Senthil Hariharan Arul

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Summary

Ph.D. candidate in Electrical and Computer Engineering with over 5 years of research experience in robotics, motion planning, and reinforcement learning. Proficient in C++, Python, and TensorFlow, with a strong publication record in top-tier robotics and AI conferences. Expertise in developing algorithms for multi-robot systems and optimizing navigation and control, with experience in interdisciplinary collaboration and mentoring. Passionate about advancing general-purpose robotics enabling robots to perform diverse tasks in unstructured environments.

Education

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

• Conducting research in decentralized multi-agent collision avoidance and navigation algorithms, exploring geometric, optimization, and reinforcement learning approaches.

• Enhanced cooperative navigation in dense scenarios using Multi-Agent Reinforcement Learning (MARL) methods leveraging selective inter-agent communication and visual transformers, leading to a 24% improvement in navigation success.

• Currently researching safe social navigation methods and uncertainty quantification for effective robot navigation in crowded scenes. Exploring Multi-Agent Reinforcement Learning (MARL) and Large Language Models (LLMs) for emergent formations in multi-robot applications.

• Mentored junior graduate students on research projects, resulting in co-authored publications.

Applied Scientist Intern — May 2023 – Aug 2023
Amazon Lab126 — *Sunnyvale, CA, USA*

Project: Object-Goal Navigation

• Developed object goal navigation methods to handle occlusions and object displacements. This improved success metrics by 16% and was successfully evaluated using simulations and physical robots.

• The method constructs probability maps using Visual Language Models (VLM) to reduce false positives and guide the Model Predictive Controller (MPC), facilitating autonomous object goal navigation for ground robots.

Applied Scientist Intern — May 2022 – Aug 2022
Amazon Lab126 — *Sunnyvale, CA, USA*

Project: Reducing Robot Freezing Behavior

Mentor: Jong Jin Park

• Explored cost formulations to mitigate robot freezing issue for a Model Predictive Control (MPC) based trajectory planner, improving autonomous navigation behavior in probabilistic scenarios.

• Formulated a cost compliant with stability and safety definitions associated with control barrier functions, enabling safe planning under uncertainty.

• Continued research as part of the *Amazon Lab126 Seed Grant 2022-2023 (link).*

Research Intern — May 2016 – Aug 2016
McMaster University — *Hamilton, ON, Canada*

Project: Autonomous Collaborative Robotic Arm

Advisor: Prof. Gary Bone

• Implemented model-based collision avoidance for a CRS F3 robotic arm using point cloud data from Microsoft Kinect.

• Designed vision-based modeling and grasping software to identify and model objects in 3D, computing end-effector orientation for effective grasp.

• Amongst approximately 120 undergraduate students selected across India to pursue funded summer research through MITACS.

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.RO].