John Harwell

Curriculum Vitae

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Education

2016–2022 **Ph.D. in Computer Science**, *The University of Minnesota*, Twin Cities.

2016–2018 **M.S. in Computer Science**, *The University of Minnesota*, Twin Cities.

2009–2013 **B.S. in Computer Science and Engineering**, *The University of Wisconsin*, Madison, *Magna cum laude*.

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. "SIERRA: A Modular Framework for Research Automation". In: *Proceedings of the 21st International Conference on Autonomous Agents and Multiagent Systems*. AAMAS '22. Virtual Event, New Zealand: International Foundation for Autonomous Agents and Multiagent Systems, **2022**, pp. 1905–1907.

[2] **J. Harwell**, A. Sylvester, M. Gini. "Characterizing The Limits of Linear Modeling of Non-Linear Swarm Behaviors". In: *Autonomous Robots* **(2022)**. Under review. URL: http://arxiv.org/abs/2110.12307.

[3] 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.

[4] **J. Harwell**, M. Gini. "Improved Swarm Engineering: Aligning Intuition and Analysis". In: *Robotics and Autonomous Systems* **(2021)**. URL: http://arxiv.org/abs/2012.04144.

[5] **J. Harwell**. "A Theoretical Framework for Self-Organized Task Allocation in Large Swarms". In: *Proceedings of the 19th International Conference on Autonomous Agents and MultiAgent Systems*. AAMAS '20. International Foundation for Autonomous Agents and Multiagent Systems, **2020**.

[6] **J. Harwell**, L. Lowmanstone, M. Gini. "Demystifying Emergent Intelligence and Its Effect on Performance In Large Robot Swarms". In: *Proceedings of the 19th International Conference on Autonomous Agents and MultiAgent Systems*. AAMAS '20. International Foundation for Autonomous Agents and Multiagent Systems, **2020**.

[7] A. Chen, **J. Harwell**, M. Gini. *Maximizing Energy Battery Efficiency in Swarm Robotics*. **2019**. URL: http://arxiv.org/abs/1906.01957.

[8] **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, **2019**.

[9] **J. Harwell**, M. Gini. "Swarm Engineering Through Quantitative Measurement of Swarm Robotic Principles in a 10,000 Robot Swarm". In: *Proceedings of the Twenty-Eighth International Joint Conference on Artificial Intelligence, IJCAI-19*. International Joint Conferences on Artificial Intelligence Organization, **2019**.

[10] N. White, **J. Harwell**, M. Gini. *Socially Inspired Communication in Swarm Robotics*. **2019**. URL: http://arxiv.org/abs/1906.01108.

[11] **J. Harwell**, M. Gini. "Broadening applicability of swarm-robotic foraging through constraint relaxation". In: *2018 IEEE International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR)*. **2018**.

[12] H. Başağaoğlu, J. Blount, J. Blount, B. Nelson, S. Succi, P. Westhart, **J. Harwell**. "Computational performance of SequenceL coding of the lattice Boltzmann method for multi-particle flow simulations". In: *Computer Physics Communications* 213 **(2017)**.

Experience

2016–Present **Academic Researcher**, University of Minnesota, Minneapolis, MN.

Investigated the conditions under which some form of self-organizing structure will collectively emerge in multi-robot systems, and how the structure can be predicted from first principles. Developed partial solution to the Parallel Bricklayer Problem.

- Modeled 3D structures using graph theory to prove that suitable algorithms exist to provably manipulate graphs represented structures with certain properties from one state to another.
  - Funded through a UMII Fellowship and a Graduate Research Fellowship.
- Modeled Poisson and non-Poisson distribution collective behaviors using Ordinary Differential Equations (ODEs) and first-principle derivations in a foraging task [2].
  - Funded through a UMII Fellowship and a Graduate Research Fellowship.
- Collaborative effort to investigate the origin of collective intelligence using task allocation, graph theory, and matroids [11, 6].
  - Funded through a UMII Assistantship and GAANN Fellowship.
- Developed methodology for measuring major design principles of multi-robot systems: scalability, self-organization, flexibility, and robustness; application to real-world foraging scenarios [9, 4].
  - Funded through GAANN, UMII Fellowships and a Graduate Research Fellowship.

2016-present **Lead Developer**, Swarm Robotics Research Libraries, Github.

- Innovated automated research pipeline: generating inputs, running experiments, processing results, and generating camera-ready deliverables (python, matplotlib, pandas, ARGoS, ROS).
- Supported R&D through application of design patterns, modern language features to maximize reusability (Boost).
- Supported R&D through iterative profiling and refinement of computationally intensive simulations for deployment on High Performance Computing (HPC) clusters (VTune, PBS, SLURM, gdb).

2016–Present **Mentor and Advisor**, University of Minnesota, Minneapolis, MN.

Mentored high school and undergraduate students interested in AI and robotics.

- Designed engaging opportunities including contributing to published papers and large C++ software projects.
- Guided multiple undergraduates interested in graduate school and academic research.
  - Three successfully applied for undergraduate research grants.
  - Three successfully published and presented original research at workshops and conferences [7, 10, 3].

Summer 2017 **Software Development Intern**, Cray, Inc., Minneapolis, MN.

Built reusable Linux kernel modules suitable for HPC environments to reduce development cycle time of Cray DataWarp software.

2013–2016 **Research Engineer**, Southwest Research Institute, San Antonio, TX.
Computational optimization of computationally intensive simulations [12]. Engineered high quality software for embedded systems, specializing in avionics and spacecraft applications.

- Application of genetic algorithms to maximize performance of fluid flow simulations with temporally varying computational characteristics on heterogeneous cluster computing hardware.
- Developed flight software for 8 satellite constellation for hurricane monitoring as main developer of bootstrap (SPARC assembly), system device drivers (UART, I2C, SpaceWire, custom protocols), application, and scientific data processing flight software in collaboration with NASA and the University of Michigan (RTEMS, C).
- Enhanced utility of POSIX-flavored filesystems for embedded spacecraft applications by developing new file system with smaller, configurable memory footprint and increased robustness compared to current solutions (C, gdb).

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 OOP paradigm, algorithmic fundamentals and control flow, and basics of version control and IDEs.
- 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.

Skills

Theory	Stochastic processes, ODE modeling, graph theory, queueing theory, linear optimization, code performance analysis
Algorithms	Parallel, greedy, biomimetic, graphical, distributed task allocation
Data Structures	Graphs, trees, R-trees, Poisson queues, heaps, maps
Software Development	Design patterns, OOP, inheritance, polymorphism, concurrent programming
Languages	Proficient: C (kernel programming, embedding systems programming) C++ (C++17, templates, template metaprogramming) Familiar: Fortran, SPARC, bash, MATLAB Python (data visualization, data processing)
Software Tools	Intel/GNU/LLVM compilers, LLVM toolchain, git, cmake, gdb, valgrind, VTune
Platforms	Linux: Ubuntu, Raspberry PI Real-time OS: RTEMS Robotics: ARGoS, ROS, Turtlebot3 High Performance Computing (HPC): SLURM, PBS
Interfaces	Proficient: Boost, OpenMP, pandas, matplotlib Familiar: MPI, FPGA specs, UART, I2C

Service and Outreach

2022-Present **Committee Involvement**, Journals and Conferences.
- 2022 Autonomous Robots and Multi-Robot Systems (ARMS) Program Committee

2018-Present **Ad Hoc Reviewer**, Journals and Conferences.
- Transactions on Robotics (TRO)
- Autonomous Agents and Multi-Agent Systems (AAMAS)
- 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 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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Dr. Shana Watters[1]
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[1] Teaching reference.