YIHAO CAI

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EDUCATION

Wayne State University **Aug. 2023 – Present**

- **Major**: **Computer Engineering** – **Doctor of Philosophy** (GPA: 3.95/4.0) ***Greater Detroit, MI, USA***
- **Relevant Course**: Robotic Systems, Control Systems, Online Adaptive ML, Directed Research, Doctoral Seminar, etc.

Worcester Polytechnic Institute **Sep. 2021 – May. 2023**

- **Major**: **Robotics Engineering** – **Master of Science** (GPA: 3.8/4.0) ***Worcester, MA, USA***
- **Relevant Course**: Robot Dynamics/Control, Human Robot Interaction, Motion Planning, Operating Systems, Software Security, etc.

Nanjing University of Posts and Telecommunications **Sep. 2016 – Jun. 2020**

- **Major**: **Telecommunications Engineering** – **Bachelor of Science** (GPA: 3.43/4.0) ***Nanjing, Jiangsu, China***
- **Relevant Course**: Digital Signal Processing, Automation Control Theory, Computer Network, Algorithm Design in C++, etc.

RESEARCH EXPERIENCE

Wayne State University **Aug. 2023 – Present**

Department of Electrical and Computer Engineering | Graduate Research Assistant ***Detroit, MI, USA***

- Advised by *Prof. Yanbing Mao*, I conducted self-directed research in Physics-AI, focusing on integrating established physical models with neural networks to enhance system performance. My work specifically addresses safety concerns in autonomous systems, with applications in areas such as unmanned vehicles, self-driving cars, and robotics. I designed and trained physical models in simulation and successfully performed a real-world transfer to a physical quadruped robot.

Technical University of Munich **Apr. 2024 – Jun. 2024**

Cyber-Physical Systems in Production Engineering | Visiting Scholar ***Munich, Bavaria, Germany***

- I collaborate with *Prof. Marco Caccamo*'s group to embed safety layers that accelerate the training and deployment of AI in safety-critical systems. I developed a hybrid design featuring a real-time patch as a high-assurance module and an RL agent as a high-performance module, successfully tested on both a cartpole simulation and a real-world quadruped robot.

Worcester Polytechnic Institute **Sept. 2021 – Aug. 2022**

Department of Robotics Engineering | Graduate Laboratory Assistant ***Worcester, MA, USA***

- WPI HiRO lab aims at building effective interfaces to improve teleoperation performance (e.g. increasing awareness, reducing motion sickness) during human robot interaction. One application would be the tele-nursing robots -- I established a VR-based multi-camera platform that facilitates interface design for remote tasks including locomotion and manipulation.

Stanford University **Jan. 2018 – Feb. 2018**

Department of Computer Science | Exchange Student ***Palo Alto, CA, USA***

- As part of an undergraduate academic program, I visited Stanford University as an exchange student -- I took AI-related courses and jointly worked with a group affiliated to the Stanford AI Lab on a computer vision system for intelligent robotic arms.

WORKING EXPERIENCE

ABB Inc. (USA) **Jan. 2023 – May. 2023**

R&D Engineer, Department of Robotics & Discrete Automation | Internship ***San Jose, CA, USA***

As an R&D engineer in the robotics team, I focus on developing cutting-edge CV/ML solutions to increase the overall performance of robotic arms in pick-and-place sorting tasks. My contributions include:

- Building a software framework on Nvidia Jetson Orin by setting up a GPU computing pipeline (with CUDA, TensorFlow) and optimizing model inference with TensorRT, achieving a 20x speed improvement over the previous architecture.
- Researching and exploring state-of-the-art Transformer-based DLNN models (Mask3D) for 3D semantic instance segmentation, creating high-performance training pipelines to address limitations of the current approach using RGB image data.
- Innovating a 2D-based method for labeling 3D point cloud data and generating batches to train customized models.

Hillstone Networks Co., Ltd **May. 2021 – Aug. 2021**

Software Development Engineer, Department of Cloud Security | Full-Time ***Beijing, China***

- As a software engineer, I work on developing and integrating security layers for cloud platforms. Contributions:
  - Managing Docker container clusters with Kubernetes and designing security schemes based on CIS Benchmarks to protect against container threats; implementing RPC frameworks (RESTful, gRPC) to build microservice modules using Golang.
  - Leveraging Linux kernel and OS-level modules (SELinux, AppArmor, eBPF), I develop application-level policies to secure Docker components (dockerd, containerd, runc), enhancing container security by approximately 15%

Whale Cloud Technology Co., Ltd **Jul. 2020 – Mar. 2021**

DevOps Engineer, Department of International & Operation Center | Full-Time ***Nanjing, China***

- In the role of DevOps engineer, I manage and deliver communication service products throughout their lifecycle:
  - Configuring the web environment by building an automation framework with Shell to deploy Java middleware (Nginx, Dubbo, Redis) on servers, and ensuring security using Iptables packet filters and other flow analysis tools (Tcpdump, Wireshark).
  - Overseeing end-to-end product delivery by designing functional test cases in an agile development environment, setting up a CI/CD pipeline for blue-green deployment, and maintaining Oracle databases by creating stored procedures.

RESEARCH WORK

Runtime Learning in Unknown Environments with Safety Assurance **Apr. 2024 – Sep. 2024**

- Learning safely in dynamic and unknown environments is challenging due to unpredictable changes and the need for timely system responses. To address this, a verifiable safety controller is incorporated into a hybrid learning framework using a real-time dynamic model. The architecture consists of a teacher and a student, with several key features: **1). Unsafe Behavior Correction:** The teacher corrects the student's unsafe actions by runtime learning (***Video***); **2). Robustness:** Handles real-time unknowns (***A1 Demo*** / ***Go2 Demo***); **3). Generalization:** Generalize across different robots (Unitree A1 -> Go2), and environments (Pybullet -> IsaacGym); 4). **In-time Response**: Safety performance exceeds that of policies with fixed models (***Video***).

Simplex-enabled Safe Continual Learning Machine **Feb. 2024 – Jun. 2024**

- This work proposes a design that ensures safety for the autonomous systems in a Reinforcement Learning (RL) environment. The framework features a hybrid architecture with two controllers: 1). A High-Assurance Controller (HAC), which has safety guarantee and prioritizes safety over performance; and 2). A High-Performance Controller (HPC), a Deep Reinforcement Learning (DRL) agent that delivers high performance but may potentially generate unsafe actions. This architecture addresses challenges in DRL, such as the Sim2Real gap and RL uncertainties like Out-of-Distribution (OOD). The feature is validated on a simulated Cart-Pole system (***GitHub***) and a real Unitree A1 quadruped robot (***GitHub***). Resources: (***Article***) (***Video***)

PROJECT WORK

Hover-Cartpole: A Mobile Platform for Assisting the Blind **Sep. 2023 – Dec. 2023**

- I design and prototype a wheeled robot from hardware to software independently. This physical platform intended to assist the blind individuals with the navigation tasks in daily life. (***GitHub***)
- For software, I integrated a 2D RPLidar with a Raspberry Pi using ROS for autonomous navigation. For hardware, I reverse-engineered a hoverboard motherboard to serve as robot's low-level controller and assembled BLDC motors as power units

Using Reinforcement Learning to Provide More Robust Congestion Control **Sep. 2022 – Dec. 2022**

- To improve congestion control (CC) robustness in TCP layer, I design and implement a distributed RL-based framework in a virtual network environment (Mininet) and extend its interfaces for customized network topology using synthetic data (***GitHub***)
- Make a system analysis and test the final performance by comparing it with other traditional CC algorithms (TCP Cubic) in a three-by-three dumbbell network topology with different metrics (Bandwidth, Router Buffer Usage, etc.)

WPI HiRO (Human-Inspired Robotics Laboratory) Lab Assistant **Aug. 2021 – Sept. 2022**

- I create an IBVS (Image-based Visual Servoing) scheme with two 6-Dof Kinova arms model by combination of Unity3D and ROS for shared autonomous teleoperation which uses Oculus VR headset for remote scenario telepresence (***GitHub***)
- Development of physical wearable system with RealSense Cameras (sensing), HTC VIVE Trackers (body data) and VR Headset (gaze data + presence) in Unity3D using C#. Design user study and analyze data for research on active telepresence (***GitHub***)

National University Sci & Tech Innovation Program – *SLR (Sign Language Recognition)* **Sept. 2018 – Jan. 2020**

- Data Extraction of sign language features from a batch of video frames captured by KinectV2 (using C++) plus image-processing algorithms from OpenCV (Edge Detection, Threshold Segmentation, Image Filtering) for performance optimization. (***GitHub***)
- Implementation of Neural Networks (C3D, LSTM, R(2+1)D, etc.) to train model and model parameters tuning on server

University Automation Science Laboratory Robotics Researcher **Jan. 2017 – Dec. 2018**

- Design robot URDF model (using SolidWorks) for simulation and integrate tools/algorithms into the physical robotic platforms (TurtleBot, DOBOT Arm, etc.) to perform some basic tasks (Navigation, Locomotion, Grasping, etc.)
- Build a framework for robot hand-eye coordination system using Halcon and MATLAB, plus implementation of it for object detection and grasping without collision using motion planning algorithms from MoveIt library.

PUBLICATIONS

- **Runtime Learning of Quadruped Robot in Wild Chaotic Environments** *(On Submission)*
  Yihao Cai, Hongpeng Cao, Yanbing Mao, Lui Sha, Marco Caccamo **In *IROS 2025***
- **Runtime Learning Machine** *(On Submission)*
  Hongpeng Cao, Yanbing Mao, Yihao Cai, Lui Sha, Marco Caccamo **In *ACM Transactions on Cyber-Physical Systems***
- **Simplex-enabled Safe Continual Learning Machine** *(ResearchGate)*
  Yihao Cai, Hongpeng Cao, Yanbing Mao, Lui Sha, Marco Caccamo **In *arXiv:2409.05898 (CS->AI/Robotics)***
- **A Framework for Multimodal Sign Language Recognition under Small Sample based on Key-frame Sampling**
  Jianyu Wang, Jianxin Chen, Yihao Cai **In** *Fifth International Workshop on Pattern Recognition* ***(IWPR) 2020***

PEER REVIEW

- *2024* IEEE *Transactions on Control of Network Systems (IEEE TCNS)*
- *Automation, Control and Intelligent Systems, Journals of Science Publishing Group, 2024 – Present*

HONORS / AWARDS

- Candidate of Tau Beta Pi Honor Society (WPI Massachusetts Alpha Chapter) **2022**
- First Prize in 2018 National Artificial Intelligence Internet Innovation Competition **2018**
- Third Prize in National University Mathematics Modelling Competition **2018**
- Third Prize in 2018 China National Service Robot Competition **2018**
- First Prize in Provincial University Advanced Mathematics Contest **2017**
- Faculty Honors: Faculty Academic Excellence Scholarship, Civilian Award **2016 – 2017**

EXTRA-CURRICULAR

- IEEE Student Member (Region 4 – Central USA, Southeastern Michigan Section) **2024 - Present**
- Talent Member of Wayne Robotics Team at Wayne State University **2023 - Present**
- Member of Cyber Security and Rho Beta Epsilon (Robotics) Club in WPI **2021 - 2023**
- Founder Member of University Piobot Robotics Club in NJUPT **2017 - 2019**
  Team Leader of Robotics Arm Team, organizing instruction lessons and participating in national robotics competitions and projects

SKILLS

- **Programming Languages:**
  - C/C++, Python, MATLAB, C#, Shell, Golang, Assembly**,** HTML5/CSS, JavaScript, PL/SQL, VHDL/Verilog
- **AI & Robotics:**
  - **AI Framework:** TensorFlow, PyTorch, Keras, RLlib, TensorRT, CUDA/cuDNN, OpenCV, Scikit-learn
  - **Simulator:** IsaacGym/IsaacLab, OpenAI Gym, Pybullet, Gazebo, Unity3D, Blender, Mininet
- **Tools & Platforms:**
  - **Software:** Vim/Emacs, VSCode, Android Studio, CLion, PyCharm, Qt Creator, SolidWorks, AutoCAD
  - **DevOps/Web:** CMake, Docker/Kubernetes, Oracle Database, Flutter, .Net Framework, Git and SVN