New Multi-Robot Algorithms and Coordination Strategies by Storing Data in the Environment Using Physical Alphabets

Michael Otte, University of Maryland

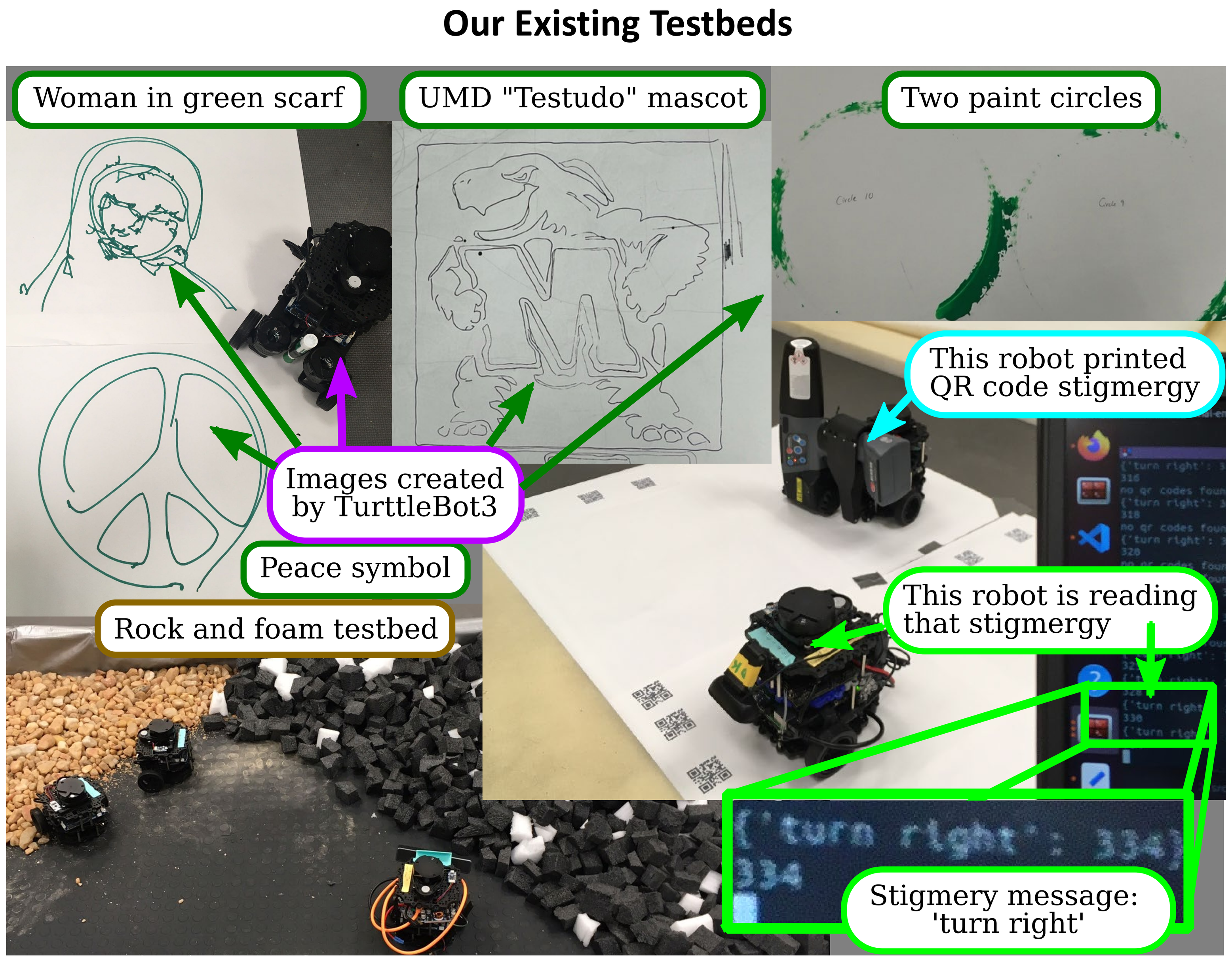
www.ottelab.com

Wireless communication infrastructure that is typically used for multi-robot coordination may be severely curtailed in disaster scenarios and in remote natural environments. There is a need for new algorithms that allow robots to coordinate without wireless communication. Insects, people, and other groups of biological agents often communicate and coordinate their actions by storing information in the environment, for example, by depositing chemical pheromones, erecting street signs, or altering the shape/state of the environment itself (e.g., cairns and blazes on hiking trails). The concept of storing information in the environment for communication and collaboration is called *stigmergy.* This effort aims to build on these ideas to take a fundamentally different approach to the use of stigmergy in multi-robot algorithms, one in which robots read and write multi-symbol messages directly upon/into the physical environment using onboard sensors and actuators for the purposes of storing and communicating large amounts of digital data.

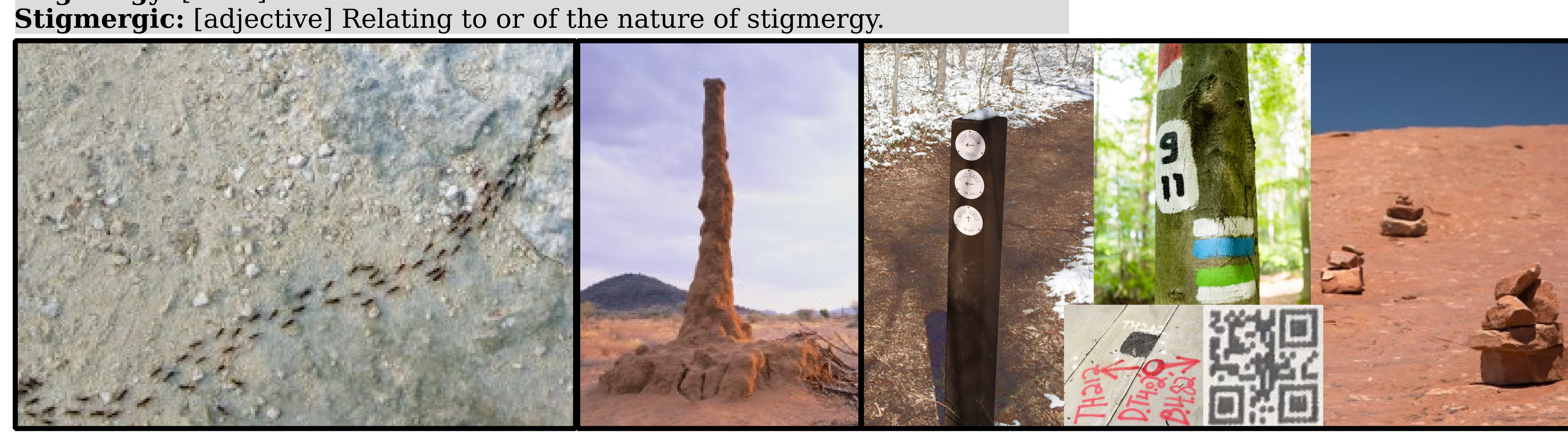
Broader Impacts

Robot swarms could also assist in human mass-evacuation after disaster events by discovering safe paths through disaster areas, directing emergency workers to victims in need of help, and directing evacuees to safety along escape routes. Human readable stigmergy such as arrows and maps showing routes to safety could be printed on the environment and updated in real time to communicate preferred escape routes in dynamically evolving disaster scenarios. Multi-agent algorithms that use stigmergy will enable the use of robot swarms in environments where traditional forms of wireless communication are unavailable or very poor, such as disaster scenarios with damaged communication infrastructure and/or remote natural wilderness environments.

Our Existing Testbeds



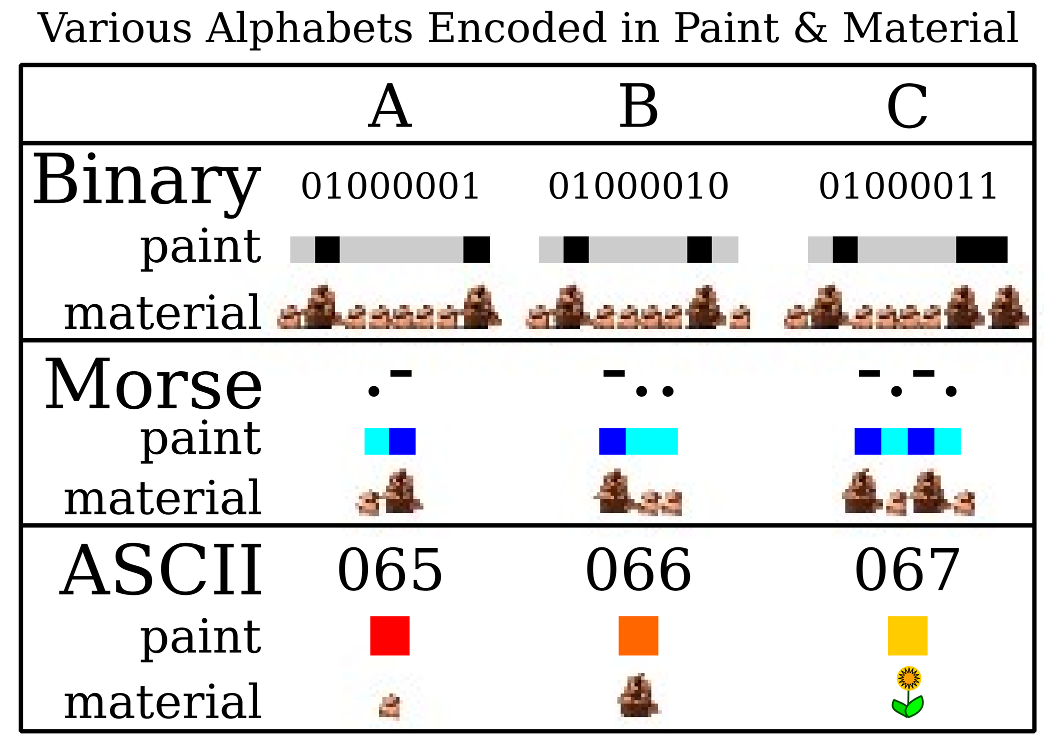
Stigmergy: [noun] A mechanism of indirect coordination via the environment.
Stigmergic: [adjective] Relating to or of the nature of stigmergy.



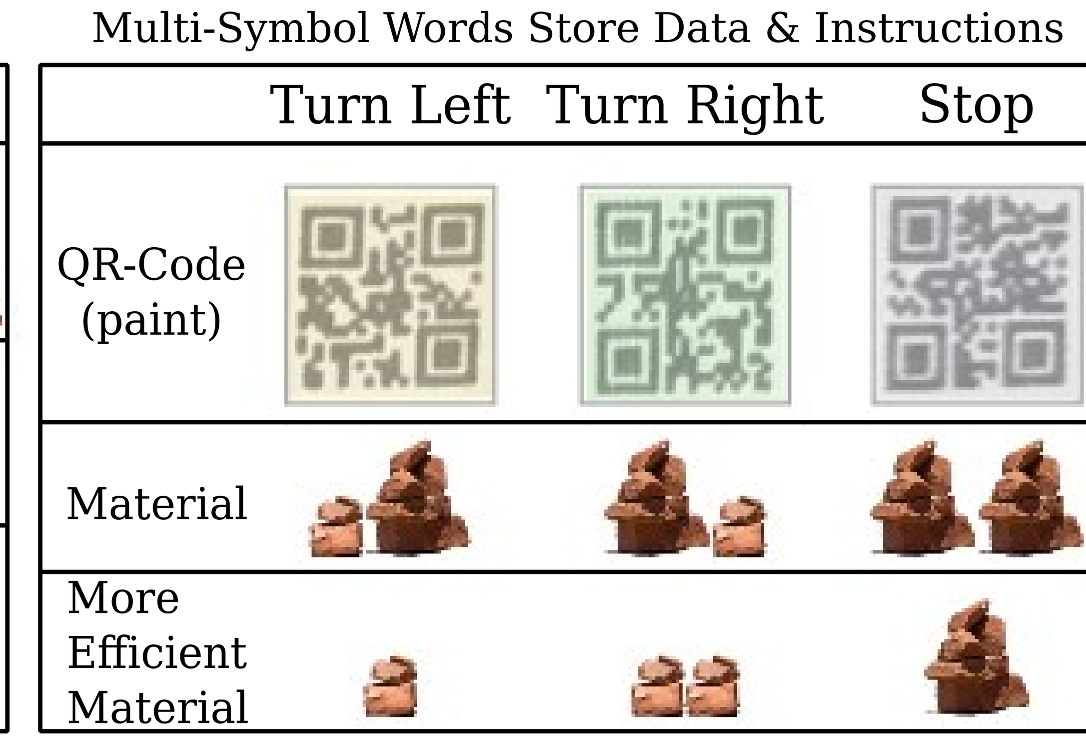
Ant Stigmergy — Termite Stigmergy — Human Stimergy: signs, blazes, QR-codes, cairns, etc.

Multi-Symbol Stigmergy: Stigmergy that uses alphabets of symbols for data transmission and error correction.

Various Alphabets Encoded in Paint & Material



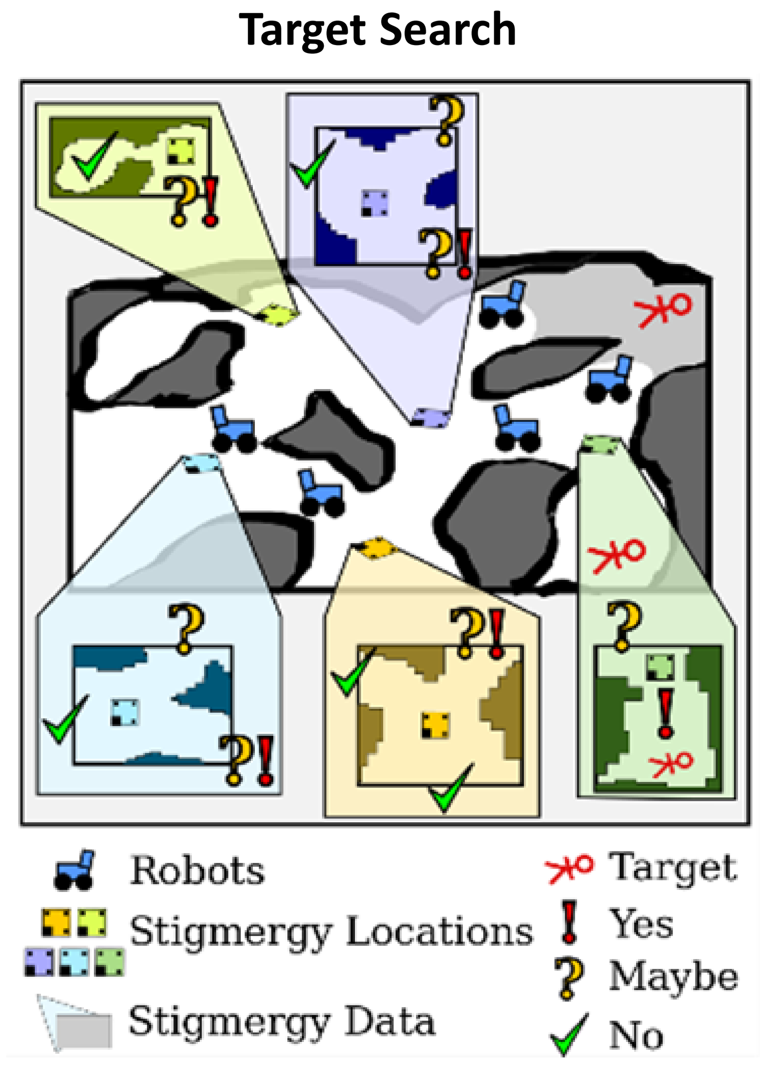
Multi-Symbol Words Store Data & Instructions



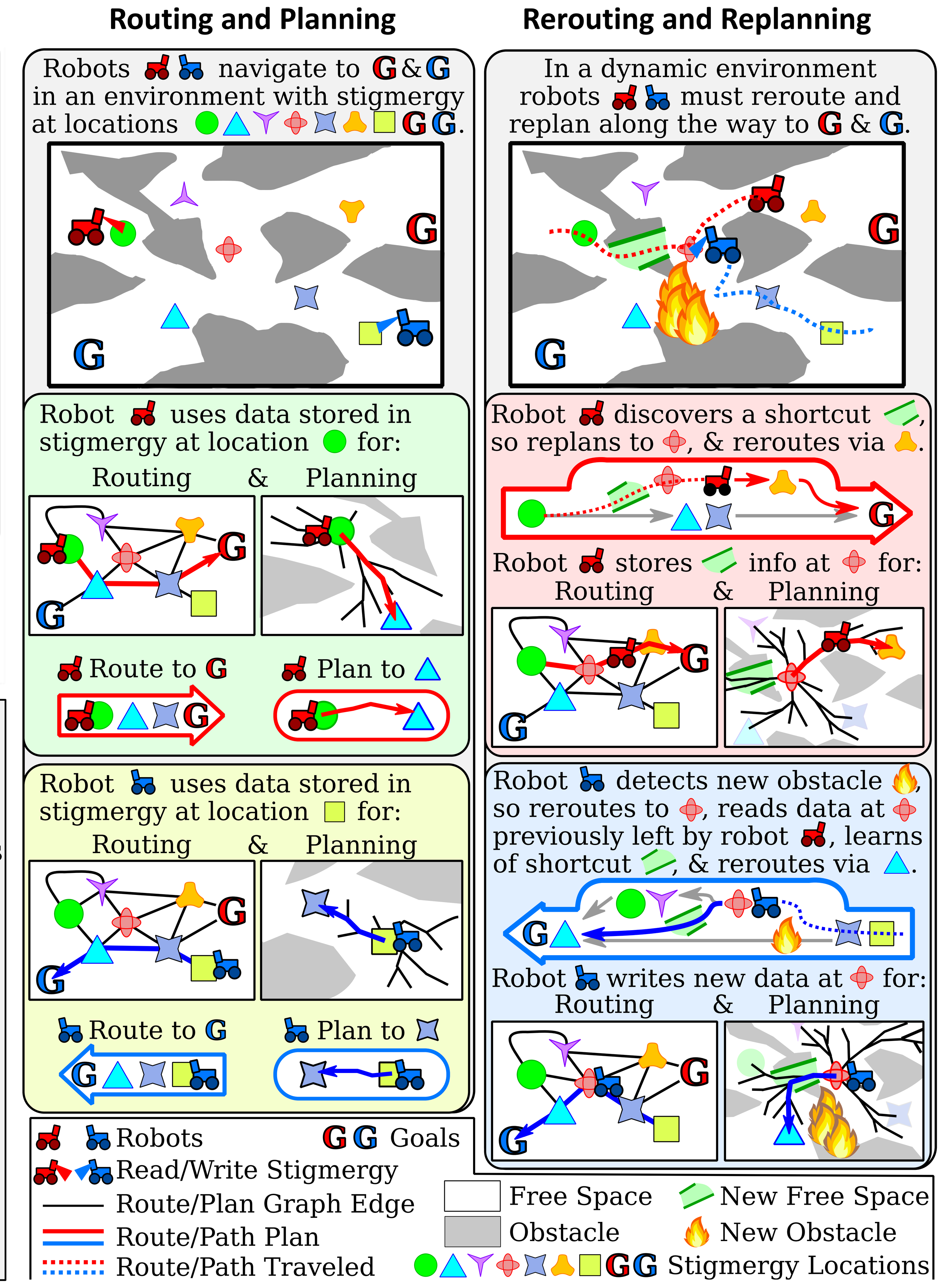
Outline of Research Plan

Task 1: Experimental characterization of multi-symbol stigmergy.
Task 2: Understand tradeoffs of using multi-symbol stigmergy in multi-robot target search.
Task 3: Understand tradeoffs of using multi-symbol stigmergy in multi-robot (re)routing and (re)planning.
Task 4: Understand the application of distributed computing concepts to multi-symbol stigmergy.

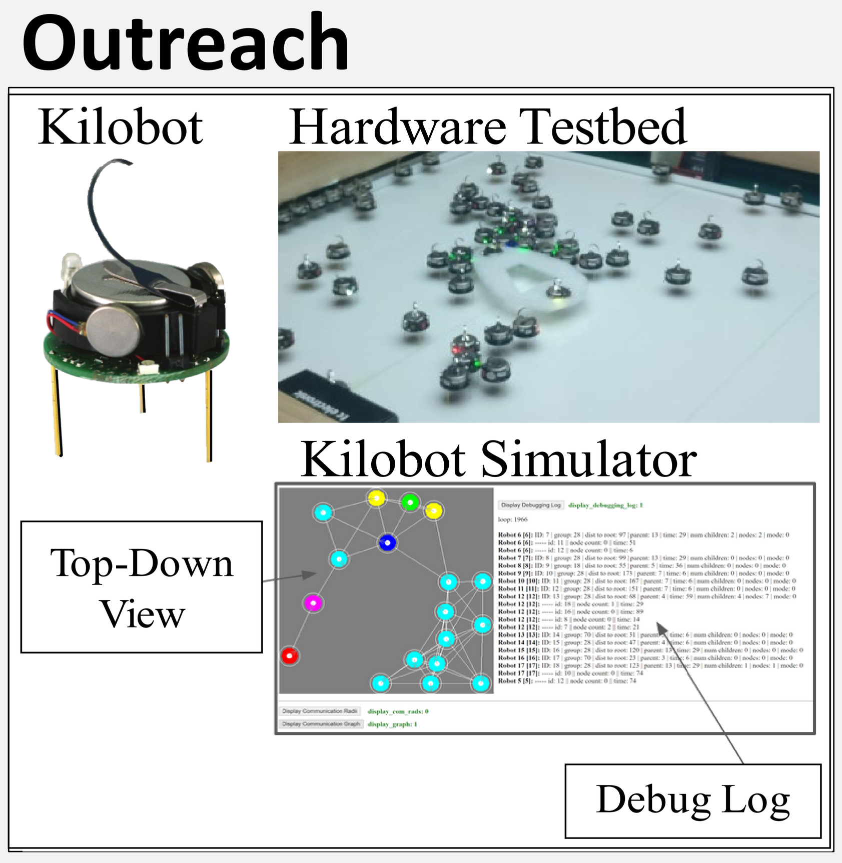
Target Search



Routing and Planning — Rerouting and Replanning



Outreach



My lab has used Kilobots for 34 (of 45 total) high school and undergrad research projects.

- During the Covid-19 pandemic, I created a Kilobot simulator that runs in a web browser (Firefox, etc.).
  - Enabled 13 high school, 2 community college, and 14 undergraduate interns to do remote and hybrid internships (including 3 students from HBCUs).
  - Works on lower-end computers to ensure access to interns from diverse socioeconomic backgrounds.
  - C code that runs on the simulator will compile on the Kilobot hardware, e.g., the 200-Kilobot swarm in our lab.
- **This Effort:** Train high school teachers to do the same via workshops (hardware + simulator) and donations of robot swarms.

2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

Award ID#: N/A