USC Viterbi
School of Engineering

EE 562: Random Processes in Engineering (Fall 2020)

Units:	4
Instructors:	Urbashi Mitra, Professor
	ubli@usc.edu – Include EE 562 in subject
Office Hours:	By Appointment, ONLINE
	Mohammad Reza Rajati, PhD
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Office Hours:	By Appointment, ONLINE
TA(s):	Amirhesam Abedsoltan
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Office Hours:	TBD
Grader(s):	TBD
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Lecture:	Friday, Saturday, 3:00 pm –4:50 pm ONLINE
Discussion:	Friday, 5:00 pm –5:50 pm ONLINE
Webpages:	Piazza Class Page for everything except grades
	and USC DEN Class Page for grades
	– All HWs, handouts, solutions will be posted in PDF format
	– *Student has the responsibility to stay current with webpage material*
Prerequisite:	EE 503 and EE 510
Other Requirements:	Computer programming skills.
	Using R is highly recommended.
	Knowing R (or willing to learn it) is highly recommended.
	Fourier, Laplace, and z transforms, complex variables,
	contour integrals, and residue theory.
Tentative Grading:	Assignments 20%
	Midterm Exam 35%
	Final Exam 45%
	Participation on Piazza* 5%

Letter Grade Distribution:

$\geq$ 93.00	A	73.00 - 76.99	C
90.00 - 92.99	A-	70.00 - 72.99	C-
87.00 - 89.99	B+	67.00 - 69.99	D+
83.00 - 86.99	B	63.00 - 66.99	D
80.00 - 82.99	B-	60.00 - 62.99	D-
77.00 - 79.99	C+	$\leq$ 59.99	F

Disclaimer: Although the instructors do not expect this syllabus to drastically change, he reserves every right to change this syllabus any time in the semester.

Note on e-mail vs. Piazza: If you have a question about the material or logistics of the class and wish to ask it electronically, please post it on the piazza page (not e-mail). You may post it anonymously if you wish. Often times, if one student has a question/comment, other also have a similar question/comment. Use e-mail with the professor, TA, graders only for issues that are specific to you individually (e.g., a scheduling issue or grade issue).

Catalogue Description: Practical applications of machine learning techniques to real-world problems. Uses in data mining and recommendation systems and for building adaptive user interfaces.

Course Description: This course provides a rigorous introduction to probability and stochastic process theory and is geared towards first and second year graduate students in electrical engineering, computer science, industrial and systems engineering and other departments. The course will include a review of basic concepts of probability theory including probability spaces, random variables, expectation, and related convergence concepts. It will also cover Gaussian random vectors, minimum mean square estimation and conditional expectation. It will then introduce stochastic processes and key limit theorems. Other topics to be covered include stationary and wide sense stationary processes, correlation and covariance functions, power spectral density, Poisson processes, discrete and continuous-time Markov chains, martingales, basic calculus of random processes, random processes in linear systems and Wiener filtering. The course will provide examples of applications in queueing networks, communications and autonomous systems.

Course Objectives:

- Introduction to basic concepts, definitions and limit theorems about random processes
- Exploring key properties and applications of various kinds of random processes in engineering including communications, networks and autonomous systems

Exam Dates:

- **Midterm Exam :** Wednesday, Oct 14, 9:30-11:20 AM
- **Final Exam:** Monday Dec 7, 2:00 PM- 4:00 PM PST as set by the university

- **Very Important Note**: The MW section of this course will have the same midterm and final exam dates. If you are not able to take the exam on those dates, you should not take this course.

Textbooks:

- **Required Textbook:**

  1. Bruce Hajek, *Random Processes for Engineers*, Cambridge University Press, 2015. (Hajek)
     Preprint available at http://www.ifp.illinois.edu/~hajek/Papers/randomprocJuly14.pdf. (No guarantee that it is exactly the same as the main version).

- **Recommended Textbooks:**

  1. Robert A. Scholtz, *Random Processes for Engineers*, Preprint, 2017. (Will be posted as a handout)
  2. Henry Stark and John Woods, *Probability, Statistics, and Random Processes for Engineers*, 4th ed., Prentice Hall, 2011.
  3. John Gubner, *Probability and Random Processes for Electrical and Computer Engineers*, Cambridge University Press, 2006.

Grading Policies:

- The letter grade distribution table guarantees the *minimum* grade each student will receive based on their final score. When appropriate, relative performance measures will be used to assign the final grade, at the discretion of the instructors.
  - Final grades are non-negotiable and are assigned at the discretion of the instructors. If you cannot accept this condition, you should not enroll in this course.
- Your two lowest homework grade will be dropped from the final grade.
- *Participation on Piazza has up to 5% extra credit, which is granted on a competitive basis *at the discretion of the instructors.*

- **Homework Policy**
  - Homework is assigned on an approximately weekly basis. A one-day grace period can be used for each homework with 10% penalty. *Absolutely no late homework will be accepted after the grace period. A late assignment results in a zero grade.*
  - Poor internet connection, failing to upload properly, or similar issues are NOT acceptable reasons for late submissions. If you want to make sure that you do not have such problems, submit homework eight hours earlier than the deadline. Please do not ask the instructors to make individual exceptions.
  - Homework solutions and simulation results should be typed or *scanned* using scanners or mobile scanner applications like CamScan and uploaded (photos taken by cell-phone cameras and in formats other than pdf will NOT be accepted).
  - Students are encouraged to discuss homework problems with one another, but each student must do their own work and submit individual solutions written/ coded in their own hand. Copying the solutions or submitting identical homework sets is written evidence of cheating. The penalty ranges from F on the homework or exam, to an F in the course, to recommended expulsion.

  - Posting the homework assignments and their solutions to online forums or sharing them with other students is strictly prohibited and infringes the copyright of the instructors. Instances will be reported to USC officials as academic dishonesty for disciplinary action.

- **Exam Policy**
  - **Make-up Exams:** No make-up exams will be given. If you cannot make the above dates due to a class schedule conflict or personal matter, you must drop the class. In the case of a required business trip or a medical emergency, a signed letter from your manager or physician has to be submitted. This letter must include the contact of your physician or manager.
  - Midterm and final exams will be closed book and notes. No calculators are allowed nor are computers and cell-phones or any devices that have internet capability. One letter size cheat sheet (back and front) is allowed for the midterm. Two letter size cheat sheets (back and front) are allowed for the final.
  - All exams are cumulative, with an emphasis on material presented since the last exam.

- **Grade Adjustment**
  - If you dispute any scoring of a problem on an exam or homework set, you have one week from the date that the graded paper is returned to request a change in the grade. After this time, no further alterations will be considered.

- **Attendance:**
  - Students are highly encouraged to attend all the lectures and discussion sessions and actively participate in class discussions.

- **Suggestions**:
  - Remember the big picture.
  - Read the book and supplementary sources.
  - Prepare your own summaries from texts and notes.
  - Work as many problems as you can.

Important Notes:

- Textbooks are secondary to the lecture notes and homework assignments.
- Handouts and course material will be distributed.
- Please use your USC email to register on Piazza and to contact the instructors and TAs.

FRIDAY	SATURDAY
Aug 28th **1** **Probability Spaces** (Hajek Ch. 1) σ-fields Kolmogorov Axioms Properties of Probability Measures Borel-Cantelli Lemmas	29th **2** **Random Variables** (Hajek Ch. 1) Definition CDFs Discrete and Continuous Random Variables Statistical Properties of Random Variables Conditioning
Sep 4th **3** **Random Vectors** (Hajek Ch. 3) Random Vectors and Matrices Complex Random Variables and Vectors Covariance Matrices Decorrelation and Karhunen-Løéve Expansion Simulation of Random Vectors Transformations of Random Vectors* Characteristic Functions	5th **4** **Random Vectors** (Hajek Ch. 3) Linear and Affine Minimum Mean-Square (MMSE) Error Estimation of Random Vectors Wiener Filters “Causal” Estimates Estimation of Covariance Matrices* MMSE Estimates
11th **5** **Gaussian Random Vectors** (Hajek Ch. 3) Definitions Characteristic Functions of Gaussian Random Vectors Singular Covariance Matrices* Detection and Hypothesis Testing* Simulation Decorrelation Complex Gaussian Vectors and Circularity	12th **6** **Stochastic Convergence** (Hajek Ch. 2) Random Samples vs. Random Sequences (Statistical View vs. Process View) Modes of Convergence Hierarchy of Modes of Convergence
18th **7** **Stochastic Convergence** (Hajek Ch. 2) Examples and Counter-examples Skokhorod’s Representation Theorem Continuous Mapping Theorem Lévy’s Continuity Theorem Slutsky’s Theoreom	19th **8** **Limit Theorems** (Hajek Ch.2) Weak Law of Large Numbers Strong Law of Large Numbers Monte-Carlo Methods Bootsrtap* The Central Limit Theorem (CLT) Berry-Esseen Theorem

Friday	Saturday
25th **9** **Limit Theorems** (Hajek Ch. 2) Binomial Approximation Chi-squared Approximation Generalized CLT for Stable Distributions (Kolmogorov-Gnedenko) Extreme-Value Theorem (Fisher-Trippet-Genedenko CLT) Lindeberg-Feller CLT The Statistical View vs. The Process View	26th **10** **Introduction to Random Processes** (Hajek Ch. 4) Discrete-Time vs. Continuous-Time Random Processes Brownian Motion Characterization of Random Processes Mean and Correlation Functions Covariance Function Cross-correlation Functions Complex Random Processes
Oct 2nd **11** **Introduction to Random Processes** (Hajek Chs. 4, 8) Strict-sense and Wide-sense Stationary (WSS) Processes Estimation of Correlation Functions WSS Processes Through LTI Systems Time-Domain and Frequency-Domain Analysis Power-Spectral Densities (PSDs) for WSS Processes	3rd **12** **Introduction to Random Processes** (Hajek Ch. 9) White Noise Characterization of Correlation Functions Matched Filters Wiener Filters
9th **13** **Introduction to Random Processes** (Hajek Ch. 4) Causal Wiener Filters The Wiener Khinchin Theorem Mean-Square Ergodic Theorem for WSS Processes PSDs for non-WSS processes	10th **14** **Advanced Concepts in Random Processes** (Hajek 4.5-4.8) The Poisson Process Properties Jump Times, Arrival Times, Interarrival Times Derivation of Poisson Probabilities* Compound Poisson Processes
16th **15** **Advanced Concepts in Random Processes** (Hajek 4.5-4.8) Shot Noise Renewal Theory Wiener Processes The Wiener Integral Itô and Stratonovich Geometries Random Walks Approximations of Wiener Processes	17th **16** **Advanced Concepts in Random Processes** (-) Specifications of Finite and Infinite Random Sequences and Kolmogorov Consistency* Continuous-time Processes Gaussian Processes

FRIDAY	SATURDAY
23rd **17** **Mean-Square Calculus** (Hajek Ch. 7) Mean-Square Continuity and Differentiability Stochastic Differential Equations Hilbert and Banach Spaces of Random Variables Mean-Square Integrability Mean-Square Integrals	24th **18** **Mean-Square Calculus** (Hajek Ch. 7) Karhunen-Loéve Expansion The Wiener Integral Projection Theorem and The Orthogonality Principle
30th **19** **Mean-Square Calculus** () More Rigorous Definitions of Conditional Expectation and Probability Filterations and Filtered Spaces* Spectral Representation of Processes	31st **20** **Markov Processes** (Hajek Ch. 6.1-6.4) Countable state Markov Chains Classification (recurrence/transience)
Nov 6th **21** **Markov Processes** (Hajek Ch. 6.1-6.4) Convergence Birth-death processes	7th **22** **Markov Processes** (Hajek Ch. 6.5-6.9) Ergodicity Mean arrival time
13th **23** **Markov Processes** (Hajek Ch. 6.5-6.9) Stability discrete time queueing systems	14th **24** **Markov Processes** () Continuous-time Markov Chains: Examples Birth-death processes Kolmogorov differential equations Limiting probabilities
20th **25** **Martingales** (Hajek Ch. 10) Martingales: Definition Martingale differences, Level crossings	21st **26** **Martingales** (Hajek Ch. 10) Stopping times Azuma's maximal inequality Martingale convergence theorem

Notes:

- Items marked by * will be covered only if time permits.
- Items in blue will be taught by Prof. Mitra. The rest will be taught by Dr. Rajati.

Statement on Academic Integrity: USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand

and abide by these principles. SCampus, the Student Guidebook, contains the University Student Conduct Code (see University Governance, Section 11.00), while the recommended sanctions are located in Appendix A. See: http://scampus.usc.edu.

Emergency Preparedness/Course Continuity in a Crisis In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies. See the university's site on Campus Safety and Emergency Preparedness: http://preparedness.usc.edu

Statement for Students with Disabilities: Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. Website: http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html

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