Shambhavi Singh

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EDUCATION

University of Michigan, Ann Arbor Aug 2024 — Present
Doctor of Philosophy (Robotics)

Birla Institute of Technology and Science, Pilani, India Aug 2018 — May 2023
Master of Science (Physics)
Bachelor of Engineering (Electrical and Electronics)

RESEARCH EXPERIENCE

Carnegie Mellon University Pittsburgh, PA
Research Staff June 2022 – June 2024

Hierarchical Multi-Agent Planner for Modular Structure Assembly [C1][W1] *with Prof. Howie Choset*

- Devised planner leveraging graph-theoretic concepts (A* Search, Topological Sorting, Minimum Spanning Tree) and operations research algorithms (Task Allocation and Scheduling) to obtain optimal assembly plans, parallelize assembly for multiple agents and find collision-free agent paths with Multi-Agent Path Finding algorithms (Conflict-based Search and Prioritized Planning).
- Implemented speed-up techniques with smart heuristic functions, and profiling tools (Python cProfile library), improving solve time by two orders of magnitude over timestep-optimal baselines, maintaining solution quality

3D Decomposition for Multi-Agent Collective Construction [C2][W2] *with Prof. Howie Choset*

- Implemented a novel 3D structural decomposition method to enable solving a large-search-space planning problem as multiple smaller sub-problems. Used a Mixed Integer Linear Programming (MILP) formulation and conducted over 500 large-scale experiments using a state-of-the-art optimization solver - Gurobi
- Brought down computation time of test cases in baselines from the order of a few days to a few hundred seconds.
- Generated a dataset of 200 modular structures with varying structural densities for comparison with baselines

Birla Institute of Technology and Science, Pilani Goa, India
Undergraduate Researcher Aug 2019 – May 2022

Ad-hoc Airborne Networks in Multi-Agent Exploration for Disaster Response *with Prof. Sarang Dhongdi*

- Built a framework for analyzing ad-hoc networks of aerial vehicles under constrained mobility conditions. This work was developed for robust and reliable exploration of disaster-prone areas by teams of aerial vehicles.
- Framework used NS3 and ROS, further emulating the network on Intel boards that can be mounted on real drones.
- Analyzed airborne networks with different drone mobility settings

Development and Control of 3 R-P-S Parallel Manipulator System *with Prof. Ashwin Prabhakaran*

- Conducted kinematic and static analysis of dynamic system - for multiple design iterations. Simulated in MATLAB
- Developed platform with linear actuators, motor controllers, and ESP32 microcontroller. Implemented model-based controller to achieve end-effector trajectory-tracking. [code]

PUBLICATIONS

(Key: S = submitted, W = workshop, C = conference)

[C1] Hierarchical Planning for Long Horizon Multi-Agent Collective Construction [paper] [graphics]
Shambhavi Singh, Zejian Huang, Akshaya Srinivasan, Geordan Gutow, Bhaskar Vundurthy and Howie Choset
accepted at IEEE International Conference of Robotics and Automation (ICRA), 2024

[C2] Multi-Agent Collective Construction using 3D Decomposition [paper]
Akshaya Srinivasan, **Shambhavi Singh**, Geordan Gutow, Howie Choset and Bhaskar Vundurthy
IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2023

[W1] Hierarchical Propositional Logic Planning for Multi-Agent Collective Construction [paper]
Shambhavi Singh, Akshaya Srinivasan, Geordan Gutow, Bhaskar Vundurthy and Howie Choset
Workshop on Future of Construction at IEEE International Conference on Robotics and Automation (ICRA), 2023

[W2] Multi-Agent Collective Construction using 3D Decomposition [paper]
Akshaya Srinivasan, **Shambhavi Singh**, Geordan Gutow, Howie Choset and Bhaskar Vundurthy
Multi-Agent Path Finding Workshop at Association for the Advancement of Artificial Intelligence (AAAI), 2023

TECHNICAL PROJECTS

- **Power System Design for Solar UAV** [news article] - Designed electrical system which used energy from solar panels mounted atop wings of a fixed-wing model to power on-board sensors. Project won 1st Prize in the Boeing BUILD Competition 2019, out of 82 shortlisted student teams at IIT Bombay, India.
- **Gripper-equipped Mobile Robot** - Arduino-powered robot with servo-actuated gripper for pick-up and place tasks, walking on inclined paths, teleoperated using an RF communication module.
- **Quadcopter Trajectory Tracking** - Autonomous trajectory tracking with a custom-built drone using PID control. Implemented using ROS and PX4 Autopilot for processing odometry data for position estimation and tracking.
- **Self-reconfiguring Modular Robots** - Led mechanical design team to design a novel and secure module-locking mechanism in Solidworks for self-reconfiguration of identical modules. Manufactured using Ultimaker 3D Printer
- **Model Predictive Control of 2 Link Arm** [code] - Simulation and control of planar 2 D-O-F arm using ROS
- **6 D-O-F Manipulator Arm for Mars Rover** [website] - Development and inverse kinematic control of end-effector for heavy-object manipulation (carrying loads), and precision manipulation tasks (soil sample testing).
- **Hybrid Round-Robin Process Scheduling Algorithm** [code] - Development of scheduler optimized for long-duration processes and high-traffic loads using Shortest Job First with Round-Robin and dynamic quantum times.
- **Bipedal Gait on Inclined Surfaces** [code] - Dynamic gait analysis of non-linear and chaotic patterns emergent in biped locomotion on inclined surfaces. Developed and visualized using MATLAB.
- **Low Power Automatic Hand Dryer** [code] - Using sensor interfaces and interrupts of ESP32 microcontroller
- **Density Function Theory Experiments for materials in Semiconductor Devices** [code] - Simulating and visualizing properties of Metals (Al, Cu, Ni, Fe and Ag) and Single and Bi-layer Graphene, implemented in Fortran.

SKILLS AND COURSEWORK

- **Languages and Frameworks:** C++, Julia, Python, Fortran, ROS, Pytorch, Gurobi, cProfile, Networkx, NS3
- **Tools and Softwares:** Docker, Vim, Git, Github, Anaconda, Jupyter, Solidworks, CoppeliaSim, AutoCAD, Proteus
- **Computer Science Coursework:** Computer Programming, Object Oriented Programming, Machine Learning, Operating Systems, Embedded Systems Design, Digital Design, Microprocessors and Interfacing
- **Mathematics Coursework:** Advanced Calculus, Linear Algebra, Differential Equations, Probability and Statistics, Numerical Analysis (as Computational Physics), Optimization

INDUSTRY EXPERIENCE

RMJ Automation   Mysore, India
Embedded Systems Design Intern   May 2020 – Aug 2020

- Worked in a team of 3 to design a Digital Panel Display Meter based on LPC2138, a 32-bit RISC Microcontroller. Designed device equipped with temperature, current, and voltage sensing to display sensor input on LCD screen.
- Built using Proteus - PCB design software. Sensor interface programmed using Embedded C on Keil4.

VOLUNTEER AND CO-CURRICULAR EXPERIENCE

Student Volunteer at ICRA 2024, IROS 2023 and AAAI 2023   May 2024

- Served as a volunteer at various conferences with oral/poster presentations. Awarded scholarships for registration or travel expenses to these conferences.

Nirmaan - Non-Profit Organization *Employment Operations Volunteer*   Aug 2020 – May 2023

- Organized skill workshops and professional training for economically underprivileged women.
- For the same group of women, led a team of students to find sellers for hand-made products and supply raw materials.

Student Faculty Committee *Electronics Department Representative*   Aug 2020 – May 2022

- Facilitated transition to online classes during COVID-19 by representing 100+ students to faculty in bi-weekly meets.

Aerodynamics and Aviation Club *Coordinator*   Aug 2019 – May 2021

- Organized quadcopter building workshops, aeromodelling workshops and tech expos. [news article]
- Designed and taught a mini-course on Aerodynamics and Aviation to undergraduate students. Mentored students on technical projects and managed pooled inventory and budgets of projects.

Sandbox - Robotics Makerspace *Manager*   Aug 2018 – May 2021

- With a team of 8 students, responsible for inventory management, infrastructure maintenance (3D printers, Laser cutters, Plasma cutters, Drill stations), and procurement of new equipment with a $12,000 annual budget.