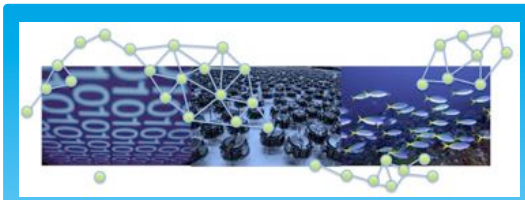


CS289
Bio-inspired Multi-agent Systems

Radhika Nagpal rad@eecs.harvard.edu
Fall 2017: Tues, Thurs 11:30-1, MD 223

Announcements

* CS289 Course Staff
  * Radhika Nagpal (MD 235, rad@eecs)
  * Website: main repository of all information on the class
  * https://canvas.harvard.edu/courses/29752
* **Limited Enrollment Process**
  * Please fill out the **Google Enrollment Form** online on the website homepage **by tonight,** and add the class to your crimson cart.
  * I will get back to you by tomorrow midnight (Friday) about the final enrollment decisions. And I will approve online by Monday morning.
* Next week Tuesday's Assignment: Reading and Review
  * There is a **paper reading due next week tuesday**. You will email me a short review before class, as explained on the website.

Collective Intelligence in Nature

Bio-inspired Collective Systems

* Collective Intelligence in Nature
  * Complex goals can be achieved by collectives of relatively simple and limited individuals
  * Parallelism, robustness, adaptability
* Emerging Novel Distributed Systems
  * Massive numbers, small scales, embedded
  * Challenge: *how do we construct robust and predictable systems?*

Emerging Distributed Systems

Bio-inspired Collective Systems

* Collective Intelligence in Nature
  * Complex goals can be achieved by collectives of relatively simple and limited individuals
  * Parallelism, robustness, adaptability
* Emerging novel distributed systems
  * Massive numbers, small scales, embedded
  * Challenge: *how do we construct robust and predictable systems?*
* Collective "Artificial" Intelligence
  * Extract *robust and scalable engineering techniques* from our understanding of biological collectives.

What This Course is About

Grad-level Research Area Course

* Survey Bio-inspired Approaches and Applications
  * Three main topic areas:
    * **Swarm Intelligence** ("social animals" as a metaphor)
    * **Cellular Automata & Self-Assembly** ("cell" as a metaphor)
    * **Evolutionary Computing** ("evolution" as a metaphor)

    Also, **Human Collectives** (as student presentations)
* **Read papers (primary sources)**
  * Read papers on models of natural distributed systems
  * Read papers on applications to systems design
  * Discuss and Present
* **Conduct Research (final project)**
  * Extend an existing paper's results, apply biological principle to a distributed systems problem, solve computational/theory problem related to collective intelligence, or model a biological system

How This Class Works

- Reading and Class Participation
- Paper Reviews
- Lecture Presentation
- Class Project

How This Class Works

- **Reading and Class Participation**
- Paper Reviews
- Lecture Presentation
- Class Project

* Reading and Class Participation
  * Each class has 2 papers assigned for reading, one primary paper and one for context (Interdisciplinary)
  * In class we will discuss the papers, lessons and implications, what "principle" can be generalized, etc.
  * Caveat: useless if you don't do the readings!

How This Class Works

- Reading and Class Participation
- **Paper Reviews**
- Lecture Presentation
- Class Project

* Paper Reviews
  * Due by 7am before class day
  * Post to cs289 discussion board (email for now)
  * Format: See guidelines on the website
  * Paper review due **next tuesday**: send via email to rad@eecs.harvard.edu

How This Class Works

- Reading and Class Participation
- Paper Reviews
- **Lecture Presentation**
- Class Project

* Presenter Days
  * Some classes are "presenter days"
  * Everyone does one presenter paper (in pairs).
  * The goal is for the presenter (you) to look into the subject in more depth and educate the class on an additional interesting topic.
  * This year presenter days focus on human collectives

How This Class Works

- Reading and Class Participation
- Paper Reviews
- Lecture Presentation
- **Class Project**

* Final Research Project (in pairs)
  * Goal is to explore a topic of *your interest* in more depth
  * Project: Theory, bio-inspired distributed systems application, models of biology, even robotics
  * Key: Choosing the *Scope* of the problem (1 month)
  * Deliverables: Presentation + Paper
  * **READ FINAL PROJECT GUIDELINES and examples online**

How This Class Works

- Reading and Class Participation
- Paper Reviews
- Lecture Presentation
- Class Project

* Grades are roughly
  * 1/2 InClass Participation, Reviews, Presenter Day
  * 1/2 Final Project

Schedule: See Online

Roughly

Swarm Intelligence (4 weeks)
Cellular Computing (2 weeks)
Evo Computing (2 weeks)
----- FINAL PROJ PROPOSAL -------
Presenter Days (2 weeks)
---- FINAL PROJECT DUE--------

*Final project scope: 1 month
(no readings and reviews)

Final Project Dates (tentative)

Oct 12 (tentative)
Discussion & team formation day

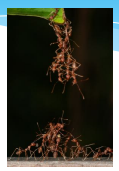
Nov 2 (Thurs)
Proposal due
Nov 28 (Tues) and 30 (thu)
Final project presentations
Dec 7 (Thu)
Final papers due by 11pm

Three Topics Areas

* Swarm Intelligence
* Cellular Computing
* Evolutionary Computing

Swarm Intelligence
Social Animals as a Metaphor

Swarm Intelligence
Social Animals as a Metaphor


* Simple rules
* Amazing Global properties
* Handbook of algorithms?

Swarm Intelligence
Inspire New Systems Design

- Optimization algorithms
- Networks (e.g. Routing, Synchronization)
- Swarm Robotics! (movies)

Swarm Intelligence

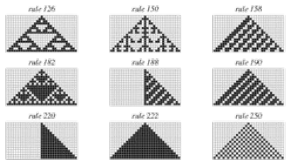
* Models of social insects and animal coordination
  * *Primitives:* Search, Transport, Sync, Flocking, Construction
  * *Principles: e.g.* Stigmergy & Distributed consensus
  * *Reading:* biology and applied math papers
* Algorithms and Applications
  * **Many "generic" algorithms that have wide application**
  * *Reading:* Applications to Optimization, Networks, Robotics
* *Open Question: Analysis and Synthesis*

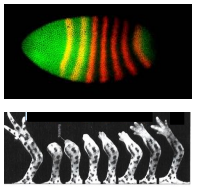
Three Topics Areas

* Swarm Intelligence
* Cellular Computing
* Evolutionary Computing

Cellular Computing
Cells as a Metaphor

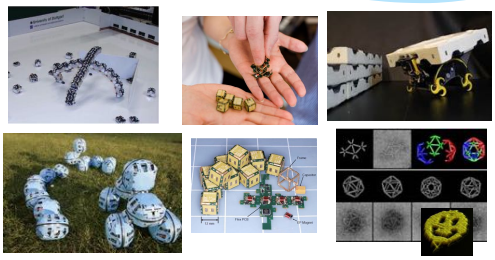
* Pattern Formation, Self-assembly, Self-repair





Cellular Robotics

* Self-reconfiguring Robotics, also Collective Construction
* Programmable Materials; DNA self-assembly



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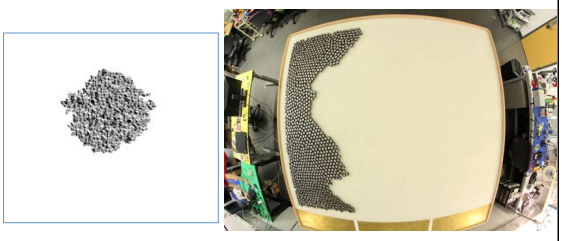


Cellular Computing

- Models from Multi-cellular Biology
  - *Local:* Gradients, Directed growth, Stochastic rules
  - *Global:* Cellular Automata; Self-assembly; Regeneration
- Algorithms and Applications
  - **Global-to-local Compilers and Theory**
  - Algorithmic approaches to self assembly and self-repair
  - Robotics and Programmable Materials
- Open Question: Scalability and Hardware

Three Topics Areas

- Swarm Intelligence
- Cellular Computing
- Evolutionary Computing

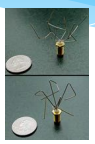
Evolution as a metaphor


The World == Complex goals & Dynamic environments
An Amazing Variety of "Solutions"

- Evolution as Population + Variation + Selection
- Evolution as optimization/learning
- Evolution as a design process…

Evolution as a tool

- Evolutionary algorithms for search and optimization, and applied to design and robotics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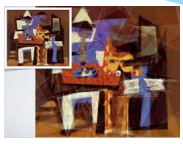
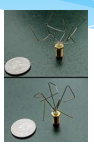

Evolution-inspired Computing

- Evolutionary Computing
  - Evolution as optimization using a population of agents
  - Different algorithmic flavors (e.g. genetic programming)
- Applications
  - **General Algorithms: Optimization and Search problems**
  - Evolutionary Design and Programming "Invention"
  - Evolutionary Robotics and Robot Collectives
- Open Question: Applying evolution to collectives

Three Topics Areas, plus

* Swarm Intelligence
* Cellular Computing
* Evolutionary Computing
* *Presenter Days: Human Collectives*

CS289

* Final Reminders
  * Fill out the **Google Form** (link on cs289 website)
  * There are Papers to read starting next week
    * email review to Radhika
* Questions?