

HARSH GOEL

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RESEARCH INTERESTS

My research lies in the intersection of **multi-agent system, reinforcement learning, and robotics**. I am interested in developing methods for **social robots or agents** i.e., agents learning to cooperate and interact with each other. I am inspired by recent advances in **control and optimization, and reinforcement learning** for cooperation learning in real world multi-agent or multi robot systems. Some applications of my research are in **information gathering** via multi-robot systems, and **traffic signal control**.

EDUCATION

University of Pennsylvania | Philadelphia, PA, USA

Aug 2021 – May 2023

Candidate for Master of Science in Engineering, Concentration: Robotics (GPA:4.00/4.00)

- **Thesis:** Learning goal-conditioned control policies for waypoint reaching in aerial vehicles and aerial manipulators (in progress)
- **Advisor:** Dr. Vijay Kumar and Dr. Pratik Chaudhari
- **Relevant Coursework:** Learning in Robotics, Advanced Computer Vision, Machine Learning Theory, Advanced Robotics, Model Predictive Control, and F1-Tenth Autonomous Racing

National University of Singapore | Singapore

Aug 2016 – May 2020

Bachelor of Engineering, Mechanical Engineering and Minor in Computer Science (GPA:4.88/5.00)

- **Dean's List:** Fall 2016, Fall 2017, Spring 2017, and Fall 2019
- **Advisor:** Dr. Guillaume Sartoretti and Dr. Marcelo H. Ang Jr
- **Relevant Coursework:** Artificial Intelligence, Machine Vision, Advanced Robotics, Neural Networks, and Linear Systems Theory

PUBLICATIONS & PRESENTATIONS

Harsh Goel, Laura Jarin Lipschitz, Sandeep Agarwal, and Vijay Kumar. Informative Path Planning for Sematic Classification via Reinforcement Learning. Manuscript in preparation for the *Robotics, Science and Systems (RSS 2023)*

Harsh Goel, Yifeng Zhang, Mehul Damani, and Guillaume Sartoretti. Distributed Cooperation Learning for Large Scale Traffic System. In review for *Proc. of the 22nd International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2023)*

Harsh Goel, Laura Jarin Lipschitz, Saurav Agarwal, Sandeep Manjanna & Vijay Kumar. Reinforcement Learning for Agile Active Target Sensing with a UAV. Presented at the *2nd Workshop on Trends and Advances in Machine Learning and Automated Reasoning for Intelligent Robots and Systems Reasoning with IEEE/RSJ International Conference on Intelligent Robots and System (IROS 2022) Kyoto, Japan, 2022*

THESIS & TECHNICAL REPORTS

Harsh Goel, Efficient Exploration to map unknown environments via autonomous robots. Bachelor's Thesis. Supervisor: Dr. Guillaume Sartoretti, NUS, 2020

Harsh Goel, Controlled Assembly Procedures using the Kuka Robotic Manipulator with limited position sensing from Microsoft Kinect. Undergraduate Research Opportunity Report (UROPs) Supervisor: Dr. Marcelo H. Ang Jr, NUS, 2018

TECHNICAL SKILLS

Programming Languages: Python, C++, Java

Machine Learning: PyTorch, TensorFlow, Scikit and Ray (distributed learning)

Mathematical Analysis: MATLAB and SIMULINK

Robotics: ROS, Docker and OpenCV

Others: Git, SciPy, SolidWorks

RESEARCH EXPERIENCE

Research Assistant at Kumar Lab | University of Pennsylvania, Philadelphia, PA

Dec 2021 – present

- Project 1:
 - Developed a **learning-based motion planning** method with motion primitives to localize targets via quadrotors.
 - Trained and benchmarked light-weight transformers and RESNET networks with RL algorithms such as PPO, SAC and A3C and benchmarked performance with greedy heuristics, CMA-ES, MIPP and MCTS
 - Demonstrated learnt planner on Kumar Autonomy Stack with Gazebo Simulations (**IROS'22 workshop**)
- Project 2:
 - Adapting **multi-agent reinforcement learning** for cooperative and persistent target search and tracking
- Project 3:
 - Researching methods for learning **goal conditioned control policies** for **reference tracking and waypoint reaching** for aerial vehicles and aerial manipulators that can be leveraged for general aerial vehicle tasks

Deep Learning Research Engineer | *National University of Singapore, Singapore* **Aug 2020 – Aug 2021**

- Introduced adaptations to a multi-agent RL algorithm COMA for fully decentralized and stable cooperation learning in large scale traffic systems
- Demonstrated that this led to **performance improvements of over 20%** in terms of traffic throughput in large scale urban networks comprising over 200 traffic signals (**AAMAS'23 submission**)
- Developed **Graph Neural Networks** and attention-based models for cooperative decision-making in traffic signal control

Research Intern at Marmot Lab | *National University of Singapore, Singapore* **May 2020 – Aug 2020**

- Developed, investigated and trained **self-attention-based policy networks with Reinforcement Learning** for cooperative multi-agent information gathering
- Benchmarked algorithms against evolutionary optimization approaches grounded in ergodic theory

Undergraduate Research Dissertation | *National University of Singapore, Singapore* **May 2020 – Aug 2020**

- Researched **evolutionary optimization** approaches for **information gathering** for mapping with individual robots
- Developed multi-agent simulation environment in Gazebo to benchmark **multi-agent mapping** algorithms

Research Intern Thales Research and Technology | *Thales Alenia Asia, Singapore* **Jan 2019 – July 2019**

- Investigated and formulated optimal control algorithms **for coverage control via multiple satellites**
- Tested **robustness of control algorithms to state estimation and sensor fusion** via Kalman Filters (UKF'S and EKF's)
- Optimised and tested control algorithms **for deployment on real satellites in Low Earth Orbit** on Thales satellite simulator

TEACHING EXPERIENCE

ESE 546 Principles of Deep Learning | *University of Pennsylvania, Philadelphia* **Aug 2022 – Dec 2022**

Teaching Assistant

- Penn's main graduate course on Deep Learning Principles. I conducted office hours to answer student questions, graded assignments and mentored 5 student final projects

CIS 522 Deep Learning | *University of Pennsylvania, Philadelphia* **Jan 2022 – May 2022**

Teaching Assistant

- Penn's breadth graduate course in the fundamentals of deep learning. I conducted weekly recitations, mentored student final projects and updated weekly course assignments for students

CIS 520 Introduction to Artificial Intelligence | *University of Pennsylvania, Philadelphia* **Oct 2021 – Dec 2021**

Teaching Assistant

- Introductory graduate course to Classical Artificial Intelligence. I maintained auto graders for the assignments, conducted office hours and a recitation, and graded student homework and exams

WORK EXPERIENCE

Robotics Software Developer | *MovelAI, Singapore* **May 2020 – Aug 2020**

- Adapted RRT based motion planning algorithms for site inspection with MovelAI's software stack on ROS
- Developed UI on node.js with **real time mapping and visualisation of faults during robot operation**

Robotics Engineering Intern | *A*STAR, Singapore* **May 2018 – Aug 2018**

- Engineered a vision pipeline for **object recognition (YOLOV2)** and a **dynamics prediction pipeline** in ROS to identify and interpolate poses of fast-moving objects in 3D for reactive interception by UR5 Robot Arm
- Adapted PID control algorithms for reactive interception over predicted **states** on Odroid XU-4 hardware

RELEVANT PROJECTS

Neural MMO Challenge (IJCAI23) on AICrowd | *University of Pennsylvania* **Jan 2022 – May 2022**

- Decentralized cooperative foraging and exploration with a team of 16-128 agents via Reinforcement Learning

University Rover Challenge 2020 | *National University of Singapore* **Aug 2019 – Dec 2020**

- Engineered systems for the entire rover for challenges such as autonomous navigation through rough terrain, and remote assembly with onboard robotic arm
- Developed motion planning pipeline on ROS for rover navigation tasks

NASA Robot Mining Challenge 2019 | *University of Illinois, Urbana Champaign* **Aug 2018 – Dec 2018**

- Integrated and coded a custom local path planning pipeline in move base ROS with SLAM for a space mining robot