6.207/14.15: Networks
Course Information

Description

Networks are ubiquitous in our modern society. The World Wide Web that links us to and enables information flows with the rest of the world is the most visible example. But it is only one of many networks within which we are situated. Our social life is organized around networks of friends and colleagues. These networks determine our information, influence our opinions, and shape our political attitudes. They also link us, often through important but weak ties, to everybody else in the United States and in the world. Economic and financial markets also look much more like networks than anonymous marketplaces. Firms interact with the same suppliers and customers and use web-like supply chains. Financial linkages, both among banks and between consumers, companies and banks, also form a network over which funds flow and risks are shared. Systemic risk in financial markets often results from the counterparty risks created within this financial network. Food chains, interacting biological systems and the spread and containment of epidemics are some of the other natural and social phenomena that exhibit a marked networked structure.

This course will introduce the tools for the study of networks. It will show how certain common principles permeate the functioning of these diverse networks and how the same issues related to robustness, fragility and interlinkages arise in several different types of networks.

Time and Place: Mondays and Wednesdays, 2:30-4:00pm, Room: 32-141.

Instructors:
Prof. Daron Acemoglu
Room: E52-380B, E-mail: daron@mit.edu, Phone: (617) 253 1927

Prof. Asu Ozdaglar
Room: 32-D630, E-mail: asuman@mit.edu, Phone: (617) 324 0058

TAs:
Kostas Bimpikis
E-mail: kostasb@mit.edu

Ozan Candogan
E-mail: candogan@mit.edu

Recitation: Fridays, 11:00-12:00pm.

Course Webpage: http://stellar.mit.edu/S/course/6/fa09/6.207J/

Prerequisites: Basic probability at the level of 6.041 or 14.30. Since the course is aimed at developing a systematic understanding and analysis of networks and processes over networks, the students will be expected to work with mathematical models and analytical reasoning.

Course Requirements

- Homeworks, 20 %
- Midterm Exam (on November 4th), 40 %
- Final Project, 40 %

Homeworks

- There will be bi-weekly homework sets. There will also be some computational assignments (MATLAB). Homework solutions will be handed out on the day that the homework is due. Late homeworks will be heavily discounted.
- You may interact with fellow students when preparing your homework solutions. However, at the end, you must write up solutions on your own. Duplicating a solution that someone else has written or providing solutions to be copied is not acceptable. If you do collaborate on homework, you must cite, in your written solution, your collaborators.

Final Projects

Final project will be on a topic of your choice that overlaps with the course. You will be expected to work in groups of 2 or 3 people. The project will be due at the end of the exam week. More details on project format and possible topics will be circulated later in the semester.

Textbook:

The lecture slides we will provide and post on the course website contain all of the information and material you need for the course.

In addition, two textbooks are useful supplements and you will benefit from studying one or both of those, particularly to obtain additional details or different derivatations and discussions. The first is the forthcoming manuscript, David Easley and Jon Kleinberg (EK), *Networks, Crowds, and Markets: Reasoning about a Highly Connected World*, Cambridge University Press, which covers most of the topics at a level somewhat lower than this class. Copies of this book are available for purchase from MIT Copytech. At

a level that is slighly more advanced than our course is Matthew Jackson, *Social and Economic Networks*, Princeton University Press, which is a useful reference both for substantive and technical material.

The analysis of economic and social networks heavily relies on game theory. Of course, the course does not presume any game theoretic background, though some of the students will have taken 14.12 or may be cross registered at the same time as this course. We will cover all of the game theory that you need as we go along. Two books that are excellent references are:

- Martin Osborne, *Introduction to Game Theory*, Oxford University Press, 2003.
- Robert Gibbons, *Game Theory for Applied Economists*, Princeton University Press, 1992.

In addition, we will also refer to a variety of other books that are non-technical. These will be particularly useful in providing you with context and possible real-world applications. Some of the material in these books is overblown, so be warned. These are:

- Malcolm Gladwell, *The Tipping Point: How Little Things Can Make a Big Difference*, Little, Brown & Co.
- James Surowiecki, *The Wisdom of Crowds: Why Do Many Are Smarter Than the Few and How Collective Wisdom Sharpens Business, Economies, Societies, and Nations*, Doubleday Publishing.
- Albert-Laszlo Barabasi, *Linked: How Everything Is Linked to Everything Else and What It Means for Business, Science and Everyday Life*, Penguin Books.
- The old classic, Thomas Schelling, *Micromotives and Macrobehavior*, WW Norton & Co., is still relevant.

Finally, we will also refer to the following book for Markov chains:

- Dimitri Bertsekas and John Tsitsiklis, *Introduction to Probability, Second edition*, Athena Scientific.

Syllabus

- **Lecture 1 (September 9)**: Introduction to economic, social and communication networks [Acemoglu]

  Reading: EK, Chapter, 1 (also skim Chapters 3-5); Jackson, Chapter 1.

  Optional Reading: Gladwell, Chapters 1 and 2; Barabasi, Chapters 1-4; Granovetter (1973); Munshi (2004).

- **Lecture 2 (September 14)**: Graph theory and social networks [Ozdaglar]

  Directed and undirected graphs, paths, cycles, diameter, clustering, bipartite graphs. Applications: the web as a directed graph, graphical representation of homophily.

  Reading: EK, Chapters 2 and 13; Jackson, Chapters 2 and 3.

- **Lectures 3 and 4 (September 16 and 21)**: Branching processes and random graph models [Ozdaglar]

  Review of branching processes, Erdös-Renyi graphs, degree distribution, phase transition, connectedness, giant component. Applications: tipping, six degrees of separation, disease transmissions.

  Reading: Jackson, Sections 4.1.1, 4.2.1-4.2.5, and 4.3.

  Optional Reading: Gladwell, Chapter 3; Barabasi, Chapter 3 (read this chapter again after this lecture) and Chapter 10.

- **Lectures 5-7 (September 23, 28, and 30)**: Rich get richer phenomena, power laws, small worlds [Ozdaglar]

  Preferential attachment, degree distributions, clustering. Applications: firm size distributions, link analysis and web search, PageRank, decentralized search and navigation.

  Reading: EK, Chapters 18, 20, and 14; Jackson, Chapter 5 and Section 7.3.

  Optional Reading: Barabasi, Chapters 5-7; Gladwell, Chapter 6.

- **Guest Lecture (October 5)**: Dr. danah boyd (Microsoft Research)

- **Lecture 8 (October 7)**: Epidemics [Ozdaglar]

  SIR and SIS models of diffusion. Applications: spread of information and disease, genetic inheritance.

  Reading: EK, Chapter 21; Jackson, Section 7.2.

  Optional Reading: Barabasi, Chapters 5-7; Gladwell, Chapter 6.

- **Lectures 9 and 10 (October 13 and 14)**: Introduction to game theory [Acemoglu]

  Games, strategies, payoffs, extensive and normal forms, Nash Equilibrium. Applications: tragedy of the commons, coordination games.

  Reading: Osborne, Chapters 1-4; Gibbons, Chapter 1; EK, Chapter 6.

- **Lectures 11 (October 19)**: Modeling network traffic and strategic network formation [Acemoglu]

  Negative externalities, congestion, Braess' paradox, potential games. Application: congestion tax in London.

  Reading: EK, Chapter 8; Jackson Chapter 6.

  Optional Reading: Schelling, Chapter 1, Surowiecki, Chapter 7.

- **Lecture 12 (October 21)**: Evolution, learning and myopia vs. rationality [Acemoglu]

  Evolutionarily stable strategies, fictitious play, emergence of Nash equilibrium from rules of thumb, limits of myopic behavior. Application: rules of thumb in traffic.

  Reading: EK, Chapter 7; Osborne, Chapter 13.

- **Lectures 13 and 14 (October 26 and 28)**: Dynamic and repeated games, and cooperation and trust in networks [Acemoglu]

  Subgame perfect Nash equilibrium, repeated games, prisoners' dilemma, repeated games over networks. Application: emergence of cooperation in social networks.

  Reading: Osborne, Chapters 5, 6 and 14; EK, Chapter 6; Gibbons, Chapter 2;

  Optional Reading: Surowiecki, Chapter 6.

- **Lectures 15 and 16 (November 2 and 4)**: Network effects, innovation, tipping, and contagion [Acemoglu]

  Positive externalities, strategic complements, path dependence, diffusion of innovation, tipping in technology, financial, and product markets. Application: the rise of Microsoft and contagion phenomena.

  Reading: EK, Chapters 17 and 19, Jackson, Section 9.6-9.7.

  Optional Reading: Gladwell, Chapters 3 and 6; Barabasi, Chapter 10.

- **Midterm (November 9)**

- **Lectures 17 and 18 (November 16 and 18)**: Games of incomplete information [Acemoglu, Ozdaglar]

  Bayes rule, Bayesian Nash equilibrium, first price and second price auctions. Applications: spectrum auctions, market for lemons, keyword-based advertising.

Reading: EK, Chapters 9, 15, and 22; Osborne, Chapter 9; Gibbons, Chapter 3.

- **Lectures 19 and 20 (November 23 and 25)**: Wisdom of the crowds, information aggregation over networks [Ozdaglar]

  Review of Markov Chains, law of large numbers, Condorcet jury theorem, imitation and social influence, consensus and gossip algorithms. Application: prediction markets.

  Reading: Jackson, Section 8.3.

- **Lectures 21 and 22 (November 30 and December 2)**: Herding and informational cascades [Acemoglu, Ozdaglar]

  Bayesian learning, benefits of copying, herd behavior, informational cascades. Applications: consumer behavior, financial markets.

  Reading: EK, Chapter 16, Jackson, Sections 8.1-8.2.

  Optional Reading: Surowiecki, Chapters 1-4; Gladwell, Chapter 2; Barabasi, Chapter 10.

- **Lecture 23 (December 7)**: Markets and networks [Acemoglu]

  Competitive equilibrium, equilibrium as matching, markets as networks, bargaining and trading on networks. Application: matching.

  Reading: EK, Chapters 10-12.

  Optional Reading: Jackson, Chapter 10, Schelling, Chapter 3.

- **Lecture 24 (December 9)**: Organizations and networks [Acemoglu]

  Decision making in organizations and societies, social choice, political economy. Application: committee decisions.

  Reading: EK, Chapters 23 and 24.

  Optional Reading: Surowiecki, Chapters 9-11.