ECE 440 - Introduction to Random Processes

Syllabus - Fall 2019

Time: Mondays and Wednesdays, 4:50-6:05 pm.
Place: Gavett Hall 206.
Class website: [http://www.ece.rochester.edu/~gmateosb/ECE440.html](http://www.ece.rochester.edu/~gmateosb/ECE440.html)

Instructor: Gonzalo Mateos (gmateosb@ece.rochester.edu).
Office hours: Tuesdays 11 am, 726 Computer Studies Building.
Teaching assistants: Yang Li (yli131@ur.rochester.edu), Chang Ye (cye7@ur.rochester.edu) and Rasoul Shafipour (rshafipo@ur.rochester.edu).

TA office hours:
- Mondays 1:00 pm to 2:00 pm, 701 Computer Studies Building (Chang).
- Wednesdays 1:00 pm to 2:00 pm, 701 Computer Studies Building (Rasoul).
- Fridays 1:00 pm to 2:00 pm, 701 Computer Studies Building (Yang).

Textbook:
Good general reference. Available online from the University of Rochester library.

Additional reading:
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. 28, 36 points), take-home final (Dec. 15-18, 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) Queuing systems
3) Predator-prey population dynamics
4) Arbitrages and stock options pricing
5) Radar
6) Principal component analysis

For a detailed description of the course contents including a lecture-by-lecture schedule, visit the class website at [http://www.ece.rochester.edu/~gmateosb/ECE440.html](http://www.ece.rochester.edu/~gmateosb/ECE440.html).
<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Homework</th>
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<tbody>
<tr>
<td>Wed. 8/28</td>
<td>Introductions, class organization, motivating example</td>
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<td>Mon. 9/2</td>
<td>Labor day - No class</td>
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<tr>
<td>Wed. 9/4</td>
<td>Probability spaces, conditional probability, independence</td>
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<tr>
<td>Mon. 9/9</td>
<td>Random variables, discrete and continuous, expectations</td>
<td>HW1 due</td>
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<tr>
<td>Wed. 9/11</td>
<td>Multiple RVs, joint distribution, expectations</td>
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<tr>
<td>Mon. 9/16</td>
<td>Bounds, convergence notions and limit theorems</td>
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<tr>
<td>Wed. 9/18</td>
<td>Conditional probabilities, distributions and expectations</td>
<td>HW2 due</td>
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<tr>
<td>Mon. 9/23</td>
<td>Markov chains, examples, Chapman-Kolmogorov equations</td>
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<tr>
<td>Wed. 9/25</td>
<td>Gambler’s ruin problem, discrete-time queuing models</td>
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<td>Mon. 9/30</td>
<td>Classes of states, irreducible Markov chains</td>
<td>HW3 due</td>
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<tr>
<td>Wed. 9/30</td>
<td>Limiting distributions</td>
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<td>Mon. 10/7</td>
<td>Ergodicity</td>
<td>HW4 due</td>
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<td>Wed. 10/9</td>
<td>Ranking of nodes in graphs</td>
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<td>Mon. 10/14</td>
<td>Fall term break - No class</td>
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<td>Wed. 10/16</td>
<td>Exponential times, memoryless property, counting processes</td>
<td>HW5 due</td>
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<tr>
<td>Mon. 10/21</td>
<td>Poisson processes, interarrival times, definitions, examples</td>
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<td>Wed. 10/23</td>
<td>Continuous-time Markov chains, birth and death processes</td>
<td>HW6 due</td>
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<td>Fri. 10/25</td>
<td>Midterm review lecture</td>
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<td>Mon. 10/28</td>
<td>Midterm</td>
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<td>Wed. 10/30</td>
<td>Transition probability function, Kolmogorov’s equations</td>
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<td>Mon. 11/4</td>
<td>Limiting distributions, ergodicity, balance equations</td>
<td>HW7 due</td>
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<tr>
<td>Wed. 11/6</td>
<td>Queuing theory, M/M/1, M/M/2, queue tandem</td>
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<td>Mon. 11/11</td>
<td>Traveling to IEEE GlobalSIP’19 - No class</td>
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<tr>
<td>Wed. 11/13</td>
<td>Predator-prey population dynamics, Lotka-Volterra model</td>
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<td>Fri. 11/18</td>
<td>Markov and Gaussian processes</td>
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<tr>
<td>Mon. 11/20</td>
<td>Brownian motion, geometric Brownian motion, white noise</td>
<td>HW8 due</td>
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<tr>
<td>Wed. 11/20</td>
<td>Arbitrages and risk neutral measure</td>
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<td>Mon. 11/25</td>
<td>Black-Scholes formula for options pricing</td>
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<td>Wed. 11/27</td>
<td>Thanksgiving recess - No class</td>
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<td>Mon. 12/2</td>
<td>Stationary processes, implications, wide-sense stationarity</td>
<td>HW9 due</td>
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<td>Wed. 12/4</td>
<td>Linear filtering of wide-sense stationary processes</td>
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<td>Mon. 12/9</td>
<td>Matched filter, Wiener filter</td>
<td>HW10 due</td>
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<td>Principal component analysis</td>
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