UC San Diego

COGS 118C: Neural Signal Processing (in Python)

Summer Session I 2019

Lecture: M-Th 2-3:20pm, CENTR222
Instructor: Richard Gao (rigao@ucsd.edu)
Office Hours: Friday, 11am, CSB 235

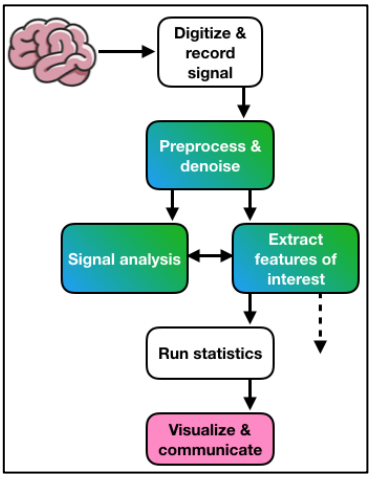
Lab: MW 3:30-4:30pm CENTR222
TA: Simon Niu (sniu@eng.ucsd.edu)
Office Hours: Thursday, 3:30pm, CSB 235

Course Websites

- All course material can be accessed from the GitHub course website [link].
- Assessments are submitted and grades posted on Gradescope [link: M7XNK3]
- All clarification questions and discussions should be posted on Piazza [link].

Texts and Other Resources

- Signal Processing for Neuroscientists – *Introduction to the Analysis of Physiological Signals* by Wim van Drongelen [download ink]
- Gross et al., 2014. *Journal of Neuroscience Methods* [download ink].
- **Software**: Anaconda (py3.7) and git (git terminal or Github Desktop)



+ Are you excited by the notion of controlling an exoskeleton with your brain signals?
+ Are you curious about the scientific pursuit of dissecting the neural basis of our minds?
+ Are you driven by creating consumer neurofeedback technologies that can improve our lives?
+ Or are you simply fascinated with decoding the brain as an extremely complex electrochemical system?

Learning how to analyze brain signals, as well as understanding their biological origins, are the first steps to accomplishing all of the above. Moreover, these methods are also **broadly applicable** to data such as sound waves (speech, music) and stock market fluctuations.

I. Course Objectives & Learning Outcomes

The overarching goal of this course is to prepare advanced undergraduate students for graduate studies and industry careers in (computational) neuroscience. Specifically, by the end of the course, students should acquire, in a **collaborative** fashion:

1. **Physiology**: knowledge of cellular and physiological processed involved in various neural signals (from action potentials to EEG).
2. **Theory**: mathematical understanding of signal processing algorithms.
3. **Coding**: a personal portfolio of Python programming toolboxes that demonstrates practical proficiency and application in neural signal processing.
4. **Critical thinking**: reading and communication skills to critique and present scientific findings centered on articles in neuroscience.

II. Course Content & Schedule

This course covers **theoretical** foundations and **practical** applications of neural signal processing. Topics center on methods for analyzing EEG/field potentials and spike trains. Some applications to neural imaging (microscopy, fMRI) will also be discussed. There will also be broad exposure to decomposition (PCA, ICA) and nonlinear techniques (dynamical systems, neural networks), as well as state-of-the-art methods from current computational neuroscience research. See visual roadmap on last page.

The course follows a backwards design: the objective is the final project and presentation. All labs and assessments are designed as hands-on building blocks of that deliverable, while lectures and discussions deliver that theoretical knowledge.

Week	Day	Date	Lecture	Topic
W1	M	1-Jul	L1	Introduction
	M	1-Jul	Lab1	**Tech Setup + Math Review + A0**
	T	2-Jul	L2	Neurophysiology & modalities
	W	3-Jul	L3	Time-series: sampling and ADC
	W	3-Jul	Lab2	**A1: time-series & epoch analyses**
	Th	4-Jul	HOLIDAY	
W2	M	8-Jul	L4	Epoch, averaging & trial-based analysis
	M	8-Jul	Lab3	**A1 + paper discussion**
	T	9-Jul	L5	Correlation & Convolution
	W	10-Jul	L6	Fourier analyses: FT, DFT, FFT
	W	10-Jul	Lab4	**A2: code your own Fourier Transform**
	Th	11-Jul	L7	Time-frequency analyses
W3	M	15-Jul	T1	Test 1
	M	15-Jul	Lab5	**paper discussion**
	T	16-Jul	L8	Filters & wavelets
	W	17-Jul	L9	Hilbert-based methods
	W	17-Jul	Lab6	**A3: code your own filter & Hilbert**
	Th	18-Jul	L10	Equivalence of kernel methods
W4	M	22-Jul	L11	Nonlinear TS methods ***
	M	22-Jul	Lab7	**paper discussion**
	T	23-Jul	L12	Spikes, physiology, and spike-LFP analyses
	W	24-Jul	L13	Spike train models
	W	24-Jul	Lab8	**A4: spike & LFP analyses**
	Th	25-Jul	L14	Population models & analyses
W5	M	29-Jul	T2	Test 2
	M	29-Jul	Lab9	**paper discussion**
	T	30-Jul	L15	Denoising and Statistical analyses
	W	31-Jul	L16	Other modalities ***
	W	31-Jul	Lab10	**Work period for project**
	Th	1-Aug	L17	Wrap-up
Finals	F	2-Aug	3-6pm	Final project presentation

III. Assessment Information and Due Dates

Pts	Assessment	Details	Due Date
5	A0: numpy, linear algebra & complex numbers	Getting comfortable with python, Jupyter, numpy and coding in general; math review	Tues 7/2 **11:59pm**
10	A1: time-series & epoch analyses	Getting familiar with working with & plotting time series; epoch-based analyses	Tues 7/9 **11:59pm**
10	A2: code your own Fourier Transform	Writing Fourier Transform from scratch	Sat 7/13 **11:59pm**
10	A3: code your own filter & Hilbert	Apply filtering & writing Hilbert Transform from scratch	Sat 7/20 **11:59pm**
10	A4: spike & LFP analyses	Moving closer to the final goal! Plus spikes	Sat 7/27 **11:59pm**
12.5	Test 1	Physiology, sampling theorem, Fourier properties	Mon 7/15
12.5	Test 2	More physiology, time-frequency properties, filter & Hilbert	Mon 7/29
20	Project + Presentation	See project rubric for detailed breakdown	Sat 8/3 **11:59pm**
7	Attendance	Literally just for showing up (0.5 per non-test lecture, 14 out of 16)	
3	Reading Questions	Submitting Qs for readings before class (1 for good question, 0.5 for bare minimum)	Sundays **11:59pm**
2	Peer Contribution	Freebie for helping peer with coding, good in-class contribution, Piazza answers, etc.	
2	SONA	Participate in SONA experiment. 1 credit per hour	
1	Rounded up if within 1 point of next boundary	More freebies	
105	Total		

There are 105 total points possible for this class (out of 100), several of which also have multiple tries (drop lowest). Tests and projects will also have internal bonus points.

A = 90-100% **B** = 80-89% **C** = 70-79% **D** = 60-69% **F** = 59%-below
Cutoffs: 90-92.9% for A-, 93-96.9% for A, 97-99.9% for A+; same for B to D.

All graded assessments will be returned within 3 days of the deadline (assignments and tests). Assessment feedback and grades can be discussed during TA and instructor office hours. Grades are not curved and no other bonus points will be assigned at the end of the course so **please do not negotiate for extra points at that time**.

Late submission policy: 0.8x compounding multiplier for every day an assignment is late by, and 0 if not received after grades are returned. For example, if you hand in an assignment 2 days past deadline, and scored 90% on it, you will receive a final grade of 90*0.8*0.8 = 57.6%. Late reading questions will receive 0 if submitted after discussion. See instructor to discuss special circumstances.

IV. Participation, Attendance, and Collaboration
This course is designed to be heavily collaborative: during lectures via activities and discussions, during labs via helping one another, and during the final group project. For this reason, points are awarded for lecture attendance, as well as for helping others and asking questions during class. Absences for medical reasons, personal emergencies, and sincerely held religious belief, observance, or practice may be accommodated after discussing with instructor. (See Academic Regulations and Policies)

While each person has to submit their own assignment solutions, you are encouraged to work together (without plagiarizing). Suspiciously similar assignment solutions (same variable names, code structure, comments, etc.) will be reviewed, and suspected offenders interviewed for clarification. If plagiarism is confirmed, all parties will receive 0 for that assignment and be reported to Academic Integrity. A good way to demonstrate independent work is to make regular commits to your git repository!

V. Recommended Prerequisites
Mathematics 18, 20A/B or 31AH
Cognitive Science 14B or Psychology 60
Cognitive Science 18, 108, or 109, or Computer Science equivalent

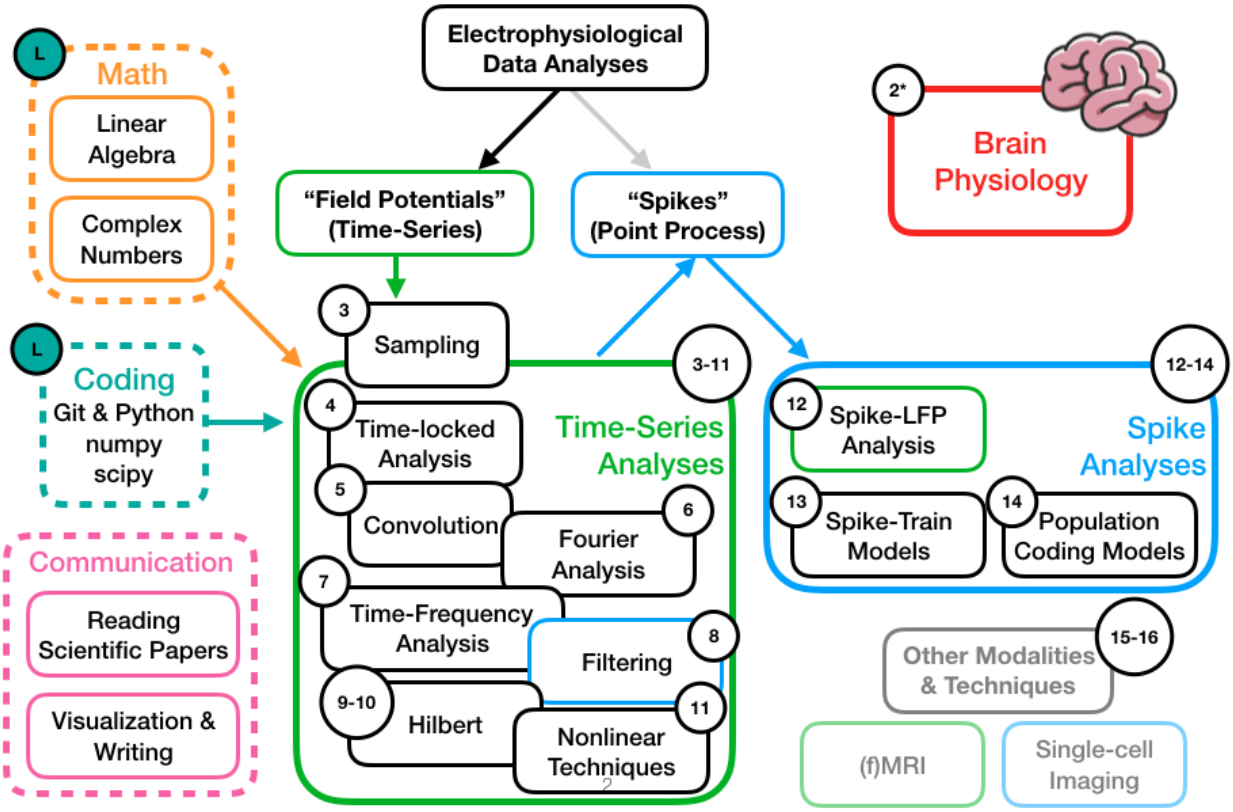
While all core concepts will be introduced from scratch, a good grasp of college-level calculus, linear algebra, complex numbers, Python/MATLAB programming, as well as introductory neurobiology is recommended.

Prerequisite requirements can be waived by the instructor, as assessed on a case-by-case basis. In general, we do not discourage students from taking courses that interest them. However, given the rapid pace of summer sessions and the integration of several advanced topics in this class, you will get much more out of it if you don't have to start the course playing catch-up.

VI. Diversity and Inclusion
It is my intent that this course is a positive experience for students from all diverse backgrounds and perspectives, and that all students feel welcomed and valued by our learning community. It is my intent to present activities and materials that are respectful of diversity: gender identity, sexuality, age, disability, race, ethnicity, language, religion, and culture. Your suggestions are encouraged and appreciated.

Please let me know of your learning needs so that I can meet them in class and/or help connect you with appropriate campus resources. **If you go by a name or use pronouns that differ from your official UCSD records, please let me know so that I can address you correctly.**

VII. Course Roadmap



VIII. Expectations and Agreement

I, the instructor, agree to:
+ Prepare lectures and activities that allow you to actively engage with course material.
+ Scaffold your learning through labs, lectures, and reading discussions.
+ Communicate to you what I know, and inform you when I do not know.
+ Foster a safe and open community in which all members are welcome and valued.
+ Allow ample time in class for questions, clarifications, and discussion.
+ Be accessible outside of class via office hours, email, and appointments. If you email me, you can expect a response within 24 hours (or by Monday if it's the weekend).
+ Communicate to and consult with you any changes to the syllabus and course.

By signing, you agree to:
+ Read the entire syllabus.
+ Participate in class and engage with me, your classmates, and course content.
+ Complete assignments in a timely manner.
+ Recognize when you are confused and seek clarification from me, your classmates, and/or outside resources.
+ Be respectful of your classmates at all times.
+ Keep me informed of your needs and concerns relevant to the course.
+ Follow UCSD's policy of academic integrity (see below).

Signature (Name): Jason Lin _____ Date: _____