

STAT 4630/5630

Computational Bayesian Statistics

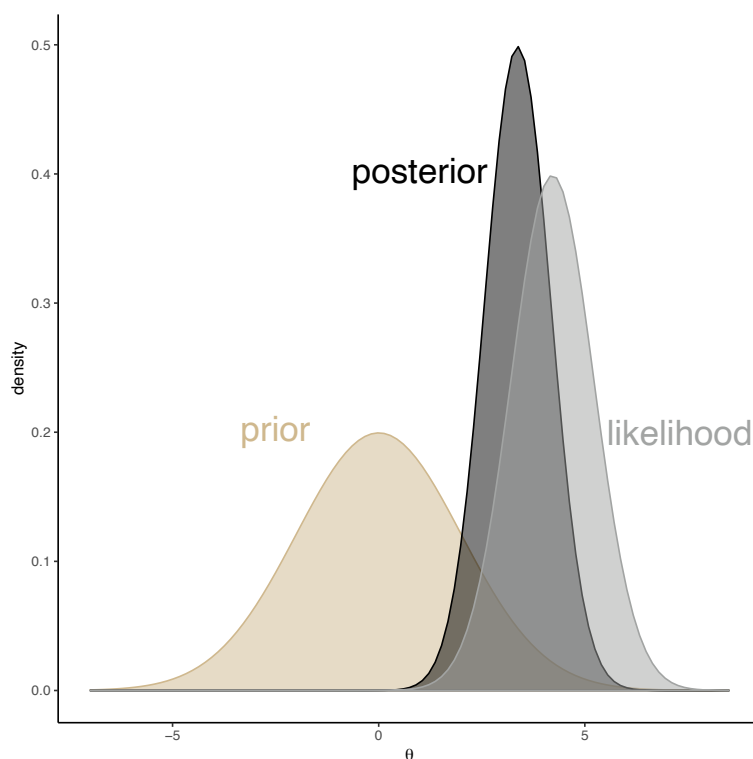
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Course Description

“Compared with Bayesian methods, standard [frequentist] statistical techniques use only a small fraction of the available information about a research hypothesis (how well it predicts some observation), so naturally they will struggle when that limited information proves inadequate. Using standard statistical methods is like driving a car at night on a poorly lit highway: to keep from going in a ditch, we could build an elaborate system of bumpers and guardrails and equip the car with lane departure warnings and sophisticated navigation systems, and even then we could at best only drive to a few destinations. Or we could turn on the headlights.”—Aubrey Clayton, *Bernoulli’s Fallacy*

In this course, we will “turn on the headlights”. That is, we will study Bayesian statistical inference methods, and we will regularly compare Bayesian methods to standard, frequentist methods (the methods covered, for example, in STAT 4520/5520 Introduction to Mathematical Statistics). Our goal will be to gain an extensive Bayesian toolkit, to understand what justifies the use of these tools, and compare and contrast them with frequentist methods.

Specific topics may include: an introduction to Bayesian inference, conjugate, improper, and “objective” prior distributions; Bayesian estimation; an introduction to Bayesian statistical modeling, e.g., linear regression, generalized linear models; Bayes’ factors; multinomial and non-normal approximation to likelihood and posteriors; the EM algorithm; data augmentation; and Markov Chain Monte Carlo (MCMC) methods.



Prerequisites (minimum grade C- in each):

1. either STAT 3400 Applied Regression or STAT 4010/5010 Statistical Methods and Applications II; **and**

2. either STAT 4520/5520 or MATH 4520/5520 Introduction to Mathematical Statistics or STAT 5530 Mathematical Statistics; **and**
3. prior programming experience

Recommended prerequisite: APPM 4560 or STAT 4100 Markov Processes, Queues, and Monte Carlo Simulations.

Learning Objectives

By the end of this course, students should be able to:

1. Articulate the logic of Bayesian inference and compare and contrast it with frequentist inference.
2. Utilize conjugate, improper, and objective priors to find posterior distributions.
3. Articulate the need for computational approaches to Bayesian inference and implement various computational approaches to find posterior distributions.
4. Assess the decision-theoretic and frequentist properties of Bayesian estimators.
5. Develop and apply Bayesian techniques in the context of linear and generalized linear models.
6. Evaluate the ethical consequences of the use (or misuse) of statistical methods.

Required Text:
Bayesian Statistical Methods by
Brian Reich and Sujit K Ghosh
(<https://bit.ly/3EojOUQ>)

Course Webpage

Course materials, such as this syllabus, the course schedule, homework assignments, and general updates will be uploaded to our Canvas page. Please check our Canvas page frequently!

Assignments

A Note about Jupyter and R

On many assignments in this course, we will use the R programming language; we will run R within the web application Jupyter. Both Jupyter and R are great (free) tools for data analysis/science, and I think they will be beneficial to you beyond this course. We will spend a class period downloading these programs and becoming comfortable using them. Learning new languages and applications can be difficult and frustrating, but also rewarding. I'm here to help you on this journey! Taking the first in-class Jupyter assignment seriously will make all future assignments much easier.

Homework (35%)

Homework will be due, on average, roughly once every other week (with a few weeks off and a few back to back weeks here and there). Due dates and times will appear on Canvas assignments. Late homework will not be accepted or graded, except in extraordinary circumstances. You are asked to electronically submit a Jupyter file and an html version of that Jupiter file to Canvas; these files will contain your answers to both sections. Ideally, your answers to theoretical section will be typeset in Markdown cells (below each question) using LaTeX. You may also embed a properly scanned pdf of handwritten answers to theoretical questions into the Jupyter file. Computational portions of the homework should include all relevant R code and output, and a write-up and interpretation of your results. You can collaborate with your classmates on the homework assignments, but you must write up the results independently of each other.

Exams (20% each, 40% total)

There will be one midterm exam and one final exam. The date of these exams are on our course schedule (on Canvas).

Final Project (15%)

Instructions for the final project will be given out in class. This project provides an opportunity for students to answer important scientific or business related questions by conducting a thorough data analysis using the tools from this course (or extensions of those tools). There will be a written and short presentation component to the project.

Classwork/Participation (10%)

Participation in this course is essential for doing well. We will frequently have opportunities for class participation. The majority of this portion of your grade will come from “in-class” assignments. In addition, active participation in class, online discussion, attending office hours, and, potentially, pop quizzes can also help your participation grade.

Grade Determination

See Canvas for the grading scheme. I reserve the right to lower the percentage points needed to obtain the corresponding letter grade.

Policies Trigger Warning

It is possible that discussions in this course, especially those pertaining to real-world data, could be potentially disturbing or traumatizing. If you feel the need to leave class during a discussion that you find disturbing or traumatizing, for however long, you may do so without academic penalty. You will, however, be responsible for any material you miss. If you do leave class for a significant time, please make arrangements to get notes from another student (or see me). If a topic is disturbing to you to the extent that you do not feel comfortable

working on it, I am happy to try to make reasonable accommodations, e.g., work with you on a different topic that demonstrates the same (or similar) learning objectives.

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, see the policies on [classroom behavior](#) and the [Student Conduct & Conflict Resolution policies](#).

Requirements for COVID-19

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to [Student Conduct and Conflict Resolution](#). For more information, see the policy on [classroom behavior](#) and the [Student Code of Conduct](#). If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

CU Boulder currently requires masks in classrooms and laboratories regardless of vaccination status. This requirement is a precaution to supplement CU Boulder’s COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the [Public Health Office](#) (contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the [Public Health Office](#) (contacttracing@colorado.edu).

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.

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](#).

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university 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 university policies, [reporting options](#), and the support resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are 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. To learn more about reporting and support options for a variety of concerns, visit [Don't Ignore It](#).

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 message me with any due dates that conflict with religious holidays. I am happy to make an accommodation.

See the [campus policy regarding religious observances](#) for full details.