(Applied) Bayesian Statistical Inference and Modeling
Edps 590BAY
Fall 2022

Instructor: Carolyn J. Anderson
Office rm 236C Education Building
Office hours: Tuesday 1:00-3:00 & by appointment

Meetings: Tuesday/Thursday 10:00-11:20am, rm 242 Education Building

Overview: Bayesian methods have become more prevalent in statistics including inference, prediction, up-dating probabilities as more data become available, and fitting complex models. A Bayesian approach solves many problems that are difficult under a traditional frequentist approach. In classical and Bayesian statistics, a specific or single value for population parameters are fixed but unknown. It is the values of these parameters, whether a single proportion or coefficients of a complex model, that are interesting. Classical and Bayesian statistics differ in terms of interpretation of the concept of probability and inferential summaries. In classical statistics, probability is defined in terms of long run frequencies; whereas, in Bayesian statistics probability is a degree of belief. In the latter, inference is based on an estimated probability distributions of possible values of the unknown quantities. The probability distributions are based on prior beliefs and data.

This seminar will cover the basics of Bayesian inference and application of Bayesian methods for fitting models to data. The specific topics beyond foundational concepts and procedures will be determined based on student's interests and needs. This will be an active and collaborative learning course where material will be presented by the instructor or students and in class exercises worked out in small groups.

Prerequisite: At least one statistics course beyond Psych 506/507 or Edps 581/582 and consent of the instructor.

Textbook: You can use either

Gelman, A., Carlin, J.B., Stern, H.S., Dunson, D.B., Vehtari, A., & Rubin, D.B. (2013) *Bayesian Data Analysis, 3rd Edition*. Capman & Hall/CRC. ISBN-13: 978-1439840955.

Or

Kruschke, J. (2014). Doing Bayesian Data Analysis: A tutorial with R, JAGS, and Stan. 2nd Edition. ISBN-13: 978-0124058880.

The former is ``the reference'' on the subject and is more mathematical. The latter has a higher words/math ratio than the former and you can get an online version for free (to those associated with the University) by going to the UofI library and search for it.

Also, a good book is R. McElreath (2016). *Statistical Rethinking: A Bayesian Course with Examples in R and STAN*. CRC Press. You can all access this book from the Illinois online library.

Evaluation: 30% participation, 30% assignments (including reading), 40% course project (presentation). The range of projects is very board.

Computing: We will use R for computation, especially JAGS, rStan, and brms. You should to bring a laptop to course meetings.

Course web-site: An open access link to the course web-site can be found at https://cja.education.illinois.edu. Besides course information and materials, there are links to multilevel web-sites. This site is open access.

Illness: If you are sick, do **NOT** come to lecture or the instructor's office hours.
We will follow the university policy regarding measures to prevent the spread of covid 19, which could change. You are not required to wear face coverings; however, feel free to do so if you so desire. See https://covid19.illinois.edu/on-campus/on-campus-instructors.

Fair Use/Plagiarism Policy: Please see go to the following link for policy on academic integrity: http://education.illinois.edu/edpsy/about/academic-integrity The definition as spelled out in this document is
"The definition of plagiarism is straightforward: Presenting someone else's words, materials, manner of expression, or ideas as your own. This means that even if another person agrees to let you present his or her content as if it were yours, it is still plagiarism. Plagiarism does **not** require intent: it can be intentional or unintentional."
I take this very seriously.

Emergencies: Review http://police.illinois.edu/emergency-preparedness
In an emergency in this building, we'll have three choices: **RUN** (get out), **HIDE** (find a safe place to stay inside), or **FIGHT** (with anything available to increase our odds for survival).

First, take a few minutes this week and learn the different ways to leave this building (exits are to the North, South and two to the West). If there's ever a fire alarm or something like that, you'll know how to get out, and you'll be able to help others get out too.

Second, if there's severe weather and leaving isn't a good option, go to a low level, in the Education building the east side of the basement (away from windows).

If there's a security threat, such as an active shooter, **RUN** out of the building if we can do it safely or **HIDE** by finding a safe place where the threat cannot see us. We will lock or barricade the door and we will be as quiet as possible, which includes placing our cell phones on silent. We will not leave our area of safety until we receive an Illini-Alert that advises us it is safe to do so. If we cannot run out of the building safely or we cannot find a place to hide, we must be prepared to fight with anything we have available in order to survive.

Remember, RUN away or HIDE if you can, FIGHT if you have no other option.

Finally, if you sign up for emergency text messages at emergency.illinois.edu, you'll receive information from the police and administration during these types of situations.

If you have any questions, go to police.illinois.edu, or call 217-333-1216

Tentative Course Schedule and Topics
The readings are a rough guide.

	Reading	
Topic	**Gelman et al.**	Kruschke
Introduction & Brief History of Bayesian Statistics • Pre-1900 • Early 1900s • World War II and code breaking • Advent of readily available computer power • In class practice: R basics • Assignment #1	S.B. McGrayne (2011). *The Theory that Would Not Die*, University Press	
Beliefs and Probabilities • Requirements of a system of beliefs • Types of distributions: marginal & conditional • Bayes theorem • Expected values • Definitions, etc. • In class practice: Conditional probabilities and more R • Assignment #2	chapter 1	ch 1, 2, & 4
Estimation and Inference for a Proportion • Priors, likelihood & posterior distributions in action • Credible intervals • High density intervals • Example: height of presidential candidate • In class practice: 2018 General Social Survey Data • Assignment #3	2.1-2.4	ch 5 & 6
Inference of mean of a normally distributed variable • Likelihood of normally distributed variable • Conjugate Prior of normal • Posterior • Analytic solution for estimation and inference of mean Given known variance. • Example: Anorexia data • Example: You get what you pay for • Assignment #4	pp39-68 ch 11	pp 450-459
Inference of mean & variance of normal	pp63-69	pp449-454

- Likelihood
- Priors
- Analytic solution
- Revisit anorexia data
- Monto Carlo sampling
- Revisit getting what you pay for data

MCMC: Gibbs Sampling pp275-278 pp143-221 documentation on jags, rjags, runjags, and coda

- Bayesian Computing
- Markov chain
- Gibbs sampling for univariate normal
- JAGS
- Assessing convergence of algorithm
- Simple linear regression
- Handling missing values
- Practice

Linear Regression Models ch 6, 11 ch 17, 18. 19

- Generalized linear models
- Bayesian simple linear regression
- Missing values
- Robust (i.e., t-distribution)
- Discrete predictors
- Model evaluation (posterior predictive checks, integration Via Monte Carlo simulations.

Multiple Linear Regression ch 18,19, 20

- Multiple regression
- Model evaluation
- Model comparison
- Practice

Multilevel (hierarchical) Regression Models schools example ch9

- Hierarchical/nested data
- Simple example: Anorexia data
- Bayesian estimation
- More complete example: 20 schools from NELS
- Logistic regression (GSS 5 vocabulary items)

Metropolis and Metropolis-Hastings Alogrithms pp275-291 pp143-218

- Metropolis algorithm
- Revise Anorexia data
- Metropolis algorithm for mean & variance of normal
- Anorexia data

- Metropolis-Hastings algorithm

Hamiltonian Monte Carlo, STAN, and brms	12.4-12.6	ch 14
	appendix C	

- Advantages of Hamiltonian Sampler MCMC
- General idea of how HMC works
- Stan language and examples
- Interfaces including brms R package

Topics of Student's choice

Student Project Presentations