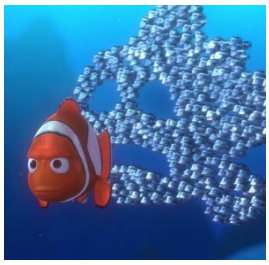
Self-Reconfigurable "Cellular" Robots

CS289

Science Fiction



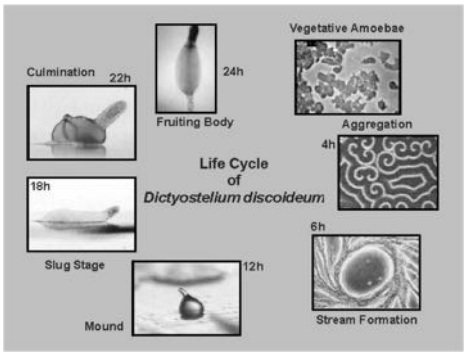

Science Fiction

Science Fiction

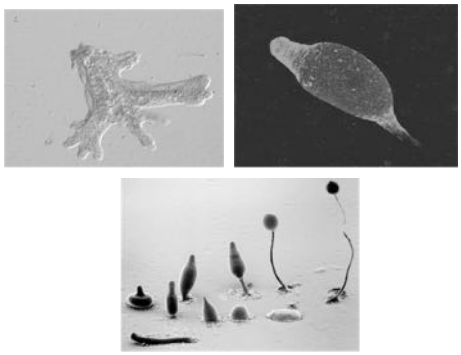
Reality

Stranger than Fiction?

Cellular Slime Mold



Cellular Slime Mold



Army Ants, Bridges & Bivouacs!

Daniel Kronauer, Rockefeller Univ;, Simon Garnier, NJIT; Scott Powell, G. Washington Univ

Reality

to Robots….

Challenges

What is a necessary & sufficient individual "module" to create interesting "collective" robots.

- **Mechanical Design Challenge**
  - Movement, attachment, power
- **Programming Challenge**
  - Global-to-local, scalable, robust

Both are closely linked……

Mechanical Design Challenge

- Historical
  - CEBOT (Fakuda), Fracta (Murata)
- Chain-style Robots
  - Polybot, Superbot, Mtran (Yim, Shen, Murata/Kurokawa)
- Lattice-style Robots
  - E.g. ATRON (Ostergaard, Stoy)
- Stochastic Robots
  - Programmable Parts, Molecube (Klavins, Lipson)
- Programmable Materials
  - Pebbles (Rus) Claytronics (Goldstein)
- Applications:

From Space Exploration to Novel Displays!

Kilobots Self-Assembly

"Bucket of Stuff" metaphor

Challenges

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Challenges

What is a necessary & sufficient individual "module" to create interesting "collective" robots.

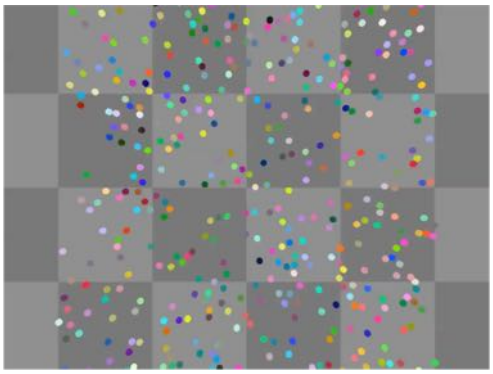
- **Mech**
  - Mo
- **Progra**
  - Glo

Programming Challenge => Many Approaches

1. Centralized Planning
   1. Find minimum number of steps to transform shape A to B.
   2. But, mostly NP hard and fragile
2. Decentralized:
   1. Cellular Automata (ala Lindemayer grammars, Rus et al)
   1. DevelBio-inspired (e.g. morphogen gradients, Shen et al)
   2. Chemistry-Inspired ("tiles" that stick to each other, Klavins et al)

Both are closely linked……

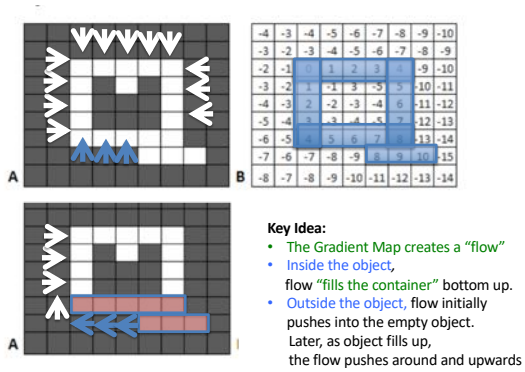
S-DASH Algorithm



Discussions

The goal of the DASH algorithm is "programmable self-assembly with self-repair"

- *What are the key elements of the DASH algorithm?*



Key Idea:
- The Gradient Map creates a "flow"
- Inside the object, flow "fills the container" bottom up.
- Outside the object, flow initially pushes into the empty object. Later, as object fills up, the flow pushes around and upwards

SDASH (later algorithm):
Added distributed coordinate formation, and "gossip" based scale belief.

Discussions

- What are the differences between:
  - DASH vs Biology ("French Flag" approach)
  - DASH vs Kilobots (Abstract->Physical)

Kilobots Self-Disassembly

Programmable self-disassembly for shape formation in large-scale robot collectives

Melvin Gauci, Radhika Nagpal, Michael Rubenstein
DARS 2016

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Robots