

Education

- 2016–2022 **Ph.D. in Computer Science**, *University of Minnesota*, Twin Cities.
2016–2018 **M.S. in Computer Science**, *University of Minnesota*, Twin Cities.
2009–2013 **B.S. in Computer Science and Engineering**, *University of Wisconsin*, Madison.

Ph.D. Thesis

- Title *Analysis of Collective Behavior in Robot Swarms*
Advisor Dr. Maria Gini
Description This thesis developed new theoretical tools for measuring, modeling, controlling, and (critically) predicting the behavior of bio-inspired multi-agent systems from small (≤ 5 agents) to large ($\geq 10,000$ agents) scales. Applications to foraging and construction tasks in dynamic, dangerous, and unknown environments.

Research Interests

Bio-inspired algorithms and design for dangerous and dynamic environments with unreliable communication and unknown workloads. Multi-agent modeling, task allocation, stochastic and differential equation modeling, graph theory, queueing theory approaches.

Publications

- [1] **J. Harwell**, L. Lowmanstone, M. Gini. “Provably Manipulable 3D Structures using Graph Theory”. In: *Proc. Int’l Conf. on Autonomous Agents and Multiagent Systems (AAMAS)*. **2023**, pp. 2550–2552.
- [2] **J. Harwell**, L. Lowmanstone, M. Gini. “SIERRA: A Modular Framework for Accelerating Research and Improving Reproducibility”. In: *2023 International Conference on Robotics and Automation (ICRA)*. **2023**, pp. 9111–9117.
- [3] **J. Harwell**, A. Sylvester, M. Gini. “An empirical characterization of ODE models of swarm behaviors in common foraging scenarios”. In: *Autonomous Robots* (**July 2023**).
- [4] **J. Harwell**, L. Lowmanstone, M. Gini. “SIERRA: A Modular Framework for Research Automation”. In: *Proc. Int’l Conf. on Autonomous Agents and Multiagent Systems (AAMAS)*. Virtual Event, New Zealand, **2022**, pp. 1905–1907.
- [5] M. Jeong, **J. Harwell**, M. Gini. “Analysis of Exploration in Swarm Robotic Systems”. In: *Intelligent Autonomous Systems 16*. Ed. by Marcelo H. Ang Jr, Hajime Asama, Wei Lin, and Shaohui Foong. Cham: Springer International Publishing, **2022**, pp. 445–457.
- [6] **J. Harwell**, M. Gini. “Improved Swarm Engineering: Aligning Intuition and Analysis”. In: *IEEE Transactions on Robotics* (**2021**).
- [7] **J. Harwell**. “A Theoretical Framework for Self-Organized Task Allocation in Large Swarms (Doctoral Consortium)”. In: *Proc. Int’l Conf. on Autonomous Agents and Multi-Agent Systems (AAMAS)*. Richland, SC, **May 2020**, pp. 2191–2192.
- [8] **J. Harwell**, L. Lowmanstone, M. Gini. “Demystifying Emergent Intelligence And Its Effect On Performance In Large Robot Swarms”. In: *Proc. Int’l Conf. on Autonomous Agents and Multi-Agent Systems (AAMAS)*. **May 2020**, pp. 474–482.
- [9] A. Chen, **J. Harwell**, M. Gini. *Maximizing Energy Battery Efficiency in Swarm Robotics*. **2019**. URL: <http://arxiv.org/abs/1906.01957>.






- [10] **J. Harwell**. "A Unified Mathematical Approach for Foraging and Construction Systems in a 1,000,000 Robot Swarm". In: *Proceedings of the Twenty-Eighth International Joint Conference on Artificial Intelligence, IJCAI-19*. International Joint Conferences on Artificial Intelligence Organization, **July 2019**, pp. 6438–6439.
- [11] **J. Harwell**, M. Gini. "Swarm Engineering Through Quantitative Measurement of Swarm Robotic Principles in a 10,000 Robot Swarm". In: *Proc. 28th Int'l Joint Conf. on Artificial Intelligence (IJCAI-19)*. **July 2019**, pp. 336–342.
- [12] N. White, **J. Harwell**, M. Gini. *Socially Inspired Communication in Swarm Robotics*. **2019**. URL: <http://arxiv.org/abs/1906.01108>.
- [13] **J. Harwell**, M. Gini. "Broadening applicability of swarm-robotic foraging through constraint relaxation". In: IEEE, **May 2018**, pp. 116–122.
- [14] H. Baaolu, J. Blount, J. Blount, B. Nelson, S. Succi, P. M. Westhart, J. R. Harwell. "Computational performance of SequenceL coding of the lattice Boltzmann method for multi-particle flow simulations". In: *Computer Physics Communications* 213 (**2017**), pp. 92–99.

Experience

- 2023–present **Senior Embedded Software Engineer**, **SATELLES**, Minneapolis, MN.
 - Architecture, implementation, and maintenance of a custom QEMU emulator to (a) reduce risk in commercializing custom in-house ASIC and (b) support prototype development and testing.
 - Leveraged reusable software modules for bare metal, embedded applications to accelerate development and meet aggressive deadlines. Hardware, software driver debugging.
- 2022–2023 **Postdoctoral Researcher**, **SIFT**, Minneapolis, MN.
 - Developed models of flocking behaviors to extract control policies and parameters automatically from trajectory data to estimate physical properties and limits of vehicles.
 - Reduced debugging time by enhancing in-house tooling for efficient visualization of multivariate spatio-temporal data of large-scale multi-agent systems.
 - Contributed to business development through market research and proposal writing.
- 2016–2022 **Researcher**, UNIVERSITY OF MINNESOTA, Minneapolis, MN.
 - Achieved publication of 9 papers at top conferences and journals, including 6 first author papers, through strong writing and organization skills, and collaboration with other researchers.
 - Derived cuboid structure model using graph theory to develop simple algorithms to provably manipulate graphs (structures) from one state to another [1].
 - Demonstrated robust predictions of steady-state collective foraging behaviors up to practical engineering limits using differential equation modeling [3].
 - Showed that the origin of collective intelligence in task allocating swarms lies in self-organized learning task relationships, rather than costs [8].
 - Reduced development cycles and increased utility of automated design methods through better measurements for design principles of multi-agent systems.
- 2016–2022 **Research Group Leader**, UNIVERSITY OF MINNESOTA, Minneapolis, MN.
 - Mentored high school and undergraduate students interested in AI, robotics, and academic research to apply for grants, publish original research, and present at workshops.
 - Managed parallel undergraduate research projects through weekly meetings, check-ins. Helped students to develop as independent researchers: fostered excitement in research through freedom of topic choice and technical approach, and clarity in student goals through project scoping.
- Summer 2017 **Software Development Intern**, CRAY, INC., Minneapolis, MN.

Built reusable Linux kernel modules for HPC environments to reduce development cycle time of Cray DataWarp software.
- 2013–2016 **Research Engineer**, SOUTHWEST RESEARCH INSTITUTE, San Antonio, TX.
 - Led flight software development on NASA subcontract for Cyclone Global Navigation Satellite System (**CYGNSS**) in collaboration with the University of Michigan.
 - Reduced computing costs through computational optimization of large-scale simulations.
 - Developed prototype NASA cFS-compatible file system with configurable memory footprint and increased robustness for flash-based media.

Projects

- 2016-present **Author**, CORE SWARM LIBRARY, .
- Middleware-esque C++ library providing a transparent, zero-cost API to different robotics platforms (ROS1, ARGoS, etc.), for both real and simulated robot types.
 - Computationally optimized for efficient execution with systems of over 10,000 robots on HPC clusters and on real systems of Raspberry PI-powered TurtleBot3 robots.
- 2016-present **Author**, C/C++ DEVELOPMENT CORE, C , C++ .
- Focused on reusability to kickstart development on any C/C++ project.
 - C++ modules: metric collection, logging, spatial reasoning, data structures.
 - C++ generic design patterns: decorator, factor, FSM, prototype, singleton, visitor.
 - C modules: data structures, minimal stdlib, publisher/subscriber bus, logging mechanisms for bare-metal/embedded applications.
- 2017-present **Author**, SIERRA: SCIENTIFIC METHOD AUTOMATION, .
- Given a user query of an independent variable over a range, generate experimental inputs, run experiments, process results, and generate visualizations [2].
 - Plugin-based python framework supports any agent type, platform (e.g., simulator, ROS1, real robot), or execution environment (e.g., HPC cluster, real robot).
- 2016–2022 **Author**, FORDYCA: FORAGING ROBOTS USE DYNAMIC CACHES,  Github.
- Consistent use of design principles: SOLID, DRY/WET, interface segregation, etc.
 - Scalable events-based architecture to drive agent controllers.
 - Novel generic event dispatch approach via compile-time reflection.
- 2013–2016 **Lead Developer**, CYGNSS.
- Developed LEON2 SPARC bootstrap (bare metal) for custom board bring up.
 - Delivered system device drivers: UART, I2C, SpaceWire, FPGA.
 - Integrated system and application software in RTEMS OS using 4MB memory, 50 Mhz processor.

Fellowships and Awards

- 2022 DAAD AInet Fellow - AI and Robotics (\$N/A)
- 2020–2021 UMII MnDRIVE Graduate Fellowship (\$51,177)
- 2019–2020 GAANN Fellowship (\$20,560)

Presentations

- 2022 A LATTICE MODEL OF MANIPULABLE ENVIRONMENTS FOR PROVABLE MANIPULATION, International Conference on Autonomous Agents and MultiAgent Systems (AAMAS) ARMS Workshop
- 2021 A ROBUST MODEL FOR PREDICTING COLLECTIVE BEHAVIOR IN LARGE ROBOT SWARMS, International Conference on Robotics and Automation (ICRA) Real World Swarms Workshop
- 2020 DEMYSTIFYING EMERGENT INTELLIGENCE AND ITS EFFECT ON PERFORMANCE IN LARGE ROBOT SWARMS, International Conference on Autonomous Agents and MultiAgent Systems (AAMAS)
- 2020 A THEORETICAL FRAMEWORK FOR SELF-ORGANIZED TASK ALLOCATION IN LARGE SWARMS, International Conference on Autonomous Agents and MultiAgent Systems (AAMAS) Doctoral Consortium
- 2020 ROBUSTNESS ANALYSIS IN LARGE ROBOT SWARMS, International Conference on Autonomous Agents and MultiAgent Systems (AAMAS) ARMS Workshop
- 2019 SWARM ENGINEERING THROUGH QUANTITATIVE MEASUREMENT IN 10,000 ROBOT SWARMS, International Joint Conference on Artificial Intelligence (IJCAI)
- 2019 FROM FORAGING TO CONSTRUCTION IN A 1,000,000 ROBOT SWARM, International Joint Conference on Artificial Intelligence (IJCAI) Doctoral Consortium
- 2018 BROADEN APPLICABILITY OF SWARM-ROBOTIC FORAGING THROUGH CONSTRAINT RELAXATION, International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAN)

- 2018 GENERALIZING TASK PARTITIONING APPROACHES TO ROBOT SWARM FORAGING, International Conference on Robotics and Automation (ICRA) Real World Swarms Workshop
- 2015 A SIMPLE FLASH FILE SYSTEM FOR EMBEDDED SPACE APPLICATIONS, Flight Software Workshop

Teaching Experience

- Spring 2021 **Instructor**, INTRODUCTION OF COMPUTING AND PROGRAMMING CONCEPTS, University of Minnesota, Department of Computer Science.
Introductory undergraduate python course via Zoom (30 students).
- Covered object oriented programming, algorithmic fundamentals and control flow, and basics of version control and development environments.
 - Developed new course material, assignments, and exam questions.
- 2016–2018 **Teaching Assistant**, SOFTWARE DESIGN AND DEVELOPMENT, University of Minnesota, Department of Computer Science.
Guided students (class size 100+) in developing a large-scale C++ software project.
- Tutored students in application of software design principles.
 - Introduced students to common industry toolchains (git, cmake, gcc, gdb).
 - Comprehensively answered student questions in weekly office hours, and actively engaged students with weekly hands-on labs covering course material.
- Theory Bio-inspired modeling, stochastic processes, differential equation modeling, graph theory, queueing theory
- Algorithms Parallel, greedy, bio-inspired, graphical, task allocation
- Data Graphs, trees, R-trees, Poisson queues, heaps, maps, C++ STL
- Structures
- Platforms Bare-metal: SPARC LEON2, Arduino Linux: Ubuntu, Raspberry PI
Real-time OS: RTEMS
Robotics: ARGoS, ROS1, Turtlebot3
High Performance Computing (HPC): SLURM, PBS
- Languages **Proficient:** C (kernel/embedded systems/firmware programming)
C++ (C++17, templates, metaprogramming)
Python (data visualization/processing, REST)
Familiar: Fortran, SPARC, bash, MATLAB
- Interfaces **Proficient:** Boost, OpenMP, pandas, matplotlib
Familiar: MPI, FPGA specs, UART, I2C
- Software **Writing:** Design patterns, OOP, polymorphism, concurrent programming
Development **Devops:** GitHub Actions, GitLab CI, Ansible
Tools: Intel/GNU compilers, LLVM toolchain, cmake, gdb, valgrind, VTune, git, svn

Service and Outreach

- 2022-Present **Committee Involvement**, JOURNALS AND CONFERENCES.
- 2022 Autonomous Robots and Multi-Robot Systems (ARMS) Program Committee
 - 2023 Autonomous Agents and Multi-Agent Systems (AAMAS) Program Committee
 - 2023 Associate for the Advancement of Artificial Intelligence (AAAI) Program Committee
- 2018-Present **Ad Hoc Reviewer**, JOURNALS AND CONFERENCES.
- Frontiers in Robotics and AI
 - Transactions on Robotics (TRO)
 - Autonomous Agents and Multi-Agent Systems (AAMAS, AGNT)
 - International Conference on Artificial Intelligence (IJCAI)
 - International Conference on Robotics and Automation (ICRA)
 - Swarm Intelligence
 - International Conference on Intelligent Robots and Systems (IROS)

- 2018–2019 **Instructor**, MNDRIVE SUMMER TECHNOLOGY CAMP, University of Minnesota.
Led outreach activities aimed at broadening the interests of elementary and middle school students in historically underrepresented demographics in STEM.
- 2018–2020 **Instructor**, MNDRIVE YOUTH TECHNOLOGY OUTREACH, Minneapolis, MN.
Designed accessible science curriculum and led bi-weekly programming, Arduino, or science related activities. Orchestrated student groups to foster collaboration on technically challenging tasks.

References

Dr. Maria Gini

Department of Computer Science
University of Minnesota

✉ gini@umn.edu

☎ (612) 625-5582

Dr. Nikolaos Papanikolopoulos

Department of Computer Science
University of Minnesota

✉ papan001@umn.edu

☎ (612) 625-0163

Dr. Shana Watters¹

Department of Computer Science
University of Minnesota

✉ watt0087@umn.edu

☎ (612) 626-9381

Dr. Junaed Sattar

Department of Computer Science
University of Minnesota

✉ junaed@umn.edu

☎ (612) 626-7235

Dr. Emilie Snell-Rood

Department of Evolution, Ecology, and
Behavior

University of Minnesota

✉ emilies@umn.edu

☎ (612) 624-7238

¹Teaching reference.