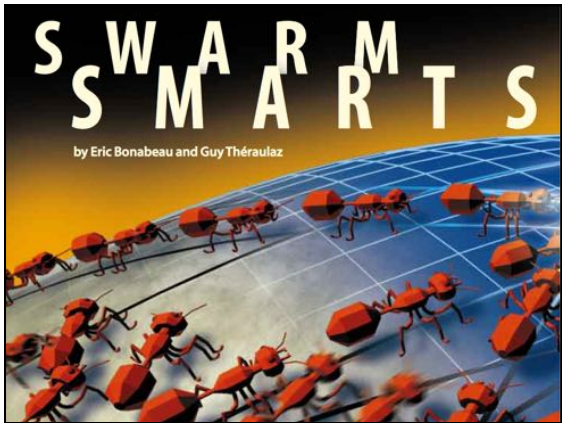
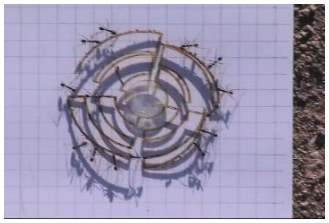



CS289: Collective Transport



Stephen Pratt, Arizona State University

Stephen Pratt,
Spring Berman,
Arizona State University



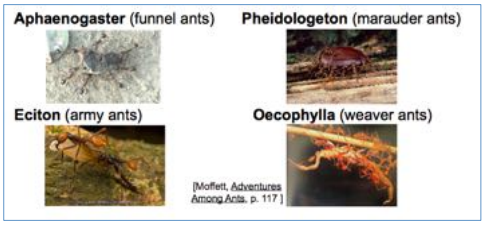
Collective Strategy for Obstacle Navigation during Cooperative Transport by Ants

Helen F. McCreery, Zachary A. Dix, Michael D. Breed, Radhika Nagpal
University of Colorado and Harvard University
Journal of Experimental Biology, Nov 2016
*Overview Video*

## Collective Transport in Ants

Evolved independently several times, but developed to much higher levels in some species.

Holldobler & Wilson, The Ants; Moffett, Adventures Among Ants; Exists in 40/283 genera




## Why Evolve Collective Transport?

- Group raiders (e.g. army ants)
  - Massive colonies need large intake of fresh prey, high rates of prey capture, and efficient movement of large prey.
- Desert ants (e.g. Aphenogaster)
  - Not as aggressive, group retrieval is important to rapidly escape competition by other ants

A "Distributed Consensus" Problem

- Most cases, if ants can agree on direction towards nest, and align forces, then they will be successful.

**Key Open Question:**

- How **"simple"** can ant be and still execute this behavior?
- How much **"coordination"** is required?

## Discussion 1

What are the criteria and constraints for a successful cooperative transport algorithm?

**On the "Global Goal"**
(e.g. obstacle type, success metric, terrain)

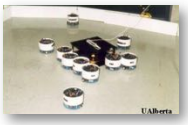
**On the "Agent"**
(e.g. sensing requirements, actions, prior/global knowledge)

## Collective Transport by Robots

Many Applications and Many approaches!

- Warehouses, automated construction, mining, manufacturing, disaster response….
- But unclear how sophisticated a robot needs to be?

Original
(Kube&Zhang, Maja Mataric)




Ant-Inspired
(e.g. swarmbot)

Control Theory
(e.g. caging, towing, etc)

## Collective Transport by Robots

- Many Complexities
  - Manipulators: push-only, pull-only (towing), push-pull
  - Global Knowledge: goal (localization), object details, localization
  - Communication and Sensing

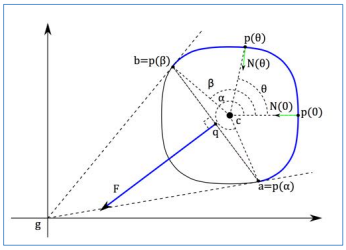
  *Current paper has excellent Related Work section.*

- **Ant-Inspired Approaches**
  - Box-pushing (e.g. Kube-Zhang), SwarmBot (e.g. Dorigo)

    *But: Still no mathematical understanding*
  - **Recent: e,g, Current Paper => mathematical proofs**
    - Proof that you can get away with little to no coordination in a large scenario space! Impacts both robots and biology.

- **Control Theory approaches**
  - Caging, Towing, Lifting (e.g. Kumar Upenn)
  - More industrial focus: *precision* manipulation (& analyzable)
  - High levels of knowledge and coordination required

## Modeling Collective Transport




Proof Structure! For collective behavior

- Make simplifying assumptions on agents
- Predict composite action for dt time step [ Composite Force, Composition Rotation]
- Prove convergence [i.e. for every time step, distance to goal strictly decreases]

## Discussion 2

Explicit communication between robots
- When/how would this help?

Other Open Problems
- Robots navigating terrains with obstacles
  (e.g. McCreery videos, today's paper)
- Flying robots! Or lifting/going up walls
  (harder dynamics, more coordination needed?)
- Human collective transport!
  (e.g. Reverse-engineer with a physics game)

## Humans!

- What mechanisms do people use to solve similar problems?
- Is explicit communication necessary?