PRAJIT KRISSHNAKUMAR

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SUMMARY

- With 5 years of experience, I specialize in multi-UAV coordination algorithms that use Machine Learning, developing advanced simulation environments and efficient sim-to-real transfer.
- Strong background in all 4 main aspects of Robot autonomy - Perception, Localization, Planning, and Motion Control, with demonstrated success in integrating these components for hardware deployment.
- Highly skilled in machine learning, reinforcement learning, and multi-objective optimization, with a particular focus on applications for Unmanned Aerial Vehicles.
- 11 conference papers at leading robotics and aviation conferences, such as IROS, MRS, DARS, and AIAA. One Best Paper award in IEEE Multi-Robot and Multi-Agent Systems (single track, 18% acceptance rate)
- Have experience leading teams of 10+ masters and undergrad students in large research projects.

EDUCATION

University at Buffalo — **Buffalo, NY**
Ph.D., Robotics and Machine Learning, GPA 3.7/4.0 — Aug 2021 – Jan 2025

University at Buffalo — **Buffalo, NY**
M.Sc., Robotics and Machine Learning, GPA 3.7/4.0 — Aug 2021

Kumaraguru College of Technology — **Coimbatore, India**
B.E., Mechatronics Engineering — June 2018

TECHNICAL SKILLS

Programming Languages: Python, C++, MATLAB, Java, C#
Optimization: Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Bayesian Optimization, Gradient-based optimization, Linear Programming
Frameworks/Libraries and tools: NumPy, Keras, PyTorch, ROS, ROS2, OpenCV, Pandas, Unreal Engine, Unity3D, PyBullet, Gazebo, Scikit learns
Research Areas: Reinforcement Learning, Swarm Robotics, Imitation Learning, Deep Learning, Multi-objective optimization, Hardware-in-the-loop simulation, Human-in-the-loop simulation, Graph Neural Networks.
Estimation: Linear and Nonlinear estimation methods e.g., Kalman Filter, Particle filter.

EXPERIENCE

Ph.D., ADAMS Laboratory, University at Buffalo — *Aug 2020 – present*

Co-design of Physical Design and Behavior of Multi-robot Systems

- Investigated the interdependence of physical design (body) and AI (brain) in Multi-robot Systems, identifying limitations in traditional methods where ad hoc modifications to design often lead to suboptimal performance.
- Innovated a framework integrating nature-inspired Talent metrics (parameters that depend on the physical design and influence the robot's AI) with a policy gradient Reinforcement Learning to address the co-design challenges of multi-robot systems.
- Demonstrated that this method provides a lossless decomposition, achieving results comparable to global optimization under ideal conditions while reducing the required computational time and resources by at least 60%.
- Validated the framework through extensive testing on swarms exhibiting search behaviors (signal source localization), achieving morphologies that outperformed traditional sequentially designed systems by at least 16%, proving the efficacy of simultaneous optimization over conventional methods.

Enhanced Multi-Robot Task Allocation: Co-Design with Talent-Infused Graph Reinforcement Learning

- Implemented an advanced co-design framework for UAVs, tailored for multi-robot task allocation in emergency flood response scenarios. This approach integrates Graph Reinforcement Learning with a talent-infused policy gradient approach to optimize behavior and physical design concurrently.
- Conducted a case study using our co-design framework to compare single-robot systems with multi-robot teams' task efficiency. The study identified scenarios where multi-robot systems excel due to task parallelism and analyzed differences in behavior/morphology combinations between single and multi-robot designs. The optimized single-robot system achieved a 100% task completion rate, outperforming the multi-robot setup's 87% in identical conditions.

Multi-Robot Heterogeneous Swarm Operations (Funded by DARPA, Best Paper Award)

- Developed a tactical framework for managing complex heterogeneous swarm missions, integrating multiple swarm behaviors such as path planning, formation control, and task allocation. This framework is designed to enhance the effectiveness of missions like search and rescue operations and planetary exploration
- Demonstrated the generalizability of our tactical swarm framework by deploying it in complex search and rescue missions utilizing UAVs and UGVs in simulated real-world environments with three distinct types of adversaries.
- Developed and critically assessed four tactical methods: MLP-based Reinforcement Learning, Graph Reinforcement Learning, Neuroevolution of Augmented Topologies (NEAT), and bi-partite graph matching. Both NEAT (with just 7k parameters) and bi-partite graph matching excelled, achieving a 100% success rate across various maps and swarm configurations, showcasing superior performance and adaptability.

Urban Air Mobility Vertiport Management

- Formulated the urban air mobility vertiport air-traffic control system as a Markov Decision Process (MDP) and developed a sophisticated virtual environment using Unreal Engine to simulate this MDP for scaled-down multi-rotor vehicles.
- Developed and implemented a Graph Reinforcement Learning (GRL) method to manage real-time air traffic control at vertiports, optimizing the scheduling of VTOL aircraft take-offs and landings with considerations for safety, delay, and battery levels.
- Benchmarked the GRL policy against three other methods: an MLP-based RL agent, a Random agent, and a First-Come-First-Serve approach, demonstrating that the GRL policy consistently avoided collisions in all tested scenarios.
- Successfully transferred the GRL policy, initially trained in Unreal Engine, to real-world application with four Crazyflie UAVs in a motion capture environment, and the case studies indicated 0 collisions, demonstrating effective sim-to-real transfer. (Video).

Open-Source Hardware/Software Architecture of Human FPV UAV Autonomy Demonstrations

- Led a team of 2 master's and 4 undergraduate students to develop an open-source quadcopter/drone platform equipped with 2 FPV cameras and a graphical user interface, allowing pilots to experience flight from the drone's perspective. The system also records flight data in parallel, providing valuable datasets for developing imitation learning models replicating human piloting behavior.
- Developed a digital twin platform using Unreal Engine, serving as a software alternative to the physical drone hardware previously mentioned. Both the hardware and software frameworks have been open-sourced and were presented at an aviation conference.
- Developed open-source Python framework for hardware deployment of decentralized multi-UAV coordination algorithms and tested area coverage and multi-robot task allocation (MRTA) algorithms with 3 quadcopters outdoors (1 Pixhawk-based and 2 parrot Anafi) and in digital twin. Videos: MRTA, Coverage

Research Aide, Motion Simulation Laboratory, University at Buffalo *Feb 2021 – Aug 2021*

Simulation developer

- Developed a 3D world (UB City) in unreal engine for the creation of T&E network to forecast future modes of human transport during autonomous operation, particularly hybrid ground-flight vehicles and Advanced Air Mobility (AAM)
- Integrated the world with a MOOG Motion platform, a six-degree-of-freedom system driven by six DC servomotors, and a real Ford passenger cabin. This setup enables users to experience a genuine driving environment within a simulated world, surrounded by a 360-degree, 16-foot diameter, and 6-foot-high screen, resulting in an authentic and comprehensive vehicle simulation experience.

Wipro Technologies, Chennai *Aug 2018 – Oct 2019*

- Responsibilities included developing Automation frameworks using Selenium to run automation tests for core banking software and teaching automation testing to manual testers.
- Planned and oversaw automation testing in various banking applications.

PUBLICATIONS

- KrisshnaKumar, P., Paul, S., and Chowdhury, S., A Talent-infused Policy-gradient Approach to Efficient Co-Design of Morphology and Task Allocation Behavior of Multi-Robot Systems, Distributed Autonomous Robotic Systems (DARS), NYC, Oct. 28-30, 2024.
- Xiao, H., KrisshnaKumar, P., Pothuri, J., Soni, P., Butcher, E., Chowdhury, S., An Open-source Hardware/ Software Architecture and Supporting Simulation Environment to Perform Human FPV Flight Demonstrations for Unmanned Aerial Vehicle Autonomy, AIAA AVIATION 2024 Forum, Las Vegas, NV, Jul 29-Aug 2, 2024.
- KrisshnaKumar, P., Paul, S., Manjunatha, H., Gupta R., Esfahani, E., and Chowdhury, S., Towards Physically Talented Aerial Robots with Tactically Smart Swarm Behavior thereof: An Efficient Co-design Approach, International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, American Society of Mechanical Engineers, Washington D.C., Aug 26-28, 2024.
- KrisshnaKumar, P., Witter, J., Paul, S. and Chowdhury, S., Fast Decision Support for Air Traffic Management at Urban Air Mobility Vertiports using Graph Learning, 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Michigan, US, October 2023
- Hulme, K., Karra, R., KrisshnaKumar, P., & Dmowski, R. (2023). Game Engine Modeling & Simulation (M&S) implementations to evaluate Human Performance in Transportation Engineering. In 15th International MODSIM World Conference, US, May 22-23, 2023.
- Distefano, J., Cho, H., KrisshnaKumar, P., Chowdhury, S., & Esfahani, E. (2023). Framework for Analyzing Human Cognition in Operationally-Relevant Human Swarm Interaction. International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. Vol. 87295. American Society of Mechanical Engineers, Aug, 2023.
- Liu, F., Boonrath, A., KrisshnaKumar, P., Botta, E. M., & Chowdhury, S. (2023). Learning Constrained Corner Node Trajectories of a Tether Net System for Space Debris Capture. AIAA AVIATION 2023 Forum, San Diego, June 26-28, 2023.
- KrisshnaKumar, P., Witter, J., Paul, S. and Chowdhury, S., Graph Learning based Decision Support for Multi-Aircraft Take-Off and Landing at Urban Air Mobility Vertiports, AIAA SciTech, AIAA 2023, National Harbor, MD, January 23-27, 2022.
- Zeng, C., KrisshnaKumar, P., Witter, J. and Chowdhury, S., Efficient Concurrent Design of the Morphology of Unmanned Aerial Systems and their Collective-Search Behavior, 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Kyoto, Japan, October 2022.
- Zeng, C., Hecht, G., KrisshnaKumar, P., Shah, R., Chowdhury, S. and Botta, E. Learning Robust Policies for Generalized Debris Capture with an Automated Tether-Net System. AIAA SciTech, AIAA 2022, San Diego, CA, January 3-7, 2022.
- Behjat, A., Manjunatha, H., KrisshnaKumar, P., Jani, A., Collins, L., Ghassemi, P. and Distefano, J., Doermann, D., Dantu, K., Esfahani, E. and Chowdhury, S., Learning Robot Swarm Tactics over Complex Adversarial Environments, International Symposium on Multi-Robot and Multi-Agent Systems (MRS'21), IEEE, Cambridge, UK, Nov. 4-5, 2021. (**Best Paper Award**)

WORKSHOP/SPOTLIGHT PRESENTATIONS

- KrisshnaKumar, P., Paul, S., Manjunatha, H., Esfahani, E. and Chowdhury, S., A Talent-infused Reinforcement Learning Approach to CoDesign of Tactical UAV Swarm, AAAI 2024, AI4Design Bridge.
- KrisshnaKumar, P., Paul, S., Behjat, A., Manjunatha, H., Esfahani, E. and Chowdhury, S., Comparative Exploration of Three Approaches to Learning Heterogeneous Robot Swarm Operations Over Abstracted Complex Adversarial Environments, ICRA 2023, London, Multi-Robot Learning workshop.

JOURNAL ARTICLES

- Manjunatha, H., KrisshnaKumar, P., Distefano, J., Jani, A., Behjat, A., Ghassemi, P., Chowdhury, S., Dantu, K. and Esfahani, E.T. (2021) Shasta: A simulator for human and swarm team applications. Autonomous Robots (Under Review)
- KrisshnaKumar, P., Witter. J., Collins L., Varma P., Ghassemi, P., Dantu, K., Esfahani, E.T. and Chowdhury, S., Scalable and Load-Balanced Coverage Path Planning for Multi-Robot Teams Surveying Non-Convex Areas, Robotics and Autonomous Systems (Under Review)

- KrisshnaKumar, P., Paul, S., Behjat, A., Manjunatha, H., Esfahani, E. and Chowdhury, S., Swarm Tactical Framework for Complex Heterogeneous Missions in Adversarial Environments, Swarm and Evolutionary Computation (Under Preparation)
- KrisshnaKumar, P., Zeng, C., Bhatt, A., and Chowdhury, S., A Talent-infused Policy Gradient Approach for Co-design of Morphology and its Search Behavior, Journal of Mechanical Design (Under Preparation)

PUBLICATIONS UNDER REVIEW

- KrisshnaKumar, P., Pothuri, J., Xiao, H., Oddiraju, M. and Chowdhury, S., A A Physical-Digital Twins Environment for Real Outdoor Testing of Multi-Unmanned Aerial Vehicle Coordination and Applications, International Conference on Robotics and Automation (ICRA), 2025.
- Bhatt, A., Cora, M., Merlo, F., Krisshnakumar, P., and Chowdhury, S., Experimental Setup with Acoustic Source and Software Pipeline to Evaluate Multi-Robot Signal Source Localization Algorithms. International Conference on Robotics and Automation (ICRA), 2025.

TEACHING & MENTORING

Teaching:

- Co-taught graduate-level course "Learning for Autonomous Systems" (MAE 600, Spring 2024) at University at Buffalo
  - Prepared slides and lectured classes
  - Developed and graded assignments
  - Mentored students for course projects
- Teaching Assistant
  - Engineering Computation (EAS 230) – Undergraduate (Spring 2022)

Invited Guest Lecture:

- "Deep Learning for Robotics" at University at Buffalo: Lecture on Reinforcement Learning for Multi-robot Systems

Mentoring:

- Jhoel Witter: (Master's thesis - Scalable Multi-Agent Coordination: Area Coverage, Target Localization and Vertiport Traffic Management via Learning) – University at Buffalo
- Aditya Bhatt: (Master's thesis – Learning Based Down-sampling for Scalable Decentralized Decision Making in Swarm Search) – University at Buffalo
- Haosong Xiao: (Master's thesis - Creating physical platforms, experimental setup, and GUI to Support Human FPV Flight Demonstrations for Autonomy) – University at Buffalo
- Jagadeswara P K V Pothuri: (Master's thesis – Tracking of dynamic UAV through Reinforcement Learning) – University at Buffalo
- Mary Corra, Franklin Merlo, Camden Bartlo, Eric Butcher, Hanvit Cho, Ria Gupta, Ajith Kottaram, Nishanth Gopinath, Emma Ressman, Awais Ahmad (Undergraduates – Hands-on Experiments with Teams of Tiny Ground Robots and Drones)

AWARDS & HONORS

- IEEE International Symposium on Multi-Robot and Multi-Agent Systems (MRS), 2021, Best Paper Award for the paper "Learning Robot Swarm Tactics over Complex Adversarial Environments"
- IEEE 2021 Conference on Systems and Technologies for Remote Sensing Application through Unmanned Aerial Vehicles, 2021, Excellence in Student Contributions
- Embedtrix – 1st place in Internet of Things (IoT) competition, Amrita University, Coimbatore, 2017

COURSES TAKEN

- Optimization in Engineering Design, Heuristic Optimization, Continuous Control Systems, Computer Vision, Computational Vision, Robotics Algorithms, Reinforcement Learning, Multi-agent Reinforcement Learning, Learning for Autonomous Systems, Machine Learning, Deep Learning