Management Science and Engineering 221
Stochastic Modeling

Tuesdays and Thursdays, 1:30-2:50 PM
Skilling Auditorium
3 units

Instructor:

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Course staff:

Hongseok Namkoong
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Lectures and discussion section:

There will be discussion sessions on Fridays, in Gates B03 from 12:30-1:20 PM. We will also
schedule special review sessions for the midterm and final exam.

Canvas:

Course materials (lectures, homeworks, etc.) will be available via Canvas: canvas.stanford.edu. All announcements and Q&A will also be handled through Canvas; you are responsible for keeping up with what is posted there. All communications to the course staff should also be sent through Canvas, rather than e-mail.

Course description:

A more detailed title for this course might be “Stochastic Modeling of Time-Dependent Systems.” We will be focusing almost entirely on dynamic models of random phenomena, and, in particular, on Markov chains in discrete time and Markov jump processes in continuous time.

The tentative list of topics (not necessarily in order of presentation):

1. Markov models in discrete time
   (a) Basic definitions, calculating transition probabilities
   (b) Forwards and backwards equations
   (c) Absorption probabilities, expected hitting times, and infinite horizon expected reward
   (d) Long-run behavior and the equilibrium distribution
   (e) Regeneration and LLN for Markov chains
   (f) Convergence to equilibrium
   (g) Reversibility
   (h) Markov chain Monte Carlo
      (i) Parameter estimation for Markov chain models
      (j) Filtering and hidden Markov chains
      (k) Controlled Markov chains and optimal stopping

2. Markov models in continuous time
   (a) The exponential distribution and the Poisson process
   (b) Markov jump processes
   (c) Forward and backward equations
   (d) The embedded Markov chain
   (e) Analogs of discrete time results
   (f) Queueing models
3. Gaussian time series models
   (a) Autoregressive models
   (b) Introduction to factor models

Grading
You are responsible for keeping up with all announcements made in class and for all changes in
the schedule that are posted on the class website.
The grade will be based on the following:

- 35% problem sets
- 20% midterm in-class midterm on Feb 15th, location: STLC111
- 45% final exam on Mar 19th, 12:15pm

Problem Sets
There will be a total of 6 problem sets. All assignments will be posted to the course website, and
will be handed in on Gradescope (www.gradescope.com, entry code 9X3K7N). Problem sets are
assigned and due as follows:

- Problem Set 1 handed out on January 11, due January 19
- Problem Set 2 handed out on January 18, due January 26
- Problem Set 3 handed out on January 30, due February 9
- Problem Set 4 handed out on February 16, due February 26
- Problem Set 5 handed out on February 22, due March 5
- Problem Set 6 handed out on March 1, due March 15

Depending on their length and difficulty, the total number of points in each set might vary.

You can discuss the assignments among yourselves, but everybody must turn in his/her own written
solutions in his/her own words. If you do a substantial subset of the work on your problem set
with others, document on each assignment the other students that you worked with.

If you are having difficulty, find help right away—do not wait until you fall even further behind! There is an obvious temptation to wait until the day before the due date to do all the work on
the problem sets, and I can assure you this approach does not correlate well to success in the class.
Late policy: Late submissions are in general not allowed with the exception of medical or other serious issues. If you have medical or other serious reasons that require an extension, please contact the teaching staff via email.
Please familiarize yourself with the Stanford Honor Code; violations will be prosecuted to the fullest extent of the (Stanford) law.

Exam Policy

The midterm exam will be an in-class midterm on Thursday, February 15th from 1:30 PM to 2:50 PM. The final exam will be held on Monday, March 19th, 2018 from 12:15 PM to 3:15 PM. You should only register for the class if you are certain you can take the exams on these dates. For the midterm, one sheet of letter-sized paper is allowed (with both sides). For the final, two sheets of letter-sized paper is allowed (with both sides). If printed, the text font size should be no smaller than 8pt.

Matrix computing

One of the most valuable features of Markov chain theory in practice is that it has deep connections to linear algebra and matrix analysis. To numerically explore this connection, at least one assignment in the course will be computational.

Matlab. One potential choice of software is Matlab, a widely used software package for linear algebra (among other things); several other assignments will be easier for you if you have some facility with software such as Matlab. Matlab is available on the all Stanford UNIX/Linux machines, and a short Matlab tutorial will be available on Canvas. More details on accessing Matlab on the UNIX/Linux machines can be found here:

www.stanford.edu/services/sharedcomputing/
www.stanford.edu/group/farmshare/cgi-bin/wiki/index.php/Matlab-interactive

A useful means of using X Windows programs such as Matlab remotely on Macs (Apple X11) and PCs (VNC Client) is described here:
itservices.stanford.edu/service/sharedcomputing/moreX

Matlab review: A Matlab review session will be arranged by one of the CAs early in the quarter. Time and location to be announced.

Prerequisites

This course is intended for masters students and first year Ph.D. students, and is particularly targeted at students who wish to use Markov chains for applied work in operations and management. The main prerequisite for the course is probability at the level of MS&E 220; an acceptable substitute is Stat 116. Note that this is a hard constraint; we will not be reviewing any of the material from these courses in class. Students without this prerequisite can only enroll with permission of
the instructor. The other primary prerequisite for the class is some familiarity with linear algebra and matrices, at the level of Math 51. If you have taken probability elsewhere and would like to know if you satisfy the prerequisite, contact Prof. Glynn via e-mail prior to registering for the course.

**Textbook**

You will only be tested on material presented in lectures, and learned through the problem sets. Some of the problems and supplementary material will draw on *Introduction to Probability Models* (Eleventh Edition), by Sheldon Ross; this is the recommended textbook for the class, and available online for Stanford students at:


Most students find it valuable to have the book for an alternate presentation of the same material seen in lecture. Note that older editions of this book are typically available used at a significant discount; these are generally fine as well.

A few other books to consider, for an alternate perspective (presented in increasing order of difficulty):

- Bertsekas and Tsitsiklis, *Introduction to Probability*. This is an excellent introduction to basic probability, at the advanced undergraduate level. It contains two chapters on random processes and (finite state) Markov chains.

- Norris, *Markov Chains*. This is a slightly more mathematical treatment of the subject, but one of the most clearly presented versions of the material available.

- Durrett, *Essentials of Stochastic Processes*. This book is also more mathematical than Ross’ book; it is a good place for an introduction to *martingales* that is not very technical.

- Grimmett and Stirzaker, *Probability and Random Processes*. This book is a comprehensive treatment of basic probability and Markov chains, at a more rigorous pace than the books above.