Biologically-inspired Distributed Computing

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Robust Collective Behavior

Design systems capable of self-organization, self-repair

Distributed Systems

- Swarm robotics
- Sensor Networks

Inspiration: Biological Systems

- Synthetic Biology
- Reconfigurable Robots
Programming Myriads

High-level Programming Languages in terms of Goals / Tasks

Global-to-Local COMPILER

Program for Myriads of Agents

Biologically-inspired primitives for Robust Collective Behavior
Languages for Pattern/Self-Assembly

Grammars for “constructing” pattern

COMPILER

Behavior of an individual element

Primitives for local behavior
Lessons

• Traditional advantages of compilation
  – Easily program structure at an abstract level
  – Optimize and reason at the global level
  – Conservation of low-level code (and effort)
  – Complexity proportional to structure, not the number of nodes.

• Robust
  – Small number of robust local primitives
  – Robust to random placement, node failure and message loss, asynchronous nodes
  – Best-effort (but theoretically analyzable)
Example: Programmable Self-Assembly

Goal Shape: described using block-construction representation

PROGRAMMER

Program run by identically-programmed mobile modules, based on biologically-inspired primitives
Self-Repair and Regeneration

Regenerating structures

Absence of neighbor causes circle to recreate its neighbor, which in turn recreates its neighbor - thus regenerating the broken structure.

Self-repairing patterns

If a line is broken, one part dies off and the other regrows.
Research Agenda

• How do we obtain a *robust behavior* from the cooperation of vast numbers of unreliable parts?

• How do we engineer *pre-specified global* behavior from local interactions?

• Organizational principles

• Algorithms
  – Design and analysis

• Programming models and languages
  – Catalogues of primitives
  – Means of combination
  – Means of abstraction
  – Compilation technology targeted to appropriate substrates