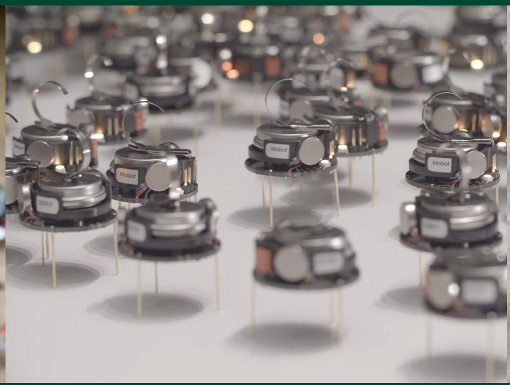
ECE693H, Spring 2025: Multi-robot System Design

“Multi-robot Systems 1”

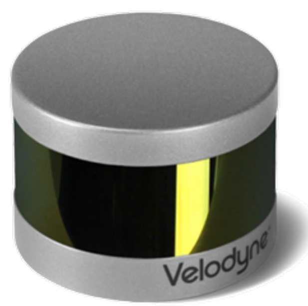




Dr. Daniel Drew

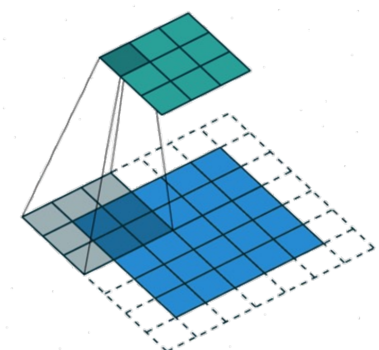
COLLEGE OF ENGINEERING
UNIVERSITY of HAWAIʻI at MĀNOA

Three Pillars

Action



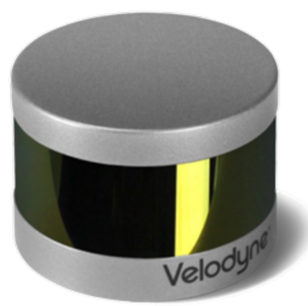
Perception



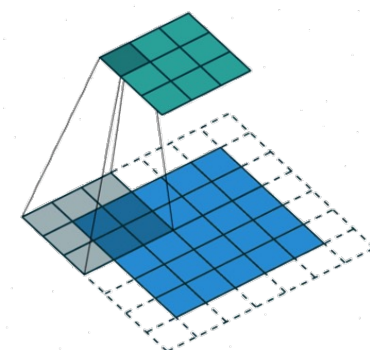
Intelligence

Three Pillars

Action



Perception



Intelligence

Questions?

Class Overview

1. Lecture (~30 minutes)
2. Subsystem check-in (~30 minutes)

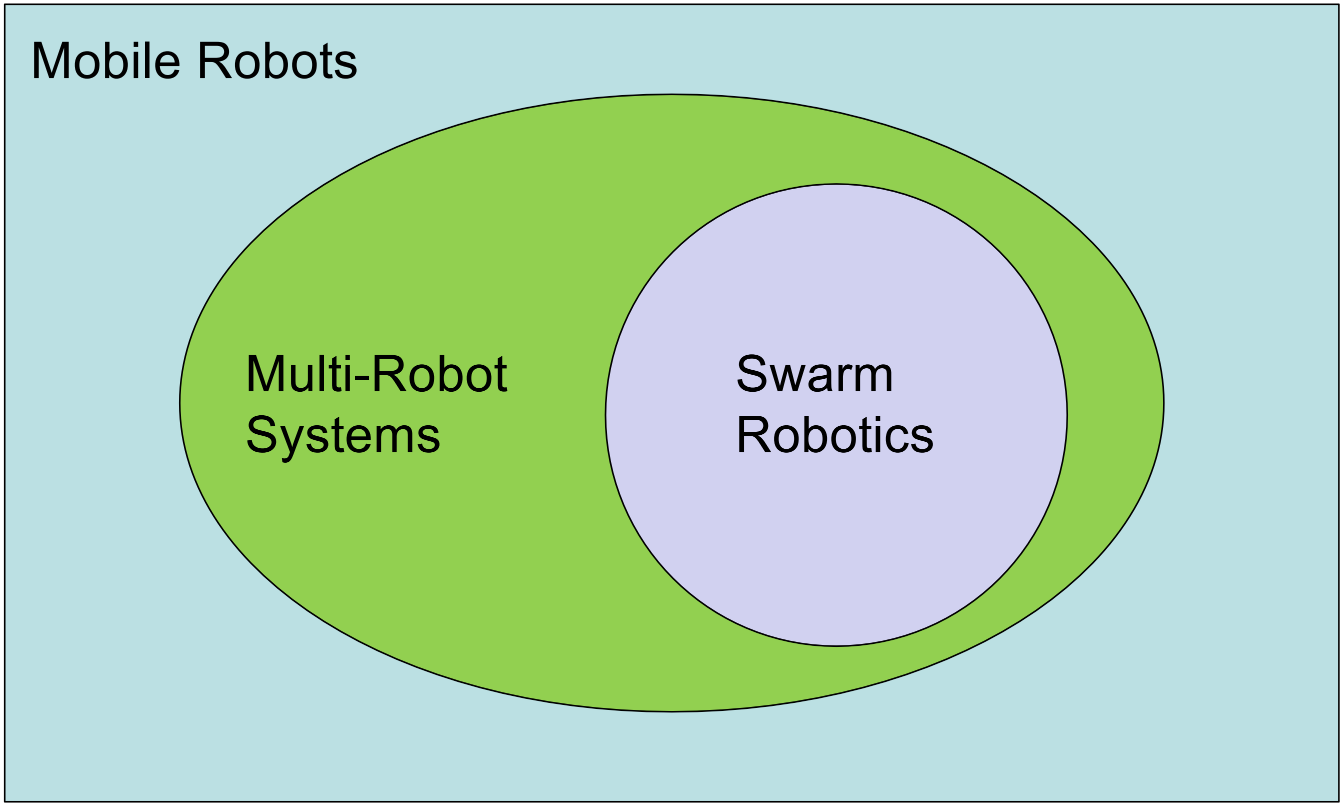
Multi-robot Systems: Lecture 1 of 4

Lecture 1: MRS Survey
Lecture 2: Motion Planning
Lecture 3: Task Assignment
Lecture 3: Communication and Control Paradigms

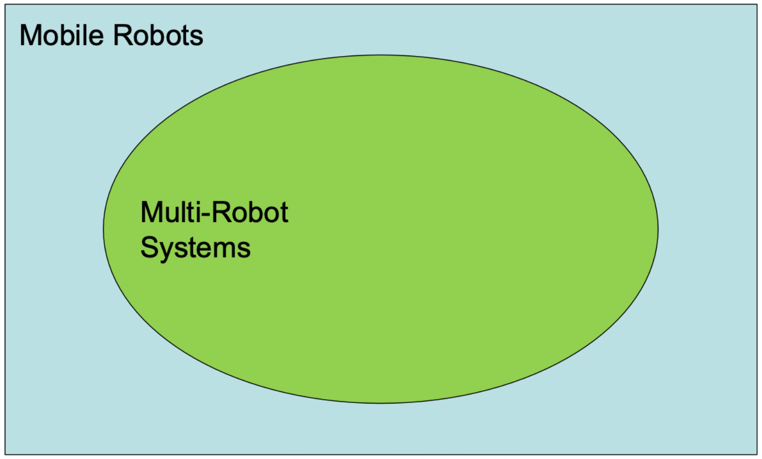
What is a multi-robot system?

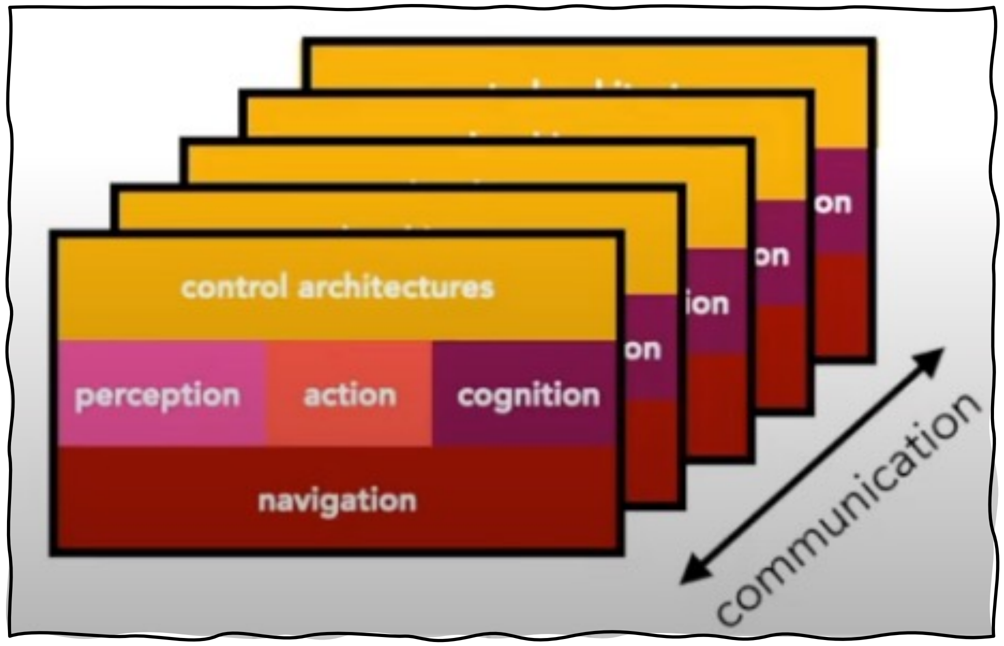
A group (>1) of robots with a common objective

What is a multi-robot system?

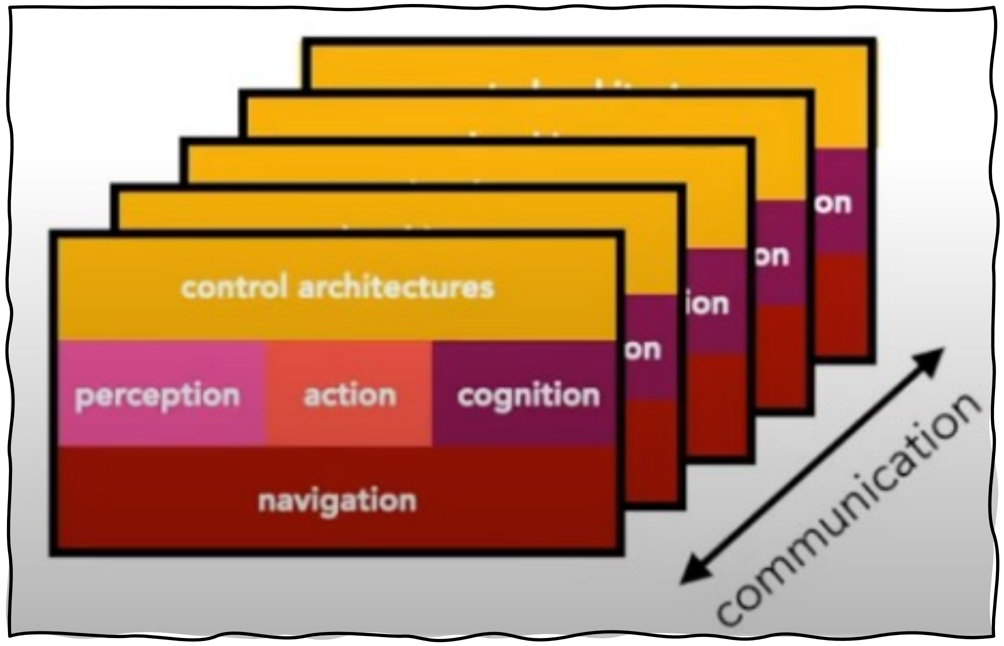


Single Robot vs Multi-robot Systems





Single Robot vs Multi-robot Systems

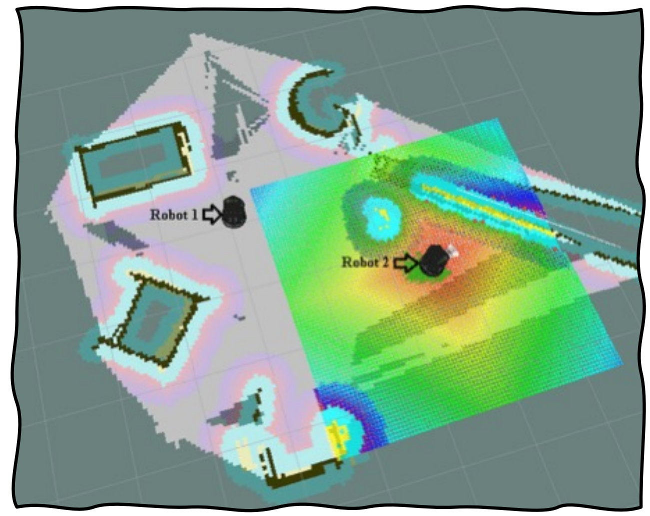


"Do it all again", while considering:

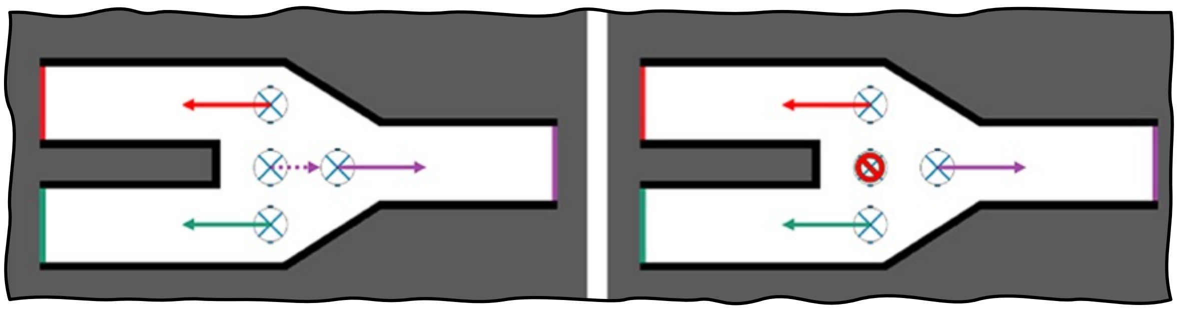
multi-robot interactions; compounding probabilities; scaling issues

Advantages of MRS

Parallelization: Spatial coverage efficiency



Redundancy: Fault and failure tolerance



Overcoming Platform Constraints:
Many cheap, cooperative platforms

MRS in the wild: Warehousing

MRS in the wild: Agriculture

MRS in the wild: Agriculture

MRS in the wild: Construction

MRS in the wild: Inspection

MRS in the wild: Inspection

MRS in the wild: Search and Rescue

MRS in the wild: Defense and Intelligence

In-class Activity: Swarm-on-a-Stick Brainstorm

Think about one of the real-world MRS just discussed.

-What is its core function, and how do the robots work together?

-How would you showcase a simplified version of this using **–S–S–**?

Assume:

- a central computer knows state $[x, y, \theta]$ of each robot
- a central computer knows distance measurements 360° from each robot
- robots have an onboard RGB LED
- “tiles” with QR codes can be placed to represent arbitrary objects

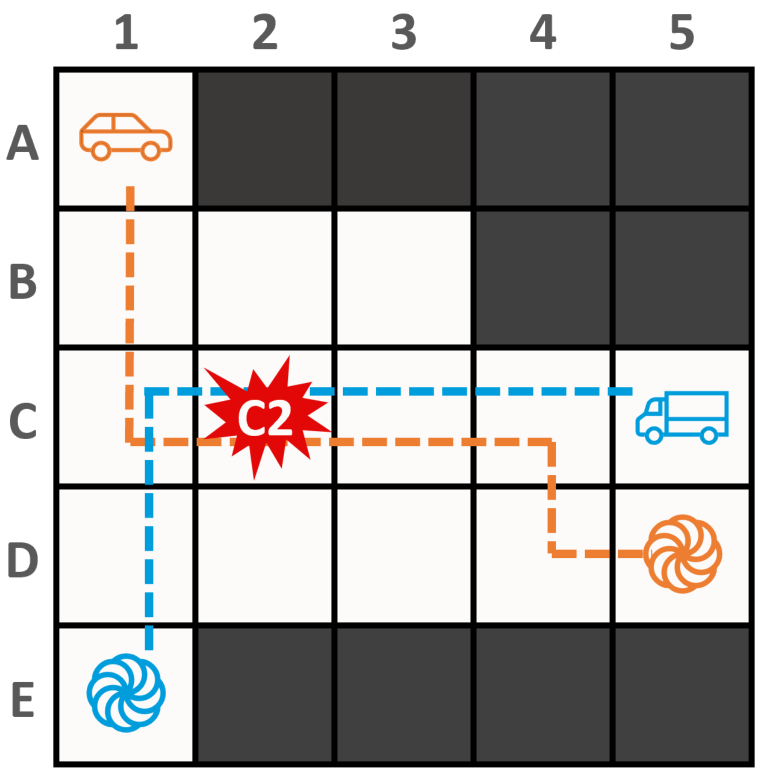
Multi-robot System Taxonomy

Control
<u>Centralized:</u> One *central* unit performs estimation and planning, then communicates with all robots to issue commands.
<u>Decentralized:</u> Individual agents make asynchronous control decisions based on their current best information.

Communication
<u>Explicit:</u> State information and observations are directly sent to/between robots, e.g., using WiFi
<u>Implicit:</u> Information is exchanged through common observations of the environment

Composition
<u>Homogeneous:</u> All robotic platforms are the same.
<u>Heterogeneous:</u> Robotic platforms may differ in payload, mobility, etc.

Key challenges in MRS: Motion Planning

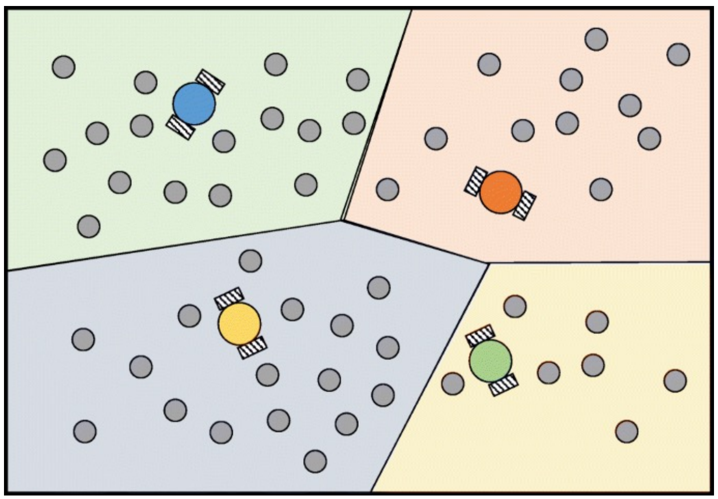


compounding uncertainty; motion dynamics become necessary; environmental changes cascade; computational complexity (NP-hard)

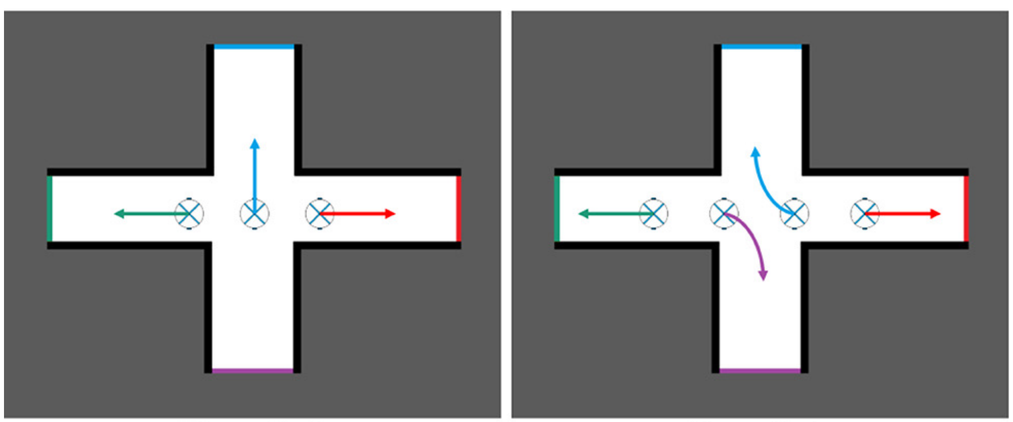

DRONES!
GUINNESS WORLD RECORDS


DRONES NAVIGATE
FOREST IN CHINA

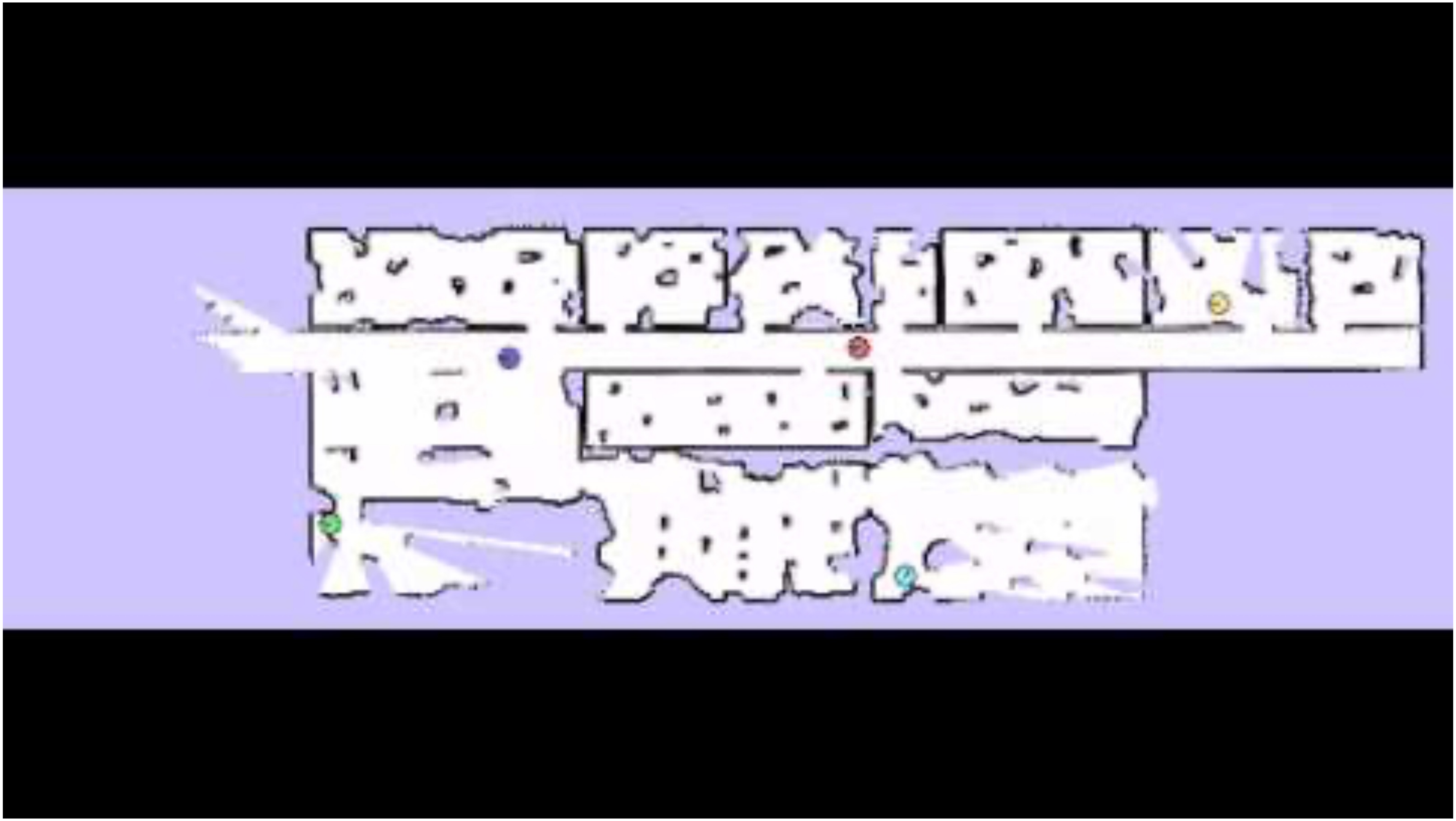
Key challenges in MRS: Task Allocation



compounding uncertainty;
computational complexity (NP-hard);
task interdependency and prioritization




Resolution
INSPECTION OF POROSITY ON SEALING SURFACES
DQI



Key challenges in MRS: Information Exchange

network throughput limits; connectivity changes from motion; variable environmental factors (e.g., obstacles); power consumption


communications engineering
Stigmergy,
robots,
and automatic
design
42
71


>> 1x

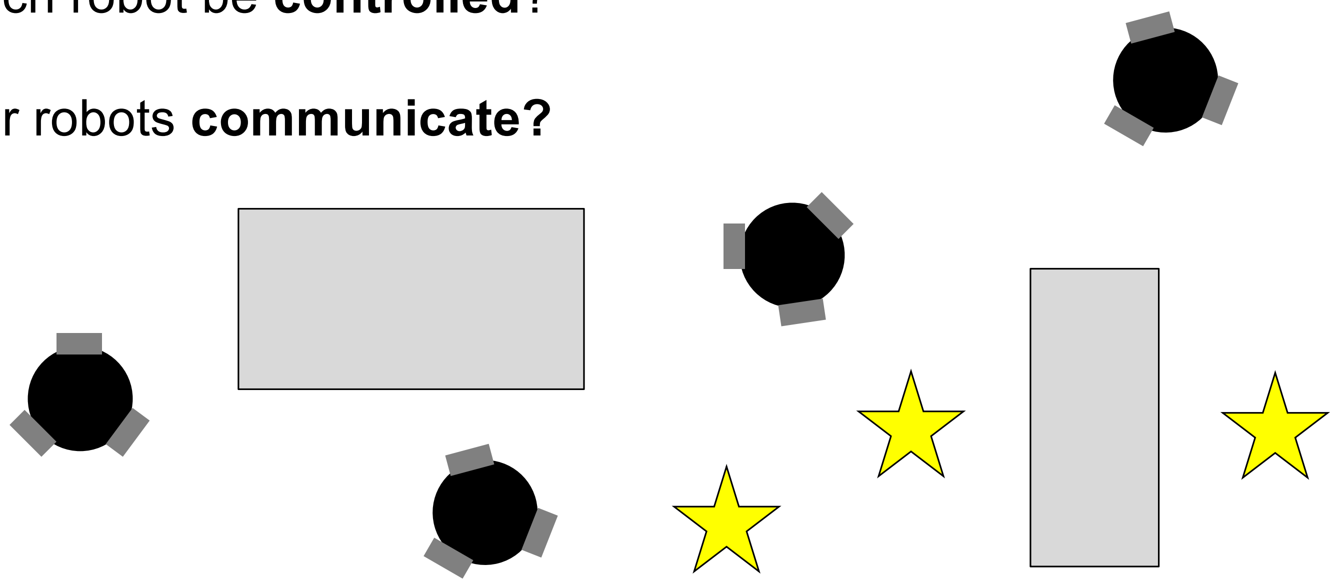
Tying back to Swarm-on-a-Stick

How will we make sure our robots do not collide when **moving**?

How will we decide **which robot** does what?

How will each robot be **controlled**?

How will our robots **communicate?**



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Questions?

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693H Robotic Subsystems

-Second Design Review Presentations are **3/10, 3/12**
-You will be expected to have **functional prototypes** complete to show by then
-You will be expected to have **PCB designs and final BoMs** complete by then

Astound-the-Class 2 is scheduled for MONDAY, MARCH 3rd