John R. **Harwell**

Artificial Intelligence · Robotics

University of Minnesota Department of Computer Science
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Education

Ph.D., Computer Science PhD — *2022 (expected)*

University Of Minnesota, Twin Cities — *Minneapolis, MN*

M.S., Computer Science — *2019*

University Of Minnesota, Twin Cities — *Minneapolis, MN*

B.S., Computer Science and Engineering, *Magna cum laude* — *2013*

University Of Wisconsin-Madison — *Madison, WI*

Research Experience

Collective Construction Algorithm Design — *University Of Minnesota, Twin Cities*

Principal Investigator — *2019–Present*

- Derived topological and graphical invariants describing a class of three dimensional structures and corresponding algorithms for guaranteed structure completion by swarms of robots without centralized control.
- Demonstrated in simulation at "natural" scales with swarms of over 1,000,000 robots and structures of real-world utility/size.

Emergent Task Allocation in Foraging — *University Of Minnesota, Twin Cities*

Principal Investigator — *2017–2019*

- Derived self-organized task allocation approach using stochastic greedy choice to relax environmental constraints of previous work.
- Utilized recursive bifurcating task decomposition, linear optimization for dynamic placement of intermediate object drop/pickup sites to maximize adaptability across a wide variety of environmental conditions.
- Applied matroid theory to study the origin of emergent intelligence within graphical task allocation methods.

Swarm Engineering — *University Of Minnesota, Twin Cities*

Principal Investigator — *2019–2020*

- Developed quantitative measurements for major principles in swarm robotics: scalability, emergence, flexibility, and robustness, and demonstrated their usefulness as a predictive design tool for 10,000 robot swarms through comprehensive analysis of real-world scenarios.
- Extended state of the art stochastic and differential equation models of foraging to predict swarm performance, scalability, and emergent behavior from first principles.

Research Interests

Swarm robotics, embedded systems, stochastic and differential equation modeling, matroid theory, graph theory, queueing theory, topology, biomimetic/distributed algorithms, task allocation.

Teaching Interests

Multi-agent robotics, mathematical modeling of robotic systems, embedded systems, algorithms, operating systems, software development.

Publications

J. Harwell and M. Gini, "Demystifying Emergent Intelligence And Its Effect On Performance In Large Robot Swarms," in *Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems, (AAMAS)*. International Foundation for Autonomous Agents and Multiagent Systems, 5 2020, pp. 474-483.

J. Harwell and 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, 7 2019, pp. 336–342.

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, 7 2019, pp. 6438–6439.

J. Harwell, "A Theoretical Framework For Self-Organized Task Allocation in Large Robot Swarms," in *Proceedings of the 18th International Conference on Autonomous Agents and MultiAgent Systems, (AAMAS)*. International Foundation for Autonomous Agents and Multiagent Systems, 5 2020, pp. 2191-2192.

J. Harwell and M. Gini, "Broadening applicability of swarm-robotic foraging through constraint relaxation," *IEEE Int'l Conf. on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR)*, pp. 116–122, May 2018.

A. Chen, **J. Harwell**, M. Gini, "Maximizing Energy Efficiency in Swarm Robotics," arXiv:1906.01957 [cs.MA], June 2019.

N. White, **J. Harwell**, M. Gini, "Socially Inspired Communication in Swarm Robotics," arXiv:1906.01108 [cs.RO], June 2019.

H. Başağaoğlu, J. Blount, J. Blount, B. Nelson, S. Succi, P. M. Westhart, and **J. R. Harwell**, "Computational performance of SequenceL coding of the lattice Boltzmann method for multi-particle flow simulations," Computer Physics Communications, vol. 213, pp. 92–99, 2017.

Conference Presentations

J. Harwell, 'Demystifying Emergent Intelligence and Its Effect on Performance in Large Robot Swarms', Auckland, NZ, 2020.

J. Harwell, 'A Theoretical Framework For Self-Organized Task Allocation in Large Swarms', Auckland, NZ, 2020.

J. Harwell, 'Robustness Analysis in Large Robot Swarms', Auckland, NZ, 2020.

J. Harwell, 'Swarm Engineering Through Quantitative Measurement in 10,000 Robot Swarms', Macau, CN, 2019.

J. Harwell, 'From Foraging To Construction In A 1,000,000 Robot Swarm', Macau, CN, 2019.

J. Harwell, 'Generalizing Task Partitioning Approaches to Robot Swarm Foraging', Brisbane, AU, 2018.

J. Harwell, 'A Simple Flash File System For Embedded Space Applications', Laurel, MD, 2015.

Research Statement

I am a member of the Artificial Intelligence, Robotics, and Vision Laboratory at the University of Minnesota, under the direction of Dr. Maria Gini, my advisor. With my eventual goal of research lab directorship, my personal vision comprises research into mathematical models for predictive control of large-scale multi-agent robotic systems to create programmable robot swarms. To this end, I bring extensive industry experience in real-time embedded system design, high performance computing, along with a theoretic background in algorithms, data structures, stochastic modeling, graph theory, and topology.

Professional Experience

Southwest Research Institute *San Antonio, TX*

Research Engineer *June 2013—Aug. 2016*

Developed software for embedded systems, specializing in avionics/spacecraft applications. Championed research into computational optimization across scales. Projects include:

- **Interstellar File Systems (IFS)**: Surveyed state-of-the-art Flash file systems for embedded spacecraft applications, and developed file system to address gaps in memory footprint size, robustness, and wear-leveling of current solutions.
- **Cyclone Global Navigation Satellite System (CYGNSS)**: Worked with NASA/University of Michigan to develop flight software.Built and tested bootstrap, system, application, and scientific data processing software.
- **Lattice Boltzmann Method (LBM) Optmization**: Increased performance of computationally intensive LBM model by up to 40X.

Cray, Inc *Minneapols, MN*

Intern *June 2017—Aug. 2017*

Led effort to create resusable Linux kernel modules suitable for deployment on Cray's supercomputing environment. Projects include:

- **Fault Injection**: Dynamic fault injection module styled after dynamic_debug. Provided run-time control of injection of errors and delays via debugfs.
- **High Speed Logging**: Replacement for dmesg for use in situations where (1) log peristence across boots is desired; (2) logging is desired in interrupt or other highly time-sensitive contexts.

Honors & Awards

2020	**UMII MnDRIVE Graduate Assistantship**	*University Of Minnesota, Twin Cities*
2018-2019	**MnDRIVE Scholar**	*University Of Minnesota, Twin Cities*
2018-2020	**GAANN Fellowship**	*University Of Minnesota, Twin Cities*
2016-2018	**Graduate Teaching Assistantship**	*University Of Minnesota, Twin Cities*

Skills

Theory	Stochastic processes and differential equation modeling, matroid theory, graph theory, topology, robotic kinematics/localization, linear optimization, computational optimization
Algorithms and Data Structures	Parallel, greedy, biomimetic, graphical, augmented/amortized data structures, distributed task allocation
Languages	C++, C, Python, Fortran, SPARC, bash, Lisp, MATLAB
Platforms	UNIX, Linux, RTEMS, ROS, Raspberry PI, Pioneer P3-DX, Swarmanoid S-bot, LEGO Mindstorms, HPC clusters
Software	Boost, OpenMP, MPI, Intel compilers/VTune, GALib, LLVM, CodeSonar, ARGoS, git, cmake