ECE693H, Spring 2025: Multi-robot System Design

“Course Intro”

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Multi-robot Systems

Multi-robot Systems: Wheeled Robots

Turtlebots

Multi-robot Systems: Micro Air Vehicles

Crazyflies

Multi-robot Systems: Millisystems

Kilobots

Fig. 1. Isometric (left) and bottom (right) views of a Kilobot. Some key features are: (A) Vibration motors, (B) Lithium-Ion battery, (C) Rigid supporting legs, (D) Infrared transmitter/receiver, (E) Three-color (RGB) LED, (F) Charging tab, and (G) Ambient light sensor. Note the 1cm line for scale.

Rubenstein et al. 2012

Multi-robot Systems vs Swarms

Multi-robot Systems vs Swarms

(adapted from slide by V. Kumar)

Multi-robot Systems vs Swarms

Unpopular opinion in public, popular opinion in private:

The term “swarm” has been used and abused, and is now meaningless.

Outline for Today

1. Introduce myself to you
2. Meet some of your classmates
3. Course info
4. In-class Activity

Course Instructor

Dr. Daniel Drew

Instructor

Assistant Professor, ECE

Course Instructor

Dr. Daniel Drew

Instructor

Assistant Professor, ECE

BS, MSE

Small-scale railgun

Nanoelectronics

PhD, EECS

Prototyping Tools

Insect-scale Millirobots

Postdoc, ME

Human-Swarm Interaction

Soft Robots

Asst. Professor, ECE

Aug. 2024

Asst. Professor, ECE

Dr. Daniel Drew – Assorted Research Projects

milliflyers

Penny-Sized Ionocraft Flies With No Moving Parts

A drone powered by electrohydrodynamic thrust is the smallest flying robot ever made

5 Feb

wsns

quadrotors

biomimetics

milliwalkers

swarms

control systems

design tools

DRL

The Drew Research Lab

ubiquitous insect-scale robots

MEMS, swarms, autonomy

DRL

The Drew Research Lab

DRL

The Drew Research Lab

Acoustic Communication and Sensing

DRL

The Drew Research Lab

Heterogeneous Swarms

DRL

The Drew Research Lab

Flying Microrobots With No Moving Parts

Dr. Daniel Drew – Also a Human Being

My wife Emily
(also UHM prof. at WRRC)

My dog Tuna

Playing Inside and Outside

My son Silas

Modern Robots in the Wild

Small Group Activity: ~2 minutes

With your neighbor(s), discuss:

- What makes something a ROBOT? No wrong answers!

Food for thought:

What Makes Something a Robot?

Course at a Glance: “Swarm-on-a-Stick”

We will create an open-source swarm robotics kit for education, from scratch.

Things you will do:
-PCB design, fabrication, and assembly
-Modeling and 3D printing structural components
-Firmware and software coding including SOTA micropython, ROS2
-Listen to lectures about autonomous mobile robots and multi-robot systems
-Become better presenters
-Become more proficient at working as part of an engineering / product design team

Course Schedule

Week	Module	Date	Lecture Topic	In-Class Activity
Week 1	Intro	1/13	Course Intro	Icebreakers
		1/15	Autonomous Mobile Robots	Subsystem Group Formation
Week 2		1/20	**MLK Day**	
	Design Phase 1	1/22	Action 1	
Week 3		1/27	Action 2	Astound the Class! 1
		1/29	Perception 1	
Week 4		2/3	Perception 2	Subsystem Check-ins 1
		2/5	Intelligence 1	
Week 5		2/10	Design Review Presentations	
		2/12		
Week 6		2/17	**President's Day**	
	Design Phase 2	2/19	Intelligence 2	Subsystem Check-ins 2
Week 7		2/24	Multi-robot Systems 1	Astound the Class! 2
		2/26	Multi-robot Systems 2	
Week 8		3/3	Multi-robot Systems 3	Subsystem Check-ins 3
		3/5	Multi-robot Systems 4	
Week 9		3/10	Design Review Presentations	
		3/12		
Week 10		3/17	**Spring Break**	
		3/19		
Week 11		3/24	The Penny Stacking Tower Challenge	
		3/26	**Kuhio Day**	
Week 12		3/31	**Veterans Day**	
	Design Phase 3	4/2	The Robot Operating System (ROS)	Subsystem Check-ins 3
Week 13		4/7	Frontiers in Robotics 1	
		4/9	Frontiers in Robotics 2	
Week 14		4/14	Skill Sharing Workshop 1	
		4/16	Skill Sharing Workshop 2	
Week 15		4/21	Skill Sharing Workshop 3	
		4/23	Skill Sharing Workshop 4	
Week 16	System Integration	4/28	Collaborative Studio Days	
		4/30		
Week 17		5/5	Private Demo Day	
		5/7	Public Demo Day	

-Three "Design Phases"

Five overarching lecture topics:
Action, Perception, Intelligence, Multi-robot Systems, Frontiers in Robotics

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		2/5	Intelligence 1	
Week 5		2/10	Design Review Presentations	
		2/12		

Two assignments in the first 5 weeks.

Assignments in 693H

Astound-the-Class: Short (~3 minute, 2 slide) individual presentations on any bit of news, cutting-edge research, or fun fact related to autonomous mobile robots and/or multi-robot systems. Examples: Killer robots in Ukraine; Dario Floreano's avian-inspired robot legs; How mantis shrimp claws work.

Design Review Presentations: ~20 minute group presentations on your robotic subsystem design progress. This can (and should) include a broad mix of technical content, things like "how we calculated this," "why we chose this," "this is what the prototype looks like."

Skill-sharing Workshop: Full period (~1 hour) sessions where <u>you</u> will lead the class in learning something integral to your subsystem efforts. Examples: 3D modeling a robot chassis; Gazebo crash course; odometry and state estimation

Final Technical Report: Writeup of your design efforts in academic-standard format.

(Ungraded) Assignments in 693H

Readings: I will assign readings (videos, textbook pages, other people's lecture notes, etc.) relevant to the week's lecture topics. You are strongly encouraged to read these in order to help reinforce things I am saying in lecture.

Tasks: I will assign tasks for you to complete that will help you stay on track for meeting your design goals. An example is downloading a specific software package and progressing through a specific tutorial.

Grading in 693H

My approach to designing a course: Get everyone to engage with the material.

My approach to grading: Everyone who works hard does well.

Graduate course grading scale: Acceptable. **B**ad. **C**atastrophic

What if I am terrible at / afraid of public speaking: That's okay.

A “Typical” Class Period

~45 minutes — Lecture

~30 minutes — Open time for design group work

(many of the periods will look very different than this!)

The Course Website + Laulima

https://danieldrew.me/693h/

and embedded in Laulima

A Disclaimer

This is a new course, and we are attempting to cover a lot of ground with a unique structure!

- Ask questions – about the course structure/schedule as well as content!

- Provide feedback via email, Canvas, office hours
- Class Feedback Surveys will be offered for Extra Credit

In-Class Activity

Course Summary 1-pager: grab a paper and pen, divide your paper in half with a line. No wrong answers, no redos (unless something horrible happens):

Top half:

1) Write down these categories, and 3-5 short bullet points that come to mind for each, in the context of robotics: Action, Perception, Intelligence

Bottom half:

2) Draw a flowchart for designing an autonomous mobile robot from scratch. This should answer questions like how it will be powered, how it will move, how it will be controlled, and how it will be built, to the best of your ability. Use numbers with units whenever possible! (Hint: don't know where to start? Start with the battery.)

Discuss In-Class Activity

Final Notes

1. Don’t forget to do the readings on the course website

2. Bringing a laptop to class is strongly suggested. Don’t have one? Talk to me after class or send an email.

3. Get software issues figured out <u>early</u>