MATH 6318.001
An Introduction to Bayesian Statistics
Department of Mathematics and Statistics
Fall 2019

A. COURSE INFORMATION

Course number/section: MATH 6318.001
Class meeting time: MW 2:00-3:15 pm
Class location: TBA
Course Website: bb9.tamucc.edu

B. INSTRUCTOR INFORMATION

Instructor: Dr. Blair Sterba-Boatwright
Office location: CI 370
Office hours: M 3:30-5:00; TTh 1-3:30
Telephone: 361-825-2724
e-mail: blair.sterbaboatwright@tamucc.edu
Skype: ber26nard
Appointments: Contact me by e-mail to set up an appointment

C. COURSE DESCRIPTION

This course is an introduction to Bayesian Statistics for scientists. Topics include: the Bayesian paradigm, along with advantages and disadvantages; brief coverage of necessary topics in probability and calculus; basics of Markov Chain Monte Carlo methods, including the Gibbs sampler and the Metropolis-Hastings algorithm; validating, comparing, and interpreting Bayesian models; and examples from literature relevant to student interests. The course assumes no prior exposure to calculus or programming.

Bayesian statistical models are used with increasing frequency across all areas of science. Even for scientists who do not intend to use Bayesian methods in their own work, it is necessary to be able to read and evaluate Bayesian analyses in the literature. This course will give students the tools to do simple Bayesian modeling on their own, as well as the foundation for more advanced models specific to their field.
D. PREREQUISITES FOR THE COURSE

MATH 6315, Statistical Methods in Research I, or the equivalent. Students with no previous background in the statistical package R should probably try to get some minimal experience with R before the start of the class. See under Software in the next section for more information about R.

E. REQUIRED TEXTBOOK(S), READINGS AND SUPPLIES

Required Textbook

Online Lectures by the Textbook Author
The author recorded his class meetings for the course he teaches from this book, much the way that I do, and has posted them on YouTube at https://www.youtube.com/playlist?list=PLDcUM9US4XdMD2ohJWJJD4mDBMnbTWw_z

These appear to be very much unedited; you can hear phones go off, doors squeak, etc. At the time of writing this, I have not had a chance to review these in depth, but in case you find these more useful than my lectures, FYI.

References
The above textbook is the most accessible text I’ve seen on Bayesian statistics for non-specialists, and uses many examples from biology. However, there are many common applications of Bayesian statistics to biology NOT covered in that book, plus additional topics in Bayesian statistics that may or may not prove important to you down the road.

• Textbooks about Bayesian statistics in general. While these are not specifically for mathematicians, they are at a higher mathematical level than our text:
  – Carlin, B. P. and Louis, T. A. (2009) Bayesian Methods for Data Analysis, 3rd edition. CRC Press. ISBN 978-1-58488-697-6. This is a classic textbook in the field. Although written at a fairly high technical level, the authors rely on references to the literature for nearly all the mathematical derivations. Includes examples using R and WinBUGS (see below FMI).
  – Gelman, A., et al. (2013) Bayesian Data Analysis, 3rd edition. CRC Press. ISBN 978-1439840955. Another classic, maybe the most cited authority outside the primary literature on Bayesian statistics. Doesn’t have the detailed examples of Carlin and Louis but covers far more topics.

• Textbooks and monographs on applications of Bayesian statistics to areas of potential interest to biologists/ecologists. Again, these are generally at a higher mathematical level than our textbook.
– Royle, J. A. and R. M. Dorazio (2008) Hierarchical Modeling and Inference in Ecology: The Analysis of Data from Populations, Metapopulations and Communities. Elsevier. ISBN 978-0-12-374097-7. I haven’t had the occasion to really use this book or King et al (2009) because I typically don’t work on these kinds of problems. However, Royle and Dorazio seems to be a standard reference for these types of analyses.

• I’m not as familiar as I could be with Bayesian applications to genetics, but the following paper is the original reference for the structure package and is relatively accessible:

• The next two papers describe the use of Bayesian statistics in stable isotope modeling:

Software
All items listed below are free and work on Windows, Macintosh and Linux platforms (although I have very little experience with the Linux versions).

• Required software: The most common general-purpose Bayesian statistical programs typically focus on computation without much effort towards graphing or interpreting the results. Therefore, the usual procedure is to employ a more comprehensive application such as R or Matlab as a user interface: information is sent by the comprehensive app to the Bayesian “engine”, which does the calculation and returns the results to the comprehensive app, where the results can be graphed, tested, etc. Our textbook is set up to use R as the comprehensive app, and Stan as the Bayesian engine. In addition, the textbook comes with an R package called rethinking, which is designed to take care of many of the details of using Stan until you become more experienced with using it. You can obtain the necessary software as follows:
- R: available from [http://cran.r-project.org](http://cran.r-project.org)
- rethinking: Start R, then, in the Console window, enter the following three commands:

```r
install.packages(c("coda", "mvtnorm", "devtools"))
library(devtools)
devtools::install_github("rmcelreath/rethinking")
```

- **Strongly recommended software:**
  - RStudio, available from [http://rstudio.com](http://rstudio.com) This is not required, strictly speaking, but is such a handy front end for R, particularly for Windows users, that I strongly recommend it.

- **Software you’ll see in the literature that we won’t be using:** Stan is the newest general-purpose Bayesian application. The oldest, and hence the one you’ll see most, is **BUGS** (Bayesian inference Using Gibbs Sampling). A similar, more recent application is **JAGS** (Just Another Gibbs Sampler). I prefer **JAGS**, both because it seems a little more powerful and because it installs and works on both Windows and Macintosh machines right out of the box, while **BUGS** is difficult to install and use on Macs. If you’re interested in using either of these, here are the links:
  - **BUGS**: the long-term stable version is called **WinBUGS** and is available at [www.mrc-bsu.cam.ac.uk/software/bugs/](http://www.mrc-bsu.cam.ac.uk/software/bugs/) while the actively developed version is called **OpenBUGS** and is available at [openbugs.net/w/FrontPage](http://openbugs.net/w/FrontPage). If you’re an R user, you’ll also want to get the **R2OpenBUGS** package for R.
  - **JAGS**: available from [http://mcmc-jags.sourceforge.net/](http://mcmc-jags.sourceforge.net/) If you’re an R user, you’ll also want to get the **rjags** and **R2jags** packages for R.

### F. STUDENT LEARNING OUTCOMES AND ASSESSMENT

Assessment is a process used by instructors to help improve learning. Assessment is essential for effective learning because it provides feedback to both students and instructors. A critical step in this process is making clear student learning outcomes that describe what students are expected to learn to be successful in the course. The student learning outcomes for this course are listed below. By collecting data and sharing it with students on how well they are accomplishing these learning outcomes students can more efficiently and effectively focus their learning efforts. This information can also help instructors identify challenging areas for students and adjust their teaching approach to facilitate learning.

By the end of this course, students should be able to:
1. conceptualize observational data as the result of a combination of stochastic processes, and build custom models for those processes
2. use R and Stan to create and calculate many standard statistical models, including regression and the generalized linear model
3. validate and interpret the resulting models using R
4. compare models to determine if one model is superior to another
5. summarize and critique Bayesian analyses from the literature

G. INSTRUCTIONAL METHODS AND ACTIVITIES

The course will use a mixture of lecture and demonstration by the instructor, as well as presentations by students based on the literature. Unless I forget, all classes will be recorded and links to the recorded versions posted on the course BlackBoard page for your convenience. It is vital that you inform me of any issue regarding your ability to access and use the recordings as soon as possible, so that we can address such issues.

H. MAJOR COURSE REQUIREMENTS AND GRADING

Learning outcomes 1-4 will be assessed using homework, while learning outcome 5 will be assessed using class presentations.

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<tr>
<th>ACTIVITY</th>
<th>% of FINAL GRADE</th>
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<tbody>
<tr>
<td>Homework</td>
<td>75%</td>
</tr>
<tr>
<td>Presentation</td>
<td>25%</td>
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</tbody>
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- Homework will involve computer-based analysis of ecological and biological datasets, plus appropriate writeups. Students submit HW electronically through BlackBoard, and are permitted to re-submit homework multiple times until the assignment is closed (see “Late Work” policy below).
- Students will choose a paper from the literature of interest to them that uses Bayesian analyses, and give a presentation to the class concerning the analysis. Students should attempt to replicate the analysis using Stan and the data used in the paper, or a similar dataset. The choice of paper is subject to instructor approval.

Based on the above, grades will be assigned according to the following scale:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Average</th>
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<tr>
<td>A</td>
<td>88-100</td>
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<tr>
<td>B</td>
<td>76-87</td>
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<tr>
<td>C</td>
<td>64-75</td>
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<tr>
<td>D</td>
<td>53-63</td>
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<tr>
<td>F</td>
<td>0-52</td>
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</tbody>
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I. COURSE CONTENT/SCHEDULE

I never take the amount of time I think I’ll take in covering topics, but here’s my best guess:

- Days 1-2: Intro material; review of probability from Stats I; a little Calculus; Chapter 1
- Days 3-4: Chapter 2
- Days 5-6: Chapter 3
- Days 7-9: Chapter 8 (← not a typo)
- Days 10-11: Chapter 4
- Day 12: Chapter 5—this is mostly about collinearity in multiple regression, not much different from Stats I/Stats II
- Days 13-14: Chapter 6
- Day 15: Chapter 7—again, this material covered in Stats II
- Days 16-17: Chapter 9
- Days 18-19: Chapter 10
- Days 20-21: Chapter 11
- Days 22-23: Chapter 12
- Days 24-25: Chapter 13
- Days 26-27: Chapter 14
- Day 28: If time permits, I’ll present a use of Bayesian analysis from the literature on a topic of interest to the class.
- Final exam period: Student presentations

Note: Changes in this course schedule will almost surely be necessary and will be announced to the class by the Instructor.

J. COURSE POLICIES

Attendance
All class meetings will be presented simultaneously live and via Webex. Students may rely on recorded versions rather than attending live, at their discretion, without prior notice to me.

Late Work and Multiple Submissions
On homework assignments, I will announce an official due date and time. However, students may continue to submit without penalty past that deadline until the answer key to that assignment is posted on BlackBoard. Once an answer key has appeared on the Blackboard site, no further late submissions are permitted.
Also, unless I announce otherwise, students are always permitted to resubmit HW assignments before the answer key is posted.

Any deadlines associated with the project will be “hard” deadlines and enforced with penalties on your grade.

Incompletes
A grade of I (Incomplete) will only be given in exceptional circumstances, such as a death in the family or personal injury that might prevent someone from taking the final test. In this case, it is the responsibility of the student to notify me as soon as possible, preferably by e-mail, and to complete the required “Incomplete Form” available from the University Registrar. If this is not done, a score of 0% will be assigned for any incomplete tests and a final grade will be computed using the criteria described above.

K. COLLEGE AND UNIVERSITY POLICIES

Academic Integrity (University)
University students are expected to conduct themselves in accordance with the highest standards of academic honesty. Academic misconduct for which a student is subject to penalty includes all forms of cheating, such as illicit possession of examinations or examination materials, falsification, forgery, complicity or plagiarism. (Plagiarism is the presentation of the work of another as one’s own work.) In this class, academic misconduct or complicity in an act of academic misconduct on an assignment or test will result in a failing grade.

Classroom/Professional Behavior
Texas A&M University-Corpus Christi, as an academic community, requires that each individual respect the needs of others to study and learn in a peaceful atmosphere. Under Article III of the Student Code of Conduct, classroom behavior that interferes with either (a) the instructor’s ability to conduct the class or (b) the ability of other students to profit from the instructional program may be considered a breach of the peace and is subject to disciplinary sanction outlined in article VII of the Student Code of Conduct. Students engaging in unacceptable behavior may be instructed to leave the classroom. This prohibition applies to all instructional forums, including classrooms, electronic classrooms, labs, discussion groups, field trips, etc.

Statement of Civility
Texas A&M University-Corpus Christi has a diverse student population that represents the population of the state. Our goal is to provide you with a high quality educational experience that is free from repression. You are responsible for following the rules of the University, city, state and federal government. We expect that you will behave in a manner that is dignified, respectful and courteous to all people, regardless of sex, ethnic/racial origin, religious background, sexual orientation or disability. Behaviors that infringe on the rights of another individual will not be tolerated.

Deadline for Dropping a Course with a Grade of W (University)
I hope that you never find it necessary to drop this or any other class. However, events
can sometimes occur that make dropping a course necessary or wise. Please consult with your academic advisor, the Financial Aid Office, and me, before you decide to drop this course. Should dropping the course be the best course of action, you must initiate the process to drop the course by going to the Student Services Center and filling out a course drop form. Just stopping attendance and participation WILL NOT automatically result in your being dropped from the class. Please consult the Academic Calendar [http://www.tamucc.edu/academics/calendar/] for the last day to drop a course.

**Grade Appeals Appeals (College of Science and Engineering)**

As stated in University Procedure 13.02.99.C2.01, Student Grade Appeal Procedures, a student who believes that he or she has not been held to appropriate academic standards as outlined in the class syllabus, equitable evaluation procedures, or appropriate grading, may appeal the final grade given in the course. The burden of proof is upon the student to demonstrate the appropriateness of the appeal. A student with a complaint about a grade is encouraged to first discuss the matter with the instructor. For complete details, including the responsibilities of the parties involved in the process and the number of days allowed for completing the steps in the process, see University Procedure 13.02.99.C2.01, Student Grade Appeal Procedures. These documents are accessible through the University Rules website at [http://www.tamucc.edu/provost/university_rules/index.html](http://www.tamucc.edu/provost/university_rules/index.html) and the College of Science and Engineering Grade Appeals webpage at [http://sci.tamucc.edu/students/GradeAppeal.html](http://sci.tamucc.edu/students/GradeAppeal.html). For assistance and/or guidance in the grade appeal process, students may contact the chair or director of the appropriate department or school, the Office of the College of Science and Engineering Dean, or the Office of the Provost.

**Disability Services**

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please call (361) 825-5816 or visit Disability Services in Corpus Christi Hall 116.

If you are a returning veteran and are experiencing cognitive and/or physical access issues in the classroom or on campus, please contact the Disability Services office for assistance at (361) 825-5816.

[http://disabilityservices.tamucc.edu/](http://disabilityservices.tamucc.edu/)

**Statement of Academic Continuity**

In the event of an unforeseen adverse event, such as a major hurricane and classes could not be held on the campus of Texas A&M University?Corpus Christi; this course would continue through the use of Blackboard and/or email. In addition, the syllabus and class activities may be modified to allow continuation of the course. Ideally, University facilities (i.e., emails, web sites, and Blackboard) will be operational within two days of the closing of the physical campus. However, students need to make certain that the
course instructor has a primary and a secondary means of contacting each student.

L. OTHER INFORMATION

Academic Advising
The College of Science & Engineering requires that students meet with an Academic Advisor as soon as they are ready to declare a major. The Academic Advisor will set up a degree plan, which must be signed by the student, a faculty mentor, and the department chair. Meetings are by appointment only; advisors do not take walk-ins. Please call or stop by the Advising Center to check availability and schedule an appointment. The College’s Academic Advising Center is located in Center for Instruction 350 or can be reached at (361) 825-3928.

GENERAL DISCLAIMER

I reserve the right to modify the information, schedule, assignments, deadlines, and course policies in this syllabus if and when necessary. I will announce such changes in a timely manner during regularly scheduled lecture periods.