XUSHENG LUO

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RESEARCH INTERESTS

Topics: Robotics; control; machine learning & AI; assured autonomy; optimization; decision making; verification.

Overview: I am broadly interested in developing principled algorithms that empower general-purpose autonomous robots to operate safely and effectively in human environments, while maintaining robustness against real-world disturbances and adversarial attacks. I approach this problem through the lens of rigorous system design, precisely *specifying* requirements followed by *synthesizing* solutions in a principled manner, with the support of *verification* processes.

ACADEMIC EMPLOYMENT

Carnegie Mellon University Pittsburgh, PA

- Postdoctoral Fellow at the Robotics Institute, School of Computer Science *Apr. 2023 – Present*
- *Advisor*: Prof. Changliu Liu

EDUCATION

Duke University Durham, NC

- Ph.D. in Mechanical Engineering | Concentration: Robotics *Aug. 2017 – Dec. 2020*
- M.S. in Mechanical Engineering | GPA: 3.9/4.0 *Aug. 2017 – May 2020*
- *Advisor*: Prof. Michael M. Zavlanos
- *Dissertation*: Scalable Control Synthesis for Multi-Robot Systems under Temporal Logic Specifications

Harbin Institute of Technology Harbin, China

- M.S. in Aerospace Engineering | GPA: 90.7/100 (Rank: 8/199) *Aug. 2015 – Jun. 2017*
- B.S. in Aerospace Engineering | Honors School (top 5%) | GPA: 90.73/100 (Rank: 1/9) *Sep. 2011 – Jun. 2015*
  - Formerly majored in Computer Science (2011–2012); transitioned to Aerospace Engineering

PUBLICATIONS

* indicates equal contribution.

I have published 6 peer-reviewed journal papers, 7 peer-reviewed conference papers, and 4 peer-reviewed workshop papers in top robotics, control and system venues, such as T-RO, RA-L, Automatica, RSS, CDC, T-CPS, ICCPS.

Refereed Journal Publications

[1] **Xusheng Luo**, Changliu Liu, "Simultaneous Task Allocation and Planning for Multi-Robots under Hierarchical Temporal Logic Specifications". *arXiv:2401.04003*, *IEEE Transactions on Robotics*, 2025.

[2] **Xusheng Luo**, Tianhao Wei, Simin Liu, Ziwei Wang, Luis Mattei-Mendez, Taylor Loper, Joshua Neighbor, Casidhe Hutchison, and Changliu Liu. "Certifying Robustness of Learning-Based Keypoint Detection and Pose Estimation Methods". *ACM Transactions on Cyber-Physical Systems* 9, no. 2 (2025): 1-26.

[3] **Xusheng Luo**, Shaojun Xu, Ruixuan Liu and Changliu Liu. "Decomposition-based Hierarchical Task Allocation and Planning for Multi-Robots under Hierarchical Temporal Logic Specifications". *IEEE Robotics and Automation Letters*, 2024, with presentation at ICRA 2025

[4] **Xusheng Luo** and Michael M Zavlanos. "Temporal Logic Task Allocation in Heterogeneous Multi-robot Systems". *IEEE Transactions on Robotics*, 38(6):3602-3621, 2022.

[5] **Xusheng Luo**, Yiannis Kantaros, and Michael M Zavlanos. "An Abstraction-Free Method for Multirobot Temporal Logic Optimal Control Synthesis". *IEEE Transactions on Robotics*, 37(5):1487–1507, 2021.

[6] **Xusheng Luo**, Miroslav Pajic, and Michael M. Zavlanos. "An Optimal Graph-Search Method for Secure State Estimation". *Automatica* 123 (2021): 109323.

Refereed Conference Proceedings

[7] Zhongqi Wei*, **Xusheng Luo***, Changliu Liu, "Hierarchical Temporal Logic Task and Motion Planning for Multi-Robot Systems". *Robotics: Science and Systems*, 2025.

[8] Tianhao Wei, Luca Marzari, Kai Yun, Hanjiang Hu, Peizhi Niu, **Xusheng Luo** and Changliu Liu. "ModelVerification.jl: a Comprehensive Toolbox for Formally Verifying Deep Neural Networks". *International Conference on Computer Aided Verification*, 2025.

[9] Shiqi Sun, Yan Zhang, **Xusheng Luo**, Panagiotis Vlantis, Miroslav Pajic, and Michael M. Zavlanos. "Formal Verification of Stochastic Systems with ReLU Neural Network Controller". *IEEE 39th International Conference on Robotics and Automation (ICRA)*, Philadelphia, USA, 2022.

[10] Yijie Zhou, Yan Zhang, **Xusheng Luo**, and Michael M. Zavlanos. "Human-in-the-loop Robot Planning with Non-Contextual Bandit Feedback". In *2021 60th IEEE Conference on Decision and Control (CDC)*, pp. 2848-2853. IEEE, 2021

[11] **Xusheng Luo***, Yan Zhang*, and Michael M. Zavlanos. "Socially-aware Robot Planning via Bandit Human Feedback". In *2020 ACM/IEEE 11th International Conference on Cyber-Physical Systems (ICCPS)*, pp. 216-225. IEEE, 2020.

[12] Le, Duc M., **Xusheng Luo**, Leila J. Bridgeman, Michael M. Zavlanos, and Warren E. Dixon. "Single-Agent Indirect Herding of Multiple Targets using Metric Temporal Logic Switching". In *2020 59th IEEE Conference on Decision and Control (CDC)*, pp. 1398-1403. IEEE, 2020.

[13] **Xusheng Luo**, and Michael M. Zavlanos. "Transfer Planning for Temporal Logic Tasks". In *2019 IEEE 58th Conference on Decision and Control (CDC)*, pp. 5306-5311. IEEE, 2019.

Refereed Workshop Publications

[14] **Xusheng Luo**, Tianhao Wei, Simin Liu, Ziwei Wang, Luis Mattei-Mendez, Taylor Loper, Joshua Neighbor, Casidhe Hutchison, Changliu Liu, "Certifying Robustness of Learning-Based Keypoint Detection and Pose Estimation Methods". Workshop on *Public Trust in Autonomous Systems, IEEE International Conference on Robotics and Automation (ICRA)*, 2025.

[15] **Xusheng Luo** and Changliu Liu. "Hierarchical Temporal Logic Specifications for Abstract Safety Tasks". Workshop on *Robot safety under uncertainty from "intangible" specifications, IEEE International Conference on Robotics and Automation (ICRA)*, 2025.

[16] **Xusheng Luo***, Shaojun Xu* and Changliu Liu. "Obtaining Hierarchy from Human Instructions: an LLMs-based Approach". Workshop on *Learning Effective Abstractions for Planning (LEAP), Conference on Robot Learning (CoRL)*, 2023.

[17] **Xusheng Luo**, Shaojun Xu, Ruixuan Liu and Changliu Liu. "Robotic Planning under Hierarchical Temporal Logic Specifications". Workshop on *Formal Methods Techniques in Robotics Systems: Design and Control, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2023.

Preprints

[18] Shaojun Xu*, **Xusheng Luo***, Yutong Huang, Letian Leng, Ruixuan Liu, Changliu Liu, "NL2HLTL2PLAN: Scaling Up Natural Language Understanding for Multi-Robots Through Hierarchical Temporal Logic Task Representation". *arXiv:2408.08188*, 2024 (*IEEE Robotics and Automation Letters*, revise and resubmit).

[19] Ruixuan Liu, Alan Chen, **Xusheng Luo** and Changliu Liu. "Simulation-aided Learning from Demonstration for Robotic LEGO Construction". *arXiv:2309.11010*, 2023.

AWARDS AND HONORS

- NSF Cyber-Physical System (CPS) Rising Stars (16.4%=36/220) *2024*
- Student Travel Grant for the IEEE 59th Conference on Decision and Control *2020*
- Outstanding Graduate of Harbin Institute of Technology *2015, 2017*
- The Samsung Scholarship *2016*
- Summer School Scholarship at Technion in Israel *2016*
- National Endeavor Fellowship *2012, 2014*

WORK AND RESEARCH EXPERIENCE

Intelligent Control Lab, Carnegie Mellon University *Apr. 2023 – Present*
Postdoctoral Fellow, supervised by Prof. Changliu Liu Pittsburgh, PA

- Created hierarchical task specification language for symbolic AI, incorporating a convex optimization-based algorithm to address long-horizon Simultaneous Task Allocation and Motion Planning (STAMP) for multiple robot arms.
- Designed a Large Language Model (LLM)-based framework to translate human instructions into hierarchical task specifications, evaluating in simulator AI2-THOR for mobile manipulation tasks.
- Developed and trained a keypoint detection neural network using PyTorch, converted the model to Flux in Julia via ONNX, and designed a verification framework for the local robustness of learning-enabled keypoint-based 6D object pose estimation from images in collaboration with Boeing.

DJI *Jan. 2021 – Feb. 2023*
Autonomous Driving Research Engineer, Planning Shenzhen, China

- Enhanced vehicle interaction models and speed profiles for adaptive lane changes in both mandatory and discretionary scenarios using C++, aligned with AUTOSAR standards. This functionality was integrated into a product and released.
- Developed safe and comfortable vehicle trajectory optimization based on the iterative Linear Quadratic Regulator (iLQR), effectively handling both static and dynamic constraints.
- Led a team of three engineers in developing a memory-enhanced driving framework, enabling vehicles to learn driving behaviors on specific routes. Designed and implemented the core architecture with a focus on route planning.
- Collaborated cross-functionally with system, perception and testing teams, and handed off the memory-enhanced driving framework to the engineering team, contributing to its market launch.
- Designed and implemented a multi-layer hierarchical evaluation framework for behavior planning and trajectory selection—including yield, overtaking, and lane changes—in urban driving scenarios, enhancing decision-making capability.

Zavlanos's Lab, Duke University *Aug. 2017 – Dec. 2020*
Research Assistant, supervised by Prof. Michael M. Zavlanos Durham, NC

- Developed a sampling-based motion planning algorithm, inspired by RRT*, for multi-robot navigation under temporal logic goals, optimizing sampling bias and reusing prior planning results to achieve computational efficiency.
- Developed a hierarchical task allocation and path planning framework inspired by the vehicle routing problem, leveraging Mixed Integer Linear Programming (MILP) to enable efficient multi-robot coordination for temporal logic tasks.
- Applied a derivative-free optimization approach with Model Predictive Control (MPC) to generate the robot trajectory, ensuring collision-free, dynamically feasible, and socially-aware motion by minimizing human negative feedback.

- Developed a graph-search-based secure state estimation algorithm for large-scale cyber-physical systems to correctly identify sensors under malicious attacks.

TALKS

Refereed Conference and Workshop Presentations

- Decomposition-based Hierarchical Task Allocation and Planning for Multi-Robots under Hierarchical Temporal Logic Specifications
  – In 2025 *IEEE International Conference on Robotics and Automation (ICRA)* *May 2025*
- Certifying Robustness of Learning-Based Keypoint Detection and Pose Estimation Methods
  – Workshop on *Public Trust in Autonomous Systems, IEEE International Conference on Robotics and Automation (ICRA)* *May 2025*
- Hierarchical Temporal Logic Specifications for Abstract Safety Tasks
  – Workshop on *Robot safety under uncertainty from "intangible" specifications, IEEE International Conference on Robotics and Automation (ICRA)* *May 2025*
- Integrating Autonomy with Formal Methods
  – Workshop on *2024 NSF CPS Rising Stars* *May 2024*
- Obtaining Hierarchy from Human Instructions: an LLMs-based Approach
  – Workshop on *Learning Effective Abstractions for Planning, Conference on Robot Learning (CoRL)* *Nov. 2023*
- Robotic Planning under Hierarchical Temporal Logic Specifications
  – Workshop on *Formal Methods Techniques in Robotics Systems: Design and Control, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* *Oct. 2023*
- Socially-aware Robot Planning via Bandit Human Feedback.
  – In *2020 ACM/IEEE 11th International Conference on Cyber-Physical Systems (ICCPS)* *April 2020*
- Transfer Planning for Temporal Logic Tasks.
  – In *2019 IEEE 58th Conference on Decision and Control (CDC)* *Dec. 2019*

Invited Talks

- Scalable Control Synthesis for Multi-Robot Systems under Temporal Logic Specifications
  – *Intelligent Control Lab* at CMU *Nov. 2022*
  – *Reliable Autonomous System Lab* at MIT *Aug. 2021*

PROFESSIONAL SERVICE

Session Chair

- Verification and Formal Methods at ICRA May 2025

Paper Review

- *Journals:*
  – IEEE Transactions on Mechatronics (T-MECH) *2025*
  – IEEE Journal of Dynamic Systems, Measurement and Control *2025*
  – IEEE Robotics and Automation Letters (RA-L) *2025*
  – IEEE Transactions on Robotics (T-RO) *2022, 2023, 2024*
  – IEEE Control Systems Letters (L-CSS) *2024*
  – IEEE Transactions on Automation Science and Engineering (T-ASE) *2021*
  – IEEE Transactions on Control of Network Systems (T-CNS) *2019, 2021*

- *Conferences:*
  – IEEE Conference on Decision and Control (CDC) *2025*
  – Robotics: Science and Systems (R:SS) *2024, 2025*
  – IEEE International Conference on Robotics and Automation (ICRA) *2024, 2025*
  – AACC/IFAC Conference on Modeling, Estimation and Control Conference (MECC) *2024, 2025*
  – IEEE International Conference on Intelligent Robots and Systems (IROS) *2022, 2025*
  – IEEE American Control Conference (ACC) *2022*
  – IEEE International Conference on Ubiquitous Robots (UR) *2021*
  – ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS) *2019, 2020*

TEACHING EXPERIENCE

Teaching Assisant, *Harbin Institute of Technology*

- "MATLAB for Engineering" taught by Prof. Changsheng Gao *Fall 2016*
- "ME 627 Linear System Theory" taught by Prof. Michael M. Zavlanos *Fall 2019*

Guest Lecturer, *Carnegie Mellon University*

- On the Application of Formal Methods to Robotics
  – In Course "16-883 Special Topics: Provably Safe Robotics" taught by Prof. Changliu Liu *Spring 2024*
- Certification of Neural Certificates and Certification of Pose Estimation Models
  – In Course "16-883 Special Topics: Provably Safe Robotics" taught by Prof. Changliu Liu *Spring 2025*

MENTORING

- Zhongqi Wei, Ph.D. student in Mechanical Engineering at CMU
- Yutong Huang, Master in Mechanical Engineering at CMU
- Letian Leng, Master in Mechanical Engineering at CMU
- Alan Chan, Highschool Student at Westlake Highschool
- Shaojun Xu, visiting undergrad at Zhejiang University. Next: Ph.D. student at Tsinghua University
- Shiqi Sun, Master in Mechanical Engineering at Duke. Next: Ph.D. student at the Chinese University of Hong Kong
- Yijie Zhou, Master in Mechanical Engineering at Duke. Next: Ph.D. student at Northwestern Polytechnical University
- Shuo Yang, visiting undergrad at Shanghai Jiao Tong University. Next: Ph.D. student at University of Pennsylvania