John R. Harwell

Robotics · Swarm Intelligence · Mathematical Modeling ·

University of Minnesota Department of Computer Science

200 Union St SE, Minneapolis, MN 55455

(651) 261-2862 | harwe006@umn.edu | www-users.cs.umn.edu/~harwe006 | jharwell | john-harwell-5b116187

Education

Ph.D., Computer Science — *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 Interests

Swarm intelligence, swarm robotics, emergent and self-organizing behaviors, task allocation, stochastic and differential equation modeling, matroid theory, graph theory, queueing theory, biomimetic/distributed algorithms.

Research Experience

Graduate Student

Advisor: Maria Gini

University of Minnesota — *2016–Present*

- Derived graph properties for a class of graphs representing three dimensional structures for provably concurrent manipulation for construction and deconstruction
- Characterized limits of linear modeling of non-linear swarm behaviors differential equation models; demonstration of practical utility
  - *This work resulted in a publication under review at AR*
  - *This work was funded through a UMII Fellowship, and a Graduate Research Fellowship*
- Examined self-organized task allocation approaches using stochastic greedy choice and matroid theory to study the effect of task graph connectivity and incomplete information on emergent intelligence
  - *This work resulted in publications in AAMAS [1] and SIMPAR [3]*
  - *This work was funded through a UMII Assistantship and GAANN Fellowship*
- Quantified major design principles in swarm robotics: scalability, emergence, flexibility, and robustness; demonstrated their usefulness as a predictive design tool through comprehensive analysis of real-world scenarios
  - *This work resulted in publications in IJCAI [2] and TRO (under review).*
  - *This work was funded through GAANN, UMII Fellowships and a Graduate Research Fellowship*

Research Engineer

Computational Optimization

Southwest Research Institute — *2015–2016*

- Championed research into computational optimization, embedded systems to large-scale HPC simulations
- Lattice Boltzmann Method (LBM) Optimization: Increased performance of computationally intensive LBM model by up to 40X
- Established genetic algorithms as a viable method for online, adaptive search to maximize performance of LBM simulations with temporally varying computational characteristics on heterogeneous computing hardware
  - *This work contributed to a publication in Computer Physics Communications*
  - *This work was funded through an internal research grants*

Professional Experience

Intern

Minneapols, MN

Cray, Inc

June 2017—Aug. 2017

Built reusable Linux kernel modules suitable for deployment on Cray's supercomputing environment

- **Fault Injection**: Dynamic fault injection module styled after dynamic_debug which 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 persistence across boots is desired; (2) logging is desired in interrupt or other highly time-sensitive contexts

Southwest Research Institute

San Antonio, TX

Research Engineer

2013–2016

Engineered high quality software for embedded systems, specializing in avionics and spacecraft applications

- **Interstellar File Systems (IFS)**: Surveyed state-of-the-art Flash file systems for embedded spacecraft applications, and pioneered 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 and University of Michigan to develop flight software; contributed bootstrap, system, application, and scientific data processing software

Publications

Conference Proceedings

[1] **Analysis of Exploration in Swarm Robotic Systems**

M. Jeong, J. Harwell, M. Gini

Proceedings of the 16th International Conference on Intelligent Autonomous Systems (IAS-16), 2021

[2] **A Theoretical Framework for Self-Organized Task Allocation in Large Swarms**

J. Harwell

Proceedings of the 19th International Conference on Autonomous Agents and MultiAgent Systems, 2020, Auckland, New Zealand

[3] **Demystifying Emergent Intelligence and Its Effect on Performance In Large Robot Swarms**

J. Harwell, L. Lowmanstone, M. Gini

Proceedings of the 19th International Conference on Autonomous Agents and MultiAgent Systems, 2020, Auckland, New Zealand

[4] **A Unified Mathematical Approach for Foraging and Construction Systems in a 1,000,000 Robot Swarm**

J. Harwell

Proceedings of the Twenty-Eighth International Joint Conference on Artificial Intelligence, IJCAI-19, 2019

[5] **Swarm Engineering Through Quantitative Measurement of Swarm Robotic Principles in a 10,000 Robot Swarm**

J. Harwell, M. Gini

Proceedings of the Twenty-Eighth International Joint Conference on Artificial Intelligence, IJCAI-19, 2019

[6] **Broadening applicability of swarm-robotic foraging through constraint relaxation**

J. Harwell, M. Gini

2018 IEEE International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR), 2018

[7] **Computational performance of SequenceL coding of the lattice Boltzmann method for multi-particle flow simulations**

H. Başağaoğlu, J. Blount, J. Blount, B. Nelson, S. Succi, P. M. Westhart, J. R. Harwell

Computer Physics Communications 213 pp. 92–99, 2017

Under Review

[1] **Improved Swarm Engineering: Aligning Intuition and Analysis**

J. Harwell, M. Gini

IEEE Transactions on Robotics, 2021

Presentations

A Robust Model For Predicting Collective Behavior In Large Robot Swarms *Montreal, CA*

International Conference on Robotics and Automation (ICRA) Real World Swarms Workshop *2021*

Demystifying Emergent Intelligence and Its Effect on Performance in Large Robot Swarms *Auckland, NZ*

International Conference on Autonomous Agents and MultiAgent Systems (AAMAS) *2020*

A Theoretical Framework For Self-Organized Task Allocation in Large Swarms *Auckland, NZ*

International Conference on Autonomous Agents and MultiAgent Systems (AAMAS) Doctoral Consortium *2020*

Robustness Analysis in Large Robot Swarms *Auckland, NZ*

International Conference on Autonomous Agents and MultiAgent Systems (AAMAS) ARMS Workshop *2020*

Swarm Engineering Through Quantitative Measurement in 10,000 Robot Swarms *Macau, CN*

International Joint Conference on Artificial Intelligence (IJCAI) *2019*

From Foraging To Construction In A 1,000,000 Robot Swarm *Macau, CN*

International Joint Conference on Artificial Intelligence (IJCAI) Doctoral Consortium *2019*

Broaden Applicability of Swarm-Robotic Foraging Through Constraint Relaxation *Brisbane, AU*

International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR) *2018*

Generalizing Task Partitioning Approaches to Robot Swarm Foraging *Brisbane, AU*

International Conference on Robotics and Automation (ICRA) Real World Swarms Workshop *2018*

A Simple Flash File System For Embedded Space Applications *Laurel, MD*

Flight Software Workshop *2015*

Teaching Experience

University of Minnesota *Spring 2021*

Instructor, *Introduction to Computing and Programming Concepts*

Taught an introductory python course via Zoom to undergraduate students. Topics covered included the OOP paradigm, algorithmic fundamentals and control flow, and basics of version control and IDEs. Developed new course material, assignments, and exam questions. 30 students.

University Of Minnesota *2016–2018*

Graduate Teaching Assistant, *Software Design and Development*

Guided students in developing a large-scale software project through (1) application of software design principles, (2) utilization of common industry toolchains, (3) weekly office hours, labs, and comprehensive grading feedback. 100+ students.

Fellowships

UMII MnDRIVE Graduate Fellowship *2020–2021*

University Of Minnesota, Twin Cities *$51,177*

GAANN Fellowship *2019–2020*

University Of Minnesota, Twin Cities *$27,560*

Honors & Awards

Graduate Research Assistantship *2021–2022*

University Of Minnesota, Twin Cities

MnDRIVE Scholar *2018–2019*

University Of Minnesota, Twin Cities

Graduate Teaching Assistantship *2016–2018*

University Of Minnesota, Twin Cities

Claude and Dora Richardson Engineering Scholarship *2010–2012*

University of Wisconsin-Madison

Harold A. and Marion F. Peterson Scholarship *2011*

University of Wisconsin-Madison

Technical Skills

Theory	Stochastic processes and differential equation modeling, matroid theory, graph theory, queueing theory, robotic kinematics/localization, linear optimization, computational optimization
Algorithms	Parallel, greedy, biomimetic, graphical, distributed task allocation
Data Structures	Graphs, trees, R-trees, queues, Poisson queues, heaps, maps, linked lists, stacks, sets, dictionaries
Languages	C: kernel programming, embedding systems programming, FPGAs C++: C++17 proficiency, templates, template metaprogramming, inheritance, polymorphism Python: data visualization, HPC drivers
Software Design	Design Patterns, OOP, Inheritance, Multi-thread/Multi-process, Versioning, Performance, Documentation
Platforms	Linux: Servers, HPC Clusters, Raspberry PI Real-time OS: RTEMS Robotics: ARGoS, ROS
Software	Boost, OpenMP, MPI, Intel compilers/VTune, LLVM, git, cmake

Projects

Swarm Intelligence ARGoS Reusable Automation (SIERRA) *SIERRA*

Developer/Maintainer *2017-present*

- Developed python framework for automating running large scale swarm experiments, processing results, and generating camera-ready deliverables using the ARGoS robotics simulator

Swarm Core Library *Swarm Core*

Developer/Maintainer *2017-present*

- Developed C++ library for task allocation, hardware/platform abstraction, various subsystems, and metric collection
- Strong emphasis on reusability through templates and extensive documentation

Swarm Robotics Project Libraries *Foraging, Construction*

Developer/Maintainer *2017-present*

- Developed C++ libraries for supporting research into foraging and construction
- Deployment on HPC clusters to simulate over 10,000 robots in parallel for large experiments

Service & Outreach

MnDRIVE Summer Youth Technology Camp *2018–2019*

- Led various activities in summer technology camps aimed at broadening the interests of elementary and middle school students in historically underrepresented demographics

MnDRIVE Youth Technology Outreach *2018–2020*

- Designed accessible science curriculum and led bi-weekly programming, Arduino, or science related activities
- Orchestrated student groups to foster collaboration on technically challenging tasks

Ad Hoc Reviewer (Journals and Conferences) *2018–Present*