

Senthil Hariharan Arul

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EDUCATION

University of Maryland

Ph.D. in Electrical and Computer Engineering, Robotics (CGPA 3.81/4)

College Park, USA

Aug 2019 – Exp. Fall. 2024

National Institute of Technology

B.Tech in Instrumentation and Control Engineering (CGPA 8.99/10)

Tiruchirappalli, India

Aug 2013 – May 2017

RESEARCH EXPERIENCE

Graduate Research Assistant

University of Maryland

Jan 2020 – Present

College Park, USA

Project: Multi-Robot Motion Planning

Advisor: Prof. Dinesh Manocha

- Led research on decentralized multi-agent collision avoidance and navigation algorithms, utilizing geometric, optimization, and reinforcement learning techniques. Focused on cooperative navigation in dense environments using Multi-Agent Reinforcement Learning (MARL) with selective inter-agent communication and visual transformers, achieving a 24% improvement in navigation success rates.
- Demonstrated expertise in decision-making under uncertainty and robust optimization, ensuring safe and reliable model behavior in complex real-world environments.
- Currently researching safe social navigation methods and uncertainty quantification to improve robot navigation in crowded settings. Additionally, exploring the application of Multi-Agent Reinforcement Learning (MARL) and Large Language Models (LLMs) for complex navigation scenarios.

Applied Scientist Intern

Amazon Lab126

May 2023 – Aug 2023

Sunnyvale, CA, USA

Project: Object-Goal Navigation

- Developed and tested object-goal navigation algorithms in complex indoor environments, focusing on ensuring robustness and reliability in dynamic, real-world scenarios by addressing challenges of occlusions and object displacements.
- Developed a probability mapping approach with Visual Language Models (VLM) encoding, specifically for object goal navigation tasks, which significantly reduced false positive rates and enhanced task accuracy.

Applied Scientist Intern

Amazon Lab126

May 2022 – Aug 2022

Sunnyvale, CA, USA

Project: Reducing Robot Freezing Behavior

- Explored novel cost formulations using Model Predictive Control (MPC) to reduce the robot freezing phenomenon in probabilistic navigation scenarios.
- Formulated a cost compliant with stability and safety definitions associated with control barrier functions, enabling safe planning under uncertainty.

Research Intern

McMaster University

May 2016 – Aug 2016

Hamilton, ON, Canada

Project: Autonomous Collaborative Robotic Arm

Advisor: Prof. Gary Bone

- Developed a model-based collision avoidance method for a CRS F3 robotic arm, utilizing 3D point cloud data from Microsoft Kinect to enhance operational safety in collaborative environments.
- Designed and implemented vision-based modeling and grasping software, which accurately identifies and manipulates objects, optimizing end-effector orientations for automated handling

TECHNICAL SKILLS

Programming Languages: C++, Python, MATLAB

Machine Learning Frameworks: TensorFlow, PyTorch

Tools: ROS, Point Cloud Library (PCL), OpenCV, Numpy, Git

RELEVANT COURSEWORK

Robotics & AI: Robotics (ENEE769M), Software Development for Robotics (ENPM 808X), Perception for Autonomus Robots (ENPM 673), Artificial Intelligence Planning (CMSC 722)

Control: Nonlinear Control (ENEE 661), Optimal Control (ENEE 664), Convex Optimization (ENEE 662)

Deep Learning: Differentiable Programming (CMSC 838B), Image Understanding (ENEE731)

INVITED TALKS

Amazon Lab126, Consumer Robotics Symposium

Mar 2024

- **Talk:** Navigating the Everyday: Improving robot mobility in household scenarios
- Co-presented with advisor Prof. Dinesh Manocha

FLAIR Talk Series, University of Oxford

Apr 2023

- **Talk:** Decentralized Multi-Agent Navigation in Complex Scenarios

SCHOLARLY ENGAGEMENTS AND CONTRIBUTIONS

Technical Reviewer: T-RO, RA-L, ICRA 2021-2024, IROS 2020-2024

Teaching: ENEE 460 Teaching Assistant, Fall 2019

Open-Source Contribution: D-ORCA: Multi-UAV Collision Avoidance Package (Presented at ROSCon 2019)

PUBLICATIONS

Journal Articles

- [1] S. H. **Arul**, A. J. Sathyamoorthy, S. Patel, M. Otte, H. Xu, M. C. Lin, and D. Manocha. "LSwarm: Efficient Collision Avoidance for Large Swarms With Coverage Constraints in Complex Urban Scenes". In: *IEEE Robotics and Automation Letters* 4.4 (2019), pp. 3940–3947. doi: 10.1109/LRA.2019.2929981.
- [2] S. H. **Arul** and D. Manocha. "DCAD: Decentralized Collision Avoidance With Dynamics Constraints for Agile Quadrotor Swarms". In: *IEEE Robotics and Automation Letters* 5.2 (2020), pp. 1191–1198. doi: 10.1109/LRA.2020.2967281.
- [3] S. H. **Arul** and D. Manocha. "SwarmCCO: Probabilistic Reactive Collision Avoidance for Quadrotor Swarms under Uncertainty". In: *IEEE Robotics and Automation Letters* (2021), pp. 1–1. doi: 10.1109/LRA.2021.3061975.
- [4] V. Zinage, S. H. **Arul**, D. Manocha, and S. Ghosh. "3D-Online Generalized Sensed Shape Expansion: A Probabilistically Complete Motion Planner in Obstacle-Cluttered Unknown Environments". In: *IEEE Robotics and Automation Letters* 8.6 (2023), pp. 3334–3341. doi: 10.1109/LRA.2023.3263376.

Conference Proceedings

- [5] S. Patel, S. H. **Arul**, P. Dhulipala, M. C. Lin, D. Manocha, H. Xu, and M. Otte. "Multi-Agent Ergodic Coverage in Urban Environments". In: *2021 IEEE International Conference on Robotics and Automation*. 2021.
- [6] S. H. **Arul** and D. Manocha. "V-RVO: Decentralized Multi-Agent Collision Avoidance using Voronoi Diagrams and Reciprocal Velocity Obstacles". In: *2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2021, pp. 8097–8104. doi: 10.1109/IROS51168.2021.9636618.
- [7] S. H. **Arul** and D. Manocha. "CGLR: Dense Multi-Agent Navigation Using Voronoi Cells and Congestion Metric-based Replanning". In: *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2022, pp. 7213–7220. doi: 10.1109/IROS47612.2022.9982110.
- [8] A. Agrawal, S. H. **Arul**, A. S. Bedi, and D. Manocha. "DC-MRTA: Decentralized Multi-Robot Task Allocation and Navigation in Complex Environments". In: *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2022, pp. 11711–11718. doi: 10.1109/IROS47612.2022.9981353.

- [9] S. H. **Arul**, J. J. Park, and D. Manocha. "DS-MPEPC: Safe and Deadlock-Avoiding Robot Navigation in Cluttered Dynamic Scenes". In: *2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2023.
- [10] S. H. **Arul**, J. J. Park, and D. Manocha. "Unconstrained Model Predictive Control for Robot Navigation under Uncertainty". In: *Accepted at 2024 IEEE International Conference on Robotics and Automation (ICRA)*. 2024.
- [11] S. H. **Arul**, D. Kumar, V. Sugirtharaj, R. Kim, X. Qi, R. Madhivanan, A. Sen, and D. Manocha. "VLPG-Nav: Object Navigation Using Visual Language Pose Graph and Object Localization Probability Maps [Accepted at IROS 2024]". In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2024.
- [12] S. H. **Arul**, A. S. Bedi, and D. Manocha. "When, What, and with Whom to Communicate: Enhancing RL-based Multi-Robot Navigation through Selective Communication [Accepted at IROS 2024]". In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2024.

Under Review

- [13] S. H. **Arul**, A. S. Bedi, and D. Manocha. *DMCA: Dense Multi-agent Navigation using Attention and Communication [Under-review at RA-L]*. 2024. arXiv: 2209.06415 [cs.R0].