ABMS OF CULTURAL EVOLUTION

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ABMS IN PHILOSOPHY

Review:

- Two Platonic puzzles: Justice and Meaning
- Difference between ABMs and population models.
- Why ABMs might help with Plato's puzzles

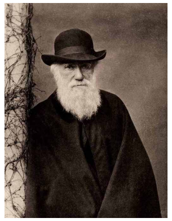
MODELS AND SIMULATIONS

Today:

- Population vs. ABMs models of cultural evolution
- Social networks
- Bounded Rationality

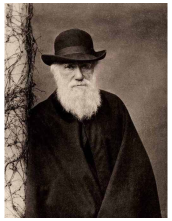
OUTLINE

From Plato to Darwin



- Plato's two puzzles: What are the origins of just behavior and linguistic meaning?
- A suggestive way of asking these questions: How did justice (respectively meaning) evolve?

Game Theory in Biology



Because we discussed how game theory might be useful in addressing Plato's puzzles, it might be helpful to discuss a common and fruitful analogy between

- Models of natural selection
- Rational Choice Theory (i.e. decision and game theory)

Decision Theory in Biology

Question: How are decision (and game theory) relevant for models of natural selection?

Decision Theory in Biology

An Informal Argument:

1. Actions = Phenotypes (e.g., traits and behaviors)
2. Payoffs = Offspring
3. By definition, organisms that have the highest actual payoffs (offspring) will become more prevalent in the population.
4. So intuitively, actions (i.e. phenotypes) that have the highest expected payoffs (offspring) will become more prevalent.
   - The expected number of offspring of an organism with a given phenotype, given the current distribution of phenotypes in the population, is often called the fitness of the phenotype.

Decision Theory in Biology

Conclusion: Nature can modeled as choosing organisms with particular phenotypes so as to maximize expected utility, where utility is number of offspring.

> *There exist deep and interesting connections, both thematic and formal, between evolutionary theory and the theory of rational choice . . . In rational choice theory, agents are assumed to make choices that maximize their utility, while in evolutionary theory, natural selection 'chooses' between alternative phenotypes, or genes, according to the criterion of fitness maximization. As a result, evolve organisms often exhibit behavioral choices that appear designed to maximize their fitness, which suggests the principles of rational choice might be applicable to them.*

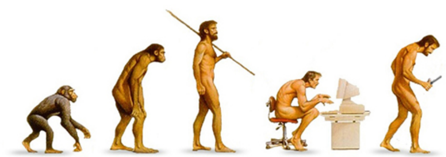
Okasha and Binmore [2012].

Decision Theory in Biology

Moral: Rational choice theory can be useful in helping us understand evolution.

What about the reverse?

Cultural Evolution

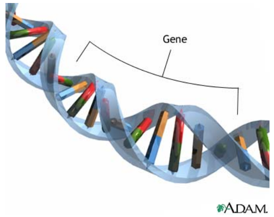


- **Observation:** The "informal" argument discusses phenotypes, i.e realized behaviors or traits.
  - Genotypes matter only insofar as they produce traits or behavior that affect survival and reproduction.
- Human culture is a collection of behaviors and artifacts: it is not primarily a genetic phenomenon.
- So models of natural selection might be applicable to modeling cultural evolution as well.

Cultural Evolution

- This is how population level models of selection (whether natural or cultural) work:
  - Selection acts on the population as a whole.
- How should we use ABMs to understand "cultural evolution"?
  - Answering these questions requires speculating about the mechanism by which culture is transmitted . . .

Cultural Evolution



Question: In biology, there is a mechanism by which traits are passed from parent to offspring: genes. What is the corresponding mechanism for culture?

> *Because of their common informational and evolutionary character, there are strong parallels between genetic and cultural modeling [Mesoudi et al., 2006]. Like biological transmission, culture is transmitted from parents to offspring, and like cultural transmission, so in microbes and many plant species, genes are regularly transferred across lineage boundaries [Abbott et al., 2003, Jablonka and Lamb, 1995, Rivera and Lake, 2004]. Moreover, anthropologists reconstruct the history of social groups by analyzing homologous and analogous traits, much as biologists reconstruct the evolution of species by the analysis of shared characters and homologous DNA [Mace et al., 1994]. Indeed, the same programs biological systematists are used by cultural anthropologists [Holden, 2002, Holden and Mace, 2003].*

Gintis [2012]. pp 216-217.

Outline

1. Review and Motivation
2. Population Models of Cultural Evolution
3. Agent-Based Models of Cultural Evolution
   - Explanatory Pattern
   - Components of ABMs of cultural evolution
     - Social Networks
     - Learning Rules and Bounded Rationality
4. NetLogo
5. References

Components of ABMs

Agent based models (ABMs) have the following components:

- Agents with properties (e.g., location, preferences, beliefs)
- Environment (e.g. a terrain)
- Initial Conditions for agents and environment
- Rules specifying how agents interact with one another and the environment

Explaining with ABMs

So to build an ABM that explains some phenomenon (e.g. just behavior and/or meaning), it suffices to do the following:

1. Describe each component of an ABM
2. Identify the phenomenon (here, just behavior or meaning) to be explained with a possible configuration of the ABM
   - Example: If we wished to explain why some species went extinct, we could build an ABM and identify its real-world extinction with the state in the ABM in which the "virtual species" dies out.
3. Show that the ABM, with high probability, converges towards the configuration identified.

ABMs of cultural evolution

In a nutshell, here's how we'll attack each of these steps for Plato's puzzles.

ABMs of cultural evolution

Step 1: Build an ABM in which agents repeatedly play a game.

- Two-player games (e.g., Prisoner's dilemma, stag hunt, Lewis signaling games) are most common.
- Models with multi-player games do exist.

ABMS CULTURAL EVOLUTION

Step 2: Identify just behavior (and or the existence of meaning) with a strategic profile in a game.

The Prisoner's Dilemma

Glaucon's definition:

> *This, they say, is the origins and essence of justice. It is intermediate between the best and the worst. The best is to do injustice without paying the penalty; the worst is to suffer it without being able to take revenge. Justice is a mean between the two extremes.*

	Justice	Injustice
Justice	$\langle 2, 2\rangle$	$\langle 0, 3\rangle$
Injustice	$\langle 3, 0\rangle$	$\langle 1, 1\rangle$

ABMS CULTURAL EVOLUTION

Step 3: We'll argue that **If**

- Players repeatedly play certain games in certain environments
- Learn to interact with one another over time in certain ways,

Then the strategic profile corresponding to just behavior (respectively, meaningful communication) will become prevalent.

ABMS OF CULTURAL EVOLUTION

Step 1: Build an ABM in which agents repeatedly play a game.

Properties of agents

Question: Who/what are the agents in these ABMs and what properties do they have?

Answer: We make no deep "metaphysical" assumptions about who/what the agents are.

We simply stipulate they have the following properties:

- Preferences over strategic profiles of the game
- Learning rules for choosing which actions/strategies to employ in light of past behavior.
- Location in a social network

Components of ABMs

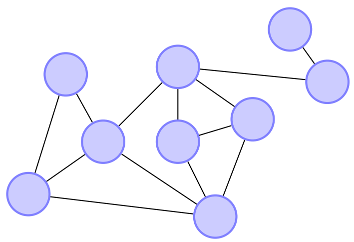
Which components of an ABM of cultural evolution remain to be described?

- ~~Agents with properties (e.g., location, preferences, beliefs)~~
- Environment
- Initial Conditions for agents and environment
- Rules specifying how agents interact with one another and the environment

Properties of agents

Question: In what type of environment do agents interact?
Answer: A social network.

Networks



Nodes = Agents
Edges = Indicate which agents "interact" , by playing a game

Common Social Networks

What are some common social networks that might be represented in this way?

- Facebook (Edges indicate the “friend” relation)
- The world-wide web (Edges indicate reciprocal links)
- Co-authorship networks (Edges indicate co-authors)
- Actor Network (Edges indicate the actors have appeared in a movie together)

Common Features of Social Networks

Many social networks share network structure.

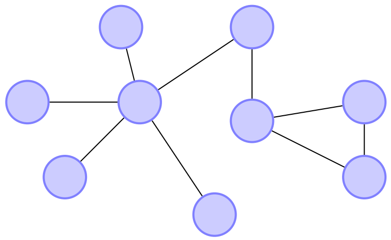
Structure of Real Scientific Networks

What types of structural properties do academic co-authorship networks and other social networks share?

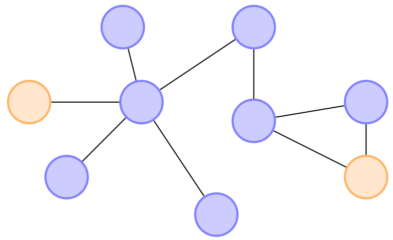
Here are four.

Small Diameters

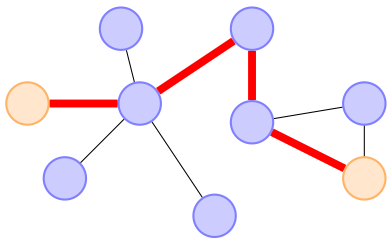
Finding the Diameter



Finding the Diameter



Diameter



Diameter: The longest-shortest path between any two nodes in the network.

Empirical Size of Connected Components

	biology	physics	mathematics
number of authors	1,520,251	52,909	253,339
diameter	24	20	27

Newman [2001]

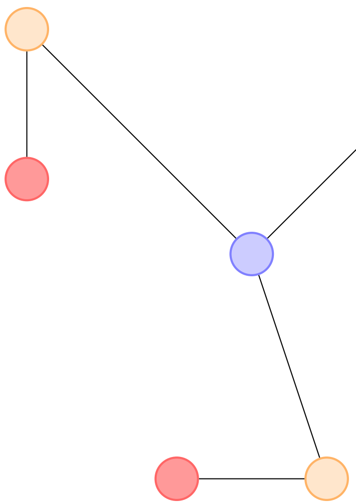
Small Diameter

Many other social networks have small diameters (and average-path-length)

- E.g., [Milgram, 1967]'s small world experiment
- E.g., The Kevin Bacon Game
- E.g., Erdös Numbers

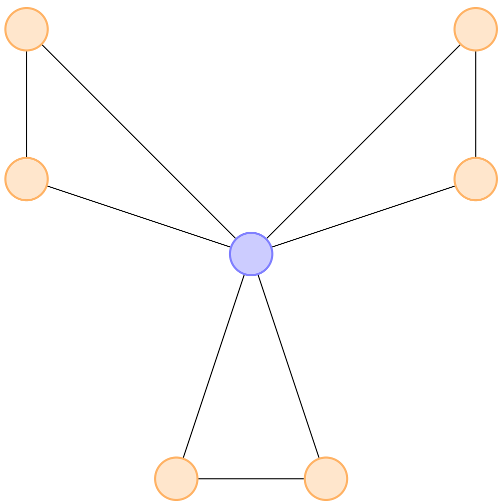
Highly Clustered

Clustering Coefficient



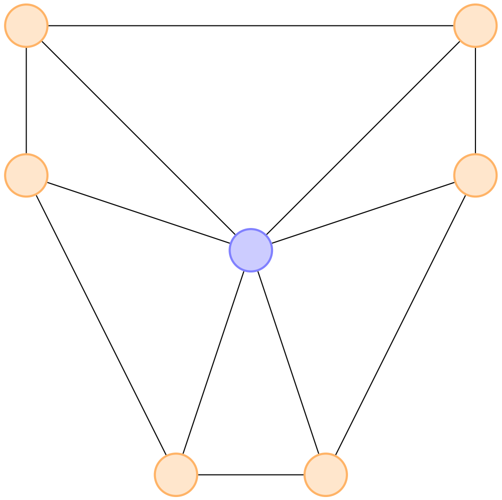
Not clustered

Clustering Coefficient



More Clustered

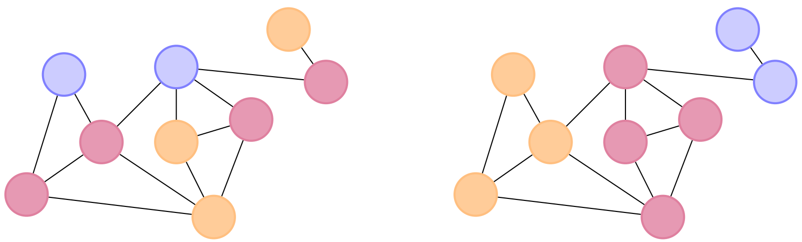
Clustering Coefficient



Highly Clustered

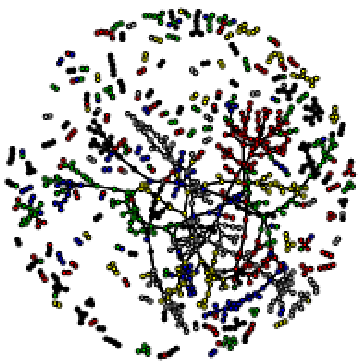
High Homophily

Homophily



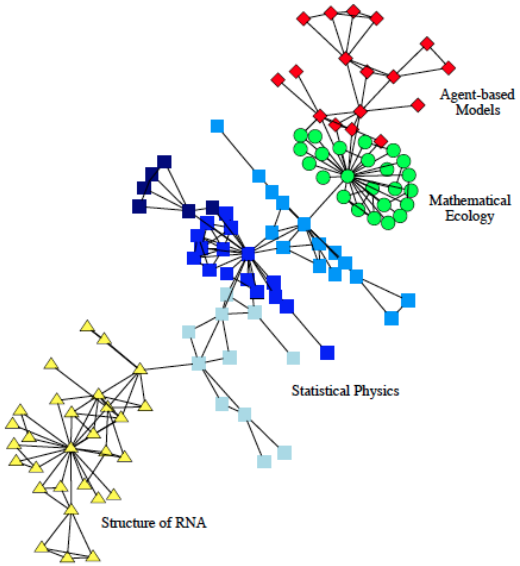
Left: A Non-Homophilous Network
Right: A Homophilous Network

High School Social Networks



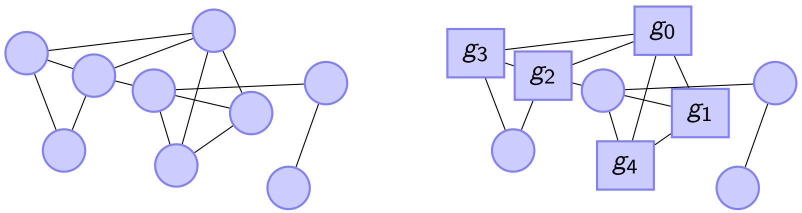
Goodreau et al. [2008]

Academic Social Networks



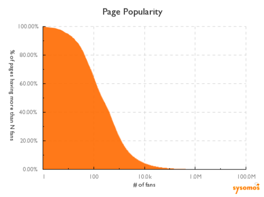
Power Law Degree Distribution

Neighborhoods



g_0's neighborhood

Power Law Degree Distribution



- Power law degree distribution
  - The degree of a node is the number of its neighbors.
  - A power law degree distribution indicates most agents have a few neighbors; few have a modest number; even fewer have many; etc.

Common Features of Social Networks

Average-path-length, diameter, degree distributions, etc. are called network structure.

Components of ABMs

Which components of an ABM of cultural evolution remain to be described?

- ~~Agents with properties (e.g., location, preferences, beliefs)~~
- ~~Environment~~
- Initial Conditions for agents and environment
- Rules specifying how agents interact with one another and the environment

Initial Conditions

Question: What properties do agents and their social network initially have?

Answer:

- Of course, when scientists know a lot about social conditions thousands of years ago, we can use those to build models . . .
- However, we often don't know much. So modelers consider a wide variety of initial conditions to ensure their conclusions are robust.
  - Example: Vary agents' initial strategies in the game.
  - Example: Vary the strength of agents' preferences.
  - Example: Vary the social network.

Components of ABMs

Which components of an ABM of cultural evolution remain to be described?

- ~~Agents with properties (e.g., location, preferences, beliefs)~~
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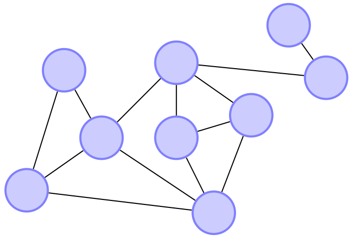
Interaction



Question: How do agents interact with one another?

Answer:

- Time is divided into discrete steps: stage 1, stage 2, etc.
- On each stage, each agent plays the game with **all** of her neighbors.
- She gets to observe her performance and that of her neighbors.

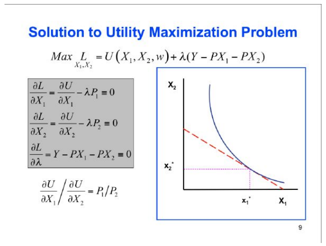
Learning Rules

Question: Which actions do agents employ, and how do they choose?

Answer:

- For simplicity, assume she chooses the same action in each of the games.
- Agents choose actions using learning rules.
  - There are dozens of learning rules; I'll describe three types.

Learning Rules: Expected Utility Maximization



Type 1: Agents are classically rational; they maximize subjective expected utility.

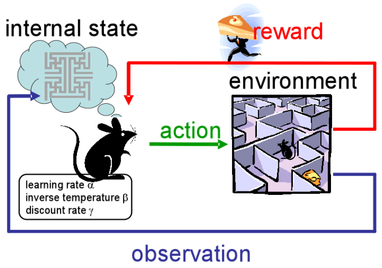
- E.g., An agent uses her neighbors past behavior to estimate the probability of their future actions. She then chooses the action maximizing her expected payoff.
- This is not common in agent-based modeling.

Learning Rules: Imitation

Type 2: Imitation Rules

- E.g., The agent adopts the best action of one of her neighbors, i.e., the action that had the highest payoff in her neighborhood.

Learning Rules: Reinforcement Learning

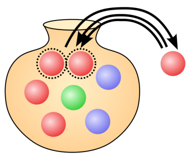


Type 3: Reinforcement learning

- Each time an action leads to some success, the agent becomes more likely to employ it in the future.
- So agents roughly employ mixed strategies in which the probability of an action is proportional to its past payoffs.

Example: Here's a specific type of reinforcement learning, sometimes called Roth- Erev reinforcement learning.

Learning Rules: Reinforcement Learning



- Imagine the agent has a big urn with different colored balls.
- Different actions ⇒ Different color balls.
  - Example: Stag = blue; Hare = red.
- On each stage, the agent pulls a ball from the urn (at random) and plays the corresponding action.
- At the end of the stage, she then replaces that ball with n many balls of the same color, where n is her total payoff.
  - For simplicity, assume payoffs are non-negative.

Components of ABMs

Which components of an ABM of cultural evolution remain to be described?

- ~~Agents with properties (e.g., location, preferences, beliefs)~~
- ~~Environment~~
- ~~Initial Conditions for agents and environment~~
- ~~Rules specifying how agents interact with one another and the environment~~

What happens?

Question: What happens in ABMs like this when agents repeatedly play prisoner's dilemmas? Stag hunts? Etc.

Answer: Let me show you some simulations . . .

NetLogo

Today's Programming Concepts:

- If-else statements
- Loops
- Procedures

Course Outline

	Lecture	Tutorial
1	Intro to ABMs; Some Game theory	Data types
2	ABMs of cultural evolution	Loops and procedures
3	Plato's Puzzles Revisited	Agent Commands
4	Group model building	

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