

CAREER:

Environmentally-Mediated Coordination in Natural and Robot Swarms

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Challenge

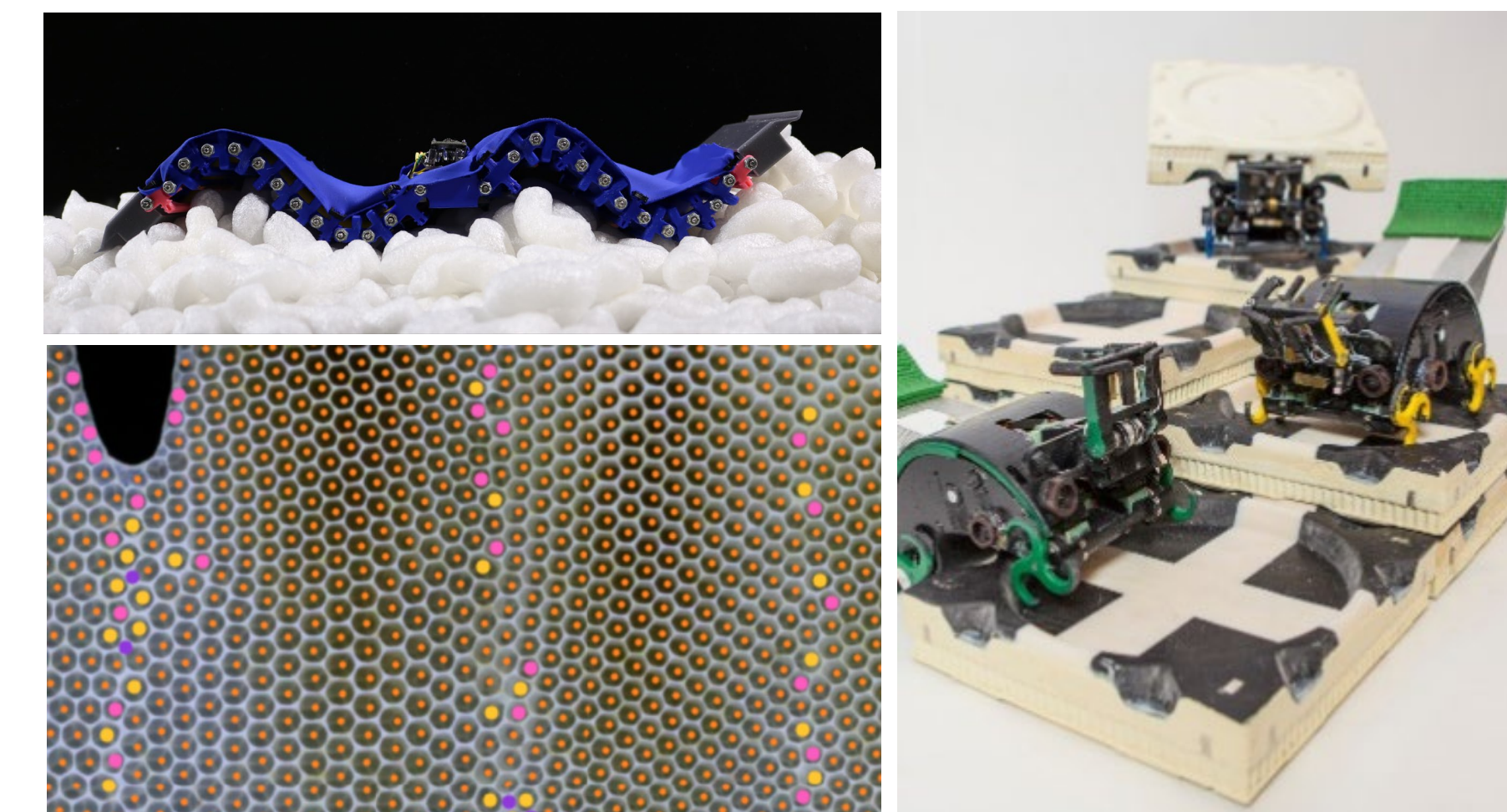
Design methodologies for environmentally-mediated swarm coordination, taking into account:

- Swarm size
- Agent reliability
- Agent motion and sensing
- Agent modifications/trace
- Environment dynamics

Solution

Thrust 1) Error propagation and mitigation in static environments

- Collective robotic construction
 - Error classes in stigmergy-driven rectilinear construction
 - Predictive local checks can mitigate error propagation (DARS 2020)
 - Decay can overcome critical errors, without necessitating global knowledge
 - Collaborative construction in dry granular media (RA-L, ICRA 2022)
- Honeycomb construction in constrained geometries (PNAS 2022)



Thrust 2) Natural coordination in highly dynamic environments

- Bees collectively locate the source of queen pheromone while swarming, by entraining air flow and pheromone
- To study this phenomena we have developed...
 - Experimental protocols for outdoor observations
 - 2D directional and amplitude flow sensing
 - Custom wind tunnel for controlled experiments
 - Robo-physical platform for translation to robotics



Thrust 3) Coordination in programmable matter which actively changes its dynamics

- Foambots modular robot platform
 - Kinematic and spring-based simulators
 - Sensing, actuation, and coordination through strain in a physically coupled collective
 - ...through coupled oscillator algorithms
 - ...through consensus algorithms
- (RA-L / IROS 2021 and RoboSoft 2022)



Intellectual merit

- This work will extend upon the concept of environmentally-mediated coordination from perfect robots operating in static environments, to include **dynamic environments** and ways to deal with realistic bounds on error and **hardware reliability**.
- Rooted in experiments with robots and natural swarms, the work will further result in a model of swarms in dynamic environments that act to integrate, diffuse, decay, and filter information.

Broader Impacts – Increase and Retention of a Diverse Workforce

- Outreach for the general public and interdisciplinary research workshops
- Shared online curricula and collaborative learning in robotics
 - ECE4960/5960 Fast Robots (37 students)
 - <https://cei-lab.github.io/ECE4960-2022/>
 - ECE3400 Intelligent Physical Systems (115 students)
 - <https://cei-lab.github.io/ece3400-2018/>

