Yuning Wu

Carnegie Mellon University
Computational Design Laboratory
5000 Forbes Ave, MMCH 403
Pittsburgh, PA, 15213

[removed]
yuningw@andrew.cmu.edu
https://ice-5.github.io/

RESEARCH INTEREST

Design, build, and optimize AI driven robots to humanely and sensitively support people in labor-intensive tasks.

Human-robot interaction, robot learning, machine learning, robotics, computational design

Favorite robots: TARS in “Interstellar”, Baymax in “Big Hero 6”, Benben from “The Wandering Earth II"

EDUCATION

2019.8 - 2024.8 (Expected) **Carnegie Mellon University**, Pittsburgh, USA

Ph.D. in Computational Design

Dissertation: “A Human-Centered, Reinforcement Learning Driven Robotic Framework for Humanely Supporting Labor-Intensive Construction Workers”

Co-Advisors: Daniel Cardoso Llach (Computational Design), Jean Oh (Robotics)

2019.8 - 2021.5 **Carnegie Mellon University**, Pittsburgh, USA

M.S. in Machine Learning

Advisor: Katerina Fragkiadaki

2010.8 - 2017.7 **Tsinghua University**, Beijing, China

M.Arch. & B.Arch. in Architecture

Focused on how robots can artistically and generatively build and interact with the physical space.

RESEARCH PROJECTS & ROBOTS

Rethinking Automation in Construction: A Reinforcement Learning Driven “Work Companion Rover” for Sensitively Supporting On-Site Construction Workers

Technical lead and main investigator, see [P1] & [P2]

Husky is an RL-driven “work companion rover” built for contextually assisting carpentry workers on-site. By bearing heavy loads and semi-autonomously navigating complex, dynamic construction environments, Husky delivers and carries essential tools and materials in the active workflow, reducing physical strain on workers and allowing them to focus on skilled facets of their work, thus improving workspace safety and fluency.

- Design and architect a multi-sensor robot prototype from a basic chassis (scratch).
- Leverage state-of-the-art (SoTA) advances in RL-based social robot navigation to enhance comfortable worker-robot interactions and encounters in active and complex indoor construction workspaces.
- Propose a novel approach to contextually align a generically pre-trained RL model to context-specific worker behavioral patterns while effectively mitigating policy shift.
- Utilize SoTA LiDAR Odometry and Mapping (LOAM) methods for unstructured site mapping and robot state estimation.
- Customize an efficient multimodal stack (LiDAR + multiple cameras) to robustly detect and track workers' movements in obstructive and cluttered construction environments.

A Distributed, Scalable RL-Driven Multi-Drone Framework for Flexible Task Cooperation on Complex Geometric Structures

Reinforcement learning research lead, see [P4]

Pixhawks is a fleet of drones driven by an RL-based multi–agent collision avoidance algorithm for conducting flexible building tasks such as brick-laying and spray-coating. The algorithmic framework enables a variable number of drones to adaptively and collaboratively execute tasks particularly related to complex-shaped geometric structures, showcasing a robotic framework for handling intricate real-world designs.

- Develop and deploy a scalable, decentralized, RL-based multi-agent collision avoidance algorithm to ensure efficient multi-drone operation within limited space.
- Customize a generalizable, curriculum-based Sim2Real pipeline using Unity MLAgents to bridge virtual training and real-world application.
- Conduct a proof-of-concept experiment with a physical drone prototype to validate the practicality and effectiveness of the framework.
- Analyze the evolving role of human workers within the emerging technical system.

Learning Dense Reward for Contact-Rich Manipulation from Limited Human Demonstrations

Independent research with Dr. Jieliang Luo and Dr. Hui Li, see [P3]

A novel dense reward —a continuous metric that reflects task progress— can be efficiently learned, rather than expert engineered, from multimodal sensory data (vision and force/torque) using a limited number of human demonstrations. The trained reward model can be used in RL for contact-rich robotic manipulation tasks such as USB insertion, door opening, and joint assembly.

- Design a novel Temporal Variant Forward Sampling (TVFS) method, robust and cost-efficient in generating learning samples from human demonstrations within a physical simulation environment.
- Introduce a self-supervised latent representation learning architecture that efficiently leverages the temporal relationships within sequential sample pairs generated by TVFS.

Teaching an AI Agent Spatial Sense by Playing LEGO

Independent research advised by Dr. Katerina Fragkiadaki, pending completion

LEGO Player is an AI agent capable of designing valid, and eventually elegant, stacked structures with LEGO blocks. Whether one is an architect or not, the way we build reflects our spatial understanding and intuition of the physical world. As children, this exploration typically begins by playing with toys like building blocks. This research retraces these initial steps by in a physical simulator (NVIDIA Omniverse Isaac Gym / PyBullet). A key aspect of this study is enabling the AI agent to develop a spatial sense, a physics inference engine, by grasping the relationships among blocks.

- Create a LEGO Playground simulation environment using NVIDIA Omniverse Isaac.
- Build a physics inference engine to predict the stability of stacked LEGO structures, leveraging both vision (Vision Transformer, ViT) and physical state (Graph Neural Network, GNN) learning structures.
- Employ Monte Carlo Tree Search (MCTS) to effectively explore valid and stable block stacking design.
- Assemble a group of “designer” agents to iteratively generate a dataset of gradually increasing stacking difficulties and heights.

Discovering Water and Ice on the Moon Pole

System engineering team member, advised by Dr. William "Red" Whittaker

MoonRanger is an autonomous, suit-case-sized moon exploration rover designed to search for signs of ice and water on the lunar pole. It is scheduled to be launched through the NASA CLPS project.

- Participate in system engineering and the high-level organization of robot components.
- Create visualization and coordination dashboard for efficient progress updates and system-wise issue diagnosis.
- Learn the architecture and prototyping of robotic systems in unpredictable and complex environments through a practical, hands-on approach.

PAPERS

[P1] Under review — **Yuning Wu**, Jiaying Wei, Jean Oh, Daniel Cardoso Llach, "*Towards Human-Centered Construction Robotics: An RL-Driven Companion Robot For Contextually Assisting Carpentry Workers*", submitted to IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). Preprint.

[P2] In revision — **Yuning Wu***, Emek Erdolu*, Jiaying Wei, Jean Oh, Daniel Cardoso Llach. "*Construction as Computer-Supported Cooperative Work: Designing a Robot for Assisting Carpentry Workers*", submitted to the ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW).

[P3] **Yuning Wu**, Jieliang Luo, Hui Li, "*Learning Dense Rewards with Temporal Variant Self-Supervision*", in the IEEE International Conference on Robotics and Automation (ICRA), Reinforcement Learning for Contact-Rich Manipulation Workshop, Philadelphia, 2022. Link.

[P4] Zhihao Fang, **Yuning Wu**, Ammar Hassonjee, Ardavan Bidgoli, Daniel Cardoso Llach, "*Towards an Architectural Framework for Distributed, Robotically-Assisted Construction: Using Reinforcement Learning to Support Scalable Multi-Drone Construction in Dynamic Environments*", In Proceedings of the 40th Annual Conference of the Association for Computer-Aided Design in Architecture (ACADIA), Philadelphia, 2020. Link.

[P5] Omer Akin, **Yuning Wu**, "*State Space Paradox of Computational Research in Creativity*", in the 19th Heron Island Conference on Computational and Cognitive Models of Creative Design (HI), 2019. Link.

HONORS AND AWARDS

2023 & 2024 — **Presidential Fellowship.** Carnegie Mellon University, TCS. Highest honors in CMU.

2022 — **Manufacturing Futures Initiatives Fellowship.** Carnegie Mellon University.

2022 — **Autodesk AI Merit Scholarship.** Autodesk AI Lab.

2021 — **Manufacturing Pennsylvania Fellowship.** State of Pennsylvania.

2020 — **GSA-Provost GuSH Grant.** Carnegie Mellon University.

2019 — **LEGO Scholarship.** LEGO Foundation.

2017 — **Distinctive Graduation Thesis.** Tsinghua University.

2011-2014 — **Siyuan Exceptional Student Fellowship.** Tsinghua University.

2013 — **Audi China Student Formula Racing Commercial Challenge Champion.** THU Racing.

WORK EXPERIENCE

2020.8 - 2023.12 **Carnegie Mellon University**, Pittsburgh, PA

Graduate Researcher and Technical Lead

Experienced the full research cycle of the "Rethinking Automation in Construction" project, including funding proposal, lab space setup, robot hardware purchase, robot architecture and prototyping, algorithm training and testing, and final evaluation on construction site among workers [P1][P2].

2021.5 - 2022.5 **Autodesk AI Lab & Robotics Lab**, San Francisco, CA

Research Intern and Collaborator

- Worked on Inverse Reinforcement Learning (IRL) methods for robotic manipulation [P3].
- Autodesk AI Lab has endowed a generous grant to CMU CoDe Lab in my name after the research internship, furthering collaboration in the field of AI and robotics.

2017.12 - 2019.8 **Metascope Technology**, Beijing, China

Co-founder and CTO

- Built a vision-based style recommendation system to help commercial architects form design drafts by capturing clients' spatial preferences.
- Customized DNN models for capturing explainable architectural styles and features.
- Leveraged statistical machine learning methods to customize client profiling models.

RESEARCH TALKS AND PRESENTATIONS

2023.5 **TCS Innovation Forum 2023 @ Cornell Tech**. "Towards Humanely Supporting Heavy Manual Labor: Leveraging AI/ML Advances to Develop a 'Work Companion Robot' for Construction Workers", invited research talk.

2023.5 **Bosch Leadership and AI Team Visit and Research Exchange**. "Collaboratively Assist, Rather Than Brutally Replace: A Reinforcement Learning Driven Robotic Framework For Supporting Construction Workers On-Site", robot demonstration and research presentation.

2022.11 **CMU Manufacturing Futures Institute Research Seminar**. "Rethinking Automation in Construction: Robotically Supported Collaborative Work in Heavy Manual Construction", invited research talk.

2022.10 **CMU 48-620 Graduate Seminars: Situating Research**. "Love, Death, and Robots: Designing AI-Driven Robots For Real-World Challenges, Complexities and Nuances", invited research talk.

2022.10 **CMU Board of Trustees Research Exhibit.** "Rethinking Automation in Construction: Introducing Mobile Robots into Existing Real-World Construction Scenes", robot demonstration and research presentation.

2022.9 **Autodesk TechX Research Exchange.** "Learning Dense Reward For Enhancing Reinforcement Learning in Contact-Rich Manipulation Tasks", invited research talk.

2022.5 **ICRA Reinforcement Learning for Contact-Rich Manipulation Workshop.** "Learning Dense Rewards with Temporal Variant Self-Supervision", poster presentation and research talk.

2021.11 **CMU 48-770 Graduate Seminars: Inquiries into Machine Learning and Design.** "Love, Death, and Robots: How Reinforcement Learning Driven Robots Can be Trained to Handle Real-World Nuances", invited research talk.

TEACHING

2022 Spring & Fall **Collaborative Instructor,** (48-749) Special Topics in Computational Design: Rethinking Automation in Construction, research-based, Carnegie Mellon University. Led and mentored a group of 4-6 MSCD master students in developing their individual research projects in AI and robotics, closely related to the ReAC project.

2021 Spring **Teaching Assistant,** (10-403) Deep Reinforcement Learning and Control, course-based, Carnegie Mellon University. Engaged in designing hands-on labs, assignments, and exams.

2020 Spring **Teaching Assistant,** (48-715) MSCD Pre-Thesis I, research-based, Carnegie Mellon University. Supported a group of 10-15 MSCD students in forming their master thesis research through literature review, writing, and discussion.

2020 Fall **Teaching Assistant,** (48-716) MSCD Pre-Thesis II: Topic Research, research-based, Carnegie Mellon University. Helped the MSCD cohort in developing their thesis proposal through discussions, presentations, and reviews.

2021 Spring **Teaching Assistant,** (48-718) MSCD Thesis Defense, research-based, Carnegie Mellon University. Supported the same MSCD cohort in preparing the final steps of their thesis defense. Consistently followed through the complete cycle of MSCD thesis research mentoring.

ACADEMIC AND VOLUNTEER SERVICES

2023 **Reviewer,** ACM Conference on Computer Supported Cooperative Work (CSCW) 2024.

2022 **Panel Moderator and Critic,** M.S. in Computational Design Thesis Defense 2022.

2021 **Panel Moderator and Critic,** M.S. in Computational Design Thesis Defense 2021.

RESEARCH PROFICIENCY

Coursework

(10-716) Advanced Machine Learning, (10-703) Deep Reinforcement Learning and Control, (10-605) Machine Learning with Large Datasets, (10-708) Probabilistic Graphical Models, (10-725) Convex Optimization, (36-700) Probablitiy and Mathematical Statistics, (16-720) Computer Vision, (16-861) Space Robotics

Skillset

Robotics: ROS, NVIDIA Omniverse Isaac, Unity MLAgents, PyBullet, Mujoco
AI/ML: Pytorch, Numpy, Scipy, Docker, CUDA
Programming: Python, C++, C#
Design & Modeling: Rhinoceros, AutoCAD

REFERENCES

Dr. Daniel Cardoso Llach

Associate Professor in Computational Design
College of Fine Art
Carnegie Mellon University

Dr. Jean Oh

Associate Research Professor in Robotics
Robotics Institute
School of Computer Science
Carnegie Mellon University

Dr. Jieliang (Rodger) Luo

Principal AI Research Scientist
Autodesk AI Lab

Dr. Hui Li

Senior Principal Research Scientist
Autodesk Robotics Lab

Dr. Katerina Fragkiadaki

JPMorgan Chase Associate Professor of Computer Science
Machine Learning Department
School of Computer Science
Carnegie Mellon University