John Harwell

Curriculum Vitae

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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. Başağaoğlu, 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 **Embedded Development Lead**, SATELLES, Minneapolis, MN.

- Demonstrated technical leadership by developing software engineering guidelines and methodologies for large software framework to support overall business goals.
- Facilitated meetings with key leaders to ensure timely decision-making and communication between stakeholders at all levels.
- Assisted in technical personnel management in 8–10 person teams.
- Drove process improvements in software process to reduce development costs: code reviews, automated tooling, etc.
- Design, implementation, and maintenance of a custom QEMU plugin to reduce risk in commercializing custom Position, Navigation, Timing (PNT) ASIC.
- Ported large software framework for embedded PNT receivers to custom ASIC.
- Developed custom probe firmware for Black Magic Debug to communicate with custom ASIC.

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 military 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 highs 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 supercomputing 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 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), or execution environment (e.g., supercomputing 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 for board bring up.
- Delivered system device drivers: UART, I2C, SpaceWire, FPGA.
- Integrated system and application software in RTEMS 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 (SIMPAR)

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.

Areas of Expertise

Theory **Modeling**: Bio-inspired modeling, stochastic processes, differential equations, graph theory, queueing theory
Algorithms:Parallel, greedy, bio-inspired, graphical, task allocation

Embedded Systems **OS**: Petalinux, FreeRTOS, RTEMS, bare-metal
Architectures: ARM Cortex-M7, SPARC LEON2
Middleware: QEMU
Design: Hardware/software trade-offs, hotfix debugging

Multi-agent Systems **OS**: Linux (ubuntu, debian, raspbian)
Platforms: ARGoS, Gazebo, ROS1, ROS2, Turtlebot3
Behavior Design: Vector fields, bio-inspired modeling, decentralized task allocation
Analysis: Differential equations, cooperative algorithms, metric design, imperfect sensor/actuator compensation

High Performance Computing **Platforms**: SLURM, PBS
Optimization: Profiling,architectural/memory/cache analysis, algorithm analysis

Technical Skills

Languages **Expert**: C: embedded, systems programming
C++: 11/14/17 with templates, metaprogramming
Proficient: C: kernel programming, python
Familiar: Fortran, bash, fish, MATLAB

Software Development	**Architecture**: Design patterns, OOP, polymorphism **Devops**: GitHub/Gitlab CI/CD, Ansible, Docker **Toolchains**: LLVM (clang-*), Intel (icx, VTune), GNU (gcc-*) **Tools**: cmake, Bazel, git, gdb, valgrind, OpenOCD, oscilloscope, JTAG, Black Magic Debug **Data Structures**: Graphs, trees, R-trees, Poisson queues, heaps, maps
Protocols	UART, I2C, SPI, NMEA
Libraries	STL, Boost, OpenMP, MPI, CMSIS, pandas

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

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[1] Teaching reference.