Computational Neuroscience

SYDE 552 / BIOL 487

University of Waterloo, Winter 2022

Instructors	Email	Meeting Times
Terrence C. Stewart	tcstewar@uwaterloo.ca	M 12:30 – 2:20pm
Michael Furlong	michael.furlong@uwaterloo.ca	F 12:30 – 2:20pm

Course Page: https://learn.uwaterloo.ca/d2l/home/778242

Prerequisites: At least 3B Systems Design Engineering OR at least 3B in the Faculty of Science and one of CS (115, 135, 200) and a 200-level STAT course.

Course Objectives: There are far more topics in computational neuroscience than can be covered in a single course. We will focus our studies on the visual system, neuron models, and current research topics. Throughout the course, we will emphasize the relationship between computational models and biological structure. By the end of the course, you should be able to:

- write code to implement and train artificial neural networks from scratch
- train deep convolutional networks for artificial vision problems
- describe the organization of the primate visual system and compare it to convolutional networks
- simulate and manipulate a variety of neuron models, from LIF to Hodgkin-Huxley

Teaching Approach: While this course was originally planned to be in-person, we will be online at least until January 27th. The online sessions will be at the normal class time (12:30-2:20 Monday and Friday), run through the Virtual Classroom in Learn. To support this, there is also a Slack channel set up that you can join here. It should be noted that the last hour of the Friday session is meant to be a Tutorial, which we will run as a free-form discussion time.

Pre-recorded Videos: In addition to the on-line sessions, there are also pre-recorded videos for the entire course available right now on YouTube. These videos were made for the course when it was taught in Winter 2021 by the same two instructors and we expect no large content changes. The main difference between those videos and the live lectures is that people can ask questions during the live lectures (whether on-line or in-person).

Required Texts: None (readings will be posted on `Learn`, including selections from the following)

Kandel et al. (2000) Principles of Neural Science, 5th edition. McGraw-Hill.

Gerstner et al. (2014) Neuronal dynamics. Cambridge University Press.

Schedule

Introduction ..... Jan 7th

1. Course Overview and Logistics
2. Neurons and the Central Nervous System

Artificial Neural Networks ..... Jan 10th – Jan 28th

3. Perceptrons
4. Regression
5. Backpropagation
6. Convolutional Neural Networks
7. Parameter Search
8. Unsupervised Learning and Reinforcement Learning

Primate Visual System ..... Jan 31st – Feb 4th

9 Low-level Visual Processing
10. Intermediate and High-level Visual Processing

Neuron Models ..... Feb 7th – Feb 18th

11. Simple Neuron Models
12. Hodgkin-Huxley Models
13. Compartmental Models
14. Synapses

The Neural Engineering Framework ..... Feb 28th – Mar 4th

15. Neural Engineering Basics
16. Neural Engineering Applications

Ongoing Research Topics ..... Mar 7th – Apr 4th

- Time Cells and Place Cells
- Numerical Cognition (?)
- Fear Conditioning in Amygdala (?)
- Recurrent Networks and Working Memory (?)
- Adaptive Control in Cerebellum (?)
- Biophysics of Drugs and Disorders (?)
- Spatial Navigation in Hippocampus (?)

Evaluation

Important Dates:

Assignment #1: Regression and Classification ..... 15% (Jan 28th)
Assignment #2: Deep Convolutional Networks ..... 15% (Feb 11th)
Assignment #3: Primate Visual System ..... 15% (Feb 18th)
Assignment #4: Neuron Models ..... 15% (Mar 7th)
Project Proposal ..... (Mar 14th)
Final Project Report: ..... 40% (Apr 26th)

Project: Students may undertake the project in groups of at most 2. A list of potential topics will be available on `Learn`; these suggestions will be updated as the lectures progress. Project groups and topics should be emailed to the instructors for approval by March 14th. Evaluation will be based on a final report consisting of an abstract, introduction (including literature review), methods (model details), results (simulations and data), and discussion. Marks will be assigned according to the content and clarity of these sections.

Late Policy: Completed work should be submitted via `Learn` by midnight on the due date. Late work may be submitted via email for reduced credit. The reduction will be 0-100% based on lateness and the reason for the delay, at the discretion of the instructors.

Fair Contingencies for Emergency Remote Teaching: We are facing unusual and challenging times. To provide contingency for unforeseen circumstances, the instructor reserves the right to modify course topics and/or assessments and/or weight and/or deadlines with due notice to students. In the event of further challenges, the instructor will work with the Department/Faculty to find reasonable and fair solutions that respect rights and workloads of students, staff, and faculty.

Online Academic Integrity: Other than the final project (which can optionally be done in groups of two), all students are expected to work individually and submit their own original work. Under Policy 71, the instructor may have follow-up conversations with individual students to ensure that the work submitted was completed on their own. Any follow up will be conducted remotely (e.g., MS Teams, Skype, phone), as the University of Waterloo has suspended all in-person meetings until further notice.

Wellness Support and Contact Information: University can be a challenging environment and it is normal to need support. Campus Wellness services are available to students through counselling and health services. If you are struggling or need someone to talk to you, please reach out. To book an appointment or learn more about the services, call 519-888-4567 x32655 or explore www.uwaterloo.ca/campus-wellness. If you're experiencing a crisis and feel unable to cope and Campus Wellness is closed, contact any of these after-hours supports: EmpowerMe (1-833-628-5589), Good2Talk (1-866-925-5454) or Here 24/7 (1-844-437-3247). They are available at any time of the day or night to help.

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Refer to the Office of Academic Integrity for more information.
Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.
Discipline: A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for their actions. [Check the Office of Academic Integrity for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline. For typical penalties, check Guidelines for the Assessment of Penalties.
Appeals: A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72, Student Appeals.
Note for students with disabilities: AccessAbility Services, located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.