**Statistical Modeling and Analysis of Neural Data (NEU 560)**
**Syllabus, Fall 2020**

**Time:** Tues/Thurs 10:00a-11:20p.
**Location:** online

**Instructor:** Jonathan Pillow (pillow at princeton).
Office hours: by appt.

**AI:** Orren Karniol-Tambour (orrenkt at princeton).
Office hours: Tuesday, 9a-10a, and by appt.

**Course webpage:** [http://pillowlab.princeton.edu/teaching/statneuro2020/](http://pillowlab.princeton.edu/teaching/statneuro2020/)
**Piazza page:** [https://piazza.com/princeton/fall2020/neu560/home](https://piazza.com/princeton/fall2020/neu560/home)

**Description:**
This course aims to introduce students to advanced statistical and machine learning methods for analyzing of neural data, with an emphasis on methods derived from regression (supervised) and latent factor (unsupervised) models. Each technique will be illustrated via applications to neural datasets. The course will have a heavy emphasis on programming, and a substantial portion of the grade will come from homework assignments that involve writing python code to implement various statistical methods and apply them to data. The topics will focus on methods for the analysis of single and multi-neuron spike train data, calcium imaging, and fMRI datasets.

Sample topics to be covered:

- neural encoding models
- logistic regression
- generalized linear models
- Poisson processes
- regularization (ridge, lasso)
- empirical Bayes / evidence optimization
- information theory
- Gaussian processes
- mixture models and the EM algorithm
- PCA, factor analysis and its extensions
- Hidden Markov Models
- Kalman filter & linear dynamical systems (LDS)
- approximate inference methods (Laplace approximation, variational inference)
- variational auto-encoders (VAEs)

**Prerequisites:**
Calculus, Linear Algebra, and familiarity with basic ideas in probability / statistics (random variables, common probability distributions, mean, variance). No previous experience with
neural data is required. Programming experience in python is helpful given that homework assignments require programming.

**Format:**
This is a lecture course (2 x 80-min lectures per week), but students will be expected to keep up with course readings, homework, and to participate actively in class. I believe that the best way to learn mathematical concepts is by actively putting them to use. The majority of the grade will therefore be based on homework assignments, which will involve both programming (implementation of algorithms) and paper-and-pencil problem solving. Students will also complete a final project, alone or in collaboration with another student, and will make a 15-minute presentation on this project during the final portion of the course.

**Requirements:**
Homework will be assigned approximately every 2 weeks. Assignments should be sent to the AI by the stated due date. Late assignments will lose 10% credit per day late. Students are encouraged to work together on homework problems, but are expected to write computer code in groups of not more than two. In-class quizzes will take place once per week. There is no final exam.

**Grading:**
Grades for will be based on
- Homework: 60%
- Quizzes: 10%
- Participation: 10%
- Final project (presentation): 10%
- Final project (writeup): 10%

**Homework:** Homework problem sets will involve a mix of programming assignments and paper-and-pencil math problems (with substantially more of the former). The goal of these assignments is to force students to put the mathematical concepts from class into practice. I believe that writing a computer program to implement or test a mathematical concept provides a much deeper understanding than merely writing down an analytical derivation. Many of the functions you write will also serve as prototypes for data analysis problems you will face in real neuroscience research.

Homeworks will be submitted in the form a Jupyter notebook. (Students will use LaTeX markup within the notebook to answer to analytical / paper-and-pencil math problems). Each homework assignment will count equally, so the homework grade will be the average over all assignments.

**Quizzes:** Every Tuesday, class will begin with a 5-minute quiz about previous material. These quizzes should be easy for students who have followed recent lectures (or successfully completed previous homework assignments). The goal of these quizzes is to make sure students retain and have an active grasp of key concepts, without assistance from AIs or fellow students. Each student can drop their three lowest quiz scores.

Makeups will not be given; students who need to miss a class can simply count any missed quizzes among their lowest three.
**Course Projects:**
All students will complete a course project on some topic related to statistical modeling and analysis of neural data, which will count for 20% of the final grade. Students may work alone or in groups of two. I will provide a list of suggested topics / project ideas, but students are also free to come up with their own proposals based on course readings, problem sets, or their own interests. Example projects might involve the implementation and extension of a method discussed in class, or the application one of these methods to neural data. I will meet at least twice with all groups to approve project proposals, and to monitor progress and offer guidance / suggestions. A special session devoted to student presentations of their projects will take place during reading period (date TBA).

**Participation:**
Participation in real-time virtual class sessions, and online on Piazza is strongly encouraged. Your questions (and answers) will help both you and your fellow students. Students are expected to attend each scheduled class and to participate fully in-class exercises and discussions. Please have your video (with whatever background you prefer to use) turned on, unless you have an unexpected difficulty or have arranged with me otherwise.

**Text:**
There is no official textbook, but several reference texts will be placed on hold at the library (and pdf versions of the first two can be found online):

- *Analysis of Neural Data*. Kass, Eden & Brown

Lecture notes and supplementary reading materials will be posted on the course website.

**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 without hep 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 10% participation grade!

**Piazza signup page:** piazza.com/princeton/fall2020/neu560

**Python:** All homework assignments will require programming solutions in Python. To install Python, we recommend installing the Anaconda development environment, which contains Python and a collection of important / popular packages. We will be using Python 3 (not Python 2), so when you install Anaconda, choose that one (currently Python 3.8). Installing Anaconda will also Jupyter (interactive notebooks) and Spyder (a development environment).
**Computing Support:**

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](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](http://www.princeton.edu/oit).

**Internet issues**

Please consult this list of [Frequently Asked Questions](http://www.princeton.edu/helpdesk) for help with connectivity speed and Internet reliability. Tiger Speed is a new [website](http://www.princeton.edu/oit) OIT developed to help students, faculty, and staff measure their internet connection from off campus to Princeton. The site will also be accessible from the Blackboard and Canvas home pages. Students with slow internet connections should check these [tips on how to improve your speed](http://www.princeton.edu/helpdesk).