Network Models in Philosophy of Science: Zollman on Transient Diversity

Models and Simulations in Philosophy
July 2nd, 2013

Review:

- "Classical" economic models in philosophy of science
  - Kitcher: Self-interested, fame seeking scientists may make for more successful science than "purely" motivated, truth-seeking ones. conduct better scientific
  - Strevens: Priority Rule encourages beneficial diversity of methodology.
- ABMs in philosophy of science
  - Weisberg and Muldoon: Risk-taking and diversity within a field in which discoveries can be made repeatedly.

TODAY

Today: [Zollman, 2010]'s ABM of communication in science.

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- More communication is not necessarily better
  - Quick access to information can lead good theories to be abandoned too quickly.
- Dogmatism is not necessarily bad
  - Dogmatic scientists make sure theories get fair hearings.
- Dogmatism and lack of communication together are likely bad
  - The prevent a community from pursuing alternative research methodologies.

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- Scientists ought to explore different research methodologies until the best of a group is found, and then explore no longer.
- Dogmatic scientists (with different beliefs) and lack of communication are just two ways of promoting transient diversity

Outline

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1. Review
2. Ulcer Case Study
3. Bandit Problems
   - In Philosophy of Science
   - Zollman's Model

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History: In 2005, Barry Marshall and Robin Warren were awarded the Nobel Prize for the discovery of the bacteria that causes ulcers.

Their landmark paper first appeared around 1983.

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- The hypothesis that bacteria causes ulcers has been around since the 19th century.
- Some doctors have successfully treated ulcers with antibiotics since the 1950s.

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The Rise of a Hypothesis

In the middle of the 20th centurty, there were several competing hypotheses about the cause of ulcers:

- Acid
- Bacteria
- Stress (post-Palmer's study)
- And variation on these.

Non-Dogmatism and Quick Dissemination

According to Zollman, two features characterized the medical community in 1954:

1. Sufficient open-mindedness (non-dogmatism) about the causes of ulcers
2. Quick dissemination of research results

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- In 1954, Palmer tests 1000 patients stomachs for bacteria and finds nothing!
- Little did he know his method did not detect the type of bacteria that produce ulcers.

After Palmer: The bacterial hypothesis was nearly universally rejected.

- Lykoudis, a Greek physician, is shunned and fined for treating ulcers with antiobiotics.

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After Palmer: The bacterial hypothesis was nearly universally rejected.

- Lykoudis, a Greek physician, is shunned and fined for treating ulcers with antiobiotics.
- Warren and Marshall cannot get their initial paper accepted into a conference with a 90% acceptance rate!

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Then: Some scientists would have continued to pursue the bacterial hypothesis, and we might have discovered the bacterial cause of peptic ulcers earlier.

Can we produce a model that explains this behavior?

Outline

Goal: Find the arm (or machine) with the highest payoff.

Tradeoff: To ensure that you find the best machine, you must experiment with inferior ones.

Applications of Bandit Problems:

- Medical Treatment [Berry and Fristedt, 1985]
- Crop choices in Africa [Goyal, 2003]
- Drilling sites [Keller et al., 2005]

Zollman [2010] claims that bandit problems can be used to represent methodological choices in the sciences.

Here are some examples from [Mayo-Wilson et al., 2011].

To study animal behavior: Biologists might use

- Field observation,
- Laboratory experiments,
- Population genetic models,
- Game theoretic models,

These techniques corresponds to different "arms" of a slot machine.

To explain some human behavior: A psychologist might use any number of theories of concepts

- Exemplar-based
- Prototype-based
- Causal-model theory
- Theory-theory

Again, these modeling techniques or theories corresponds to different “arms” of a slot machine.

Understanding the metaphor: Stochasticity

- Models, theories, and techniques are not always successful.
- So they have probabilistic returns, just like slot machines.
- In bandit problems, payoffs are i.i.d, that is
  - For each payoff r, there is some fixed probability $p(r)$ that the payoff will be r each time the arm is pulled.
  - This seems less plausible in science. We'll come back to this.

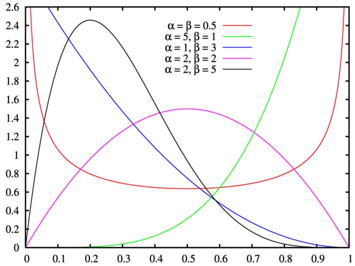
Understanding the metaphor: Exploration vs. Exploitation

- Nonetheless, some theories are generally more successful than others.
- Scientists do not want to spend their careers pursuing inferior theories.
- But they need to explore to figure out which are successful.

[Zollman, 2010] makes the following simplifications to the general bandit problem:

- Arms only give payoffs 0 or 1.
- So agents want to find the arm with the greatest probability of obtaining a payoff of 1.

This allows [Zollman, 2010] to model agents as simple Bayesian learners whose beliefs are represented by beta distributions:



The curve $p(x)$ represent how probable the agent believes it to be that the arm pays off $x\%$ of the time.

How Beta distributions work:

- For each arm, there are numbers α and β such that the agent initially believes the probability that the arm will give a payoff is $\frac{\alpha}{\beta}$.
- After n observations, of which s are 1, the agent then believes the probability of success is:

$$\frac{\alpha + s}{\beta + n}.$$

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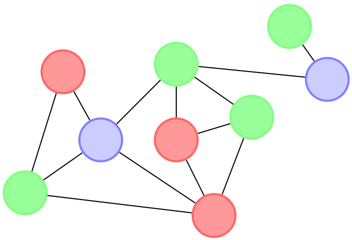
- So the bigger α and β are, the more dogmatic the agent: her beliefs will change more slowly.

[Zollman, 2010] assumes agents are myopic: they always pick the arm which they believe to have the highest expected payoff.

Outline

Networks



Nodes = Agents
Edges = Indicate which agents can view each other's data.

Again, applying bandit problems in a social setting is not new: [Goyal, 2003].

Outline

Criteria for Success: All agents converge to playing the arm with highest expected payoff.

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  - Networks with more edges converge on playing the best arm less often
- Dogmatism is not necessarily bad
  - When agents have bigger αs and βs in densely connected networks, they converge more often.
- Dogmatism and lack of communication together are likely bad
  - Sparsely connected networks with agents with big αs and βs don't converge to playing the true arm.

Outline

Model Improvements

Various ways of improving the models:

- Drop the i.i.d assumption (e.g., impose decreasing marginal returns)
- Employ different learning algorithms
- The use of networks that resemble real ones
- Dynamic networks

References I

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