Announcements

- CS289 Course Staff
  - Radhika Nagpal (MD 235, rad@eecs)
  - Website: main repository of all information on the class
  - https://canvas.harvard.edu/courses/60467

- Limited Enrollment Process
  - Please fill out
    - Google Enrollment Form on the website by Tonight, and
    - Add the class to your crimson cart.
  - I will get back to you tomorrow (Thurs) about the final enrollment decisions and wait lists. And I will approve crimson carts on Friday.

- Next Class Friday: First Assignment due (Reading + Review)
  - There is a paper reading due Friday. You will email me a short review by 7am Friday morning, as explained on the website.

What can a Group do that an Individual cannot?

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

- Massively parallel, robust, adaptive
- Challenge: how do we construct robust and predictable systems?

Collective Intelligence in Nature

- Complex goals can be achieved by collectives of relatively simple and limited individuals
- Parallelism, robustness, adaptability

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

- Extract robust and scalable engineering techniques from our understanding of biological collectives.
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!

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 before next class: send via email to rad@eecs.harvard.edu

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
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 16 (tentative)
Discussion & teams formation.
Nov 1
Proposal due
Nov 20 and 22
Presentations
Dec 9
Final papers due by 5pm

Three Topics Areas
- Swarm Intelligence
- Cellular Computing
- Evolutionary Computing
Swarm Intelligence
Social Animals as a Metaphor

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

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

Swarm Intelligence
Inspire New Systems Design

- Optimization algorithms
- Networks (e.g. Routing, Synchronization)
- Swarm Robotics (movie1 movie2)
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
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
- Evolution 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 for next class!
    - email review to Radhika
- Questions?