Evolutionary Game Theory
Economics 256 / Mathematics 256

Prof. Rob Root
Mathematics

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[ofc hrs]

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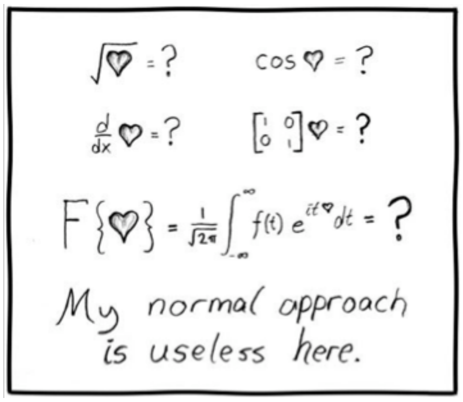

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(Even the identity matrix doesn't work normally.)
http://xkcd.com/55/ - A webcomic of romance, sarcasm, math, and language - By Randall Munroe

According to Hollywood, "Greed is good." Is this your experience? For example, when you dine at a restaurant in a city that is far from your home, one that you do not intend to visit again soon, do you leave a tip? Most people do, but why? Is it force of habit? Fear of damaging one's reputation? Altruistic concern for the servers? Support for widely accepted social conventions? Irrational or ill-considered behavior? Answers to these questions lie at the heart of our understanding of the origins of cooperation amongst humans, and exploring those answers is inherently a cross-disciplinary experience.

Text: Games, Strategies, and Decision Making, by Joseph Harrington, Jr.
Additional texts and readings available in JSTOR and the bookstore
Class notes are based on Mathematical Models of Social Evolution by Richard McElreath & Robert Boyd and The Calculus of Selfishness by Karl Sigmund.

Prerequisites: **Math** 141 or 161 or 165, and any one of the following:
Econ 101, **Biol** 102, **A&S** 102/103, **Psych** 110,
Govt 101/102/103/104, **Neur** 201, or **Phil** 200/245/250/260.

This class satisfies requirements for …
the Economics major and minor, the Computational Methods minor, and (with successful petition) a Biology or Neuroscience free elective.

The development of this course was supported by grants from the National Science Foundation (IOS-0922605, HSD 079458, and CPATH-T 0722211/0722203) and a grant for interdisciplinary course development from the Mellon Foundation through the Dean of the College.

 DRAFT

Why this course?

Mathematical structures describe the evolution of behavior in the social and biological sciences, and formal mathematical models have demonstrated the flexibility to explain how individuals interact to determine the welfare of a group, be it a species or a society. These mathematical insights are motivated by natural scientists' and social scientists' observations.

The history of economic thought has, even at its origins, recognized the organic nature of social interaction and its links to biological evolution. Adam Smith's 18th century The Wealth of Nations discussed the "emergent" effects of self-interest on improving society's welfare: even when no individual seeks to create a beneficial outcome for society, the aggregate of individuals' actions can create a desirable outcome—as if by "An Invisible Hand". Smith's earlier Theory of Moral Sentiments recognized and investigated the greater context of individual actions on the welfare of others, there positing pity, compassion and sympathy as elemental motives for human action along with self-interest.

Alfred Marshall's 19th century Principles of Economics laid out marginal analysis (thus applying calculus) as the basis for a mathematical approach to economics, yet his discussion also recognized the importance of learning and beliefs—evolutionary change. On the other hand, much of the 20th century's developments (paradigmatically with Samuelson's Foundations of Economic Analysis) in models of economic interaction overwhelmingly looked for inspiration in the mathematics developed for the physical sciences.

With work in game theory, begun by the mathematician John von Neumann and the economist Oskar Morgenstern early in the 20th century and further invigorated in mid-century by John Nash, another mathematician, came an understanding of the "strategic" nature of social interaction. Their work and the literature that followed created mathematical models capturing individuals' anticipation of their actions' effects on each other's well being.

In the final quarter of the 20th century, natural scientists recognized that these social questions explored in game theory have parallels in evolutionary biology. Thus economics, which at its classical inception had recognized the evolutionary nature of social interaction, now provided inspiration for the biological sciences. This led to evolutionary game theory.

Similar questions arose as social scientists and biological scientists looked for individual-level mechanisms that could explain observed group-level outcomes. Following our questions about restaurant tipping above, why is it that in some circumstances individuals choose to adopt mutually-beneficial "cooperative" outcomes rather than pursuing short-term individual gains, while in other instances cooperation breaks down, or simply does not occur? John Maynard Smith (an evolutionary biologist) explored these ideas in biology and Robert Axelrod (a political scientist) in the social sciences, contributing to the development of evolutionary game theory. Famously, Axelrod's The Evolution of Cooperation extolled the "conditional cooperation" exemplified by a "tit-for-tat" strategy (proposed by psychologist Anatol Rapaport) in Axelrod's Prisoners' Dilemma tournament. That canonical game was first described to a meeting of psychologists in 1950 by the Princeton mathematician Albert Tucker, following its elucidation by mathematicians Merrill Flood and Mevlin Dresher at RAND.

Contemporaneously, biologists like William Hamilton and Robert Trivers explored the origins of altruistic behavior in an evolutionary context, and identified kin selection as an evolutionarily robust mechanism for explaining sacrificial actions that benefit relations. This mechanism is conveniently summarized in the simple mathematical formulation known as Hamilton's rule. George Price and John Maynard Smith applied game theory concepts to biology, through the concept of an evolutionary stable strategy. Price also developed an equation that applied Hamilton's rule to all levels of selection, most notably group selection.

Over the last quarter century, an interdisciplinary collection of social scientists, life scientists, and mathematicians have begun to assemble an overarching theory that shows the potential to offer a unified theory of social, political, and economic behavior grounded in an evolutionary understanding of biology, for humans and all other organisms. While this theory is neither complete nor completely accepted, it has the potential to revolutionize and unify the social and life sciences.

A note on "social Darwinism"

It should be evident from the above discussion that evolutionary game theory refutes the predictions of the 19th century's "social Darwinism" ideology. That proposition (that only the strong would triumph, forcing submission by the weak) is not supported by observational evidence or by predictions from evolutionary game theory. Rather, evolutionary game theory has elucidated the ability of individuals to support each other in the pursuit of common goals even when those individuals have incentives to take actions that subvert the welfare of the group. A general finding is that individuals' strategies will evolve over time to benefit society as a whole. This is important: we can observe that people in social systems and animals in biological systems tend to adopt "cooperative" strategies that are robust to invasion from "defectors". The mathematics of evolutionary game theory helps us understand those observations that refute social Darwinism.

Grading

25% Regular homework
10% Discussant report
10% Class participation
15% Midterm #1
15% Midterm #2
25% Final exam

The discussant report will be a critique of a paper from the literature on evolutionary game theory. A list of possible papers and more details will be handed out in a few weeks.

Out of intense complexities intense simplicities emerge. — Winston Churchill

Week	Topics	Reading
1	What is social interaction? Experience playing games using the Veconlab web site	Ch. 1 & 2
2	Modeling and solving games	Ch. 3 & 4
3	Randomized strategies	Ch. 7
4	Sequential games	Ch. 8 & 9
5	Repeated interaction	Ch. 13 & 14
6	Large populations Overlapping generations	Ch. 15, class notes based on Sigmund Ch. 6
7	Evolutionary stable strategies Replicator Dynamics	Ch. 16 & 17, class notes based on Sigmund Ch. 2
8	Introduction to selection and reciprocity, Hamilton's Rule and the Price Equation: Five rules for the evolution of cooperation	Science 8Dec2006 (314)5805, 1560-1563, Chapter 1 of Dugatkin and Chapter 1 of Sigmund
9	Kin selection	Class notes based on McElreath & Boyd 2 & 3
10	Direct reciprocity	Class notes – Sigmund 3, McElreath & Boyd 4.1-3
11	Indirect reciprocity	Class notes - Sigmund 4, McElreath & Boyd 4.4
12	Network (spatial) reciprocity	Class notes – Sigmund 7, Gaylord Mathematica text
13	Group Selection Price equation	Class notes – M&B 6
14	Ultimatum game	Class notes – Sigmund 5
15	Final Exam	All of the above

We will devote some time each Friday to the NPR series, "The Human Edge"

If people are good only because they fear punishment, and hope for reward, then we are a sorry lot indeed. — Albert Einstein, physicist (1879-1955)

Other activities

Students will participate in two types of laboratory experiences throughout the semester. One variety will be classroom or computer lab demonstrations: students participate in decision-making for which they receive grades or cash. We will also explore the dynamics of evolutionary models using simulations written in the NetLogo programming language. These simulations will demonstrate the dynamics of the mathematical models, the effects of adjusting model parameters, and the consequences of changes in the models' structure.

Outcomes: As a result of taking this course, students will …

- appreciate the value of game theory as a framework for modeling social behavior in humans and other organisms.
- appreciate the utility of evolution as scientific paradigm that can explain a broad spectrum of social behaviors.
- appreciate the centrality, utility, and limitations of mathematical models in developing a scientific understanding of social behavior.
- identify strategic and evolutionary elements of specific instances of social interaction and interpret their significance.
- comprehend the elemental concepts of classical and evolutionary game theory.
- apply elements of game theory to model social and strategic situations.
- apply the concepts of game theory to identify stable and/or rational behaviors, and to interpret their mathematical meaning in a physical context.
- identify cooperative and altruistic behavior, and consider its significance and evolutionary provenance.
- comprehend and apply game theoretic explanations for cooperative and altruistic behavior.

Exam conduct and Intellectual Honesty

Cheating and plagiarism will not be tolerated.
See "Policies and Resources" at http://studentlife.lafayette.edu/ .

P**ages 7, 20-21, and 40** of the current Lafayette Student Handbook provide a clear description of intellectual honesty, plagiarism, quoting, and footnoting. Any discussion you present as your own must be so. **Read these pages of the Handbook** and abide by the standards they set. For the consequences of plagiarism, see **page 20**. In particular, "Penalties normally range from a zero on an assignment to **suspension or expulsion from the College**, depending upon the nature of the offense." http://studentlife.lafayette.edu/files/2010/02/StudentHandbook_0910_FINAL.pdf

A person is smart. People are dumb, panicky, dangerous animals and you know it.
– Agent K (Tommy Lee Jones), Men In Black