STATS/DATASCI 551/651: Bayesian Modeling

Yixin Wang
University of Michigan
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Overview

Description. This course provides basic concepts and several modern techniques of Bayesian modeling and computation. They include basic models, conjugate priors, and posterior computation, as well as techniques associated with complex models, such as hierarchical models, spatiotemporal models, and dynamical models. A substantial part of the course is devoted to computational algorithms based on Markov Chain Monte Carlo sampling for complex models. If time permits, we will also introduce advanced topics such as nonparametric Bayes, variational inference, and Hamiltonian Monte Carlo techniques. Foundational topics will be discussed when appropriate, although they are not our primary focus in this course; such topics may include decision theoretic characterization of Bayesian inference and its relation to frequentist methods, de Finetti-type theorems and the existence of priors, objective prior distributions, and Bayesian model selection.

Prerequisites. The prerequisites are previous coursework in linear algebra, multivariate calculus, and basic probability and statistics. Previous experience in numerical analysis and optimization would be helpful but is not required. Familiarity with R, Python, or a related programming language will be necessary.

Textbooks. Class readings will mainly come from the following books.

- Gelman et al. Bayesian Data Analysis. Chapman and Hall, 2005. PDF
- Hoff. A first course in Bayesian statistical methods. Springer, 2009. PDF
- Bishop. Pattern Recognition and Machine Learning. New York: Springer, 2006. PDF
- Murphy. Probabilistic Machine Learning: Advanced Topics. MIT Press, 2023. PDF

Piazza and participation bonus. All communications with the teaching team should be conducted on piazza; please do not email. If you wish to ask a question privately to the teaching team, please post a private note on Piazza; see instructions here; you can expect an answer within 48 hours during weekdays (except holidays). The GSIs and the instructor will be monitoring piazza, endorsing correct student answers, and answering questions that remain after a discussion.

As a bonus, **up to 3 percentage points will be added to your final course grade based on piazza participation.** You will get $x \cdot 3\%$ bonus points if the number of your total Piazza contributions is $(x \cdot 100)\%$ of the maximum number of contributions among all students. The number of Piazza contributions will be determined by Piazza class statistics.

Requirements and Grades

The requirements are homework assignments (30%), midterm exam (30%), final project (40%).

1. **Homework assignments (30%).** There will be (roughly biweekly) homework assignments involving problems, programming, and data analysis.

   The bottom one homework scores will be dropped; this policy is expected to accommodate circumstances where students could not complete the homework assignments due to the add/drop period, registration matters, and/or personal reasons.

   The homework assignments are due at 11:59 pm EST on Mondays.

   Submission requirements. Homework will be submitted electronically as pdfs, along with any notebook or markdown used to generate results appearing in the pdf. You must run all cells in your notebook to receive credit; we will not rerun your notebook. Any code submitted should run without errors. Note that the homework assignments may involve coding up the model and algorithm and applying it to a given dataset. You can code in Julia, Python, or R (i.e. as long as it runs in a Jupyter notebook).

   Homeworks should be written up clearly and succinctly; you may lose points if your answers are unclear or unnecessarily complicated.

   Late days. Homework due dates are strict, and you may turn in work late only with the use of "late days." *You have **seven** late days to use over the course of the semester.* For each late day you spend, you extend the deadline for homework by 24 hours. You may spend multiple late days per homework. Once you have turned in your homework you may not spend more late days to turn in your homework again.

   Once you run out of late days, you will incur a 25% penalty for each extra late day you use. Each late homework should be clearly marked as "Late" on the first page.

   The purpose of this late-day policy is to enable you to deal with unexpected circumstances (e.g., illness, family emergencies, job interviews) without having to come to me. Beyond the drops and the late days, we will only grant additional deadline adjustments if the total number of formally documented illness/emergencies exceeds three weeks.

   If dire circumstances arise (e.g., long-term illness that causes you to miss multiple weeks of lectures), please contact me as soon as possible. Due to the university grading schedule, you may not use late days to extend the deadline of the last homework assignment.

   Regrade Policy. You may submit a regrade request if you believe that the course staff made an error in grading. Any regrade requests should be submitted through Gradescope *within **seven** days* of receiving your grade. Please try to be as specific as possible with your regrade request.

2. **Midterm Exam (30%).** There will be an in-person midterm exam.

3. **Final Project (40%).** The final project is an opportunity to use and develop Bayesian models to analyze real-world data.

   The project report and project presentation is due at 11:59 PM EST on Dec 15. **No late days** are allowed for deadlines related to the course project. Submissions received after the deadline will receive a **zero** score.

   We grade your project report and presentation on both content and writing/presentation quality. Please prepare all written work using the LaTeX templates we provide.

4. **Final letter grade.** The final grade will be set so that the distribution of final grades approximately matches that of previous offerings of the course.

Schedule

The schedule is subject to change.

Introduction

1. Introduction
2. Probability: A Review of Basic concepts and Bayes' Theorem
3. One-parameter models
4. Monte Carlo approximation
5. The normal model, the multivariate normal model, and multi-parameter models
6. Posterior approximation with the Gibbs sampler and Bayesian computation
7. Group comparisons and hierarchical modeling
8. Regression models
9. Model checking & comparison
10. Finite mixture models
11. Missing data problems
12. Approximate Bayesian inference
13. Summary (and wiggle room)

Support Resources

Course recordings. Course lectures may be audio/video recorded and made available to other students in this course. As part of your participation in this course, you may be recorded. If you do not wish to be recorded, please contact the instructor during the first week of class (or as soon as you enroll in the course, whichever is latest) to discuss alternative arrangements.

Academic integrity. The University of Michigan community functions best when its members treat one another with honesty, fairness, respect, and trust. The college promotes the assumption of personal responsibility and integrity and prohibits all forms of academic dishonesty and misconduct. All cases of academic misconduct will be referred to the LSA Office of the Assistant Dean for Undergraduate Education. Being found responsible for academic misconduct will usually result in a grade sanction, in addition to any sanction from the college. For more information, including examples of behaviors that are considered academic misconduct and potential sanctions, please see https://lsa.umich.edu/lsa/academics/academic-integrity.html for more information.

You are welcome to discuss homework with your classmates, but the work that you turn in must be yours and yours alone, and you must disclose the names of those you spoke with in your homework, including both classmates and others outside the class. This disclosure applies whether a student has helped someone else or has received help. However, it is not necessary to disclose any discussion you have with the course instructor or the course GSIs.

Accommodations for students with disabilities. The University of Michigan recognizes disability as an integral part of diversity and is committed to creating an inclusive and equitable educational environment for students with disabilities. Students who are experiencing a disability-related barrier should contact Services for Students with Disabilities https://ssd.umich.edu/; 734-763-3000 or ssdoffice@umich.edu). For students who are connected with SSD, accommodation requests can be made in Accommodate. If you have any questions or concerns please contact your SSD Coordinator or visit SSD's Current Student webpage. SSD considers aspects of the course design, course learning objects and the individual academic and course barriers experienced by the student. Further conversation with SSD, instructors, and the student may be warranted to ensure an accessible course experience.

Mental Health and Well-Being. University Students may experience stressors that can impact both their academic experience and their personal well-being. These may include academic pressures and challenges associated with relationships, mental health, alcohol or other drugs, identities, finances, etc. If you are experiencing concerns, seeking help is a courageous thing to do for yourself and those who care about you. If the source of your stressors is academic, please contact me so that we can find solutions together. For personal concerns, U-M offers a variety of resources, many of which are listed on the Resources for Student Well-being webpage. You can also search for additional well-being resources here.

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