Math 70095-001: ST: Bayesian Analysis

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Fall 2022

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Class Hours: MWF 9:55-10:45 a.m.
Class Room: MSB 276

Course Description

This course aims to provide a practical introduction to Bayesian methodology with an emphasis on data analysis. Students will learn the fundamentals of Bayesian modeling and inference and the related computational strategies and algorithms. The course starts with the treatment of simple models based on a single parametric distribution, to illustrate how to conduct inference in a Bayesian setting through posterior summaries. More advanced models are then discussed, including hierarchical models and generalized linear models. To draw samples from the posterior distributions for Bayesian inference, Markov chain Monte Carlo (MCMC) methods, including the Gibbs sampler and Metropolis-Hastings algorithm are introduced. Critical issues in Bayesian data analysis such as prior specification, monitoring of MCMC convergence, sensitivity analysis and model checking will be discussed throughout the course.

Prerequisites

You must have doctoral standing. Please contact instructor if you would like to take the course, but do not satisfy the prerequisite.

Recommended Textbooks

- *Bayesian Data Analysis*, Andrew Gelman, John B. Carlin, Hal S. Stern, David B. Dunson, Aki Vehtari, Donald B. Rubin, Chapman and Hall/CRC, 3rd Edition, 2013.

- *Statistical Rethinking: A Bayesian Course with Examples in R and STAN*, Richard McElreath, Chapman and Hall/CRC, 2nd Edition, 2020.

Course Policy

Important policy for this course is detailed below.

Grading

Grades will be calculated as follows:

- Homework assignments: 30%
- Midterm exam: 30%
- Final project: 40%

The final letter grades will follow the usual scale: A=90-100; B=80-89; C=70-79; D=60-69; F=0-59. Plus and minus grades will be given at discretion of the instructor.

Homework

There will be approximately 6 homework assignments that will be posted on Canvas. Solutions must be uploaded to Canvas as a **PDF** file. Please make sure your work is clearly presented. Assignments are due at the beginning of class hour on the specified date. In general, **NO** late submissions will be accepted. In case of truly exceptional situations (e.g., family emergencies or illness), the instructor may make exceptions and allow late submission. The lowest homework score will be dropped at the end of the semester.

Midterm Exam

There will be a take-home midterm exam. The exam will be posted on Canvas at 9:00 a.m. on **October 10, 2022**, and you have to upload your solutions as a **PDF** file to Canvas by 11:59 p.m. on **October 12, 2022**. Please note that you are NOT allowed to discuss with other students and the submitted work must be your own.

Final Project

There will be a final project due on **December 12, 2022**. More details about the final project will be posted and discussed later in the semester.

Re-grades

All re-grading requests should be made in writing, within one week after receiving a grade. The request should state the specific question that needs to be re-graded, as well as a short explanation of why re-grading is necessary. The new grade may be lower than the original grade.

Academic Integrity

University policy 3-01.8 deals with the problem of academic dishonesty, cheating, and plagiarism. None of these will be tolerated in this class. The sanctions provided in this policy will be used to deal with any violations. If you have any questions, please read the policy at http://www.kent.edu/policyreg/administrative-policy-regarding-student-cheating-and-plagiarism and/or ask.

Accessibility

Kent State University is committed to inclusive and accessible education experiences for all students. University Policy 3342-3-01.3 requires that students with disabilities be provided reasonable accommodations to ensure equal access to course content. Students with disabilities are encouraged to connect with Student Accessibility Services as early as possible to establish accommodations. If you anticipate or experience academic barriers based on a disability (including mental health, chronic medical conditions, or injuries), please let me know immediately.

Student Accessibility Services (SAS) Contact Information:

- Location: University Library, Suite 100
- Email: sas@kent.edu
- Phone: 330-672-3391
- Web: www.kent.edu/sas

Diversity

Kent State University is committed to the creation and maintenance of equitable and inclusive learning spaces. This course is a learning environment where all will be treated with respect and dignity, and where all individuals will have an equitable opportunity to succeed. The diversity that each student brings to this course is viewed as a strength and a benefit. Dimensions of diversity and their intersections include but are not limited to: race, ethnicity, national origin, primary language, age, gender identity and expression, sexual orientation, religious affiliation, mental and physical abilities, socio-economic status, family/caregiver status, and veteran status.

Registration Requirement

The official registration deadline for this course is **August 31, 2022**. University policy requires all students to be officially registered in each class they are attending. Students who are not officially registered for a course by published deadlines should not be attending classes and will not receive credit or a grade for the course. Each student must confirm enrollment by checking his/her class schedule (using Student Tools in FlashLine) prior to the deadline indicated. Registration errors must be corrected prior to the deadline.

Withdrawal

The last day to drop without a grade of "W" is **September 7, 2022**. The last day to withdraw this course is **November 2, 2022**. Other important Registrar dates can be found at http://www.kent.edu/registrar/registrar-dates-term.

Tentative Schedule

The schedule is subject to change.

Week 01, 08/22 - 08/26: Syllabus

Class begins on August 26.

Week 02, 08/29 - 09/02: Review of Probability and Inference

Topics:

- Probability as a measure of uncertainty
- Statistical inference
- Frequentist/classical approach

Lab: Introduction to R, RStudio, Rmarkdown

Week 03, 09/05 - 09/09: Introduction to Bayesian Inference

Topics:

- Bayes' Theorem
- Prior and posterior distributions
- Bayesian inference in applied statistics

Lab: Fundamentals of R

Labor Day. No class on September 5

Week 04, 09/12 - 09/16: One-parameter Models

Topics:

- Specification of prior distributions
- Posterior summaries

Lab: Distributions in R

Week 05, 09/19 - 09/23: Prior Distributions

Topics:

- Noninformative priors
- Improper priors
- Weakly informative priors

Lab: Data visualization in R

Week 06, 09/26 - 09/30: Multi-parameter Models

Topics:

- Joint and marginal posterior distributions
- Sampling from joint posterior distribution

Lab: Data transformation in R

Week 07, 10/03 - 10/07: Markov chain Monte Carlo (MCMC)

Topics:

- Monte Carlo Methods
- Markov chain Monte Carlo (MCMC)
- Gibbs sampler

Week 08, 10/10 - 10/14: Midterm Exam

Exam due 11:59 p.m. on October 12 (handed out 9:00 a.m. on October 10)

Fall Break. No class on October 14

Week 09, 10/17 - 10/21: Metropolis-Hastings Algorithms

Topics:

- Metropolis algorithm
- Metropolis-Hastings algorithm

Week 10, 10/24 - 10/28: MCMC Convergence Diagnostics

Topics:

- Mixing in MCMC
- Dependence of the iterations
- Diagnostic statistics

Week 11, 10/31 - 11/04: Model Checking

Topics:

- Sensitivity analysis
- Posterior predictive checking
- Graphical checks

Week 12, 11/07 - 11/11: Model Comparison

Topics:

- Information criteria
- Hypothesis testing and Bayes factor
- Model averaging

Veterans Day Observed. No class on November 11

Week 13, 11/14 - 11/18: Regression Models

Topics:

- Bayesian analysis of classical regression
- Unequal variances

Week 14, 11/21 - 11/25: Hierarchical Linear Models

Topics:

- Exchangeability
- Mixed-effects models

Thanksgiving Break. No class on November 23 and 25

Week 15, 11/28 - 12/02: Generalized Linear Models

Topics:

- Logistic regression
- Poisson regression

Week 16, 12/05 - 12/09: Extended Topics

Topics:

- Computationally efficient MCMC methods
- Software for Bayesian analysis
- Bayesian workflow

Week 17, 12/12 - 12/16: Final Exam Week

Final project due 11:59 p.m. on December 12, 2022