Bayesian Inference

University

Semester

Days and Times: TBD

Location: TBD

Instructor: Chris Newton

Email: cnewton2@buffalo.edu

Office Hours: TBD

Course Description: This class covers Bayesian inference from the definition of probability to multilevel modeling. By the end of this course, students should understand the difference between Bayesian and frequentist methods, choose which is most appropriate for their research design, choose suitable priors, conduct Bayesian analysis with R and Stan, and interpret, communicate, and visualize their results. The lectures will cover statistical theory with code examples. Students will have weekly problem sets in R and Stan to gain practical command over the theoretical topics. In addition to problem sets, students will work on a project of their choosing throughout the semester. Some knowledge of R and basic statistics is required. No previous knowledge of Stan or Bayesian methods is needed.

Student Learning Outcomes:

- Understand the strengths and weaknesses of Bayesian and frequentist approaches.
- Build an understanding of how to select and use priors.
- Gain familiarity with Bayesian modeling in R and Stan.
- Develop an ability to communicate Bayesian results to technical and nontechnical audiences.
- Understand common issues with modeling and potential solutions.

Course Requirements: Students are expected to complete the assigned readings and attend class each week. In addition, there will be:

Problem Sets: You will have a problem set due at the end of most weeks. Theses assignments practice the skills that we learn in class. Studying the theory is not enough. These problem sets will give you plenty of practice and help you find solutions to common issues. There are no problem sets for weeks when other assignments are due.

Research Design: You will generate a causal model that you will later test statistically. For this assignment, you will propose causal relationships between variables (at least three), produce a DAG visualizing the relationships, and identify data sources.

Prior Justification: Based on your causal model, previous work in the field, and statistical research, you will define priors for all of your variables and intercept(s). You will present your arguments for why these priors are the best. Commented R/Stan code for your priors is required

Initial Results: You will present your theory, DAG, priors, model, and initial results in class. This will be in the format of an abbreviated conference presentation.

Final Project: When you present in class, you will receive feedback from your classmates and me. Based on the feedback, you will make improvements to your initial results and submit everything as a final project. Commented R/Stan code is required.

Late Work: All assignments will lose 1/3 of a letter grade (A becomes A-) every 24 hours past the deadline.

Course Materials: We will be using Richard McElreath's *Statistical Rethinking*, 2nd ed. The 1st edition of the book will also work for this class. All other materials will be distributed through the class' GitHub page.

Grading Policy:

Problem Sets	30%
Research design	15%
Prior Justification	15%
Initial Results	15%
Final Project	25%

Grade	Percentage	Grade Points
A	93-100%	4.0
A-	90-92%	3.67
B+	87-89%	3.33
B	83-86%	3.0
B-	80-82%	2.67
C+	77-79%	2.33
C	73-76%	2.0
C-	70-72%	1.67
D+	67-79%	1.33
D	63-66%	1.0
F	0-63%	0.0

Learning Outcomes:

Learning Outcome	**Assessment Measure**
Understand the strengths and weaknesses of Bayesian and frequentist approaches.	Problem Sets; Research Design; Initial Results; Final Project
Build an understanding of how to select and use priors.	Problem Sets; Prior Justification; Initial Results; Final Project
Gain familiarity with Bayesian modeling in R and Stan.	Problem Sets; Prior Justification; Initial Results; Final Project
Develop an ability to communicate Bayesian results to technical and nontechnical audiences.	Initial Results; Final Project
Understand common issues with modeling and potential solutions.	Problem Sets Initial Results; Final Project

Incomplete Grades:

A grade of incomplete ("I") indicates that additional course work is required to fulfill the requirements of a given course. Students may only be given an "I" grade if they have a passing average in coursework that has been completed and have well-defined parameters to complete the course requirements that could result in a grade better than the default grade. An "I" grade may not be assigned to a student who did not attend the course.

Prior to the end of the semester, students must initiate the request for an "I" grade and receive the instructor's approval. Assignment of an "I" grade is at the discretion of the instructor.

The instructor must specify a default letter grade at the time the "I" grade is submitted. A default grade is the letter grade the student will receive if no additional coursework is completed and/or a grade change request is

not submitted by the instructor. "I" grades must be completed within 12 months*. Individual instructors may set shorter time limits for removing an incomplete than the 12-month time limit. Upon assigning an "I" grade, the instructor shall provide the student specification, in writing or by electronic mail, of the requirements to be fulfilled, and shall file a copy with the appropriate departmental office.

Students must not re-register for courses for which they have received an "I" grade

Important Dates:

Research Design	Week 5
Prior Justification	Week 9
Initial Results	Week 14
Final Project	Finals Week

University specific policies

Academic Integrity: All students should be aware of and follow the university Academic Integrity Polity https://catalog.buffalo.edu/policies/integrity.html. Cases of academic dishonesty will not be tolerated.

Counseling Services (Mental Health): As a student you may experience a range of issues that can cause barriers to learning or reduce your ability to participate in daily activities. These might include strained relationships, anxiety, high levels of stress, alcohol/drug problems, feeling down, health concerns, or unwanted sexual experiences. Counseling, Health Services, and Health Promotion are here to help with these or other concerns. You learn can more about these programs and services by contacting:

Counseling Services: 120 Richmond Quad (North Campus), phone 716-645-2720
202 Michael Hall (South Campus), phone: 716-829-5800
Health Services: Michael Hall (South Campus), phone: 716- 829-3316
Health Promotion: 114 Student Union (North Campus), phone: 716- 645-2837

Sexual Violence: UB is committed to providing a safe learning environment free of all forms of discrimination and sexual harassment, including sexual assault, domestic and dating violence and stalking. If you have experienced gender-based violence (intimate partner violence, attempted or completed sexual assault, harassment, coercion, stalking, etc.), UB has resources to help. This includes academic accommodations, health and counseling services, housing accommodations, helping with legal protective orders, and assistance with reporting the incident to police or other UB officials if you so choose. Please contact UB's Title IX Coordinator at 716-645-2266 for more information. For confidential assistance, you may also contact a Crisis Services Campus Advocate at 716-796-4399.

Useful Resources:

- Advanced Books
  - Bayesian Data Analysis
  - Regression and Other Stories
- Readings for Specialized Topics
- Andrew Gelman's blog

Schedule

Week 1: Introduction to the Course, R and Stan

- Accessing course materials from GitHub
- R and Stan
- Chapter 1

- Example project from start to finish

Week 2: Bayesian Inference I

- Chapter 1-2
- Bayesian vs. frequentist probability
- Data generating processes
- Basic simulation

Problem Set 1 due before midnight on **Friday**

Week 3: Bayesian Inference II

- Chapter 2-3
- What is a prior?
- Bayesian updating

Problem Set 2 due before midnight on **Friday**

Week 4: Linear Models I

- Chapter 4
- DAGs
- The insignificance of significance

Problem Set 3 due before midnight on **Friday**

Week 5: Linear Models II

- Chapter 5-6
- Slope uncertainty
- Prior influence
- model checking

Research Designs due by midnight **Friday**

Week 6: Overfitting

- Chapter 7
- Why better is sometimes worse
- Prediction vs. explanation

Problem Set 4 due before midnight on **Friday**

Week 7: Interactions

- Chapter 8
- Multiplicative vs. additive effects
- Interpreting interactions
- Plotting interactions

Problem Set 5 due before midnight on **Friday**

Week 8: MCMCs and GLMs

- Chapter 9-10
- What is integration and why is it so difficult?
- Simulating the posterior distribution
- Binary DVs

Problem Set 6 due before midnight on **Friday**

Week 9: GLMs II

- Chapter 11-12
- Count DVs
- Excess 0s
- Duration

Prior Justification due before midnight on **Friday**

Week 10: Multilevel Models I

- Chapter 13
- Why different levels?
- Varying intercepts

Problem Set 7 due before midnight on **Friday**

Week 11: Multilevel Models II

- Chapter 14
- Varying slopes
- Multilevel models vs. fixed effects

Problem Set 8 due before midnight on **Friday**

Week 12: Measurement Error I

- Chapter 15
- Missing data causes and solutions

Problem Set 9 due before midnight on **Friday**

Week 13: Measurement Error II

- Chapter 16
- When GLMs just aren't enough

Problem Set 10 due before midnight on **Friday**

Week 14: Modeling Decisions

- Problems with vagueness
- Choosing statistical approaches based on scientific models

- Justification of approaches

Initial Results due before midnight on **Friday**

Week 15: Presentations
Finals Week
Final Project due before midnight, Friday