PSYCH-GA 3405

Neural Network Models of the Mind & Brain

New York University
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Instructors

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Meeting schedule

Class time: 10-11:50am on Tuesdays
Class Location: Meyer 433

Materials

Journal papers will be assigned in class
Class Slack: https://join.slack.com/t/coursediscuss-tcx6125/shared_invite/zt-2xhlkuycx-gBMr04Y6qA4YO27mwTSveQ (join the **grad-neural-nets** channel)
Google doc for assignments: https://docs.google.com/document/d/1_SqDTImYQgHOPxvAz8I1R7bNSxfqRBA-HaJ4WcoRHfM/edit?tab=t.0
We will also use Brightspace

Overview

Artificial neural networks are computational models inspired by the basics of neurophysiology and now scaled to power the most advanced AI systems in the world. Neuroscientists have been using variants of these networks for decades to try to understand all aspects of neural information processing. This course will cover the background and current state of these network models in computational neuroscience. By the end of the course you should feel comfortable discussing how and why these models are used, what we can learn from them, and how to implement and work with them.

Course Structure

This course will involve lectures, interactive journal clubs, and coding-based research assignments. Each week covers a different topic in neuroscience/psychology and has an associated research paper. Unless otherwise noted, in the second half of each class, the instructors will introduce the necessary background needed to read the assigned paper. In the first half of the next class, we will have a group discussion on the assigned paper. This group discussion will be led by a pair of students who will also be charged with implementing and

extending the model used in the paper. We also aim to teach the “hidden curriculum” around neural network use. So while your goal will be to implement these models, your assignment, in part, will be to document the process of attempting that, including where things went wrong.

Course Schedule

Jan 21 - Intros. Background on neural networks. Students pick topics.
Homework: PyTorch tutorials
Jan 28 - Pytorch and Tensorflow overviews. Lecture on emotion.
Homework: Read paper 1 on emotion and submit questions
Feb 4 - Discussion/presentation of paper 1 on emotion. Lecture on olfaction.
Homework: Read paper 2 on olfaction and submit questions
Feb 11 - Discussion/presentation of paper 2 on olfaction. Lecture on vision.
Homework: Read paper 3 on vision and submit questions
Feb 18 - Legislative Monday
Feb 25 - Discussion/presentation of paper 3 on vision. Lecture on navigation.
Homework: Read paper 4 on navigation and submit questions
Mar 4 - Discussion/presentation of paper 4 on navigation. Lecture on audition.
Homework: Read paper 5 on audition and submit questions
Mar 11 - Discussion/presentation of paper 5 on audition. Lecture on episodic memory.
Homework: Read paper 6 on episodic memory and submit questions
Mar 18 - Discussion/presentation of paper 6 on episodic memory. Lecture on learning rules.
Homework: Read paper 7 on learning rules and submit questions
Mar 25 - Spring Break
Apr 1 - Discussion/presentation of paper 7 on learning rules. Lecture on decision making.
Homework: Read paper 8 on decision making and submit questions
Apr 8 - Discussion/presentation of paper 8 on decision making. Lecture on working memory.
Homework: Read paper 9 on working memory and submit questions
Apr 15 - Discussion/presentation of paper 9 on WM. Lecture on reinforcement learning.
Homework: Read paper 10 on reinforcement learning and submit questions
Apr 22 - Discussion/presentation of paper 10 on reinforcement learning. Lecture on language.
Homework: Read paper 11 on language and submit questions
Apr 29 - Discussion/presentation of paper 11 on language. Lecture on motor control.
Homework: Read paper 12 on motor control and submit questions
May 6 - Discussion/presentation of paper 12 on motor control. General discussion.

Papers:

1. **Emotion:** “An anatomically constrained neural network model of fear conditioning” https://psycnet.apa.org/record/1995-28155-001
2. **Olfaction:** “Evolving the olfactory system with machine learning” https://www.cell.com/neuron/fulltext/S0896-6273(21)00682-6
3. **Vision:** “Unsupervised neural network models of the ventral visual stream” https://www.pnas.org/doi/full/10.1073/pnas.2014196118
4. **Navigation:** “Accurate path integration in continuous attractor network models of grid

cells." https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1000291

5. **Audition:** "A Task-Optimized Neural Network Replicates Human Auditory Behavior, Predicts Brain Responses, and Reveals a Cortical Processing Hierarchy" https://www.cell.com/neuron/fulltext/S0896-6273(18)30250-2
6. **Episodic memory:** "A neural network model of when to retrieve and encode episodic memories" https://elifesciences.org/articles/74445
7. **Learning rules:** "Random synaptic feedback weights support error backpropagation for deep learning" https://www.nature.com/articles/ncomms13276
8. **Decision making:** "Context-dependent computation by recurrent dynamics in prefrontal cortex" https://www.nature.com/articles/nature12742
9. **Working memory:** "Task representations in neural networks trained to perform many cognitive tasks" https://www.nature.com/articles/s41593-018-0310-2
10. **Reinforcement Learning:** "Prefrontal cortex as a meta-reinforcement learning system." https://www.nature.com/articles/s41593-018-0147-8
11. **Language:** "The neural architecture of language: Integrative modeling converges on predictive processing" https://www.pnas.org/doi/full/10.1073/pnas.2105646118
12. **Motor control:** "A neural network that finds a naturalistic solution for the production of muscle activity." https://elifesciences.org/articles/74445

Prerequisites

Students should be comfortable programming in Python and have familiarity with basic data science and visualization toolboxes (numpy, matplotlib). They should also have a background in the brain sciences.

Evaluation

Grades will be determined based on a student's participation in class discussions, submission of paper questions, implementation of assigned neural networks, and presentation of journal papers.

Academic integrity

Academic Integrity, Plagiarism, and Cheating (adapted from the website of the College of Arts & Science): Academic integrity means that the work you submit is original. Obviously, bringing answers into an examination or copying all or part of a paper/code straight from a book, the Internet, or a fellow student is a violation of this principle. But there are other forms of cheating or plagiarizing which are just as serious — for example, presenting an oral report drawn without attribution from other sources (oral or written); writing a sentence or paragraph which, despite being in different words, expresses someone else's idea(s) without a reference to the source of the idea(s); or submitting essentially the same paper in two different courses (unless both instructors have given their permission in advance). Receiving or giving help on a take-home paper, examination, or quiz is also cheating, unless expressly permitted by the instructor (as in collaborative projects).

Disability Disclosure Statement

Academic accommodations are available for students with disabilities. The Moses Center website is www.nyu.edu/csd. Please contact the Moses Center for Student Accessibility (212-998-4980 or mosescsd@nyu.edu) for further information. Students who are requesting academic accommodations are advised to reach out to the Moses Center as early as possible in the semester for assistance.