Mathematical Tools for Neuroscience (NEU 314)
Spring Semester, 2016

Time: Tues/Thurs 10:00-10:50am.
Location: NEU A02.

Instructor: Jonathan Pillow (pillow at princeton).

AIs: Adam Charles (adamsc at princeton).
                Alex Piet (piet at princeton).
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Description: This course aims to provide a comprehensive introduction to the mathematical and computational tools used for analyzing neural systems and neural data. The course will introduce students to topics in linear algebra, differential equations, and probability & statistics, with a heavy emphasis on applications to neurobiology. Coursework will focus primarily on problem sets requiring the implementation of various analyses and models in Matlab. The course will seek to give students both a good intuitive understanding and a practical mastery of various mathematical and computational methods, and equip them with programming and data visualization skills that are increasingly important to scientific inquiry in general, and neuroscience in particular.

Topics include:

I.   **Linear Algebra & Least Squares** (5 weeks) Vectors and matrices, orthogonality, linear projection, span, basis, vector spaces, singular value decomposition, least-squares regression, principal components analysis, linear discriminants.

II.   **Probability & Statistics** (5 weeks) Basic probability, estimation, Bayes' theorem, bias/variance, optimization, bootstrapping, cross-validation, Poisson process, generalized linear models, information theory, Bayesian inference.

III.   **Dynamics and Dynamical Systems** (3 weeks). ordinary linear differential equations, fixed points, limit cycles, stability analysis.

FORMAL STUFF

Prerequisites: Good working knowledge of calculus and high school math topics (e.g., a friendly relationship with log, exp, cos, sin, etc.). Some programming experience is helpful but not required. Matlab programming will be introduced in the early lab sessions.

Format: The course consists of two 1-hour lectures per week, and a 3-hour computer lab problem session per week. The course includes a sequence of homework assignments primarily in the form of computer programming exercises. These are essential for learning the material.

Texts: There is no textbook. Students new to Matlab may benefit from <u>Matlab for Neuroscientists, by Wallisch et al</u>. Lewis library will have two copies of this book on reserve. Supplementary reading materials will be posted on the course website.

Requirements: Take-home problem sets, approximately 1 per week, each due one week after it's assigned. There is no final (or other) exam.

Homework: Homework problem sets will involve a mix of programming assignments and paper-and-pencil math problems (with the balance tilted heavily toward the former). The goal of these assignments is to force students to put the mathematical concepts from class into practice. I firmly believe that one learns best by doing (in life, as well as in math). You will often think you understand a concept intuitively, but the act of trying to implement it or use it for some practical purpose exposes gaps in your understanding. Many of the scripts and functions you write will also serve as prototypes for real data analysis problems you will face in future research (or "in life", one never knows!). For non-programming problems, I encourage students to use LaTeX or an equation editor, but hand-written solutions are also perfectly fine. For programming assignments, we will provide a formatting template that will make evaluation and grading easier for the AIs.

Labs: There are three weekly lab sessions (T 7:30-10:20, W 1:30-4:20, Th 7:30-10:20). The primary focus of lab sessions will be to work on problem sets. The AI will begin each session with a brief overview and field any questions about lecture material. There will often be warm-up problems, but otherwise you are free to work on homework problem sets, individually or in collaboration with other students. There will be no writeup or additional assignments associated with labs, but attendance is mandatory: this is your chance to get to know fellow students and to get 1-on-1 help from the AI. Feel free to bring your own laptop.

Attendance: attendance will be taken at lab sessions, and count towards the 5% participation grade.

Grading: Each problem will be assigned a maximum number of points and graded on a scale from 0 to the maximum. Your grade for the homework is the total of graded points summed across all problems in all problem sets. Grades are based 95% on your homework grade, and an additional 5% will come from attendance and participation.

Collaboration and Academic Integrity: You are welcome to work together on problem sets (I would even encourage it), but the work you submit should be uniquely your own, prepared by your own hand. Students should understand every step in their code such that they could implement it again from scratch without help from anyone.

RESOURCES

Piazza: We encourage all students to post questions to piazza instead of sending email. This will allow others to benefit from your question, and will often result in a faster and more complete answer (since your fellow students may post answers before any of the instructors can). Please participate on piazza, and endorse questions and answers as you see fit. Piazza activity will count toward the 5% participation grade!

> Course piazza page: piazza.com/princeton/spring2016/neu314/home
> Piazza course signup link: piazza.com/princeton/spring2016/neu314

Course website: http://pillowlab.princeton.edu/teaching/mathtools16/
For now, I'm also maintaining a course website here, where I'll (probably) post lecture notes and supplementary reading materials. (Let's see—if piazza is as great as everyone says then maybe we won't need it.)

Matlab: If you have a laptop and don't have MATLAB on it, visit http://www.princeton.edu/software/licenses/software/matlab/index.xml. This has instructions on how to download, install and run MATLAB. Keep in mind that this requires the user (i.e., you) to have a valid Princeton University account (It is often the same login as your princeton.edu email).

Computing Support (worth knowing about!)**:** The OIT Help Desk is open 24 hours a day, seven days a week, to help you with your computing questions. You can reach the Help Desk at http://www.princeton.edu/helpdesk, via phone at 609-258-HELP(4357), e-mail at helpdesk@princeton.edu, or chat from the OIT home page http://www.princeton.edu/oit .