SYLLABUS FOR NBIO 228 (MATH TOOLS FOR NEUROSCIENCE)

Dates: WINTER QUARTER. Thursdays 12:30-2:30 PM in Fairchild D202.

General organization:

This course will consist of 3 main components: in-class lectures, problem sets, and a class project. There will be an optional problem set associated with every lecture. These problem sets will not be overly difficult or time-consuming but instead will (hopefully!) help you digest the material in a fun, painless, and efficient way. (The same goes for the lectures.) In general, there will be a minimal emphasis on coding, but we will try to make connections to numerical implementations and MATLAB functions that will assist in applying the lecture material to your research.

For the class projects, we envision that students will either: 1) pick a paper to work through and present (we will provide some potential paper options) or 2) use the methods discussed in class to analyze a dataset. This dataset can be provided by the student, or the course instructors - just let us know what you want to practice your math tools on! The main goal for the class projects is simply to give everyone a chance to practice their new favorite analytical tool in a fun and useful way - beyond that, we are quite flexible. Grades will be based on some combination of participation and class project.

We hope to make this course both super fun and super useful - especially for those who want to up their data analysis/modeling game (or apply more quantitative techniques to their science) but haven't taken many math courses beyond calculus. Feel free to email the instructors: Lane McIntosh (lmcintosh@stanford.edu) and Kiah Hardcastle (khardcas@stanford.edu) if you have any questions!

Schedule:

1. **Week 1 (1/5): Linear Algebra** (LM)
    - 1.1. Vectors, matrices, and geometrical interpretations of matrices
    - 1.2. Inner and outer products
    - 1.3. Matrix factorization
2. **Week 2 (1/12): Linear Algebra II** (LM, KH)
    - 2.1. Developing an intuition for eigenvalues and eigenvectors
    - 2.2. matrix decompositions continued
3. **Week 3 (1/19): Linear Algebra III** (KH)
    - 3.1. PCA
4. **Week 4 (1/26): Fourier Transforms** (LM)
    - 4.1. What it means to decompose a function into its sine and cosine components
    - 4.2. Linear filters, filtering signals, decomposing, convolutions

5. **Week 5 (2/2): Dynamical Systems** (KH)
    5.1. Analytical, qualitative, and numerical solutions to 1D linear and nonlinear ODEs
    5.2. Examples: population growth models, spiking single neuron models
6. **Week 6 (2/9): Model fitting Part 1** (KH)
    6.1. Introduction to statistical models; classification and prediction
    6.2. Principles of optimization, overfitting, data/parameters ratio, local minima
7. **Week 7 (2/16): Model fitting part II** (LM)
    7.1. Statistical models continued
    7.2. linear classifiers and SVMs, primer on neural networks
8. **Week 8 (2/23): Project proposals are due; no class (COSYNE conference)**
9. **Week 9 (3/2): Statistics** (KH)
    9.1. Formalizing concepts of variance, standard error, significance, covariance matrix
    9.2. Thinking outside the t-test and applying non-standard statistical tests (eg bootstrapping)
    9.3. How to create a statistical test from scratch
10. **Week 10 (3/9): Probabilistic Thinking** (LM)
    10.1. What is a prior? A posterior? Bayesian probability
    10.2. Topics on information theory (entropy, information)
11. **Week 11 (3/16): Oral presentations; written presentations due today**