui Cheng

Education

- **The Hong Kong University of Science and Technology** (GZ Campus) Guangzhou, China
  Ph.D. in Robotics & Autonomous Systems Thrust, Systems Hub Sept. 2022– Present
  Robotics Institute Supervisor: Prof. Jun Ma
- **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:** To achieve high-speed autonomous flight of aerial vehicles and realize high-performance precision spraying in precision farming. Trajectories must be generated in real-time to avoid collision and be close to the reference spraying path. Because of the high navigation speed, short sensing range, and unknown environments, response time is extremely limited, making generating high-quality trajectories a significant challenge. To plan high-quality trajectories in real-time, we developed memory-efficient real-time algorithms for trajectory re-planning and integrated software into agricultural aerial vehicles to realize **safe, smooth and high-speed navigation (13.8m/s)**.
    - The associated smooth return function has 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

- **Safe Learning-based Control**
  - **Real-time safety-critical 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.
  - **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.

- **Trajectory Optimization**

  • **Time reallocation for trajectory replanning** Jul. 2020 – Jun. 2021

  Designed a learning-based MPFC control paradigm for nonlinear systems under uncertain disturbances, coupling a high-level model predictive path following controller for proactivity with a low-level learning-based feedback linearization controller for adaptivity. Following that, nonlinear systems can rapidly rejoin their reference trajectory after sudden wind disturbances with stability guarantees. We programmed the designed algorithms on a quadrotor, which shows predictive and high-accuracy control performance in the presence of aerodynamic disturbances.

  • **Multi-Modal receding horizon planning for autonomous driving** Spet. 2022 – Present

  This ongoing project aims to develop autonomous driving strategies in challenging driving scenarios, including cruise driving, lane changing, vehicle following, and overtaking maneuvers, based on receding horizon optimization and ROS 2. We utilize model predictive control theories to design **a trajectory tree** algorithm using an iterative parallel method. Furthermore, we have programmed the developed algorithms on an autonomous car to achieve the above tasks in a mixed traffic flow simulation environment. In this simulation environment, the human-driven vehicles follow the synthetic intelligent driver model and the actual trajectories from the NGSIM data set in the San Francisco Bay area.

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/RSJ International Conference on Intelligent Robots and Systems (IROS)

Publications

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

  [1] **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.

  [2] 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.

  [3] 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, 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.

  [2] **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, "Mobile device target point determination method, apparatus, device and storage medium," C.N. Patent, filed Jul 2022 "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.