Bayesian models of behavior

PSYCH-GA 3405
Spring 2021
Prof. Wei Ji Ma

This syllabus is subject to change. Changes will be announced in class and by email.

COURSE DESCRIPTION

Bayesian inference is the mathematical framework for making optimal decisions and actions when the state of the world is not exactly known. This course will provide an intuitive yet mathematically rigorous introduction to Bayesian models of behavior in perception, memory, decision-making, and cognitive reasoning. While this is primarily a psychology course, we will also discuss connections to economics and neuroscience. This course is *not* about Bayesian statistics, but about theories that the brain itself is a Bayesian decision-maker. Nevertheless, we will spend some time on model fitting and model comparison.

LOGISTICS

People

Instructor: Prof. Wei Ji Ma, weijima@nyu.edu
Teaching assistant: Dr Hörmet Yiltiz, hormet.yiltiz@nyu.edu

Schedule

Mon	16:00-18:00	Office hours	via Zoom: https://nyu.zoom.us/j/93106346435
Tue	12:00-13:45	Lecture	via Zoom: https://nyu.zoom.us/j/96842369769
Wed	16:00-18:00	Recitation	via Zoom: https://nyu.zoom.us/j/99973663725

You can also make an appointment with either of us. Besides the class, we are both happy to meet about broader academic issues, such as an interest in research that you might have, your next career steps, or concerns that you have.

First class Tue Feb 2, 2021

Last class Wed May 5, 2021

Materials

We will be using the book draft *Bayesian modeling of behavior*, by Ma, Kording, and Goldreich. This will be distributed in electronic form. For programming, we will in principle use Matlab (but if you prefer Python, we can talk about it). Make sure to install this before the first recitation. If you don't have access to a license, please contact Wei Ji.

Auditing

Auditing is allowed, but we cannot guarantee that we will give feedback on work that you submit. If you are at NYU, please request to be added to the NYU Classes site.

Feedback

Anonymous feedback can be left throughout the semester on this form. Weiji will reply.

COURSE POLICIES

Didactic philosophy of this course

Our starting assumption is that you are all intrinsically motivated to learn the course material. This assumption is justified because this is a graduate course (so grades don't *really* matter), it is an elective (so nobody forced you to take the course), and the material is not easy (you could probably have chosen an easier course). We see our job as instructors to nurture this intrinsic motivation rather than interfere with it by creating strong external rewards and penalties. In other words, we want you to learn as freely as is possible within the context of a formal academic course. In practice, this translates to two policies: one on not grading and unlimited resubmissions, and one on collaboration.

No-grades policy with unlimited resubmissions

We will use gradeless teaching (for background, see here and here). The goal is to shift the focus from grades to learning. Trying to get a high grade is often not aligned with gaining understanding of and maintaining intrinsic motivation for the material.

Homework sets
In total, you will have to complete 40 homework problems across 11 homework sets. There will be a total of more than 40 problems to choose from. You will be evaluated on the proportion of problems (out of 40) that you complete to a satisfactory standard. Each homework set will have an initial and a final due date. You are allowed to make your initial submission after the initial

due date but that would give you less time before the final due date. Once the initial due date has passed, the TA will start reading the submissions. He will give you content feedback, often in the form of hints. You may resubmit incomplete problems as often as you like before the final due date, which will be four weeks after the initial due date. When you complete a problem to a satisfactory standard, we will inform you.

Project assignments and presentation
You will work on the project in the last part of the course. We will break down the work into assignments, such as finding a topic, finding relevant papers, identifying the simulations you will do, etc., all the way up to submitting a draft of your presentation slides. These assignments have to be completed before the project presentation. The instructors will give you feedback on your assignments and you will have unlimited opportunities to revise your work accordingly, but you have to do so before the presentation. Once each assignment is complete, and you give the actual presentation, your project presentation will be complete.

Project paper
The project paper has an initial and a final due date. The initial due date is April 28 and the final due date is May 12. You are allowed to make your initial submission after the initial due date but that would give you less time before the final due date. You will receive feedback on your initial submission. You may then resubmit the paper as often as you like before the final due date. If the project paper is a complete and accurate description of what you did in the project, and you incorporated our feedback in your final submission, your project paper will be complete.

Course grade
We will calculate an overall completion score between 0 and 1 based on completion of the components of the course, with the following weights:

Proportion of completed homework problems	65%
Project presentation complete (0 or 1)	15%
Project paper complete (0 or 1)	20%

Your overall completion score will be multiplied by 100, rounded to the nearest integer, and turned into a letter grade for the course as follows: 93-100 A; 90-92 A-; 87-89 B+; 82-86 B; 79-81 B-; 76-78 C+; 71-75 C; 68-70 C-; 65-67 D+; 60-64 D; 0-59 F.

Collaboration policy

Collaboration on all assignments is allowed. It's even ok to hand in the same homework if you worked on it together (in that case, please put both your names on it). However, in order to really understand the material, we strongly encourage you to work individually as much as you can. This could mean struggling for hours on a single problem, but that is often the best way to learn. If you are stuck and are working together with a classmate, it's best to ask for a hint rather

than for the solution. (Of course you can also submit incomplete work, get a hint from the TA, and resubmit.)

Recitation

Recitation serves multiple purposes: 1) recapitulate and clarify the material from the lecture; 2) do practice problems; 3) discuss homework problems after the final deadline (if needed); 4) open forum for questions and thoughts related to the course material -- you can for example bring up your own research or a paper you read.

Disability Disclosure Statement

Academic accommodations are available for students with disabilities. The Moses Center website is www.nyu.edu/csd. Please contact the Moses Center for Students with Disabilities (212-998-4980 or mosescsd@nyu.edu) for further information. Students who are requesting academic accommodations are advised to reach out to the Moses Center as early as possible in the semester for assistance.

Pandemic accommodations

All lectures and recitations will be recorded and will be available through NYU Classes for the duration of the semester. Attendance is not required.

DETAILS OF ASSIGNMENTS

Homework assignments

- All submissions must be through NYU Classes.
- All text answers should be typed (no handwriting), including equations. For equations: LaTeX is a free, recommended typesetting software that allows for beautiful equations; often, it is used on the collaborative online platform Overleaf. In Word, you can use Equation Editor for Word (free, but cumbersome), or Mathtype (not free). Please do not submit in-line (ASCII) equations - you would make the TA very unhappy.
- Insert plots into your homework instead of submitting them as separate files. Please convert to PDF before submitting. Name the PDF with the homework number, your full name and the resubmission revision (starting from 1), e.g. “HW1_fullname_vN.pdf”.
- If a problem involves Matlab coding, please submit your Matlab code as separate files. Make sure that the code runs without errors!

Project

- In the class project, you will develop a Bayesian model yourself. Allowable topics:
    - Variant or elaboration of a task from class

    - Data set or qualitative phenomenon from your own or someone else's research (or from a published paper). Simulations-only is fine.
    - Proposal for a new project
- What do you have to do?
    - Mathematically develop the details of the model.
    - Perform numerical simulations.
    - Characterize behavior, examine effects of parameters.
    - Optional: fit data, compare models.
    - Optional: collect your own data, then fit them and/or compare models.
    - A full written report (5 to 6 pages, 1.15-spaced), including Abstract, Introduction (2-3 paragraphs), Method, Results, and Discussion (2-3 paragraphs). Please format your report following CCN 2019 author's guides.
    - Presentation during the last week
- Constraints:
    - Restrict yourself to something manageable: not too much, not too complicated.
    - There has to be some "new" math (that we did not do in class).
    - To make Bayesian models most relevant, choose a well-controlled task with well-controlled stimuli.
    - Own data collection is not necessary, and might be a lot of work relative to the benefits, so is not encouraged.

SCHEDULE

Day	What	What is due (initial due dates)	Topic
Tue Feb 2	Lecture 1		Chapter 1: Uncertainty and inference in perception and cognition. Illusions.
Wed Feb 3	Lecture 2		Chapter 2: Using Bayes' rule for inference
Tue Feb 9	Lecture 3	Homework 1	Chapter 3: Bayesian inference under sensory noise: Steps 1 and Step 2
Wed Feb 10	Recitation		
Tue Feb 16	Lecture 4	Homework 2	Chapter 4: Step 3: The response distribution
Wed Feb 17	Recitation		

Tue Feb 23	Lecture 5	Homework 3	Chapter 5: Cue combination, evidence accumulation, and learning
Wed Feb 24	Recitation		
Tue Mar 2	Lecture 6	Homework 4	Chapter 6: Discrimination and detection. Link with signal detection theory.
Wed Mar 3	Recitation		
Tue Mar 9	Lecture 7	Homework 5	Chapter 7: Binary classification. Marginalization. Ambiguity.
Wed Mar 10	Recitation		
Tue Mar 16	Lecture 8	Homework 6	Chapter 8: Model fitting and model comparison
Wed Mar 17	Recitation		
Tue Mar 23	Lecture 9	Homework 7	Chapter 9: Ambiguity due to a nuisance parameter. Some color perception.
Wed Mar 24	Recitation		
Tue Mar 30	Lecture 10	Homework 8, project ideas	Chapter 10: Sameness judgment and perceptual organization
Wed Mar 31	Recitation		
Tue Apr 6	Lecture 11	Homework 9, project proposal	Chapter 11: Two-alternative forced choice and visual search
Wed Apr 7	Recitation		
Tue Apr 13	Lecture 12	Homework 10, project formalism	Chapter 12: Inference in a changing world
Wed Apr 14	Recitation		
Tue Apr 20	Lecture 13	Homework 11, project results	Chapter 13: Combining inference with utility (or psychology with economics)
Wed Apr 21	Recitation		*Work on projects*
Tue Apr 27	Lecture 14	Project results	Chapter 15: The neural implementation of Bayesian inference
Wed Apr 28	Recitation		*Work on projects*
Wed Apr 28	--	Project paper	Initial due date

Tue May 4	Presentations 1		
Wed May 5	Presentations 2		
Wed May 12	--	Project paper	Final due date.