ECE 541 Probability Theory and Stochastic Processes
Fall 2016

Goal:

To build up modern analytical and computational capabilities in probability and stochastic processes, and to apply them to the probabilistic modeling and analysis of engineering problems, signals and systems that involve uncertainty.

Catalog course description:

Axiomatic probability theory, projection theorem for Hilbert spaces, conditional expectations, modes of stochastic convergence, Markov chains, mean-square calculus, Wiener filtering, optimal signal estimation, prediction, stationarity, ergodicity, transmission through linear and nonlinear systems, sampling.

Prerequisites:

ECE 314 and ECE 340, or equivalent knowledge in elementary linear systems and probability.

Instructor:

Professor Majeed Hayat
Office: During office hours: CHTM Room 118A
E-mail: hayat@unm.edu; Web: professorhayat.com

Classroom & time

Building: ECE; Room: 132; TR: 12:30–1:45

Office hours

T&R: 2–3; M 3:00–4:00

Textbook and Notes:

Probability and Stochastic Processes for Electrical and Computer Engineers, by J. A. Gubner, Cambridge University Press, 2006 (available at the UNM Bookstore).

Online course materials: Course assignment, solutions, announcements, handouts, review materials, etc., will be available on UNM Learn to registered students (learn.unm.edu)

Topics:

1. Foundation of probability and random variables.
   Sigma algebras; probability measure; measurability and random variables; physical interpretation of sigma algebras; expectations; Markov, Jensen and Holder inequalities; distributions, distribution functions and densities; independence.
2. Random vectors. (Chapter 8)
   Random vectors and random matrices, transformations of random vectors, linear combinations of random vectors, covariance-matrix estimation.

3. Gaussian random vectors. (Chapter 9)
   The multivariate Gaussian; density and characteristic functions; conditional densities and expectations; complex valued Gaussian random vectors.
4. Introduction to stochastic processes. (Chapter 10)
   Definition and characterization; strict-sense and wide-sense stationarity; transmission through LTI systems; power spectral density; correlation functions; orthogonality principle; spectral factorization; Wiener filtering; the Wiener-Kinchin Theorem; mean-square ergodic theorem.
5. Commonly encountered stochastic processes. (Chapter 11)
   Poisson, Wiener, and renewal processes; compound Poisson process; shot noise and its generalizations; specification of stochastic processes.
6. Introduction to Markov chains. (Chapter 12)
   Definition and examples; recurrence and transience; n-step distribution; basic limit theorems; characterization of the stationary distribution; continuous-time Markov processes; application to birth-death chains.
7. Convergence of random sequences. (Chapters 13 and 14, and class notes)
   Types of stochastic convergence, basic limit theorems for expectations (dominated convergence theorem, Fatou's lemma, and bounded convergence theorem), Kolmogorov's zero-one law, Borel-Cantelli Lemma, relationship among modes of convergence, strong law of large numbers, the basic central-limit theorem, the Berry-Essen theorem (without proof).
8. Projections and conditional expectation (Chapter 14, Section 8.6, and class notes)
   Fundamentals of Hilbert-space theory and the projection theorem; the conditional expectation as a projection; properties of conditional expectations; nonlinear (optimal) estimation.

Computer usage:

A number of homework assignments require the use of Matlab

Course requirements

• 15% Homework & computer assignments. Problems and their solutions will be posted on the web periodically. The sole purpose of the homework tool is to test and deepen your understanding of the materials covered in class, notes and textbook. Solutions will be available to help you with this exercise and to offer you a benchmark for what my expectations are. Working on homework problems and mastering their solutions are essential components of this course. You are strongly encouraged to discuss any challenges with me; you are also encouraged to discuss homework problems and solutions with other students. Students who neglect homework may have serious difficulty with the course.

• 50% Two midterm examinations, see below for *tentative* dates.

• 35% Final examination.

Tentative grading policy

90 or above: A
75–89: B

60–74: C
59 or below: F

Important dates and events

Last class period: Thursday, Dec. 9
Fall break: Oct. 13–14
Thanksgiving break: Nov. 24–25
Last day to drop a course without a grade and with 100% refund: Sep. 9
Midterm I: Thursday, Sep. 29
Midterm II: Thursday, Nov. 17
Final examination: TBD

Additional references

A. Papoulis, *Probability, Random Variables, and Stochastic Processes.* McGraw-Hill, 1991. [A good undergraduate/graduate reference for probability and stochastic processes for engineers]

H. Stark and J. W. Woods, *Probability and Random Processes with Applications to Signal Processing*, 3rd Edition, Prentice-Hall, 2002. [A good undergraduate/graduate reference for probability and stochastic processes for engineers]

G. R. Grimmett and D. R. Stirzaker, *Probability and Random Processes.* Oxford Science Publications, 1992. [An introductory undergraduate/graduate course on probability and stochastic processes]

W. Feller, *An Introduction to Probability and Its Applications, vol. 1.* Wiley, 1968. [A classic textbook on probability theory]

Y. S. Chow and H. Teicher, *Probability Theory: Independence, Interchangeability, Martingales,* Springer Texts in Statistics (New York), 3rd ed., 1997. [A graduate textbook on probability theory]

P. Billingsly, *Probability and Measure.* Third Edition, Wiley Series in Probability and Mathematical Statistics, 1995. [A classic graduate textbook on probability theory]

W. Rudin, *Real and Complex Analysis.* New York: McGraw Hill, 1987. [A classic textbook on measure theory and analysis]

W. Rudin, *Principles of Mathematical Analysis.* New York: McGraw Hill, 1976. [A classic textbook on elementary analysis]

S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes.* Academic Press: New York, 1975. [A good undergraduate/graduate textbook on stochastic processes]

S. Karlin and H. M. Taylor, *A Second Course in Stochastic Processes.* Academic Press: New York, 1981. [An excellent undergraduate/graduate textbook on continuous-time stochastic processes]

P. G. Hoel, S. C. Port, and C. J. Stone, *Introduction to Stochastic Processes.* Waveland Press, Inc. 1987. [Another good textbook on stochastic processes]

H. V. Poor, *An Introduction to Signal Detection and Estimation.* Second Ed., Springer-Verlag, 1994. [An excellent textbook on applications of probability and stochastic processes to communications, signal processing and control]

Academic honesty

All students are expected to demonstrate personal integrity. Although discussions and interaction among students regarding homework assignments are strongly encouraged, each student *must show his/her individual effort.* Exchange of information during in-class or take-home examinations as well as copying homework solutions from each other is strictly prohibited. Students exhibiting any form of academic dishonesty will be subjected to penalties in accordance with UNM policies.