

Bayesian Analysis for Machine Learning and Uncertainty Quantification

STA 6348 section BAML, course # 27943, 3 credit hours

Class Periods: T7 (1:55-2:45 PM), R7-8 (1:55-3:50 PM)

Location: 211 Rogers Hall

Academic Term: Fall 2022

Instructor:

Dr. Nikolay Bliznyuk

Email: nbliznyuk@ufl.edu

Phone: 352-392-1864 (only by prior appointment)

Office Hours: 239 Rogers Hall, times TBA

Teaching Assistant/Peer Mentor/Supervised Teaching Student:

Please contact through the Canvas website

- TBA

Course Description

This course emphasizes Bayesian methodology for modeling, inference and prediction using hierarchical/multilevel models, with particular emphasis on computation (Monte Carlo and its flavors) and applications (inference and prediction in models for regression and classification, potentially with various types of statistical dependence) as intended for Master's and doctoral students in data sciences and engineering. Core topics (that are used as building blocks) include specification of probability models (models for the data layer); subjective, conjugate, and noninformative prior distributions; hierarchical models; analytical and computational techniques for obtaining posterior distributions; model checking, model selection. Bayesian model averaging and other advanced special topics of importance to machine learning and uncertainty quantification in engineering will be covered as time permits.

Course Pre-Requisites / Co-Requisites

Prerequisites: (i) mathematical statistics emphasizing inference (e.g., PHC6092 or STA6327) and regression (e.g., STA6207) or (ii) a graduate course in machine learning with emphasis on probability/statistics or (iii) permission of the instructor. Knowledge of scientific/statistical computing (e.g., in R, Python or Matlab) and undergraduate mathematics (multivariate calculus and linear algebra) appropriate for a graduate student in data sciences will also be assumed. A pretest will be given on the first day of classes to determine if a student has the prerequisites met.

Course Objectives

- Learn the language of and the principles behind Bayesian analysis - modeling, inference and prediction
- Learn and be able to use R and/or Python to implement and apply different classes of MCMC samplers
- Perform Bayesian analysis with the help of JAGS and/or Stan (software) and their R/Python interfaces
- Establish command of methods through homework and a final project
- Reinforce the use of R as a statistical computing language for data science – for statistical inference, prediction, scientific computing and data visualization

Materials and Supply Fees

None

Required Textbooks and Software

- *Bayesian Data Analysis*
- Gelman, A., et al
- 2013, 3rd edition; CRC press
- ISBN 1439840954

R/Python languages and appropriate computing environments (e.g., R Studio/Anaconda) are freely available

Recommended Textbooks

- *Bayesian Reasoning & Machine Learning*
- Barber, D.
- 2012, 1st edition; Cambridge University Press
- ISBN 0521518148

Course Schedule

week	topic
1	Introduction to Bayesian statistics
2	Binomial model/priors. Normal model/computation
3	Independent binomials/normal. Multinomial/multivariate normal
4	Data asymptotics
5	Binomial hierarchical model. Normal hierarchical model
6	Model checking
7	Hypothesis testing
	Spring Break
8	Bayesian computation
9	Monte Carlo – accept-reject sampling and importance sampling
10	Markov chains; Markov chain Monte Carlo
11	Metropolis-Hastings, Gibbs sampling
12	Bayesian regression and its flavors
13	Hierarchical linear and generalized linear (mixed) models
14	Bayesian Model Averaging
15	Advanced/special topics
	Project presentations

Advanced/special topics may include Bayesian nonparametrics, approximate Bayes, Gaussian Processes, graphical models, Bayesian networks, latent Dirichlet allocation, data augmentation and EM algorithm (listed in no particular order). Depending on the student backgrounds and interests in a given year, 1-2 weeks of lectures in the schedule above may be expedited or replaced by advanced/special topics from the above list.

Attendance Policy, Class Expectations, and Make-Up Policy

Attendance at all times is expected. Excused absences must be in compliance with university policies in the Graduate Catalog (<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance>) and require appropriate documentation. Make-ups are not allowed except for documented health, family emergency or work reasons.

Evaluation of Grades

Assignment	Total Points	Percentage of Final Grade
Homework Sets (approx. 4-5)	100 each	50%
Project	100	50%
		100%

Homework will be assigned regularly (approximately, biweekly). Project (requiring about 40 hours to complete) will consist of a proposal (10 pts), report (60 pts) and presentation (30 pts). Project details are provided in the Supplements at the end of the syllabus.

Grading Policy

Tentatively, the following grading scale will be adopted; grades may be curved to the advantage of students.

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33

83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.ua.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.ua.ufl.edu/public-results/>.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

University Honesty Policy

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

Campus Resources:

Health and Wellness

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: <http://www.counseling.ufl.edu/cwc>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.
<https://lss.at.ufl.edu/help.shtml>.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.ufl.edu/>.

Library Support, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.
<https://teachingcenter.ufl.edu/>.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers.
<https://writing.ufl.edu/writing-studio/>.

Student Complaints Campus: <https://care.dso.ufl.edu>.

On-Line Students Complaints: <http://www.distance.ufl.edu/student-complaint-process>.

SUPPLEMENTS: Project description

The project will emphasize creative application of the methods/knowledge developed in the course. Ideally, the application would be to your line of research and data (your own or of your immediate collaborators - advisor or fellow students). If you do not have suitable data, please check out the sources at the end of this description for the publicly available datasets. Otherwise, a good project could be a replication and extension of the results of a methodological paper of interest (select papers will be provided, or you may propose your own). "Creative application" does not allow merely running someone else's code without making other contributions. **Plagiarism is totally inappropriate and prohibited (just do not do it); it will result in a failing grade for the course. Course staff will run all project reports through UF Ithenticate. All work should be done individually (unless explicitly permitted by the instructor – for more ambitious projects).** *Projects already completed for other classes/causes are not acceptable. Example 1 - unacceptable: in a previous semester, a student wrote a paper for a journal or did a project for a different class, and now wants to submit it without major changes or additional relevant work as the class project. Example 2 – acceptable: in a previous semester, a student wrote a paper for a journal or did a project for a different class, but wants to do a major extension of the work using the techniques learned in this class. This would make a potentially very good project, but the student needs to be explicit about what is new and what not. Only the new work will constitute the course project in this case.* The project will be used to assess the knowledge and skills that students acquired in the course; for that reason, the work must be done individually and without assistance from the course staff.

Deliverables: a one-page proposal, a short technical report as described below, and a 10-12 minute presentation during the last week of classes followed by 3-5 minutes of questions.

Deadlines: (very tentative; will be revised appropriately each year)

(TBA; tentatively, 01-Nov): submit your proposal by email to nbliznyuk@ufl.edu if you are planning to complete the optional project, so that we can meet on Thursday during the class time (individual slots TBA after your proposals have been received).

(TBA; tentatively, last week of classes): in-class project presentations (if appropriate)

(TBA; tentatively, 10-Dec): final report (in pdf format, accompanying code and the actual data that you used, if using a publicly available source; put all in a folder named after you and create a zip or rar archive; test archive before submitting), submit using Dropbox file request (same link as above): tinyurl.com/nbliznyuk-submit-files

Expectations for the proposal (1 page):

The main goal behind the proposals is to ensure that the projects are neither too simple nor too ambitious (i.e., will require about 40 hours to complete – loosely, an equivalent of 4-5 weeks of homework effort, where writing will play a significant role), there is no duplication among students and that you have the necessary relatively clean data to analyze. Please specifically discuss what you propose to do (e.g., “big picture” and specific methods), why you focus on this particular problem (significance, motivation and relevance to the course) and available data (specifically, what are primary response variable(s) and features, what are n and p , etc). Your project should be “shovel ready”, i.e., a bit of data preprocessing may be necessary but you should not be spending more than 20% (ideally, 10%) of your total time budget on cleaning and data manipulation. The typesetting format of the proposal should be the same as for the project (please read below).

Expectations for the report (8 pages):

Report should be organized as a short paper appropriate to your field; e.g., a short abstract (100 words), intro (including motivation), background and data, methods, analysis/results, conclusions/discussion. *Any software/languages/environments may be used for the project (i.e., not necessarily R).* The length is about 8 pages (not counting references, appendices or supplements) double-spaced, using 12 pt font: roughly 6 pages of text and 2 pages for your most essential tables and figures; **single-column only**. If necessary, the paper may have an Appendix with additional figures and tables. Data, code and other supplemental information should be made available as part of “Supplementary Materials” unless the data are confidential (please discuss “deliverables” in the proposal). Please check out the project evaluation rubric in a separate file.