Math 315: Bayesian Statistics

Adam Loy

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E-mail: aloy@carleton.edu
Office Hours: Mon & Tues 2:00-3:00;
Wed & Fri 9:30-10:30; & by appointment
Office: 218 CMC

Web: github.com/aloy/math315-fall2019
Class Hours: 4a
Class Room: 319 CMC

Course Description

For decades the world of statistics was dominated by "frequentist" methods. Bayesian statistics is an alternative school of thought founded upon the idea that our beliefs about the world are constantly revised with the incorporation of new information. While this idea is intuitive, Bayesian statistics was held back by the mathematical intractability of common inferential tasks. Computers have changed that. Today, Markov chain Monte Carlo (MCMC) methods are used by Bayesians to conduct statistical inference. In this course, we will explore the Bayesian philosophy and approach to statistical inference. We will start with the basic building blocks of inference and then explore the Bayesian regression model. Along the way, you will learn how and why MCMC works, enabling you to simulate from posterior distributions so that you are not restricted to models that can be "fit" using pencil and paper.

Preparation

If you have taken probability (Math 265) and introduction to statistical inference (Math 275), then you are in good shape mathematically. We will utilize both the mechanics and the thought processes developed in these courses. However, you will not rely solely on pencil-and-paper calculations (i.e. calculus), so R programming is a potential obstacle. If you took Math 275 at Carleton, then you are in good shape. If you have ever programmed in any language, then you are in good shape. If you have never programmed and are unfamiliar with R and R Markdown, please talk to me as soon as possible.

The programming required in this course is not very fancy. We will write a few for loops as we first learn MCMC methods, but will move quickly to existing tools that efficiently implement these algorithms; thus, for the vast majority of this course we will be learning how to write scripts to run data analyses. The most important thing is to realize that it takes time to become comfortable and proficient with programming. You have to be patient with yourself. I promise I will be patient with you, as long as you make a serious effort.

Course Objectives

After this course you will be able to:

1. describe fundamental differences between the Bayesian and frequentist paradigms, along with their relative strengths.
2. select priors, write likelihoods, derive posterior distributions, and verify model and prior assumptions.
3. use Markov Chain Monte Carlo (MCMC), via R and JAGS, to sample from posterior distributions.
4. effectively summarize a posterior using tables and graphics.
5. appreciate the powerful things the Bayesian paradigm can do, along with its limitations.

Textbook

The required text for the course is

Reich, Brian and Sujit Ghosh (2019). *Bayesian Statistical Methods*. CRC Press. https://bayessm.org/.

I will supplement this textbook with readings from a few other sources, so be sure to check the course webpage for links.

Course Components & Grading Scheme

Homework (25%)

Homework assignments will be due on Tuesdays and Fridays by 4 p.m., though there will be some exceptions to this schedule for exams, midterm break, and case studies. Unexcused late homework will not be accepted. I understand that this policy is strict, so I will drop your lowest score when computing your homework score. I will provide solutions to these assignments the week after they are due.

I strongly encourage you to get to know and work with your peers in this class. They will be a valuable asset in helping you master this material. Note that working together does not mean copying solutions. All homework problems should be initially attempted by you and write-ups for the problems must be expressed in your own words. I suggest completing your write-up away from others working on the problems. Only after you have thought about the problems yourself is it valid to seek help from your peers or myself.

Case studies (15%)

Two case studies will be assigned during the term. Each case study will require a formal written report. You will complete these case studies in teams that I assign. Each case study will be worth 7.5% of the final grade.

Exams (20% each)

There will be two in-class exams, which are scheduled for

Exam #1 (20%)	Wednesday, October 16
Exam #2 (20%)	Wednesday, November 13

Project (20%)

The final project is a capstone experience synthesizing everything you have learned over the course of the term. This is an opportunity for you to exercise your creativity and create something meaningful. The project will require you to complete the entire statistical modeling process—from formulating questions to reporting your final model—using a data set of your choice. The final project is in lieu of a final exam and will be due by 3:00 p.m. on Monday, November 25.

Accommodations

Carleton College is committed to providing equitable access to learning opportunities for all students. The Disability Services office (Henry House, 107 Union Street) is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations. If you have, or think you may have, a disability (e.g., mental health, attentional, learning, autism spectrum disorders, chronic health, traumatic brain injury and concussions, vision, hearing, mobility, or speech impairments), please contact disability@carleton.edu or call Jan Foley, Student Accessibility Specialist (x4464) or Chris Dallager, Director of Disability Services (x5250) to arrange a confidential discussion regarding equitable access and reasonable accommodations.

Academic Integrity

You are expected to follow the policies regarding academic integrity established by Carleton College. All work on exams must be your own. You may collaborate on homework, but you must submit your own assignment that reflects your own thinking, work and organization. Any work you submit for a grade should be your own, not a facsimile of a classmate's work or an online solution, which would constitute academic dishonesty. To check if your homework meets this standard, imagine I asked you to explain your reasoning for each problem—you should be able to do so with ease using language similar to your submission. Finally, cell phones will be prohibited during exams.

Cases of academic dishonesty will be dealt with strictly. Each such case will be referred to the Academic Standing Committee via the Associate Dean of Students or the Associate Dean of the College. A formal finding of responsibility can result in disciplinary sanctions ranging from a censure and a warning to permanent dismissal in the case of repeated and serious offenses.