6.268
Network Science and Models
H-level, 3-0-9 units
Spring 2015

Instructor: Patrick Jaillet
TAs: Swati Gupta, Dawsen Hwang
Lectures: TR 9:30-11:00am, Rm. 4-149
Stellar Site: http://stellar.mit.edu/S/course/6/sp15/6.268/
Recitations: Friday afternoon, time and location TBD

Summary description
Introduces the main mathematical models used to describe large networks and dynamical processes that evolve on networks. Static models of random graphs, preferential attachment, and other graph evolution models. Epidemic propagation, opinion dynamics, and social learning. Applications drawn from social, economic, natural, and infrastructure networks, as well as networked decision systems such as sensor networks.

Overview
Networks are ubiquitous: social and economic networks, natural networks (e.g., in biology), infrastructure networks (e.g., communications, the internet, transportation, energy), and networked decision and control systems (e.g., sensor networks, autonomous multiagent systems).

Broadly speaking, networks can be categorized as natural (those that arise spontaneously, possibly consisting of agents that act myopically) or engineered (possibly consisting of agents whose behavior can be “programmed” towards an overall objective). Natural networks bring up the usual science questions: how to come up with models (either stylized or detailed) to describe different phenomena, validate the models, make predictions, and develop insights. Engineered networks bring up the usual engineering questions: how should the different decision nodes (“agents”) in the network be designed or programmed so as to achieve a certain overall goal (the goal could be one of resource allocation, service provisioning, or performance enhancement, in both static or dynamic environments). In fact, this distinction is not always sharp: a large part of a network structure and behavior may have emerged naturally, but there may be points at which a designer can intervene to regulate the network; alternatively, one may be interested in carrying out “engineering” tasks, such as inference or control, within a preexisting natural network.

There is a vast array of perspectives, objectives, contexts, application domains, modeling paradigms, and approaches to this subject that have emerged in recent years. This class will (a) introduce some of the major types of models; (b) study their properties and mathematical structures; (c) discuss insights provided by such models into various domains; (d) visit a sample of applications drawn from different fields.

Prerequisites
Linear algebra (at the level of 18.06) and probability (at the level of 6.041, including Markov chains) are necessary. In general, the course should be accessible to the more mathematically oriented Masters students, while also offering more advanced students the opportunity to go deeper. As the class will be covering a broad array of topics, it is expected that most students will have some gaps compared to an “ideal” background. Recitations will be used to fill needed background.
Textbook and readings

There are many books on the subject, but none covering the full array of topics in this course at the desired level. One that comes close, and which will be the official textbook, is:


Although it does not have an engineering focus, it covers most of the concepts (random graphs, network formation, gossip, diffusion and propagation models) at a mathematical level suitable for this course. It will be supplemented by handouts, and papers from the literature (mostly survey and expository papers), as needed. The book will be held on reserve at the Barker Engineering Library, as well as the first three of the following additional texts:


Coursework

A term paper or project will be required, of one of the following types: (i) read some of the literature and provide a critical report, with suggestions for further work; (ii) identify a phenomenon of possible interest, develop and discuss a model; (iii) simulate and analyze an existing model; (iv) analyze real data. Group projects will also be possible.

Papers/projects will be presented during the last week of classes. A final version of your report will be due on the last day of classes.

In addition there will be five homework sets, as well as a 2-hour evening midterm exam. The midterm exam date has been set on Wednesday 4/15. Due dates for the psets have been set as such: hw1 (2/24); hw2 (3/5); hw3 (3/19); hw4 (4/9); and hw5 (4/30).

Grading

Final grades will be determined according to the following weights:
midterm, 35%;
homework, 20%;
term project, 45%.

Collaboration policy

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 (verbatim or edited), or providing solutions for a fellow-student to copy is not acceptable. If you do collaborate on homework, you must cite, in your written solution, your collaborators. Also, if you use sources other than assigned readings in one of your solutions, e.g., a friendly “expert,” or another text, be sure to cite the source. There is no penalty for such collaboration or use of other sources, as long as it is disclosed.

In general, we expect students to adhere to basic, common sense concepts of academic honesty. Presenting somebody else’s work as if it were your own, or cheating in exams, is unacceptable, and appropriate disciplinary procedures will be followed.
Lecture Schedule (updated and final)

1. Introduction, overview of methods and applications. 2/3
3. The Erdős-Renyi random graph model — I. 2/10
4. The Erdős-Renyi random graph model — II. 2/12
5. Random graphs with given degree distribution. 2/19
6. The Chung-Lu random graph model. Markov graphs. 2/24
7. Homophily models. Geometric random graphs. 2/26
8. “Small world” models. Power laws, scale-free graph models. 3/3
9. Generative models and preferential attachment. 3/5
10. Page rank. 3/10
11. Search and navigation. 3/12
12. Application 1: Kidney exchange models 3/17
15. Models of propagation — II: The SIR model. 4/2
16. Models of propagation — III: The contact (SIS) process. 4/7
17. The voter model. Introduction to percolation theory. 4/9
18. Markov chains, random walks, and mixing times. 4/14
19. More on mixing times. Conductance and rapid mixing. 4/16
20. Rapid mixing and applications. Consensus and Gossiping. 4/23
21. Community structure detection in networks. 4/28
22. Time-varying graph models and applications. 4/30
23. Social learning in networks. 5/5
24. Wrap up lecture. Further topics on Network Sciences. 5/7
25. Project presentations. 5/12
26. Project presentations. 5/14 (last day of classes)