EECE 541 Random Signal Processing
Fall 2003

Goal:

To learn about modern analytical and computational tools in probability and stochastic processes and apply them to the analysis of random signals and systems.

Catalog course description:

Statistical description of signals and systems, correlation and power spectrum analysis, Wiener filtering, adaptive signal processing and Kalman filtering.

Prerequisites:

EECE 314, EECE 340.

Instructor:

Dr. Majeed M. Hayat, Associate Professor
Office: ECE Building, Room 323B; Tel: 277-0297;
E-mail: hayat@ece.unm.edu; Web: www.ece.unm.edu/faculty/hayat/main.htm

Classroom & time

Building: DSH; Room: 134; MW: 5:30–6:45

Office hours

T: 2:00–4:00 & Th: 2:00–4:00.

Textbook and Web utility:

Probability and Random Processes with Applications to Signal Processing, 3rd Edition, by H. Stark and J. W. Woods, Prentice-Hall, 2002 (available at the UNM Bookstore).

Students are expected to visit the course website (which can be linked to from Prof. Hayat's website, see above for the url address) frequently for announcements, handouts, assignments, and solutions.

Topics:

1. A measure-theoretic look at random variables, probability and expectations. (Chapters 1–4 [except 4.2], plus class notes).

2. Fundamental so of Hilbert-space theory; projections onto closed subspaces (class notes).

3. Conditional expectations as projections; properties of conditional expectations; connection to nonlinear estimation; problem solving in dynamical stochastic systems using conditional expectations (4.2 and notes).

4. Random vectors and elements of parameter estimation. (Ch. 5)
   Joint distribution and densities with examples, characteristic functions and moment generating functions, transformation of random vectors.
   Covariance matrices, two diagonalization techniques.
   Elements of maximum-likelihood parameter estimation.
   Introduction to linear estimation, quadratic-form minimization, projections revisited.

5. Sequences of random variables. (Ch. 6 & notes)
   Types of stochastic convergence, Kolmogorov's zero-one law, laws of large numbers, some central limit theorems.
   Discrete-time linear systems with random inputs.
   Markov chains: examples, recurrence, ergodicity, the stationary distribution.
   Birth-death chains.
   Autoregressive and moving average models, properties.

6. Stochastic processes. (Ch. 7 & notes)
   Examples: The Poisson process, shot-noise processes, Brownian motion, the Wiener process and white noise, branching processes, renewal processes, application to queuing.
   Markov processes: examples, the Chapman-Kolmogorov equations, the Kolmogorov equations, stationarity.
   Wide-sense stationarity (WSS), autocorrelation function, power-spectral density.
   Response of continuous-time LTI systems to WSS stochastic processes.

7. Representation of WSS stochastic processes. (Ch. 8 & notes)
   Hilbert-space theory revisited: L_2 spaces and approximation of L_2 functions, the Karhunen-Loeve expansion of finite power processes.
   Bandlimited stochastic processes and the Nyquist sampling theorem.

8. Mean-square linear estimation of random signals. (9.1, 9.3 plus class notes.)
   Optimality, the orthogonality principle, spectral factorization and innovations (the whitening filter).
   Optimal linear smoothing, prediction, and filtering (Wiener filtering).

9. Introduction to Kalman filtering. (9.2)
   The Kalman predictor, gain and filter; error covariance equations, application to physical auto-regressive models.

10. Selected topics (if time permits):
    Stochastic calculus and introduction to stochastic differential equations (Ch. 8).

Computer usage:

A number of homework assignments require the use of Matlab

Course requirements

- 20% Homework & computer assignments. Assignments are due in class in the beginning of the period. Late homework and other irregularities can be subject to penalty (up to 20%).

- 50% Two midterm examinations (one in-class and one take-home, see below for *tentative* dates).

- 30% 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: Wednesday, Dec. 10.
Last day to drop a course without a grade: Oct. 6.
Midterm I: Wednesday, Sep. 24.
Midterm II: Wednesday, Nov. 5.
Final examination: Wednesday, Dec. 17, 5:30 – 7:30.

References

A. Papoulis, *Probability, Random Variables, and Stochastic Processes.* McGraw-Hill, 1991.

G. R. Grimmett and D. R. Stirzaker, *Probability and Random Processes.* Oxford Science Publications, 1992.

W. Feller, *An Introduction to Probability and Its Applications, vol. 1.* Wiley, 1968.

S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes.* Academic Press: New York, 1975.

S. Karlin and H. M. Taylor, *A Second Course in Stochastic Processes.* Academic Press: New York, 1981.

H. V. Poor, *An Introduction to Signal Detection and Estimation.* Second Ed., Springer-Verlag, 1994.

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.