ENEE 324H: Engineering Probability

Time/Location

TuTh 12:30pm-1:45pm in CSI 2118

Instructor

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Office hours

M 4:00-6:00 and Tu 5:00-7:00

Teaching Assistant: Biniyam Tesfaye Taddese (discussions will meet M 9:00am in EGR 2112); email:bini01@umd.edu

See detailed course description below. Regular homework assignments will be given and are considered an essential part of the course, carrying points towards final grade.

Grading system. There will be a required term project. The final grade for the course will be based on two in-class mid-term tests (Tuesday February 27, Thursday April 5), and a final examination (Thursday May 17, 1:30-3:30 pm). Homework sets, and each of the two tests will count towards 15% of the final grade. The project will account for 25% of the final grade, and the final comprehensive examination will account for the remaining 30%. All examinations are of the **closed–book** variety and will take place in the regular classroom. In the final exam one sheet of formulae and a table of the normal distribution will be provided.

ENEE 324H: Engineering Probability (3) updated Spring 2007

Contents in Brief. Axioms of probability; conditional probability and Bayes' rule; random variables, probability distribution and densities: functions of random variables: weak law of large numbers and central limit theorem. Introduction to random processes; correlation functions, spectral densities, and linear systems. Applications to noise in electrical systems, filtering of signals from noise, estimation, and digital communications.

Course Goals. The goal of this course is to introduce the students to the basic concepts of probability, random variables, and stochastic processes so that they will have an understanding of how to deal with random phenomena (e.g. additive noise) while designing and analyzing real world systems. The concept of a probability space and the fundamental axioms of probability are presented first. This is extended to the idea of conditional probability. The concept of a (real-valued) random variable is then introduced followed by the cumulative distribution function (cdf) and probability density function (pdf). Multi-dimensional random variables and joint distributions and densities are discussed. Methods for finding the probability density functions of *functions* of random variables are studied. The concept of expected value is presented and means, variances, covariances and moment generating functions are examined. The idea of a random process is introduced and, in particular, the analysis of linear time-invariant systems with random inputs is introduced. Markov chains are defined and explored. The Nyquist-Johnson noise model is used to illustrate the role of stochastic processes in electrical engineering.

Course Prerequisite. ENEE 322 (Signals and System Theory) and completion of all lower-division technical courses in the ECE curriculum.

Topic Prerequisite. Engineering calculus (including multiple integrals); Laplace and Fourier transforms; linear time-invariant systems.

Textbook. Geoffrey Grimmett and David Stirzaker *Probability and Random Processes* , Third Edition, Oxford University Press, 2001.

References.

1. Carl W. Helstrom, *Probability and Stochastic Processes for Engineers*, Macmillan, 1991.

2. Athanasios Papoulis, and S. Unnikrishna Pillai *Probability, Random Variables, and Stochastic Processes*, McGraw Hill, 4th edition, 2002.

3. Peyton Z. Peebles, Jr., *Probability, Random Variables, and Random Signal Principles*, McGraw Hill, 4th edition, 2001.

4. P.S. Krishnaprasad, *Class Notes*, Fall 2002 edition.

Core Topics.

1. Basic Concepts of Probability. (5 classes)

(a)Review of set operations; (b)The sample space; (c)Axioms of probability; (d)Permutations and combinations; (e)Applications to discrete sample spaces; (f)Conditional probability and Bayes' rule; (g)Statistical independence; (h)Bernoulli trials and the binomial distribution.

2. Random Variables. (4 classes)

(a)Definition of a random variable and indicator random variables; (b)Cumulative distribution function (cdf); (c)Probability density function (pdf); (d)Examples of discrete and continuous random variables; (e)Functions of a random variable and methods for finding cdf or pdf of such a function.

3. Multiple Random Variables. (4 classes)

(a)Joint cdf and pdf; (b)Independent random variables; (c)Conditional density of one random variable given another; (d)Jointly Gaussian random variables; (e)Functions of two or more random variables and the transformation theorem.

4. Expected Values. (5 classes)

(a)Definition of the expected value of a random variable; (b)The mean, variance and standard deviation; (c)The covariance and correlation coefficient; (d)Expected value of functions of random variables; (e)The characteristic function and moment generating function and their applications to computing moments and pdf's.

5. Sums of Random Variables. (3 classes)

(a)The sample mean and variance; (b)The Weak Law of Large Numbers; (c)The Central Limit Theorem.

6. Random Processes. (6 classes)

(a)Definition of a random process; (b)n-th order statistics; (c)The autocorrelation function; (d)Examples including the sine wave with random phase, the random telegraph wave, the binary random wave; (e)Strict-sense and wide-sense stationary random processes; (f)The Power spectral density; (g)Wide-sense stationary random process and linear, time-invariant systems – how to find output power spectral densities and autocorrelation functions.

Optional Topics.

(a) Markov Chains; (b) Queueing; (c) Minimum mean-square error and maximum likelihood parameter estimation; (d) Hypothesis testing; (e) Algorithms for generating random numbers; (f) Game theory and randomized strategies.

Comment. This course will provide a solid theoretical base to treat uncertainty and randomness. Key concepts and techniques for calculations will be illustrated via engineering applications.

This course will have four **pillars**: (a) Bayes' theorem; (b) Limit theorems; (c) Change of variables; (d) Dynamic stochastic models. By the end of the semester these pillars should have been built and should be in good shape to support further study of science and engineering, with an appreciation for the role of uncertainty and randomness.

Sample Projects: (1) Statistical exploration of a communication protocol; (2) Blind source separation for speech; (3) Hiding of information in seemingly random data; (4) Prisoner's dilemma and other non-zero sum games; (5) Finding/building a good physical random number generator and comparing it to a good software random number generator; (6) What makes a good biometric authentication mechanism - e.g. iris scans? (7) Probability in neuroscience; (8) Coding and cryptographic applications; (9) Turing and probability.

These examples are merely illustrative.

Rules for Projects: Each student in the class should decide on a topic for the project by March 1. This is a firm deadline. Free and open discussions among the class members are encouraged in carrying out the actual work itself. A final project report is due on May 18. This too is a firm deadline.

Class website - for course notes, homework assignments, etc.

http://www.enee.umd.edu/class/enee324h