CS289 Lecture 2
Ant Foraging

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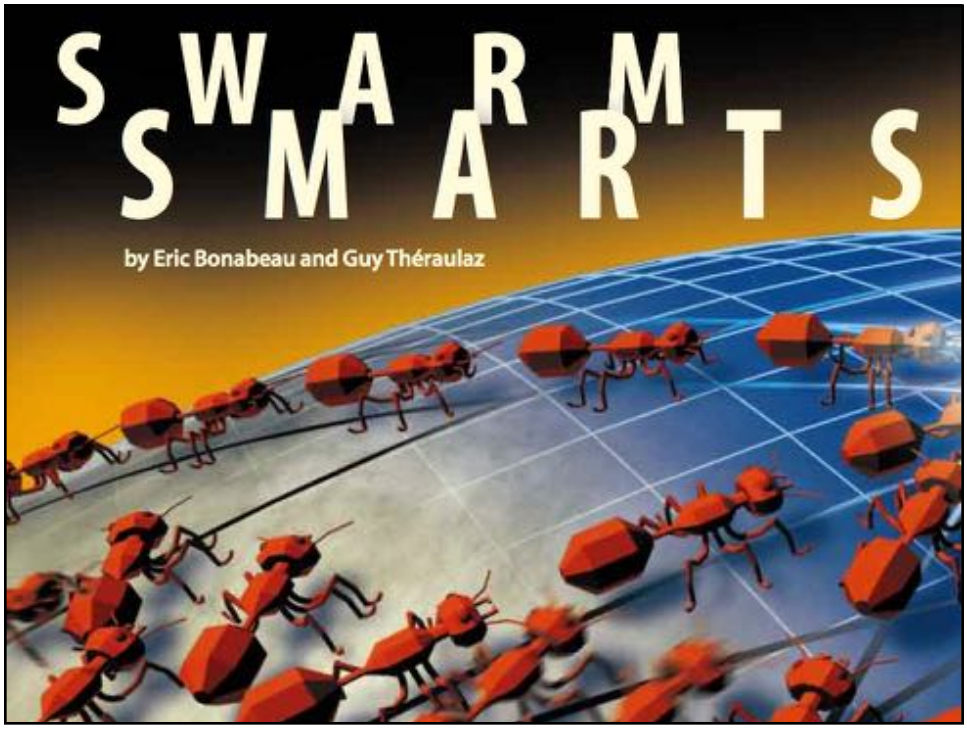

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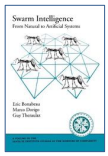
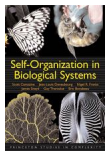
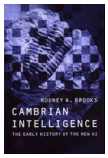
Swarm Intelligence (1990s-)







Eric Bonabeau (Physics), Guy Theralauz (BIO), Maja Mataric (AI)
Jean-Louis Deneuborg (BIO), Marco Dorigo (CS), Rod Brooks (AI)

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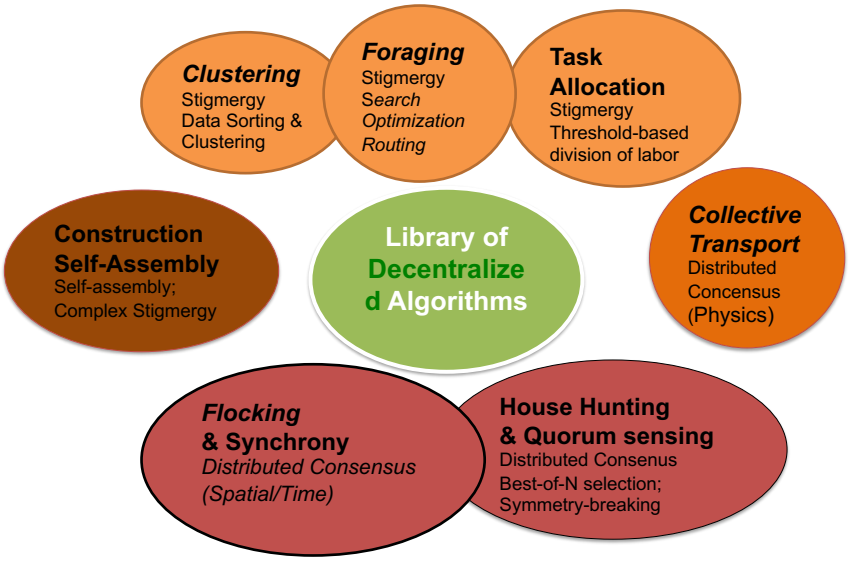
Swarm Intelligence



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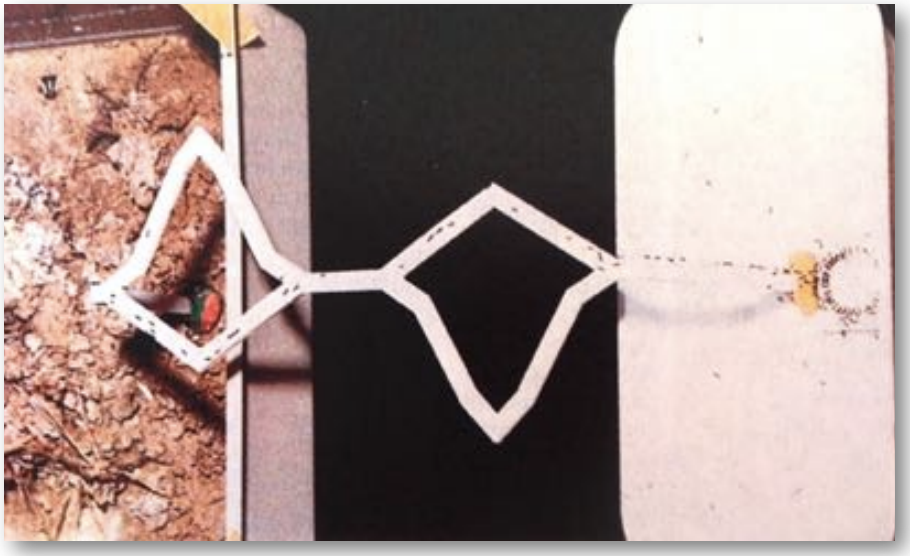

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Foraging in Pheromone-laying Species

- Iridomyrmex humilis: Argentine Ant
- Lasius niger: Black Garden Ant (common in Europe)

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Foraging for Food

- Amazing process
  - Find food is large unknown area (exploration)
  - Create single "highway" paths (many miles long)
  - Paths "improve" over time
    - Straighten and shorten, even repair
  - Solve "optimally" for complex scenarios
    - Multiple food sources, various quality, etc
- Question
  - *How smart does an individual need to be if collective is large?*
  - *How does the collective become more than sum of its parts?*
    - Answer: Not very! And Information-sharing
- How can we study the process?
  - Field studies + Lab games (or constrained scenarios)

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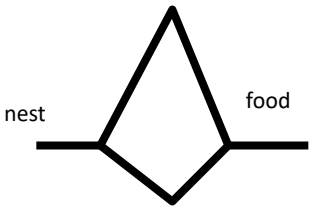
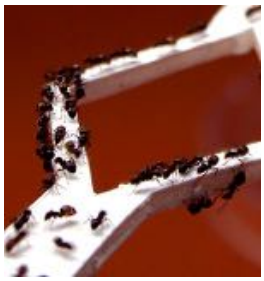
Becker et al 1992 Model





- Bridge
  - Like Prisoner's dilemma
  - Tool to understand decision-making
  - Reverse-engineering is hard!
- **3 Key Ideas**
  - Amplification (positive feedback)
  - Population (repeated)
  - Stigmergy (leave "notes" in environment)
- Implications
  - Find the shortest path
  - Select one, even if equal

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Discussion Question 1

- Name some examples where we/people use a "stigmergy" like approach to communication.

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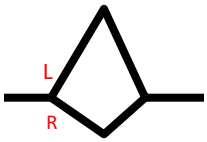
Modeling

A. Agent Choice Model

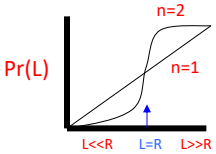
$$\Pr(L) = \frac{(k + L)^n}{(k+L)^n + (k+R)^n}$$

Or $\Pr(L) = \frac{1}{1 + (R/L)^n}$



B. Agent Update Model

Constant update of path (e.g. I humilis)
OR, Proportional to goodness
(food carrying ants behave differently)



C. Ant Model Global View

Population of independent evaluators, Sharing information, with Positive feedback
Possible models: ODEs/PDEs, or agent-based
Example, dL/dt = influx of ants * Pr(take this path)
+ influx from other side TL time ago * Pr (take this path)
- loss due to evaporation

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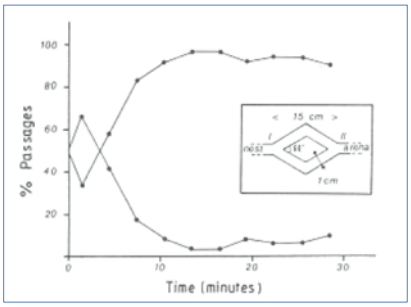

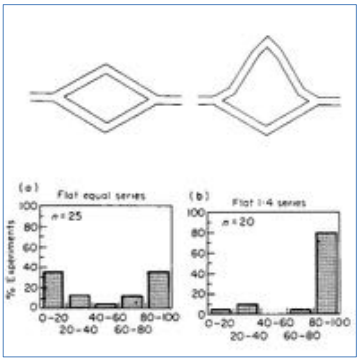

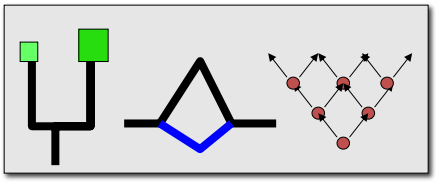

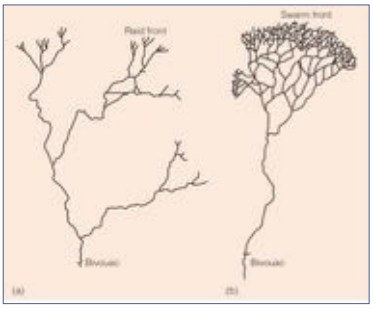

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Army Ant Bridge Formation

Simon Garnier &

Scott Powell Labs

PNAS 2015

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Discussion Question 2

- What are the important differences between
  - "stigmergy" (marking environment, implicit)
  - "direct" communication (agent-agent talking)

  as a information sharing mechanism

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Discussion Questions in Groups

1. Redesign the ants so that they allocate "proportionally" to each food source by quality (or divide proportionally based on path length)

2. Suppose you are conducting a search for a "source" in some arbitrary campus (unknown, rectangular obstacles) with humans. What strategy might you use?

Other Foraging Strategies: Army ants, Bees, Fish
Other Related Problems: Coverage

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Collective Clustering and Sorting

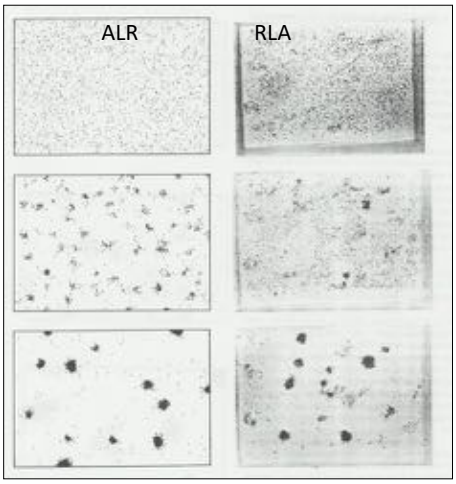
- *Concept:*
  - Ants cluster debris, larva, eggs into piles
- Behavior Model:

$$\Pr(\text{pickup}) = \frac{k^n}{k^n + f^n}$$

$$\Pr(\text{drop}) = \frac{f^n}{k^n + f^n}$$

f = fraction nearby
= 0 (nothing), 1 (lots of stuff)

No pheromones!!



Citation: Deneubourg et al, "The dynamics of collective sorting: robot-like ants and ant-like robots", Conf on Simulation of Adaptive behaviors, 1990.

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