Self-Reconfigurable “Cellular” Robots

CS289
Reality

Stranger than Fiction?

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

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......

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)
   2. 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
Merline Gauz, Kathrika Ragal, Michael Hebenstern
SAMS 2014

Robots