Haowen Lai

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

EDUCATION

University of Pennsylvania — **Philadelphia, PA, USA**
Ph.D. in Computer and Information Science — Sept. 2022 - present

Tsinghua University — **Beijing, China**
M.S. in Control Science and Engineering — Sept. 2019 - Jun. 2022

Tongji University — **Shanghai, China**
B.E. in Automation — Sept. 2015 - Jul.2019

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

RESEARCH INTERESTS

My research focuses on advancing autonomous systems and mobile robotics through **robust RF-based perception** and **multi-modal sensor fusion**. I develop algorithms and systems that enable **reliable and high-resolution perception under challenging conditions** such as occlusion, airborne obscurants, and poor lighting. My work aims to establish RF as a versatile and practical sensing modality for real-world autonomous applications.

PUBLICATIONS

[1] **H. Lai**, Z. Lan, and M. Zhao, "Non-Line-of-Sight 3D Reconstruction with Radar," *The Thirty-Ninth Annual Conference on Neural Information Processing Systems (NeurIPS)*. 2025. (Accepted)

[2] **H. Lai,** Z. Zheng, and M. Zhao, "RF-Based 3D SLAM Rivaling Vision Approaches," *The 31st Annual International Conference on Mobile Computing and Networking (MobiCom)*. 2025. (Accepted)

[3] **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. **Best Demo Award**. [pdf]

[4] 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]

[5] 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]

[6] **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]

[7] 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]

[8] **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]

[9] **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]

[10] **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.

HONORS AND AWARDS

- **Second Place** in ACM SRC Grand Finals (2/334, 21 ACM conferences) 2025
- **First Place** in ACM MobiCom Student Research Competition (SRC) 2024
- 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

MEDIA COVERAGE

- **BBC,** *Scientists work on 'superhuman' vision systems for robots*
- **Penn Today,** *Giving robots superhuman vision using radio signals*

RESEARCH EXPERIENCES

PhD Student, advisor: Prof. Mingmin Zhao **University of Pennsylvania – WAVES Lab**

Non-Line-of-Sight 3D Reconstruction with Radar *Dec. 2024 – May. 2025*

- Built the first practical and mobile system for NLOS 3D scene reconstruction.
- Proposed a novel two-stage pipeline that decouples signal interpretation from spatial reasoning.
- Developed a physics-inspired architecture that models ray tracing and surface normal to reverse multi-bounce

mirroring effects for NLOS reconstruction.

RF-based 3D SLAM Rivaling Vision Approaches *Nov. 2023 – Sept. 2024*

- 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 – BitaAI 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

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
- Journals: IEEE T-ASE, IEEE TCST, IEEE RA-L, Elsevier Measurement

Organizing Committee

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

Presentations

- Oral Presentation at the ACM International Conference on Mobile Computing and Networking *Nov. 2024*
  "Enabling Visual Recognition at Radio Frequency" Washington, D.C., USA
- Oral Presentation at the IEEE Conference on Decision and Control *Dec. 2021*
  "Reach-Avoid Differential Games via Finite-Time Heading Tracking" (remote) 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