Management Science and Engineering 336
Dynamics and Learning in Games

Mondays and Wednesdays (and some Fridays), 11:00 AM–12:15 PM
Terman Engineering Center, Room 453
3 units

Meeting dates:
March 29, 31
April 5, 7, 12, 16, 19, 21, 23, 26, 28
May 5, 7, 10, 12, 17, 19, 26, 28
June 4, 7

Instructor:

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Course webpage: http://eeclass.stanford.edu/msande336

Course description:

Game theoretic methods are prevalent in operations research, computer science, and electrical engineering. However, most engineers are typically exposed only to static game theoretic concepts, such as Nash equilibrium. In practice, engineering problems often require attention to dynamic behavior of the system under consideration, and game theoretic approaches to dynamic models are notably more challenging to apply.

This course studies the interaction of multiple decision makers in dynamic settings, i.e., dynamics and learning in games. The following is a tentative list of topics to be covered:

1. Best response dynamics and fictitious play.

   (a) Definition of discrete and continuous time fictitious play.

   (b) Stochastic/perturbed variants.
   (c) Convergence and nonconvergence.
   (d) Zero-sum and identical interest games.

2. Supermodular games.
   (a) Basic definitions.
   (b) Existence of equilibria.
   (c) Monotone comparative statics.
   (d) Best response dynamics.

3. Learning and regret minimization.
   (a) Models.
   (b) External and internal regret.
   (c) Multiplicative weights
   (d) Stochastic fictitious play
   (e) Blackwell's approachability theorem
   (f) Approachability-based algorithms
   (g) Calibration.

4. Evolutionary game theory.
   (a) Population dynamics and game theory.
   (b) Evolutionary stability.
   (c) Replicator dynamics.

5. Stochastic games.
   (a) Basic definitions.
   (b) Markov perfect equilibrium.
   (c) Existence of MPE in zero-sum stochastic games.

6. Large population dynamic games.
   (a) Motivation and setup.
   (b) Mean field equilibrium (MFE).
   (c) Existence of MFE.
   (d) MFE as an approximation to MPE.
   (e) Convergence to MFE.

(f) Examples and applications.

The course will be taught using a mix of lecture format and seminar-style discussion. These are active research areas, so much of the reading material will be drawn from relevant papers in the literature; this material will be available from the course website. The focus will be on encouraging discussion of both open theoretical questions and modeling issues. This is particularly important because many areas of the university have active research programs that draw on elements of learning and dynamics in games (computer science, electrical engineering, operations research, and economics). The course should provide a unique forum for a lively exchange of ideas across these boundaries.

Given the advanced nature of the material, it is emphasized that the course should be viewed as a *research seminar* by prospective students.

Grading

The grade will be based 75% on a project to be completed at the end of the quarter, and 25% on two problem sets to be assigned during the course of the quarter. The choice of topics for the final project will be quite broad: students can choose to either discuss and present recent research results in the field, or develop their own problem statement and analysis.

Prerequisites

Above all, the course requires broad mathematical maturity. Despite the applied interest in the material, this is a course with significant theoretical content; an ability to read, write, and think rigorously is essential to understanding the material.

The following are all required prerequisites; if you do not meet them, you may audit the class but should not register:

1. Real analysis, at the level of Math 115 or preferably Math 171, or equivalent.
2. Optimization, at the level of MS&E 211 or equivalent.
3. Probability and random processes, at the level of MS&E 220 and 221, or equivalent.
4. Game theory, at the level of Econ 203 or MS&E 246, or equivalent.

In addition, dynamic optimization at the level of MS&E 251 or equivalent is strongly recommended.

Intending students who are not comfortable with the material from the prerequisites listed above should expect to audit the course; any questions or concerns can be directed to Prof. Johari at the e-mail address above.

Textbooks

There will be no required textbook for this course. However, you may find some of the following books helpful.

Game theory books:

1. *Game Theory*, Fudenberg and Tirole. This reference should be on the shelf of every game theorist, but it is not necessarily the easiest book to learn from.
2. *A Course in Game Theory*, Osborne and Rubinstein. This is a good introductory level text in game theory, that still is quite rigorous. Although many game theory books are out there, I have found that this one is a good introduction for engineers.
3. *Game Theory: Analysis of Conflict*, Myerson. This is a more mathematically sophisticated treatment of the subject.
4. *Microeconomic Theory*, Mas-Colell, Whinston, and Green. This very large textbook is an encyclopedic reference on the subject, and likely very useful for many parts of this course.
5. *Game Theory for Applied Economists*, Gibbons. This is a basic undergraduate level text in game theory, appropriate if you have never seen the subject before; it provides an elementary treatment of most of the major topics.

Specific topics:

1. *Prediction, Learning, and Games*, Cesa-Bianchi and Lugosi. This recent text has a chapter on learning in games, which covers a significant subset of what we will do in class. They also make nice connections to online learning, forecasting, and prediction.
2. *The Theory of Learning in Games*, Fudenberg and Levine. This book is somewhat older now, but still a useful survey of various topics on learning in games.
3. *Evolutionary Game Theory*, Weibull. A nice survey introduction to evolutionary games.