

Haowen Lai

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University of Pennsylvania, Philadelphia, PA, 19104, U.S.A

EDUCATION

University of Pennsylvania

Ph.D. in Computer and Information Science

Philadelphia, PA, USA

Sept. 2022 - present

Tsinghua University

M.S. in Control Science and Engineering

Beijing, China

Sept. 2019 - Jun. 2022

Tongji University

B.E. in Automation

Shanghai, China

Sept. 2015 - Jul. 2019

- GPA: 4.85/5.00, ranking: 1/79

RESEARCH INTERESTS

My research interests center around advancing **mobile robots and autonomous driving** technology through cutting-edge work in **sensor fusion** and **robust sensing modalities**. The broader research areas include **wireless sensing**, **autonomous systems**, and **robotics**. Specifically, I focus on the application of wireless sensing technologies to ensure accurate and robust perception for robots and cars, especially in adverse conditions.

PUBLICATIONS

- [1] **H. Lai**, G. Luo, Y. Liu and M. Zhao, "Enabling Visual Recognition at Radio Frequency," *The 30th Annual International Conference on Mobile Computing and Networking (MobiCom)*. 2024. Accepted.
- [2] R. Yan, R. Deng, **H. Lai**, W. Zhang, Z. Shi and Y. Zhong, "Homicidal Chauffeur Reach-Avoid Games via Guaranteed Winning Strategies," *IEEE Transactions on Automatic Control (TAC)*. 2023. [\[pdf\]](#)
- [3] P. Yin, S. Zhao, **H. Lai**, R. Ge, J. Zhang, H. Choset and S. Scherer, "Automerge: A framework for map assembling and smoothing in city-scale environments," *IEEE Transactions on Robotics (T-RO)*. 2023. [\[pdf\]](#)
- [4] **H. Lai**, P. Yin and S. Scherer, "AdaFusion: Visual-LiDAR Fusion with Adaptive Weights for Place Recognition," *IEEE Transactions on Robotics (RA-L)*. 2022. [\[pdf\]](#)
- [5] W. Liang, **H. Lai**, Z. Shi and Y. Zhong, "Global Registration of Point Cloud Maps with Low-overlap Regions," *IEEE Chinese Control Conference (CCC)*. 2022. [\[pdf\]](#)
- [6] **H. Lai**, R. Yan, W. Zhang, Z. Shi and Y. Zhong, "Reach-Avoid Differential Games via Finite-Time Heading Tracking," *IEEE Conference on Decision and Control (CDC)*, 2021. [\[pdf\]](#)
- [7] **H. Lai**, W. Liang, R. Yan, Z. Shi and Y. Zhong, "LiDAR-Inertial based Localization and Perception for Indoor Pursuit-Evasion Differential Games," *IEEE Chinese Control Conference (CCC)*, 2021. [\[pdf\]](#)
- [8] **H. Lai**, Q. Kang, L. Pan et al., "A Novel Scale Recognition Method for Pointer Meters Adapted to Different Types and Shapes," *IEEE International Conference on Automation Science and Engineering (CASE)*, 2019. [\[pdf\]](#)

PATENTS

- [1] M. Zhao, G. Luo, Y. Liu and **H. Lai**, "Methods, Systems, and Computer Readable Media for Providing 3D Imaging Using Radio Frequencies," US Patent Application 63/626,860, filed Jan. 2024. Patent Pending.
- [2] B. Wen, J. Zhan, S. Liang, T. Lu, Q. Xiong, X. Jiang and **H. Lai**, "Registration Method based on CNN Point Cloud Object Detection," China Patent CN112700479B, authorized Feb. 2024.
- [3] **H. Lai** and X. Jiang, "A Map Construction Method and a LiDAR-inertial Odometry," China Patent CN113358112B, authorized Jan. 2023.
- [4] X. Jiang, Q. Xiong, S. Liang, J. Zhang, **H. Lai** and B. Wen, "Method and System for Localization based on Sensor Fusion," China Patent CN113375666B, authorized Dec. 2022.
- [5] **H. Lai**, J. Jiang, J. Chen and L. Jiang, "Method and System for Camera Calibration based on Deep Learning," China Patent CN109493389B, authorized Nov. 2021.
- [6] **H. Lai**, J. Chen, J. Jiang and L. Jiang "Method and System for Robot Arm Controlling based on Deep Learning," China Patent CN109352649B, authorized Jul. 2021.
- [7] Q. Kang and **H. Lai**, "Automatic Reading Method for Pointer Meters based on Scale Seeking," China Patent CN109993166B, authorized Oct. 2020.

RESEARCH EXPERIENCES

PhD Student, advisor: Prof. Mingmin Zhao

University of Pennsylvania – WAVES Lab

RF-based 3D SLAM Rivaling Vision Approaches

Nov. 2023 – present

- Built an RF-based 3D SLAM system that achieves centimeter-level localization and mapping with high-fidelity details comparable to vision-based approaches
- Introduced a novel and non-intrusive uncertainty estimation method for ML-based RF sensing, offering out-of-the-box usage and mitigating the influence of output errors
- Proposed an implicit occupancy field optimized with uncertainty-aware maximum likelihood estimation (MLE), effectively handling noise and remaining efficient

Enabling Visual Recognition at Radio Frequency

Dec. 2022 – Aug. 2023

- Developed a novel RF imaging system that brings RF resolution close to that of LiDAR, while providing resilience against conditions challenging for optical signals
- Presented a novel design that integrates a COTS mmWave sensor with a motor to significantly enhance sensing resolution and FoV, while ensuring that the system remains compact, low-cost, and practical for mobile robots
- Proposed a novel robot motion estimation algorithm that accurately estimates and compensates for robot motion, allowing for coherent combination of radio signals
- Introduced a learning model that effectively enhances vertical resolution using high azimuth and range resolutions, while maintaining efficiency with 2D convolutions

Research Intern, advisor: Prof. Sebastian Scherer

Carnegie Mellon University – Air Lab

AutoMerge: Automatic Multi-agent Cooperated Map Merging System

Dec. 2021 – Apr. 2022

- Researched on the problem of merging large-scale and low-overlap 3D point cloud maps without any prior information about their initial relative poses
- Developed an offline version, including a global localization frontend resistant to viewpoint changes and a pose graph optimization backend for fusing all local maps

Adaptive Visual-LiDAR Fusion for Place Recognition and Global Localization *May. 2021 - Oct. 2021*

- Researched on the problem of place recognition with the method that adaptively selects and weights LiDAR and visual features according to different environments
- Proposed a weight generation branch including multi-scale attention and two-stage fusion that could produce adaptive weights to adjust the importance and contribution of features of different modalities
- Reproduced the feature extraction backbone and improved it by utilizing batch normalization (BN)
- Built the whole network including data preparation, network training and evaluation in Python and PyTorch

Research Assistant, advisor: Prof. Yisheng Zhong **Tsinghua University – UAV Lab**

LiDAR-Inertial based Self-Localization and Target Perception for Robots *Jan. 2021 - Jul. 2021*

- Utilized a tightly-coupled LiDAR inertial odometry for self-localization in unknown GPS-denied environment
- Proposed a model fitting based target perception method to determine the position of opponents from point clouds
- Applied autonomous localization and perception to indoor multi-robot pursuit-evasion games

Intelligent and Unmanned Indoor Navigation Robot *Jan. 2020 - Sept. 2020*

- Tested and compared the results of mapping, localization and loop closure detection of several SLAM methods such as gmapping, RGBD SLAM v2, RTAB-MAP, etc.
- Built the wheel robots and developed a multi-robot system including visual SLAM and navigation based on ROS
- Researched on the problems of robot navigation that avoids obstacles of lower objects via RGB-D camera, and autonomous exploration with boundary search based on BFS

Research Intern, advisor: Prof. Qi Kang **Tongji University – BitAI Lab**

Vision-Based Automatic Reading System for Pointer Meters *Nov. 2018 - Aug. 2019*

- Trained the SSD + MobileNet object detection network on the MS COCO dataset to locate the dial
- Proposed an Adaptive Scale Seeking algorithm based on image characteristics to automatically read both uniform and non-uniform scale meters in constraint environment
- Built an image collection device with Wi-Fi connection based on STM32 Microcontroller Unit (MCU)
- Developed a user-friendly data management GUI for monitoring, recording and controlling the whole system

PROJECTS

Team Leader **Intel Cup ESDC 2018**

Self-Learning Model-Free Robot Arm System for Grabbing and Classification *Jan. 2018 - Aug. 2018*

- Won the national first prize (top 8% of 164 teams) of the *Intel Cup ESDC 2018* competition
- Responsible for the visual localization of robot joints and target cubes based on ArUco markers and image segmentation, respectively
- Developed the self-learning control model as a multi-layer fully connected neural network with TensorFlow, and collected motor control values and the corresponding target coordinates for training
- Implemented the communication between the two manipulators via Socket and that between the host computer and the control board through CAN bus

Team Leader, advisor: Prof. Fanhuai Shi **National Innovation Project**

Follow You up: Selfie UAV with Gesture Interaction *Apr. 2017-Apr. 2018*

- Won the third prize of the *16th Tan Kah-Kee Youth Invention Award (Shanghai)*

- Enable real-time detection and tracking of human body using RGB-D camera and machine learning, and control the drone to follow human based on the ROS framework
- Realized the segmentation of gesture based on skin color, and used TensorFlow to build CNN for recognition

INDUSTRIAL EXPERIENCE

Novauto Technology Co., Ltd. (Beijing, China)

Engineering Intern

Autonomous Driving Center, leader: Qi Xiong

Aug. 2020 - Apr. 2021

- Developed the tightly-coupled LiDAR-inertial SLAM method which was deployed and tested on real cars
- Researched on multi-sensor fusion based on factor graph, including LiDAR, IMU, GPS/RTK
- Realized the localization of vehicle in real time with previously built point cloud maps based on a combination of LiDAR inertial odometry and NDT algorithm

HONORS AND AWARDS

- Outstanding Undergraduate of Shanghai, (top 5%) 2019
- Excellent Student of Tongji University, (top 5%) 2018, 2017& 2016
- Phoenix Contact Scholarship, (excellence in study and research) 2018
- Siemens Scholarship, (top 5%) 2018
- The National First Prize in Intel Cup ESDC, (top 8% of 164 teams) 2018
- The Third Prize of the 16th Tan Kah-Kee Youth Invention Award 2018
- Qidi Scholarship of Tongji University, (excellence in research) 2017
- National Scholarship for Undergraduate, (top 2.5%) 2017
- The First Prize of Tongji Scholarship of Excellence, (top 5%) 2016

TEACHING EXPERIENCES

Teaching Assistant

University of Pennsylvania

CIS 3990: Mobile and IoT Computing

Spring 2024

- Duties: grading homework, office hours, preparing labs, answering questions

Teaching Assistant

Tsinghua University

Operations Research

Spring 2021, 2020

- Duties: grading homework and exams, answering questions

Calculus A (1)

Fall 2019

- Duties: grading homework and exams, giving exercise courses, answering questions

PROFESSIONAL ACTIVITIES

Paper Review

- Conferences: IEEE ICRA 2024
- Journals: IEEE T-ASE 2023, IEEE TCST 2023, IEEE RA-L 2023

Organizing Committee

- Co-organizer of ICRA 2022 General Place Recognition Competition *Feb. 2022 - Apr. 2022*

Presentations

- Oral Presentation at the IEEE Conference on Decision and Control *Dec. 2021*
“Reach-Avoid Differential Games via Finite-Time Heading Tracking” (online) Austin, USA
- Oral Presentation at the IEEE Chinese Control Conference *Jul. 2021*
“LiDAR-Inertial based Localization and Perception for Indoor Pursuit-Evasion Differential Games” Shanghai
- Oral Presentation at the IEEE Conference on Automation Science and Engineering *Aug. 2019*
“A Novel Scale Recognition Method for Pointer Meters Adapted to Different Types and Shapes” Vancouver

SKILLS

Language: English – Fluent, Chinese – Native, Cantonese – Native

Programming: C, C++, Python, MATLAB

Library: PyTorch, ROS, OpenCV, PCL, Open3D, Eigen, GTSAM, Qt

Technical: laser cutting (with DraftSight), 3D printing (with SolidWorks), docker