

CVEN 5454 (Quantitative Methods)
PROBABILITY AND STATISTICAL METHODS FOR NATURAL AND
ENGINEERED SYSTEMS
Fall 2025

Instructor

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Lectures: Tuesdays and Thursdays 12:30 – 1:45PM
Online: **Zoom - <https://cuboulder.zoom.us/j/94491902417> (password: probstat)**
In-person: **ECCE 1B41**

Office hours: (anytime on E-mail and by appointment)
Class page: <http://civil.colorado.edu/~balajir/CVEN5454>
Office hours: anytime on E-mail; by appointment and Walk in

Textbook(s):

1. Applied Statistics and Probability for Engineers, Montgomery and Runger (4th, 5th eds) –Wiley Publications
2. Probability Concepts in Engineering – Emphasis on applications to civil and environmental engineering - by Ang and Tang – Wiley Publications
3. [Statistical Methods in Water Resources by D.R. Helsel, R.M. Hirsch - Elsevier](#) (With R-commands)

Supplementary Books from Springer accessible via CU:

1. [A Modern Introduction to Probability and Statistics – Understanding why and how – by Dekking et al. Springer](#)
2. [Applied Probability and Statistics by Mario Lefebvre - Springer](#)
3. [Probability and Risk Analysis by Igor Rychilk and Jesper Ryden, Springer](#)
4. [Introduction to Probability and Statistics for Engineers by M. Holicky – Springer](#)
5. [Smoothing techniques with Implementation in S by Wolfgang Hardle - Springer](#)

Lectures and HWs will feature material from these and other books, research papers and online resources.

Prerequisites

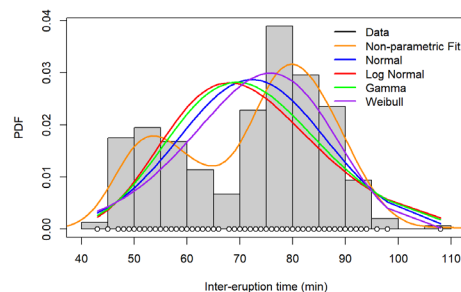
Undergraduate mathematics (calculus and algebra) and basic computer literacy (e.g. analyze and plot data, spreadsheets, programming)

Course Objectives

Research in almost any field involves making inferences and obtaining insights into the underlying processes from analyzing observations, especially in this age of big data¹. Therefore, it is critical to have a sound understanding of probability and data analysis techniques. To this end, the main objective of this introductory graduate course, in a sequence of two, is to *provide a good foundation of traditional and modern probability and statistical methods* that can be used in the analysis of environmental, hydrological, climatological and range of data from engineering applications. In addition, one of the *powerful tools for data analysis*, **R**²³ (<http://www.r-project.org>), will be introduced and exposed throughout the course.

Proposed Topics

1. Basic Probability: Conditional, Bayes and Total probability rules
2. Data visualization: scatterplots, boxplots, histograms; Sample statistics; introduction to R
3. Random Variables: Distributions (Discrete, Continuous, Joint and *Extreme Value*), *Nonparametric Density Estimation Techniques* and *Copulas*
4. Fitting probability models to data: parameter estimation - method of moments, likelihood estimation and *Bayesian approach*; *Monte Carlo and Bootstrap techniques* for simulation



¹ http://www.nytimes.com/2012/02/12/sunday-review/big-datas-impact-in-the-world.html?pagewanted=all&_r=0

² <http://www.nytimes.com/2009/01/07/technology/business-computing/07program.html>

³ http://www.nature.com/news/programming-tools-adventures-with-r-1.16609?WT.ec_id=NATURE-20141225

5. Uncertainty Quantification / Hypothesis testing: Uncertainty estimation, Confidence intervals, Differences between group means, Variance and correlation; Correlation and Mutual Information.
6. Regression: Linear Regression – (theory, simple and multiple, analysis of variance, confidence intervals, forecast and diagnostics); Logistic Regression; Robust Estimation (robust trend line)
7. Introduction to - *Bayesian Linear Regression, Generalized Linear Modeling (GLM)*

Grading:

Homework ~ 35%; Midterm (in class) ~ 20%; R-Project ~ 15%; Final (take home) ~ 30%

Proposed Schedule

Week	Topic(s)	Resources
1	Probability – basics, rules/axioms; conditional and total probability; Bayesian rule Statistics – sample, measures, data visualization (boxplots, histograms, ECDF, etc.)	Montgomery Chap 2
2		Ang & Tang Chap 2 & HW1
3		Helsel & Hirsch Chap 1-2 Montgomery Chap 6
3	Random Variables – moments, probability models for discrete variables	Montgomery Chap 3
4		Ang & Tang Chap 3
4	R-session – Introduction to R; syntax; basic commands; how to write functions etc.	R-Resources R-class project
5	Random Variables – moments, probability models for continuous variables; Extreme Value Distributions	HW 1 due
5		HW2 Montgomery Chap 4 Ang & Tang Chap 3,7 Rick Katz tutorials
5	Parameter Estimation – basics, point estimation – method of moments, max likelihood, Bayesian estimation. Fitting distributions and Monte Carlo Simulation, <i>R-commands</i>	Montgomery Chap 7
6		Ang & Tang Chap 6
6		R-Resources
6		
6	Functions of random variables, joint probability distributions; <i>Copulas</i> ; correlation; derived distributions & Monte Carlo	HW2 due
7		HW3 Montgomery Chap 5 Ang & Tang Chap 4
7	Nonparametric density estimation – Kernel density estimation; Simulation – bootstrap; Mutual Information; <i>R-commands</i>	Hand outs
8		
8	Interval Estimation – for mean, variance, correlation; using Monte Carlo and bootstrap to obtain intervals. Hypothesis Testing – basics, p-value	HW3 due
9		HW4
		Montgomery Chap 8-9 Helsel & Hirsch Chap 4
10/30	Midterm	Midterm
11	Testing differences between two groups; parametric and nonparametric tests; Goodness of PDF fits	Montgomery Chap 9,10,15
11		Helsel & Hirsch 4-8
12	Regression – assumptions, model fitting, parameter estimation; diagnostics; confidence interval; ANOVA; Best model selection; <i>R-commands</i>	Montgomery Chap 11-12
12		Helsel&Hirsch Chap 9,11
13		HW 4 due
13		HW5
Fall Break	Fall Break	Fall Break
15	Nonparametric fits – robust trend lines	Helsel & Hirsch Chap 10,12
15	Logistic Regression; <i>Bayesian Regression</i> ; <i>Introduction to GLM</i> ;	HW5 due
16		
16		
12/09	Final Exam & Exam week	R-Project due

SYLLABUS STATEMENTS

CLASSROOM BEHAVIOR:

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information on classroom behavior, Student Conduct & Conflict Resolution policies and others, see this [page](#).

COVID-19 updates

General information

Check for ongoing updates. CU Boulder employs a framework for public health and COVID-19 decision-making that follows Centers for Disease Control and Prevention (CDC) guidance. The campus will continue to work closely with Boulder County Public Health as it considers public health requirements in the Boulder community. If Boulder County Public Health adopts or modifies any requirements, the campus will immediately inform the CU Boulder community. For ongoing updates on campus COVID-19 protocols, check the [COVID-19 webpage](#) and [CU Boulder Today's COVID-19 updates](#).

ACCOMMODATION FOR DISABILITIES

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see [Temporary Medical Conditions](#) on the Disability Services website.

PREFERRED STUDENT NAMES AND PRONOUNS

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name. *Please do not hesitate to correct me if I get a pronoun incorrect (likely someone else's because this is often a 3rd person issue, not a 2nd person issue).*

HONOR CODE

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the [Honor Code website](#). *I have reported several students to the Honor Code Office. While it is my least favorite thing to do, it is one of the most important responsibilities I have as an instructor. Thus, I do not hesitate to do so when warranted.*

SEXUAL MISCONDUCT, DISCRIMINATION, HARASSMENT AND/OR RELATED RETALIATION

The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about OIEC, university policies, [reporting options](#), and the campus resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options.

RELIGIOUS HOLIDAYS

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please contact me at least 1 week ahead of time to make arrangements for any possible assignment submission changes, etc. See the [campus policy regarding religious observances](#) for full details.