Math 395/495: MENU Seminar: Statistical Network Dynamics

- **Time and Place:** MWTh 3-3:50 in Lunt 105, discussion Tu 3-3:50 Cresap 101

- **Instructors:**

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- **Prerequisites:** This course requires a serious background in linear algebra and one or more of the following: real analysis, probability, or network theory. Contact Hooper by email for consent to enroll.

- **Objectives:**
  - learn how to model complex systems with networks
  - apply dynamical systems theory to solve real-world network problems
  - conceive and carry out an original group research project on networks

- **Grading:** Grades will be determined based on performance on weekly homework sets (15%), four labs (15% each), and a final project (25%).

- **Course description:**

  Networks form a vital part of our modern world. Understanding phenomena arising from networks represents a challenge in a variety of subjects. How should the transportation system be organized? How does the brain work? How is consensus formed through interpersonal communications? Many questions on the basic structure of networks and in applications remain unanswered.

  This interdisciplinary course will will focus on applications of networks to information theory and the social sciences, combining a rigorous mathematical treatment of dynamics on networks with labs and research project that use this theory. The course will cover Markov chains, shift spaces, finite state machines, information theory, and nonlinear dynamical systems. There will be four labs designed to encourage investigation of applications:

  1. Construct a spam generator.
  2. Experiment with entropy and data compression.
  3. Implement a small scale version of Google's PageRank.
  4. Investigate a model of cultural consensus and differentiation.

  Participants are also encouraged to investigate applications compatible with their own interests, particularly when undertaking the final project. Important application areas include systems biology, finance, and epidemiology.

  While this class does have a programming component, no prior programming experience is expected. The course will introduce programming concepts as needed, and most of the programming necessary to complete the labs will be provided.

The course is designed for juniors and seniors who have completed (or are currently enrolled in) the second year of the MENU sequence, or advanced undergraduates or graduate students in any department with equivalent preparation. Graduate students should enroll under the 495 course number to receive graduate credit.

Course calendar: **L** denotes lectures, and **D** denotes discussion.

Date	Objectives
L: Mar 31- Apr 3	§1.1-1.3: Shifts, Shift spaces, and Languages. §2.1-2.2: Shifts of finite type and Graphs
D: Apr 1	Hand out "Lab 1: Spam generator" and preparation for the lab.
L: Apr 7 **L:** Apr 9-10	Markov chains Finish §2.2: Graphs and their shifts, and §1.4: Higher block shifts *Lab 1 is due on April 10th.*
D: Apr 8	Discuss Lab 1. Introduce "Lab 2: Google's PageRank."
L: Apr 14-17:	§2.3: Graph representations and §4.2: The Perron-Frobenius Theorem
D: Apr 15	Preparation for lab 2.
L: Apr 21-24	§1.5: Sliding block codes and §2.4: State splitting "§2.5: Data storage" is recommended reading. *Lab 2 is due on April 24th.*
D: Apr 22	Discuss Lab 2. Introduce "Lab 3: Entropy and data compression."
L: Apr 28-May 1	§4.1: Entropy: Definitions and basic properties §4.3: Computing entropy
D: Apr 29	Preparation for lab 3.
L: May 5 **L:** May 7-9	Form groups and brainstorm final projects. Introduction to non-linear dynamical systems *Lab 3 is due May 9*
D: May 6	Discuss Lab 3. Introduce "Lab 4: Cultural consensus and differentiation."
L: May 12-15	Fixed point analysis: Sources, sinks, and saddles. Rates of convergence. *Final project proposal is due.*
D: May 13	Preparation for lab 4.
L: May 19-22	Rates of convergence. Course summary. *Lab 4 is due May 22.* Only final projects remain.
D: May 20	Discuss Lab 4.
L: May 26 **L:** May 28-29	Discuss final projects. Final project status reports
D: May 27	Discuss final projects.
June 2-6	WCAS Reading Week

- Final projects are due by the last day of exam week, Friday, June 13th at noon.
- There will be extended office hours during reading week.

- **Attendance:** Students are expected to attend the regular class, and are highly encouraged to attend the discussion section. Excessive absences will result in a substantial grade penalty.
- **Students with Disabilities:** If you have special needs, please contact the instructors as early as possible, and no later than the first week of class.
- **Academic Integrity at Northwestern:** You must comply with the Northwestern Academic Integrity guidelines; in particular, you should always acknowledge any external research. We will communicate more specific expectations for each assignment.
- **Homeworks and Labs:** You should feel free to work with other students on both the homeworks and the labs. However, we require each student to write their own lab and homework solutions.

References

[1] Douglas Lind and Brian Marcus. *An introduction to symbolic dynamics and coding.* Cambridge University Press, Cambridge, 1995. (This is the main text for the course.)

[2] Rebecca S. Wills. Google's PageRank: the math behind the search engine. *Math. Intelligencer*, 28(4):6–11, 2006.

[3] Dr. Seuss. The Sneetches. In *The Sneetches and Other Stories*, pages 2–25. Random House Inc., 1961.

[4] other selected articles.