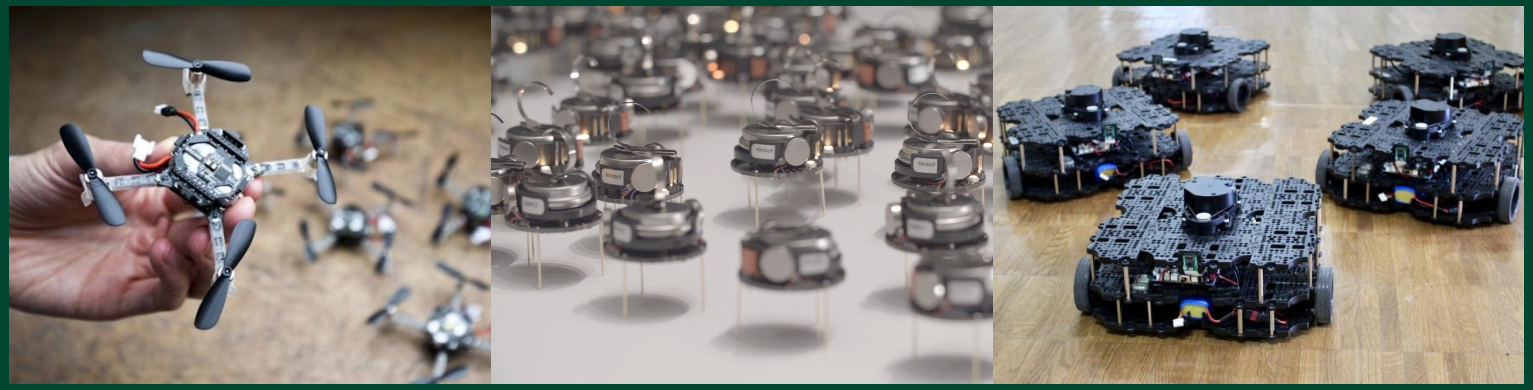
ECE693H, Spring 2025:
Multi-robot System Design

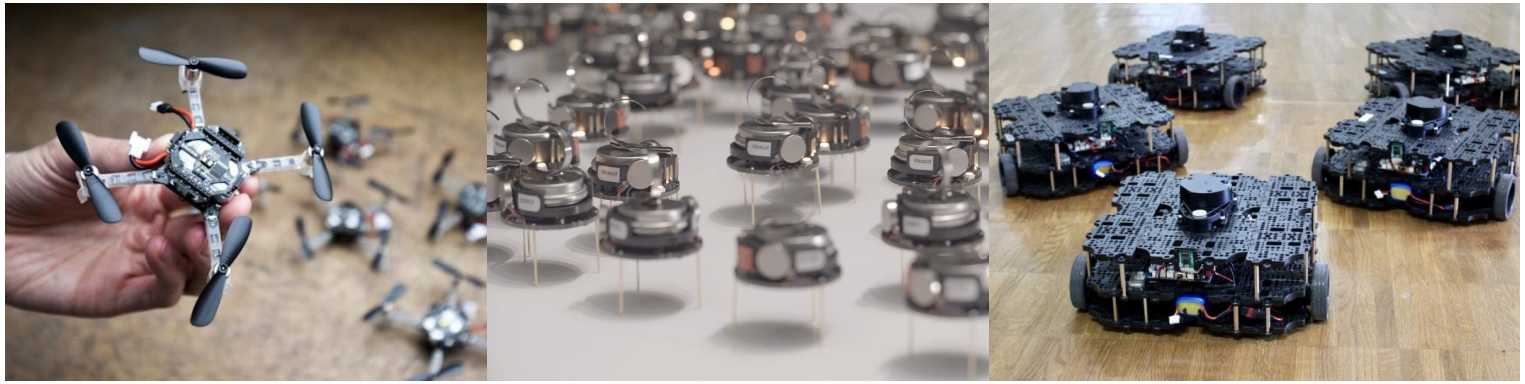
“Course Intro”



Dr. Daniel Drew

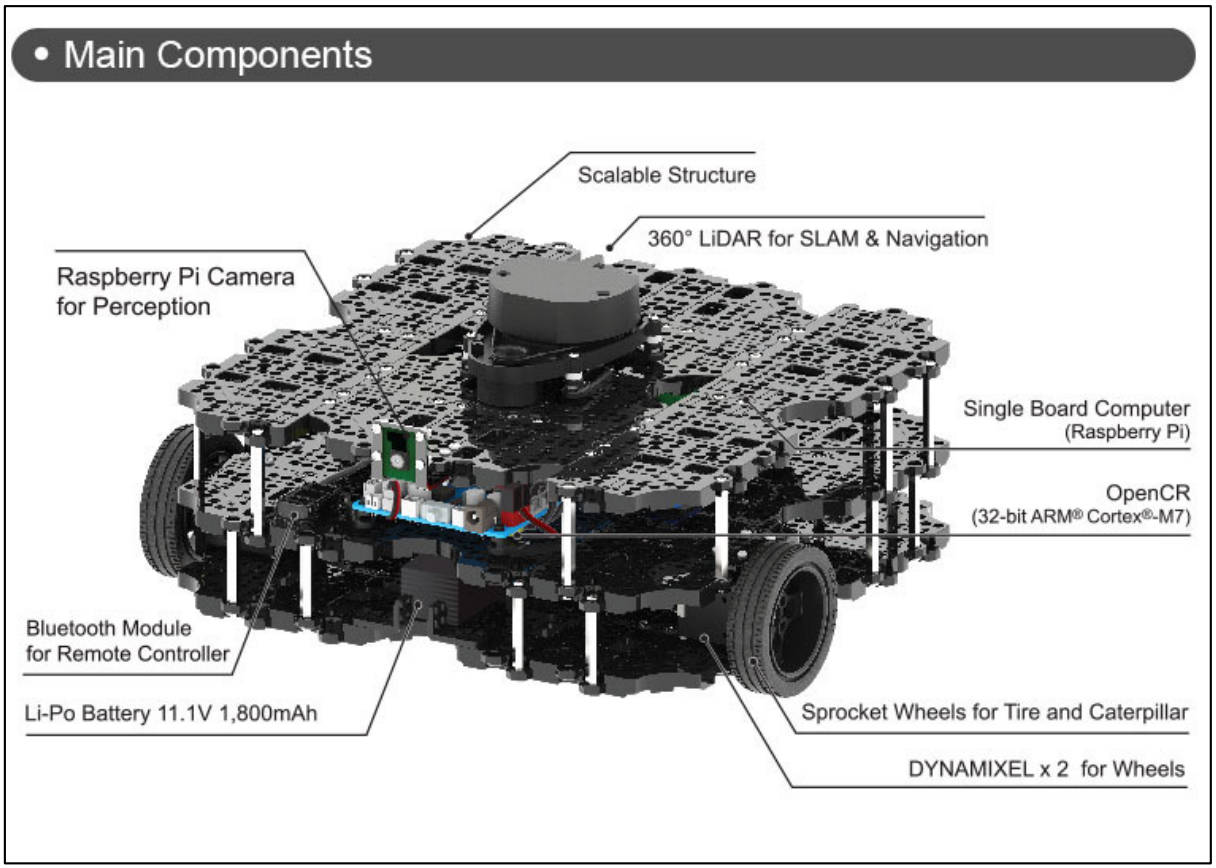
COLLEGE OF ENGINEERING
UNIVERSITY of HAWAI‘I at MĀNOA

Multi-robot Systems



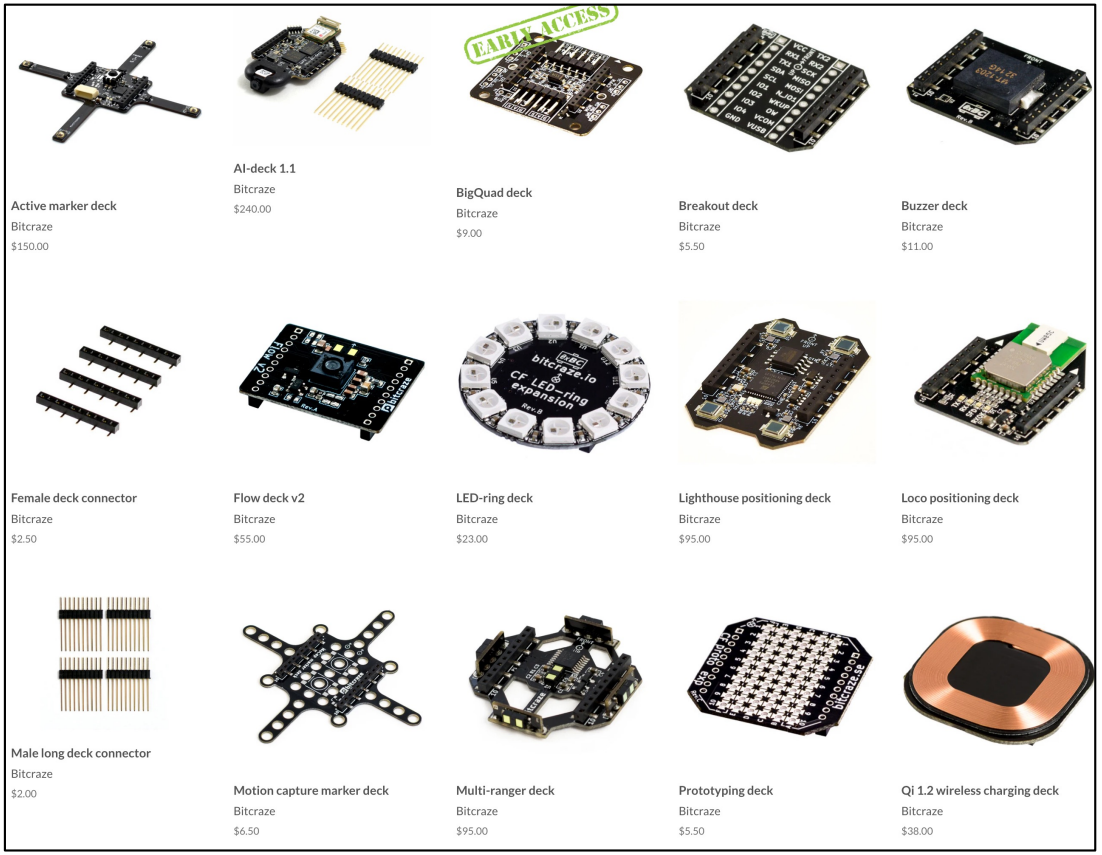
Multi-robot Systems: Wheeled Robots

Turtlebots



Multi-robot Systems: Micro Air Vehicles

Crazyflies



Active marker deck
Bitcraze
$150.00

AI-deck 1.1
Bitcraze
$240.00

BigQuad deck
Bitcraze
$9.00

Breakout deck
Bitcraze
$5.50

Buzzer deck
Bitcraze
$11.00

Female deck connector
Bitcraze
$2.50

Flow deck v2
Bitcraze
$55.00

LED-ring deck
Bitcraze
$23.00

Lighthouse positioning deck
Bitcraze
$95.00

Loco positioning deck
Bitcraze
$95.00

Male long deck connector
Bitcraze
$2.00

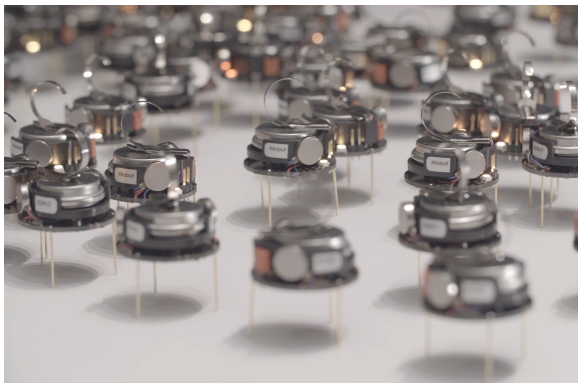
Motion capture marker deck
Bitcraze
$6.50

Multi-ranger deck
Bitcraze
$95.00

Prototyping deck
Bitcraze
$5.50

Qi 1.2 wireless charging deck
Bitcraze
$38.00

Multi-robot Systems: Millisystems



Kilobots

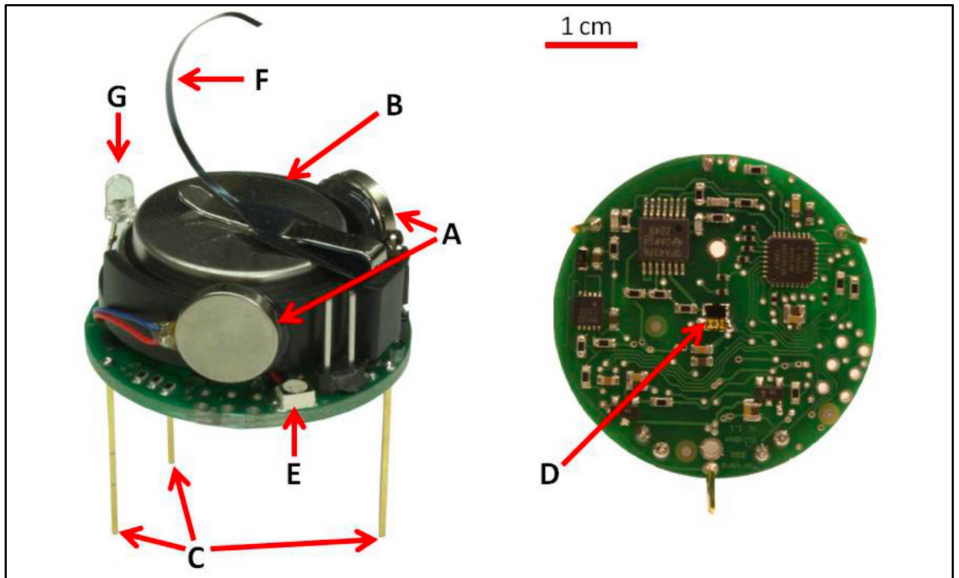
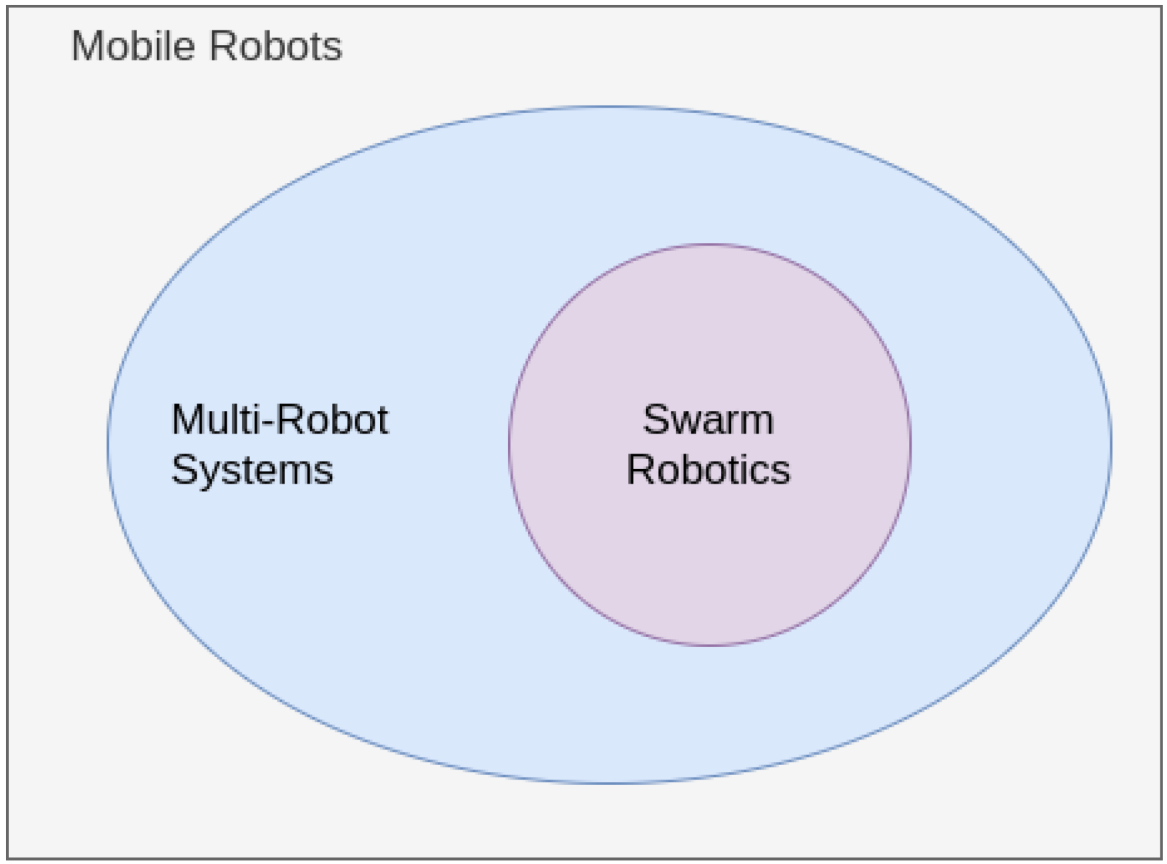


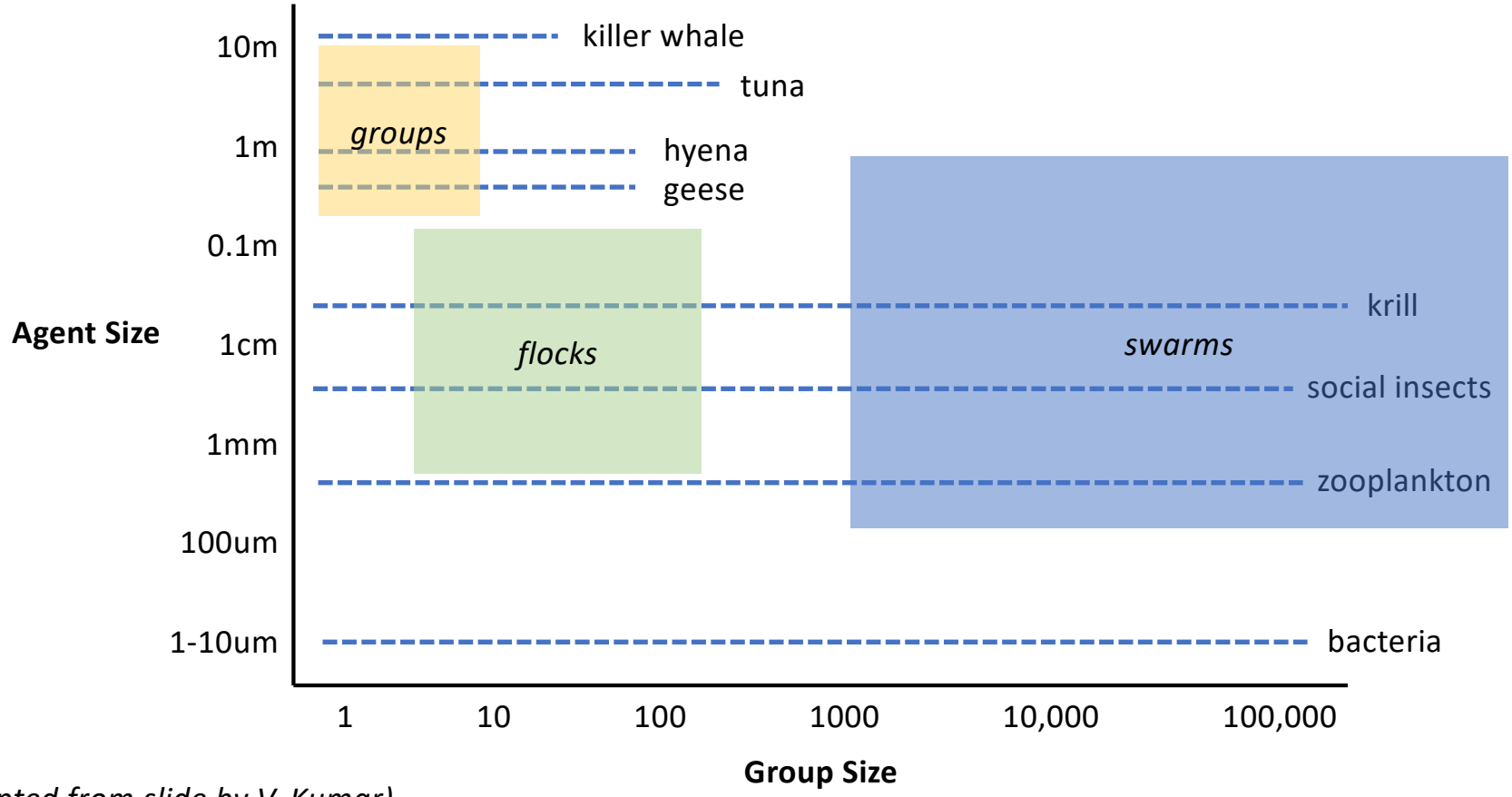
Fig. 1. Isometric (left) and bottom (right) views of a Kilobot. Some key features are: (A) Vibration motors, (B) Lithium-Ion battery, (C) Rigid supporting legs, (D) Infrared transmitter/receiver, (E) Three-color (RGB) LED, (F) Charging tab, and (G) Ambient light sensor. Note the 1cm line for scale.

Rubenstein et al. 2012

Multi-robot Systems vs Swarms

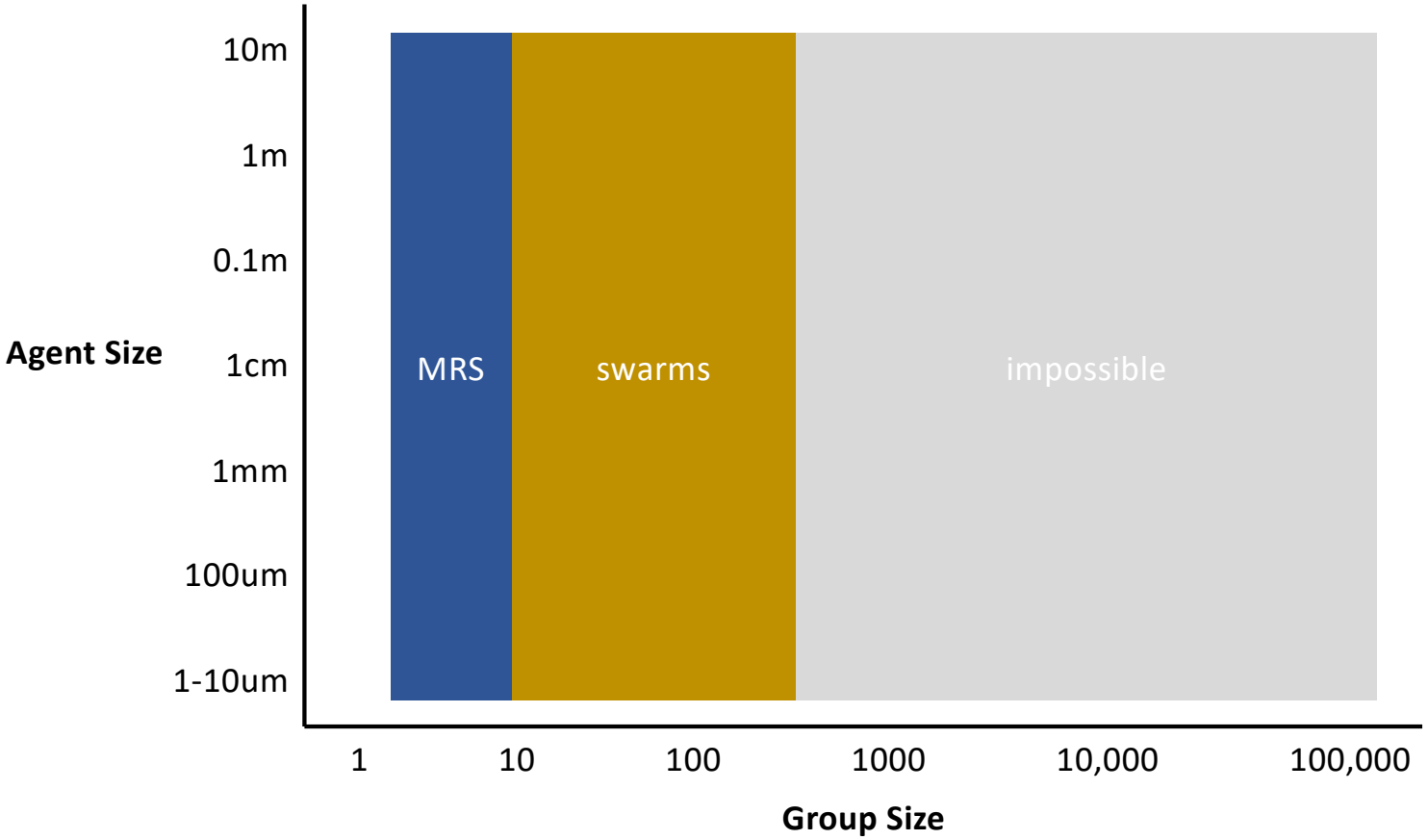


Multi-robot Systems vs Swarms



(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

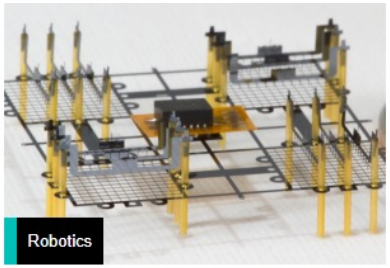
Asst. Professor, ECE

Aug. 2024

Asst. Professor, ECE

Dr. Daniel Drew – Assorted Research Projects

milliflyers

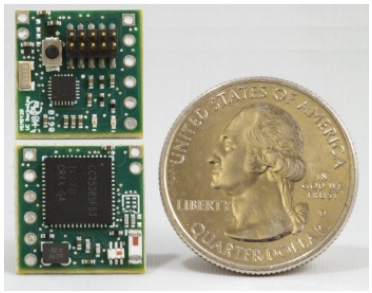


Penny-Sized Ionocraft Flies With No Moving Parts

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

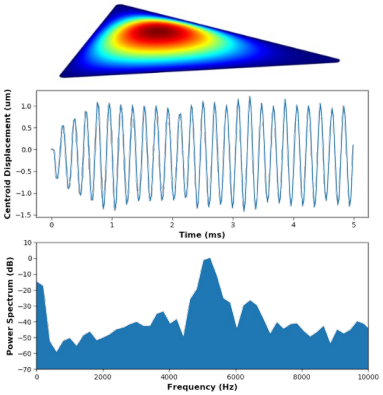
5 Feb

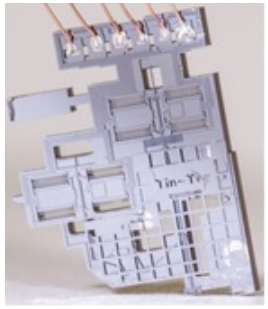
wsns



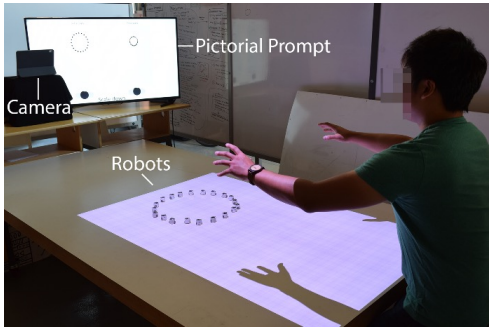
quadrotors

biomimetics

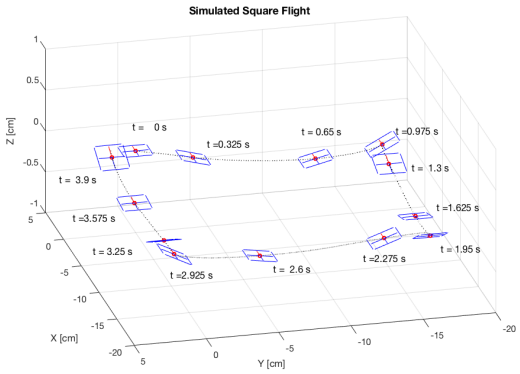




milliwalkers



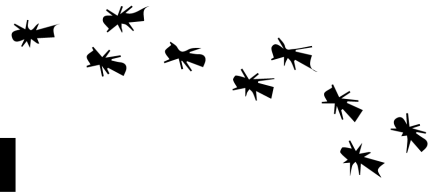
swarms



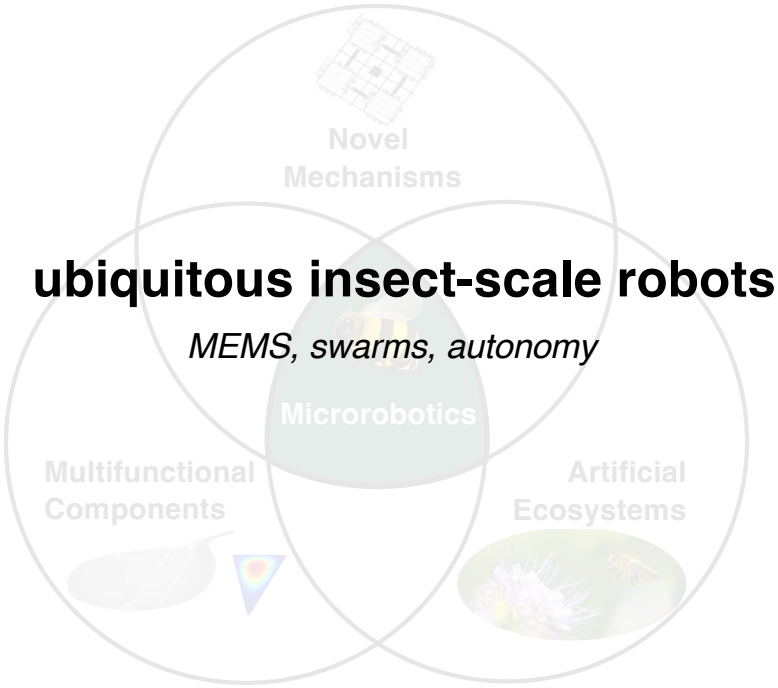
control systems

design tools

DRL



The Drew Research Lab

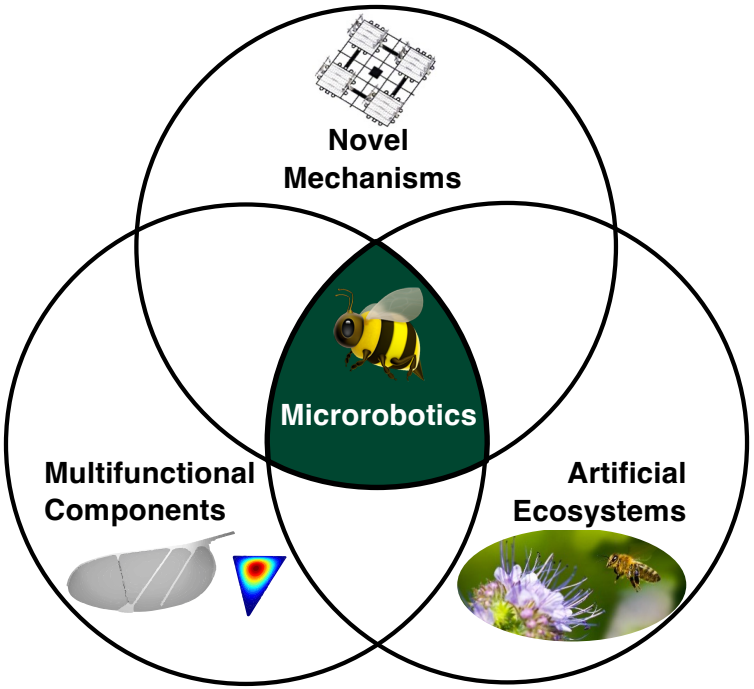


ubiquitous insect-scale robots

MEMS, swarms, autonomy

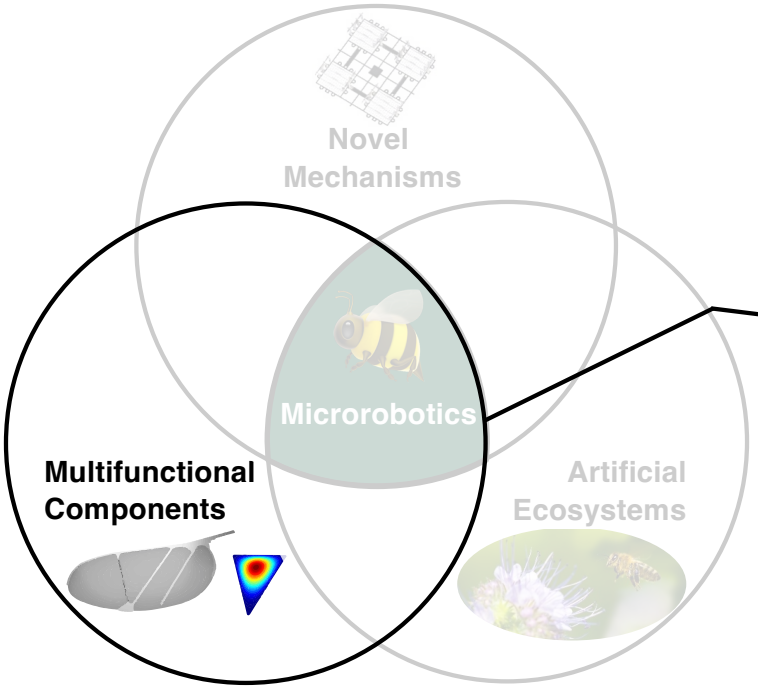
DRL

The Drew Research Lab

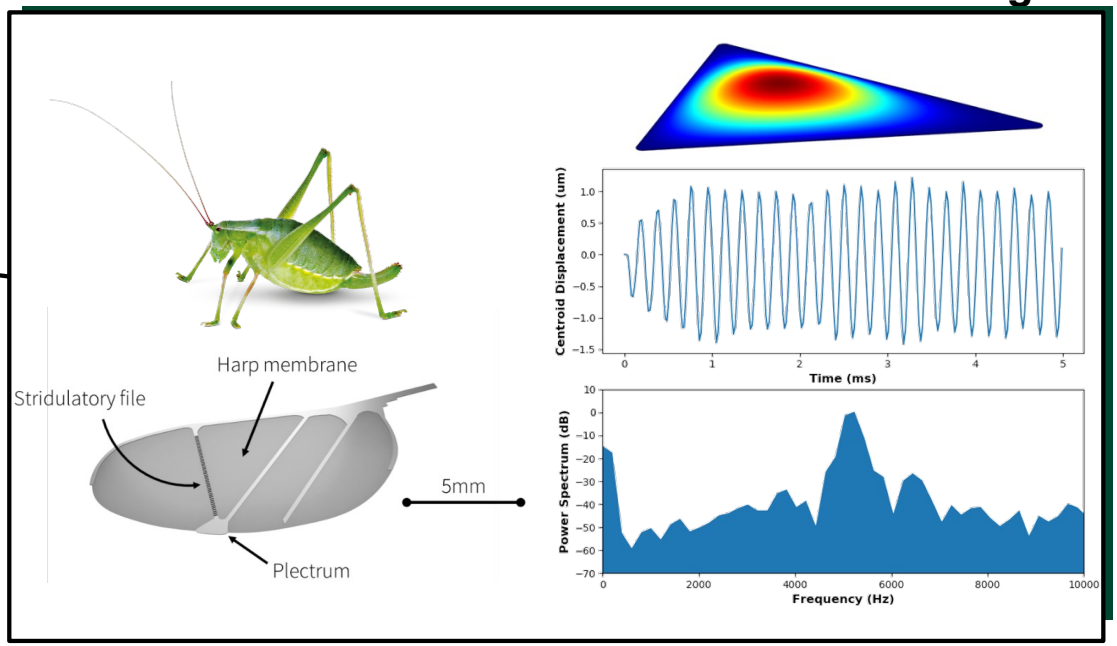


DRL

The Drew Research Lab

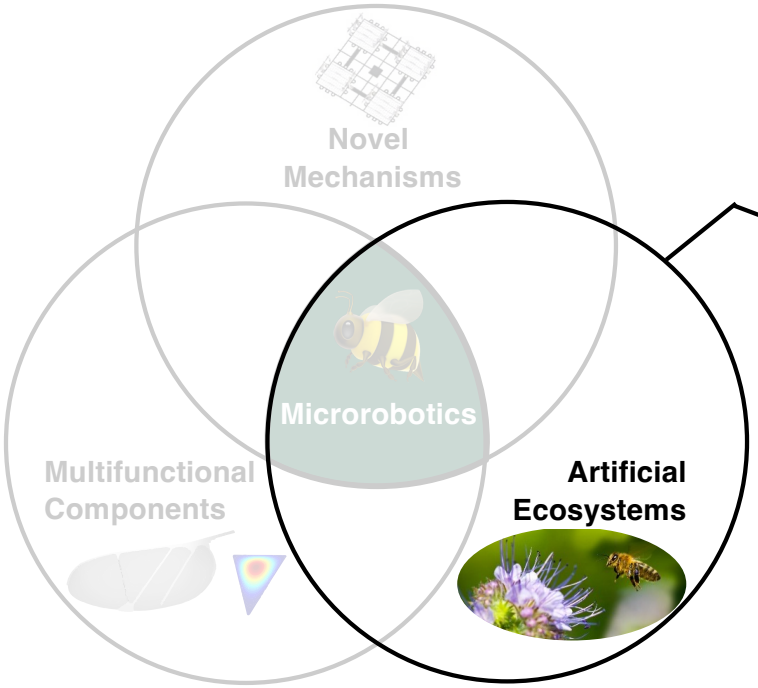


Acoustic Communication and Sensing



DRL

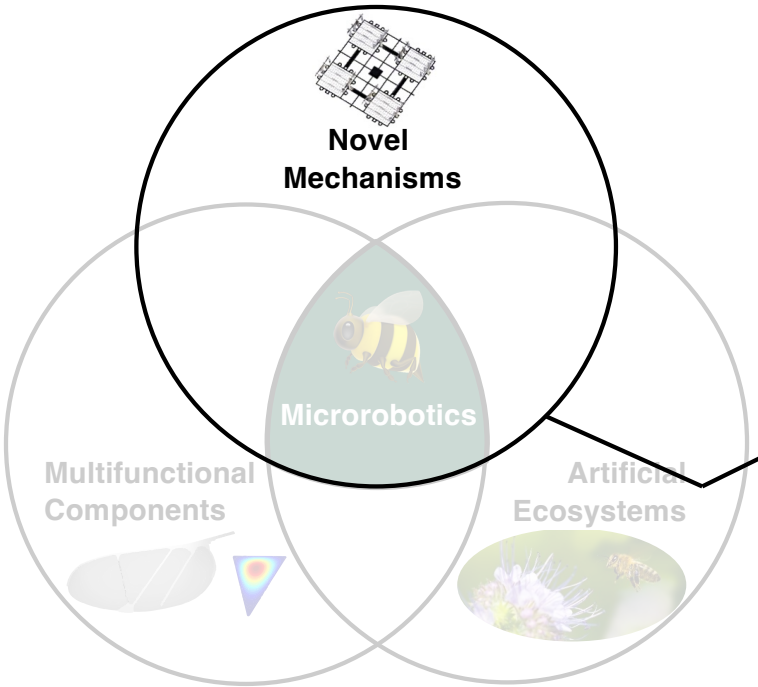
The Drew Research Lab



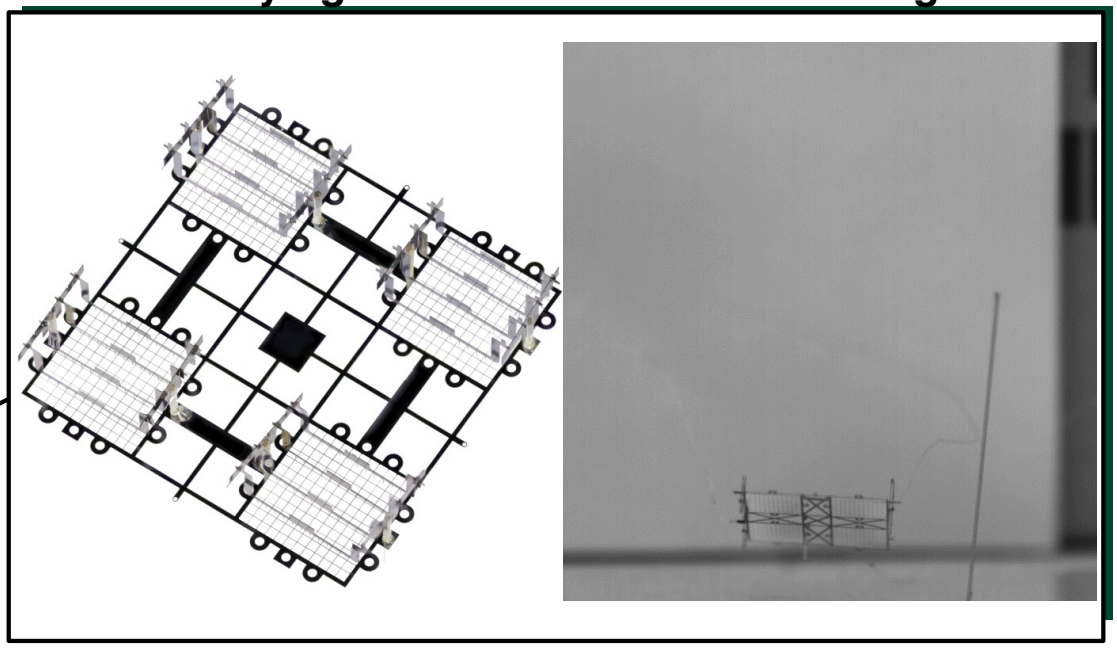
Heterogeneous Swarms

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

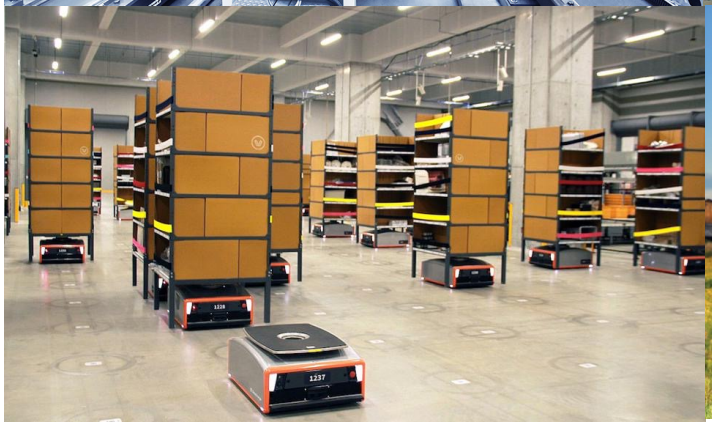
Small Group Activity: ~3 minutes

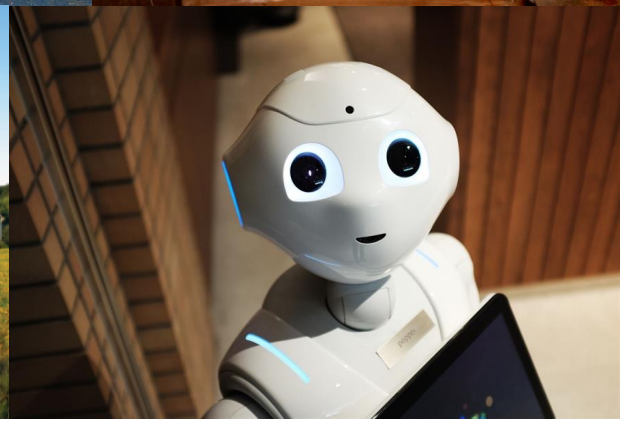
With your neighbor(s), share:

- Your name and grade level *(e.g., sophomore)*
- How you heard about this course
- What you're excited about in this course
- What you're worried about with this course *(e.g., technical content, not enough programming experience)*
- A hobby you have or interesting fact about yourself (unrelated to your academic life)

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

Course Schedule

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		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		

Two assignments in the first 5 weeks.

Assignments in 693H

Astound-the-Class: Short (~2 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 you 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.

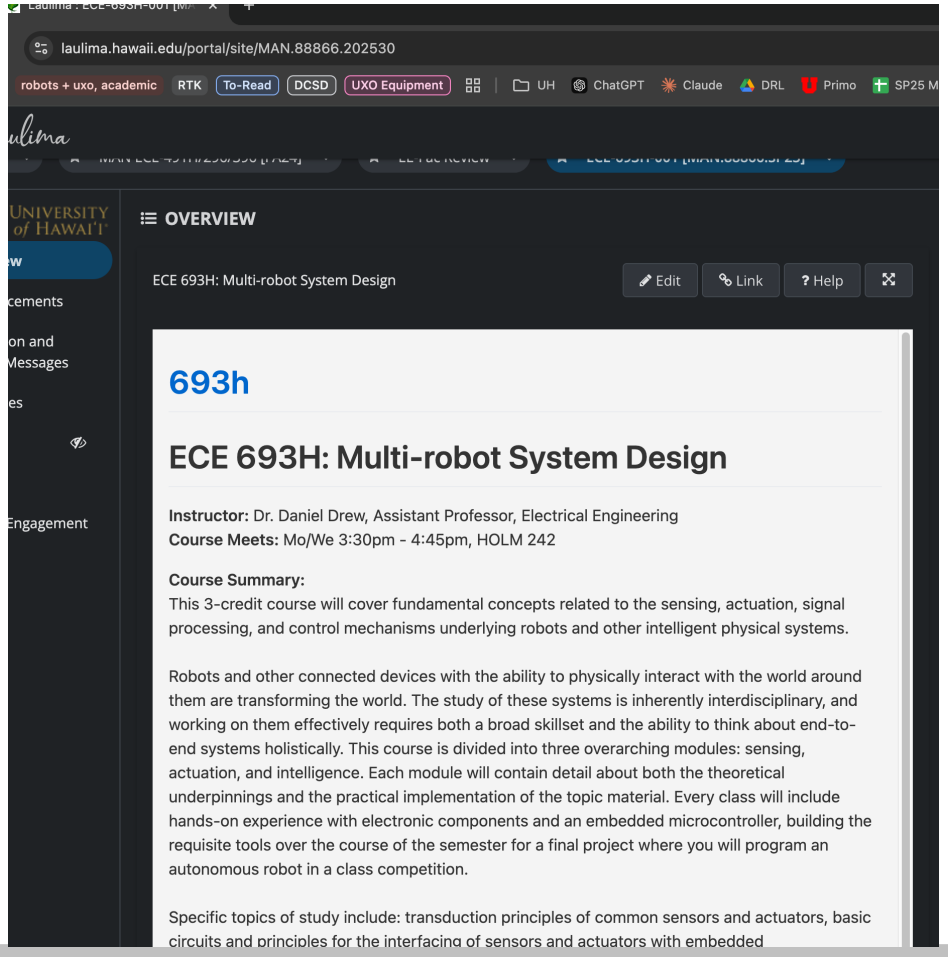
A “Typical” Class Period

~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)

Readings

Topic	Date
1. Syllabus	1/13
2. Autonomous Mobile Robots	1/15

Tasks

Topic	Date
1. The FabLab	1/13 - 1/17

Slides

Topic	Date
1. Course Intro	1/13

Assignments

Name	Due Date
1. Astound the Class 1	1/27

The Course Website + Laulima

693h

The FabLab

The College of Engineering FabLab in Holmes 448/449 is a fantastic resource for students to get hands-on experience with state-of-the-art rapid prototyping equipment. We will be making use of it throughout the semester as part of creating your robots.

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The FabLab is a maker space designed for students to fabricate their designs and collaborate. This is a teaching lab -
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- Read this short article on the FabLab
- Watch this video on the Prusa 3D printer You can also poke around the Fab Lab youtube channel to see other instructional videos!

Your mission, if you choose to accept it, is to go in the Fab Lab in the next week or so and:

- Introduce yourself to the student staff and make sure they know you are grateful for their help
- 3D print *something*. I suggest you look for something interesting on Thingiverse
- Laser cut *something*. I suggest you learn how to draw something for yourself using free software like Inkscape.
- Locate the soldering station and remind yourself which end of the iron gets hot and should never be touched with your fingers.

Please bring your creations into class so I can appreciate them.

The Course Website + Laulima

693h

Astound the Class!

Remember that this is a short (~2 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.

Sign up with your topic title on this sheet as soon as you determine it, to help prevent repeats:

- Astound the Class 1 signups

Add your presentation slides to this deck:

- Astound the Class 1 presentations

Follow the instructions — don't delete or edit the template slides!

The grading rubric follows:

Topic	1	2	3
Preparation	Unprepared delivery	Somewhat prepared delivery	Well-prepared delivery
Timing	Dramatically over or under-time	Only a minute of content	1.5 to 2.5 minutes of solid content
Context	Not clear how topic connects to course content	Somewhat clear how topic connects to course content	Topic clearly connects to course content
Slides	Poor visual quality	Visuals are somewhat helpful to the presentation effectiveness	Visuals clearly enhance presentation

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 / tasks 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 early, please!