Biology 4/510: Analysis of Neural Data

University of Oregon, Spring 2023

Lecture: Tue/Thu, 12:00 - 1:15pm, VOL 101
Discussion: Mon, 4:00 - 5:15pm, MCK 347 in CLSS
Instructor: James Murray (jmurray9@uoregon.edu)
Instructor office hours: Tue, 3:00 - 4:50pm, M443 Knight Campus
Teaching assistant: Danny Burnham (dburnham@uoregon.edu)
Teaching assistant office hours: Wed, 1 -2pm, 450 Knight Campus

Description: This course will focus on developing basic tools and techniques from probability, statistics, and scientific computation that are useful in data analysis, applying these techniques to the analysis of data from publicly available neuroscience datasets.

Prerequisites:

- Coding. The homework assignments for this course will be done in Python. While previous experience with coding in Python or a similar coding language will make this course easier, it is not strictly required. Students who are new to coding in Python should plan to invest some extra hours of work during the early weeks of this course. Links to introductory tutorials online will be provided.
- Math. No prior background in probability or statistics is assumed. The course will make some use of basic calculus, so Math 246 or 251 or a similar introductory calculus course are prerequisites.
- Neuroscience. It will be assumed that students have taken a course in neuroscience previously and are familiar with basic facts about neural circuits, e.g. what spikes and firing rates are. It is recommended that students who don't have any neuroscience background but are eager to learn about it should discuss their situation and possible additional reading materials with the instructor during the first week of class.

Textbook: Analysis of Neural Data by R. Kass, U. Eden, and E. Brown (referred to as KEB in sections below). The UO library provides free access to a PDF version of the book. There are also a limited number of copies available at the campus bookstore.

The above textbook contains all the material needed for the course. However, because textbooks vary in their level of detail and mathematical rigor and balance between practical examples vs. mathematical exposition, some students may find additional resources useful. The following textbooks cover most of the topics that are covered in this course, though none of them focuses on neuroscience:

- An Introduction to Statistics with Python with Applications in the Life Sciences, by Thomas Haslwanter
- An Introduction to Statistics and Data Analysis, by Ott and Longnecker
- Probability and Statistics for Engineering and the Sciences, by Jay Devore

In addition to the main textbook, additional tutorials and resources on Python, mathematical background, and neuroscience background will be posted on the course's Canvas page.

Learning outcomes: By the end of this course, students will have obtained the following skills:

- Using Python for scientific computing.
- Understanding and applying concepts from statistics that make it possible to draw conclusions about patterns and relationships in data, as well as to quantify the degree of confidence about these conclusions.
- Performing standard analyses on recordings of neural activity and behavior from neuroscience experiments.
- Proposing questions about relationships between neural activity and behavior and formulating approaches for answering these questions quantitatively and presenting the results clearly.

Schedule: The following schedule of topics to be covered is approximate and may be subject to modification:
Week 1:
- Lecture: Intro to neural data analysis (KEB Ch.1); Intro to probability (KEB Ch. 3.1)
- Lab: Intro to Python, part 1

Week 2:
- Lecture: Random variables (KEB Ch. 3.2); Multiple random variables (KEB Ch. 4.1-2)
- Lab: Intro to Python, part 2

Week 3:
- Lecture: Linear fits (KEB Ch. 4.2); Maximum likelihood (KEB Ch. 7.2)
- Lab: Probability and random vectors, part 1

Week 4:
- Lecture: Analyze paper led by instructor; Standard error and confidence intervals (KEB Ch. 7.3)
- Lab: Probability and random vectors, part 2

Week 5:
- Lecture: Analyze papers in small groups; Hypothesis testing and p values (KEB Ch. 10.3)
- Lab: Intro to final project datasets

Week 6:
- Lecture: Small-group paper presentations; Linear regression, overfitting (KEB Ch. 12.1, 12.4)
- Lab: Hypothesis testing and p values

Week 7:
- Lecture: Overfitting; classification with logistic regression
- Lab: Overfitting

Week 8:
- Lecture: Final project demonstration
- Lab: Classification

Week 9:
- Lecture: Dimensionality reduction with principal component analysis
- Lab: No lab (Memorial Day)

Week 10:
- Turn in final project; Final project presentations

Class format: This class will be held in person. Class time will involve blackboard lectures, interactive coding demonstrations, work by students in small groups, and presentations given by students on neuroscience papers and final projects. The coding demonstrations will be based on tutorial Python notebooks, which can be found on course Canvas page.

This course will also feature a weekly lab section. The main purpose of this section will be to give students additional practice and support with coding, particularly for those students who are new to it. In addition, this time may be used to interactively discuss homework assignments and final projects.

Homework: Homework assignments will be posted on the course Canvas page and will consist of a mix of pen-and-paper calculations together with implementations and applications of machine learning algorithms to real and synthetic data using Python notebooks. Homework assignments will be submitted via Canvas, and solutions to homework assignments will be posted to Canvas approximately one week after each assignment due date. Please do not share these solutions with anyone who is not currently enrolled in the class. Details about how to complete and turn in homework assignments can be found on the course's Canvas page.

During the term, each student will be granted a total of 7 days to be late on homework assignments. This means that one assignment may be turned in one week late without penalty during the term, or seven assignments may be turned in one day late, or any other combination. After the 7 days have been used up, late assignments will no longer be accepted and will receive a grade of zero.

Students are welcome and encouraged to discuss and work together on their homework assign-

ments in small groups. So that all students have a chance to participate, this works best in groups of 2-4 students. Each student must complete and submit their work independently, however, and under no circumstances should a student copy work directly from another student.

Expected classroom behavior: Students are expected to behave respectfully toward each other and toward the instructor during class time. This includes refraining from from using cell phones during lectures.

Evaluation:

- Homework (60%). Homework assignments are the most important component of this course and will consist primarily of writing code in the form of Python notebooks to analyze publicly available neuroscience data. Homework assignments will also feature some short mathematical exercises on topics that are covered during the lectures and in the reading. Homework assignments will include additional, more in-depth exercises that are required for graduate students enrolled in the course but are optional for undergraduates.
- Final project (40%). Students will perform a novel analysis on a publicly available dataset, write a short report (4-5 pages) on the results, and prepare a 7-minute presentation on their findings to present to the class. While each student will do their own analysis and prepare their own report and presentation, groups of students will be assigned to work on the same dataset and will be encouraged to discuss what they are doing with each other. Projects by graduate students enrolled in the course will be expected to be somewhat longer and more rigorous.

Grade policy: Final grades will be assigned as follows:

- A : 90.0%-100%. Excellent mastery of material, including well executed assignments largely free of errors and a clearly presented and well-thought-out final project.
- B : 80.0%-89.9%. Good mastery of most material, including mostly well executed assignments and final project despite some errors.
- C : 70.0%-79.9%. Adequate mastery of some or most material, including reasonable level of effort on assignments and final projects.
- D : 60.0%-69.9%. Poor mastery of material and/or failure to attempt completing some assignments.
- F : 59.9% and below. Quality of performance is unacceptable and/or failure to attempt numerous assignments or a final project.

with intermediate grades as in: B- = 80.0% to 82.9%, B = 83.0% to 86.9%, B+ = 87.0% to 89.9%.

Attendance: Attendance, while strongly encouraged, is not required for this course.

What follows is a general description of various University of Oregon policies, not specific to this course.

Academic Disruption due to Campus Emergency: In the event of a campus emergency that disrupts academic activities, course requirements, deadlines, and grading percentages are subject to change. Information about changes in this course will be communicated as soon as possible by email, and on Canvas. If we are not able to meet face-to-face, students should immediately log onto Canvas and read any announcements and/or access alternative assignments. Students are also expected to continue coursework as outlined in this syllabus or other instructions on Canvas. In the event that the instructor of this course has to quarantine, this course may be taught online during that time.

Academic Misconduct: The University Student Conduct Code, available at https://conduct.uoregon.edu, defines academic misconduct. Students are prohibited from committing or attempting to commit any act that constitutes academic misconduct. By way of example, students should not give or receive (or attempt to give or receive) unauthorized help on assignments or examinations without express permission from the instructor. Students should properly acknowledge and document all sources of information (e.g. quotations, paraphrases, ideas) and use only the sources and resources authorized by the instructor. If there is any question about whether an act constitutes academic misconduct, it is the students' obligation to clarify the question with the instructor before committing or attempting to commit the act. Additional information about a common form of academic misconduct, plagiarism, is available at `https://researchguides.uoregon.edu/citing-plagiarism`.

Accessible Education: The University of Oregon is working to create inclusive learning environments. Please notify me if there are aspects of the instruction or design of this course that result in disability-related barriers to your participation. You are also encouraged to contact the Accessible Education Center in 360 Oregon Hall at 541-346-1155 or `uoaec@uoregon.edu`.

Basic Needs: Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live and believes this may affect their performance in the course is urged to contact the Dean of Students Office (346-3216, 164 Oregon Hall) for support. This UO webpage includes resources for food, housing, healthcare, childcare, transportation, technology,finances, and legal support: `https://blogs.uoregon.edu/basicneeds/food`.

Inclement Weather: It is generally expected that class will meet unless the University is officially closed for inclement weather. If it becomes necessary to cancel class while the University remains open, this will be announced on Canvas and by email. Updates on inclement weather and closure are also communicated in other ways described here: `https://hr.uoregon.edu/about-hr/campus-notications/inclement-weather`.

Mental Health and Wellness: Life at college can be very complicated. Students often feel overwhelmed or stressed, experience anxiety or depression, struggle with relationships, or just need help navigating challenges in their life. If you're facing such challenges, you don't need to handle them on your own—there's help and support on campus.

As your instructor, if I believe you may need additional support, I will express my concerns, the reasons for them, and refer you to resources that might be helpful. It is not my intention to know the details of what might be bothering you, but simply to let you know I care and that help is available. Getting help is a courageous thing to do—for yourself and those you care about.

University Health Services help students cope with difficult emotions and life stressors. If you need general resources on coping with stress or want to talk with another student who has been in the same place as you, visit the Duck Nest (located in the EMU on the ground floor) and get help from one of the specially trained Peer Wellness Advocates. Find out more at `health.uoregon.edu/ducknest`.

University Counseling Services (UCS) has a team of dedicated staff members to support you with your concerns, many of whom can provide identity-based support. All clinical services are free and confidential. Find out more at counseling.uoregon.edu or by calling 541-346-3227 (anytime UCS is closed, the After-Hours Support and Crisis Line is available by calling this same number).