Master Course Description

Course No: 391
Course Name: Probability for Information and Communication Engineering
Credits: 4

Course Coordinator: Payman Arabshahi, Associate Professor, Electrical and Computer Engineering

Catalog Description: Introduces probabilistic concepts for Electrical and Computer Engineering majors with applications to information/data science, signal processing, and communication systems. Includes accompanying Python labs that apply probabilistic concepts to these application domains.

Course Pre-requisites: either E E 235, or E E 241; and either MATH 126, or MATH 136.

Learning Objectives: At the conclusion of the course, the student will understand basic axioms of probability and how to compute relevant statistics:

1. Be familiar with basic discrete and continuous random variables
2. Be proficient with fundamental data processing principles
3. Apply probabilistic modeling and inference to problems in information and communication engineering.

Course Structure: The class meets for two lectures a week, each consisting of 100-minutes. Homeworks and labs that include programming and analysis of data are assigned weekly for a total of 8 assignments over the quarter. There is one midterm exam and one final exam.

Evaluation Details: Midterm exam (30%), Final exam (35%), Homeworks and Labs (35%).

Syllabus Topics: (roughly following the textbook)

High level: develop skill/intuition in basic probability via discrete random variables and simulations; brief introduction to continuous random variables (students will get a deeper review in EE 416 of continuous random variables), plus basic statistical tools (correlation, scatterplots, simple regression), plus applications of all of these concepts in Information and Communication Engineering.

Probability Concepts (2 weeks) – sample space, history and approaches, probability vs statistics, sets, subsets, outcomes and events, independence and conditional probability, Bayes rule, categorical variables such as 2x tables and sample surveys, combinatorics of permutations and combinations. Examples drawn from: randomized models of communication channels, noise in control systems.

Discrete Random Variables (5 weeks) – Examples of Random Variables (Bernoulli, Binomial and Geometric), probability mass functions, expectations, basic data processing - sample moments, histograms and empirical distributions, functions of random variables, principles of Monte Carlo simulation, parameter estimation, confidence intervals. Examples drawn from: Binary erasure channel/ binary symmetric channel, MAP/ML inference for discrete signal constellations, time-series models drawn from multiplication of random variables.

Continuous Random Variables (1.5 weeks) – Basic continuous random variables including uniform, exponential, and Gaussian. Mathematical properties: memoryless-ness, basic Computer generation, fitting of parameters, and goodness-of-fit metrics. Examples drawn from AWGN (Additive White Gaussian Noise) channels, Poisson processes in signal processing and control.

Concepts of Dependence (1.5 weeks) – correlation and covariances, conditional expectation and conditional variance. Examples drawn from: MMSE estimation, signal detection.

Sample Labs

The labs will be comprised of programming and will be accompanied by appropriate Jupyter Notebooks.

1. Channel simulation: Simulate a communication channel and understand the relationship between the transmitted bits and received bits. Simulate a simple error correction code and calculate the error rate.
2. BitTorrent and the Coupon collector problem: Simulate the BitTorrent network protocol and understand its relationships to the coupon collector problem.
3. Correlation: Given sets of points find the correlation between the various variables.
4. Distribution fitting: Given datasets, fit the appropriate distributions and the parameters.
5. Maximum likelihood signal detection: Decode the transmitted signal from a communication channel using ML detection.
6. Law-of-large-numbers simulation: Generate data according to prescribed distributions and test out the law-of-large-numbers confidence intervals. Understand bias in sampling.
7. Time-series simulations: Random processes such as Bitcoin block mining inter-arrival distribution, simulating memoryless-ness.

Examples will be drawn from the following fields:

1. Communication systems
2. Signal and image processing
3. Internet data analytics
4. Computer engineering and reliability
5. Computational biology and neuroscience

ABET Student Outcome Coverage:
This course addresses the following outcomes:
H = high relevance, M = medium relevance, L = low relevance to course.

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. **(H)**

(2) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. **(M)**

(3) An ability to communicate effectively with a range of audiences. **(M)**
(5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. **(M)**

(6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions. **(H)**

(7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies. **(M)**

Program Specific Outcomes
The ABET Requirement

All EE and Engineering undergraduates are required to meet an ABET accreditation requirement in Probability and Statistics. ABET requires:

"The curriculum must include probability and statistics, including applications appropriate to the program name; mathematics through differential and integral calculus; sciences (defined as biological, chemical, or physical science); and engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components"

Religious Accommodations
Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at Religious Accommodations Policy (https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/). Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form (https://registrar.washington.edu/students/religious-accommodations-request/).

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