Senthil Hariharan Arul

Phone: 240-706-5771 | **Email:** sarul1@umd.edu | **LinkedIn:** /in/senthilarul | **GitHub:** /senthilarul | **Google Scholar:** Senthil Hariharan Arul

Education

University of Maryland — College Park, USA
Ph.D. in Electrical and Computer Engineering, Robotics (CGPA 3.81/4) — *Aug 2019 – Exp. Fall. 2024*

National Institute of Technology — Tiruchirappalli, India
B.Tech in Instrumentation and Control Engineering (CGPA 8.99/10) — *Aug 2013 – May 2017*

Research Experience

Graduate Research Assistant — Jan 2020 – Present
University of Maryland — *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) for off-road terrain mapping and Large Language Models (LLMs) for complex social navigation scenarios.

• Mentored Undergraduate and Graduate Students in robotics navigation research, leading to co-authored publications in top robotics conferences and journals.

Applied Scientist Intern — May 2023 – Aug 2023
Amazon Lab126 — *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 — May 2022 – Aug 2022
Amazon Lab126 — *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 — May 2016 – Aug 2016
McMaster University — *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

Simulators: Gazebo, MuJoCo, Isaac Sim

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 Student Summit (Univ. of Maryland College Park) Nov 2024

- **Talk**: Navigating the Everyday: Improving robot mobility in household scenarios

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 Assistant: ENEE 460 - Control Systems (Fall 2019), ENEE 641 - Mathematical Foundations for Computer Engineering (Fall 2024)

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 ICRA 24]*. 2024. arXiv: 2209.06415 [cs.RO].

[14] K. Weerakoon, M. Elnoor, G. Seneviratne, V. Rajagopal, S. H. **Arul**, J. Liang, M. K. M. Jaffar, and D. Manocha. *BehAV: Behavioral Rule Guided Autonomy Using VLMs for Robot Navigation in Outdoor Scenes [Under-review at ICRA 24]*. 2024. arXiv: 2409.16484 [cs.RO]. URL: https://arxiv.org/abs/2409.16484.