ECE 440 - Introduction to Random Processes

Syllabus - Fall 2024

Time: Mondays and Wednesdays, 4:50-6:05 pm.
Place: Gavett Hall 202.
Class website: http://www.hajim.rochester.edu/ece/sites/gmateos/ECE440.html

Instructor: Gonzalo Mateos (gmateosb@ece.rochester.edu).
Office hours: Tuesdays 10:30 am, 726 Computer Studies Building.
Teaching assistant: Hamed Ajorlou (hajorlou@ur.rochester.edu).
TA office hours: Fridays 2:30 pm to 3:30 pm, 701 Computer Studies Building.

Textbook: We will use lecture slides to cover the material. Good general reference

- John A. Gubner, *"Probability and Random Processes for Electrical and Computer Engineers,"* Cambridge University Press.

Available online from the University of Rochester library.
Additional reading:

- Sheldon M. Ross, *"Introduction to Probability Models,"* 13th. edition, Academic Press. (Earlier editions are fine.)

Both books are on reserve for the class in Carlson Library.

Prerequisites: Useful to have good background in Probability Theory (of which we will do a fast-paced review the first five lectures), as well as Calculus and Linear Algebra (i.e., integrals, limits, infinite series, differential equations, vector/matrix notation, systems of linear equations, eigendecomposition). For homework assignments we will use Matlab.

Credit distribution: Homework assignments (10, 28 points), in-class midterm (Oct. 30, 36 points), take-home final (Dec. 15-17, 36 points).
Grading: At least 60 points are required for passing (C grade), a B requires at least 75 points, and an A at least 92. There is no curve. Undergraduate (ECE 271) students are expected to complete the same assignments and exams, but will be awarded extra 10 points counting towards the final grade.

Academic dishonesty: Academic dishonesty will be dealt with according to the University of Rochester's Academic Honesty Policy.

Class description: Introduction to Random Processes (ECE 440) is an entry-level graduate class that explores stochastic systems. The latter could be very loosely defined as anything random that changes in time, and the evolution of such systems is mathematically described by a random process. Stochastic systems are at the core of a number of disciplines in engineering, for example communication systems and machine learning. They also find application elsewhere, including social systems, markets, molecular biology and epidemiology, just to name a few.

Class objectives: The goal of the class is to learn how to model, analyze and simulate stochastic systems. With respect to analysis we distinguish between what we could call theoretical and experimental analysis. By theoretical analysis we refer to a set of tools which let us discover and understand properties of the system. Naturally, probability theory plays a key role as the mathematical language that allows us to quantify uncertainty. The theory can only take us so far and is usually complemented with numerical analysis of experimental outcomes. Although we use the word experiment more often than not we simulate the stochastic system in a computer and analyze the outcomes of these virtual experiments.

Topic outline: The topics covered in ECE 440 can be split into five thematic blocks

1) Introduction (1 lecture)
2) Probability review (5 lectures)
3) Discrete-time Markov chains (6 lectures)
4) Continuous-time Markov chains (7 lectures)
5) Gaussian, Markov, and stationary random processes (8 lectures)

Application domains we will explore to illustrate the usefulness of the theory include

1) Web search and Google's PageRank©
2) Optimal decision making and reinforcement learning
3) Queuing systems
4) Predator-prey population dynamics
5) Arbitrages and stock options pricing
6) Radar
7) Principal component analysis

For a detailed description of the contents including a lecture-by-lecture schedule, see the class website http://www.hajim.rochester.edu/ece/sites/gmateos/ECE440.html.

Date	Description	Homework
Mon. 8/26	Introductions, class organization, motivating example	
Wed. 8/28	Probability spaces, conditional probability, independence	
Mon. 9/2	Labor day - No class	
Wed. 9/4	Random variables, discrete and continuous, expectations	HW1 due
Mon. 9/9	Multiple RVs, joint distribution, expectations	
Wed. 9/11	Bounds, convergence notions and limit theorems	
Mon. 9/16	Conditional probabilities, distributions and expectations	HW2 due
Wed. 9/18	Markov chains, examples, Chapman-Kolmogorov equations	
Mon. 9/23	Gambler's ruin problem, discrete-time queuing models	
Wed. 9/25	Classes of states, irreducible Markov chains	HW3 due
Mon. 9/30	Limiting distributions	
Wed. 10/2	Ergodicity	HW4 due
Mon. 10/7	Ranking of nodes in graphs	
Wed. 10/9	Exponential times, memoryless property, counting processes	
Mon. 10/14	Fall term break - No class	
Wed. 10/16	Poisson processes, interarrival times, definitions, examples	HW5 due
Mon. 10/21	Continuous-time Markov chains, birth and death processes	
Wed. 10/23	Transition probability function, Kolmogorov's equations	HW6 due
Fri. 10/25	Midterm review lecture	
Mon. 10/28	Traveling to Asilomar 2024 - No class	
Wed. 10/30	In-class midterm exam	
Fri. 11/1	Limiting distributions, ergodicity, balance equations	
Mon. 11/4	Queuing theory, M/M/1, M/M/2, queue tandem	HW7 due
Wed. 11/6	Predator-prey population dynamics, Lotka-Volterra model	
Mon. 11/11	Markov and Gaussian processes	
Wed. 11/13	Brownian motion, geometric Brownian motion, white noise	HW8 due
Mon. 11/18	Arbitrages and risk neutral measure	
Wed. 11/20	Black-Scholes formula for options pricing	
Mon. 11/25	Stationary processes, implications, wide-sense stationarity	HW9 due
Wed. 11/27	Thanksgiving recess - No class	
Mon. 12/2	Linear filtering of wide-sense stationary processes	
Wed. 12/4	Matched filter, Wiener filter	HW10 due
Wed. 12/9	Principal component analysis	