Bayesian modeling of behavior
Fall 2017
Wei Ji Ma

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

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 data analysis, but about theories that the brain itself is a Bayesian decision-maker. Nevertheless, we will spend some time on model fitting and model comparison.

Prerequisites

- Strong command of Calculus 1 or equivalent
- Introductory course in probability or probability-based statistics.
- Ability to code in Matlab. If you have not coded in Matlab before, you will be ok if you have other programming experience and do a tutorial before the course starts.

Email Wei Ji if you have any questions about prerequisites.

Lecturer

Prof. Wei Ji Ma, weijima@nyu.edu, 212 992 6530

Weekly schedule

Lecture	Wednesdays, 4-6 pm	Meyer 815
Recitation	Thursdays, 2-4 pm	Meyer 815
Office hours	By appointment	Meyer 754 (Wei Ji's office)

Materials

- *Bayesian modeling of perception*, by Ma, Kording, and Goldreich. Will be distributed in electronic form.
- You will need Matlab. If you have a laptop, please install Matlab on it before the course starts. Instructions for if you are on the Meyer building network: http://localweb.cns.nyu.edu/unixadmin/#august10-2015.

Grading
The total grade will be calculated as follows:

Best 8 of 11 homework sets	55%
Project	30%
Participation	15%

Letter grade
Your numerical grade will be turned into a letter grade according to the following scale: 90-100 A; 87-89 A-; 84-86 B+; 80-83 B; 77-79 B-; 74-76 C+; 70-73 C; 67-69 C-; 64-66 D+; 60-63 D; 57-59 D-; 0-56 F.

Homework

- There will be 11 homework sets. The lowest three homework grades will not be counted.
- Homework is due at 4 PM on Wednesday, through NYU Classes → Assignments. Late homework will not be accepted by the system and will count as 0. No extensions for any reason.
- How to submit:
    - All text answers should be typed (no handwriting).
    - Equations: LaTeX is a free, recommended typesetting software that allows for beautiful equations. In Word, you can use Equation Editor for Word (free, but cumbersome), or Mathtype (not free). Do not submit in-line (ASCII) equations.
    - Insert plots into your homework instead of submitting them as separate files. Convert to PDF before submitting. Name the PDF with the homework number and your last name, e.g. "HW1_Ma.pdf".
    - If a problem involves Matlab coding, submit your Matlab code as separate files. Make sure that the code runs without errors!
- We will not provide answer keys. However, we will discuss any homework problem in recitation upon request.

Policies on collaboration and cheating

- You are expected to work on these homework assignments independently. If you are stuck on a problem: Try your best first – this could mean struggling for hours, but that is often the best way to learn. If you are still stuck, the preferred method is to contact Wei Ji for help.
- If you ask a classmate for help after trying hard yourself, then you must indicate on your homework whom you worked with on what. You will not be penalized for learning with your peers. We ask that you say who you worked with for two reasons: 1) Honesty. 2) We want to know what material is difficult so we can spend more time helping you learn. If you relied on a peer for a challenging question then we want to make sure that you understand the material before test time.

- Under no circumstances should you copy a classmate's answer, even if you modify it slightly. Copying someone else's work is cheating, is easy to detect, and will yield a grade of 0.
- If someone asks you for help on the homework: do not give them your answer – this is cheating and will yield a grade of 0. First, make sure that the person you are helping has tried their best on the homework. You will only hurt them come exam time if you just handed them the answers all semester. Second, explain how you got started and how you thought about the problem. If you can help someone learn that way, that is impressive.

Project

- In the class project, you will develop a Bayesian model yourself.
    - 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
    - Written report (5 to 6 pages, 1.15-spaced)
    - Presentation during last week
- 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)
    - Proposal for a new project
- Constraints:
    - Restrict yourself to something manageable: not too much, not too complicated.
    - There has to be some math that we did not do in class.
    - Choose a well-controlled task with well-controlled stimuli.

Participation

- Attendance is mandatory. Your participation grade will be based on attendance, as well as on participation during lecture and recitation.
- To request an excused absence, please email Wei Ji in advance.

Schedule

Day	What	What is due	Topic
Wed Sep 6	No lecture!		*Conflict with Cognitive and Computational Neuroscience conference*
Thu Sep 7	Lecture 1		Why Bayesian inference? Uncertainty in perception, cognition, and decision-making
Wed Sep 13	Lecture 2	Homework 1	Probability and probability distributions; noisy internal representations
Thu Sep 14	Recitation		
Wed Sep 20	Lecture 3	Homework 2	Three steps of Bayesian modeling: Combining a measurement with a prior
Thu Sep 21	Recitation		
Wed Sep 27	Lecture 4	Homework 3	Understanding Bayesian models: What can go wrong. Optimality. Bias.
Thu Sep 28	Recitation		
Wed Oct 4	Lecture 5	Homework 4	Cue combination, evidence accumulation, and learning.
Thu Oct 5	Recitation		
Wed Oct 11	Lecture 6	Homework 5	Discrimination and detection. Link with signal detection theory.
Wed Oct 12	Recitation		
Wed Oct 18	Lecture 7	Homework 6	Binary classification. Marginalization. Ambiguity
Thu Oct 19	Recitation		
Wed Oct 25	Lecture 8	Homework 7	Model fitting and model comparison
Thu Oct 26	Recitation		
Wed Nov 1	Lecture 9	Homework 8	Ambiguity due to a nuisance parameter. Plus some color perception.
Thu Nov 2	Recitation		
Wed Nov 8	Lecture 10	Homework 9	Sameness judgment and perceptual organization
Thu Nov 9	Recitation		
Wed Nov 15	Lecture 11	Homework 10	Two-alternative forced choice and visual search
Thu Nov 16	Recitation		
Wed Nov 22	No lecture!	Homework 11	*Thanksgiving break*
Thu Nov 23	No lecture!		*Thanksgiving break*
Wed Nov 29	Lecture 12		Inference in a changing world
Thu Nov 30	Recitation		*Work on projects*
Wed Dec 6	Lecture 13		Combining inference with utility (or psychology with economics)
Thu Dec 7	Recitation		*Work on projects*
Wed Dec 13	Lecture 14		Neural basis of Bayesian inference
Thu Dec 14		Presentation	*Project presentations*
Fri Dec 15		Project report	