EE 24: Probabilistic Systems Analysis

Lecturer: Shuchin Aeron, shuchin@ece.tufts.edu
TA: Changgyu Lee

Course Information

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1 Basic Information

- **Instructor**: Shuchin Aeron, JCC 549, shuchin@ece.tufts.edu
- **Main Textbook**: Introduction to Probability by Dimitri Bertsekas and John Tsitsiklis, 2nd Edition, Athena Publications, 2008 - For short we will refer to this book as B&T.
- **Teaching Assistants**: Changgyu Lee, Changgyu.Lee@tufts.edu
- **Office Hours**: Please see Piazza page for the course.
- **Course Website**: The course will be actively managed via Piazza as well as using Gradescope. You will receive an email to enroll in the course on Piazza. All the exams and hw will be managed via gradescope and all the class discussions, class notes, will be managed via Piazza.

1.1 Other resources

1. Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers, by Roy D. Yates and David J. Goodman, John Wiley and Sons
2. Introduction to Probability Models, Sheldon M. Ross, 10th edition.
3. Two treatise on "Introduction to Probability Theory and its Applications", Vol. 1 and Vol. 2, by William Feller - a very accessible source with a lot of examples.
4. Wikipedia :-) - freely use as needed.

2 Overview

This course introduces fundamentals of probability theory. To quote from the main textbook "Probability (theory) is common sense reduced to calculation" - Laplace. Therefore, the aim is to formalize this "calculation" that allows to model practical problems as a probabilistic system allowing for rigorous inference within this framework. In this course we will emphasize on the following aspects.

- Why need a mathematically formal set-up to study probability? You will see that it helps address several paradoxes in games of chance and helps resolve such issues concretely.
- We will apply probability to model systems where uncertainty is inherent and understand what it means to infer under a probabilistic model.
- A major part of the course will focus on study of and manipulation of random variables and various quantities such as expectation, variance, moment generating functions, etc. associated with them. While it may appear that these are not of any significant application during the course, one reaps the benefits later on when considering applications to statistics and machine learning.

3 Tentative Schedule, Course contents, and Chapter coverage from B&T

Note: The HW are issued at points when we are done covering the necessary material as indicated below. The due date for each HW will also depend on the length of the assignment and exam schedule.

1. Chapter 1: Discrete Sample space, Events, Algebra of Events, Probability Space.

   (a) Lecture 1: Basic set-theory, Basic Counting and Enumeration
   (b) Lecture 2: Probability models (Discrete), Sample space, Algebra of Events, Probability Law, Axioms of Probability (Law) Issue HW 1
   (c) Lecture 3: Conditional Probability, Bayes Rule, Law of Total Probability
   (d) Lecture 4: Independence, Conditional Independence, Construction of probability models using independence and conditional independence. Issue HW 2.

   In chapters 2-3 while developing the notion of random variables, we will study some important random variables that naturally appear in modeling many systems. These are (a) Uniform, (b) Poisson, (c) Exponential, (d) Geometric, (e) Gaussian, (f) Binomial, (g) Bernoulli.

2. Chapter 2: Discrete Random Variables, Properties of Random Variables, Expectation, Variance, etc.

   (a) Lecture 5: Discrete Random Variables, PMF of a random variable, function of a random variable. Joint PMFs.
   (b) Lecture 6: Expectation, mean, and, variance. Conditioning. Issue HW 3
   (c) Lecture 7, 8: Conditional independences, Independent random variables Issue HW 4.

   Mid-Term EXAM I on Chapters 1 & 2, Tentative Date: February 22, 2024

3. Chapter 3: Probability Space for continuous random variables, General Random Variables and their properties.

   (a) Lecture 9: General Random Variables, CDF, PDF, Issue HW 5
   (b) Lecture 10: Joint CDF, PDF, Expectation, Conditioning
   (c) Lecture 11: Conditional expectation, Law of total expectation, Bayesian inference Issue HW 6

4. Chapter 4: Further topics on random variables

   (a) Lecture 12: Derived Distributions, Covariance and correlation, pdf of sum of independent random variables
   (b) Lecture 13, 14: Conditional expectations and variance - Law of total variance Issue HW 7

   Mid-term EXAM II on Chapters 3 & 4, April 2nd, 2024

5. Chapter 5: Statements and understanding of limit theorems

   (a) Lecture 15: Markov and Chebyshev Inequalities
   (b) Lecture 16: Weak and Strong Law of Large numbers, Central Limit Theorem

6. Chapter 8: Bayesian Statistical Inference - We will cover a subset of topics from this chapter.

   (a) Lectures 17-20 - MAP estimator, Bayes Least Squares Estimator, Properties of the estimators Issue HW 8

7. Chapter 9: Classical Statistical Inference - We will cover a subset of topics from this chapter.
   (a) Lectures 21-23 - Hypothesis testing, Maximum Likelihood (ML) estimation, Confidence Intervals. Issue HW 9

Final EXAM II on Chapters 3, 4, 8, & 9 Date: TBD

3.1 Homework and Exams

There will be 9 HW, 2 MidTerm Exams, and a Final Exam. The weight distribution for the final grade is as follows.

1. **HW** - 50% **NOTE:** The HW are very important in this course. Please do spend a lot of time solving for them and also go over the solutions that are provided by the instructor and TA.

   HW submission: All HW are to be submitted and graded via gradescope.

   HW delays: Delays are not permitted unless there is a strong reason. Please contact the instructor and TA beforehand if the delay is to be anticipated and each case will be dealt on an individual basis.
2. **Mid-Terms** - 15% each totaling to 30%
3. **Final Exam** - 20%

3.2 Academic Misconduct Policy

Academic misconduct will not be permitted in this class. All such conduct identified by the instructor or the TA will be reported. The students are required to be aware of the guidelines and resources. These can be viewed at this link: `http://go.tufts.edu/AcademicIntegrityPolicy`.