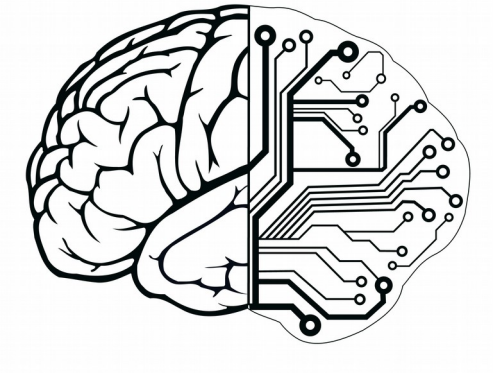
COMP596
Brain-Inspired Artificial Intelligence

Course Outline
Winter 2020



Number of credits: 3

Instructor
Dr. Blake Aaron Richards – blake.richards@mcgill.ca

Teaching assistant
Raymond Chua – raymond.chua@mail.mcgill.ca

Prerequisites
There are no specific prerequisites for this course, but you will not do well in it if you do not have at least the following:

(1) Some basic **knowledge of how to code**, ideally in Python.

(2) Some basic **background in linear algebra, multivariate calculus, and statistics** (introductory undergrad classes are fine, but CEGEP/high-school maybe not).

If you do not have this background and you take this class anyway, you will likely be disappointed with your experience. Speak to me in the first week if you are unsure.

Lectures and location
Tuesdays and Thursdays from 1:05 PM to 2:25 PM in ENGMC103
Lectures will be 50 minutes, from 1:05 PM to 1:55 PM. This will be followed by a 5 minute break, then 25 minutes of class discussion from 2:00 PM to 2:25 PM. **Note:** *there is a small grade for participation in the discussions, and the discussions will depend on both the lecture materials and the assigned papers. So do the readings and engage in the discussion.*

Office hours

Blake's office hours:
Tuesdays and Thursdays from 10:30 AM to 12 PM at the MNI, Penfield Pavilion, Room 765

Raymond's office hours:
Tuesdays and Thursdays from 2:30 PM to 3:30 PM at the MNI, Penfield Pavilion, Room 765

Feel free to come to office hours to discuss class material or get help with the assignments.

Course overview and learning outcomes/objectives

The brain is a sophisticated information processing device, capable of generating intelligent behaviour in a wide range of environments. In fact, despite all our advances in machine learning, it is still the most powerful, generalizable learning machine on Earth. The primary goal of the field of Artificial Intelligence (AI) is to make machines that can replicate the capabilities of the brain, and potentially at some point, exceed them.

Given this, it is unsurprising that a large number of AI researchers have sought inspiration from the brain in their work. In fact, the dominant paradigms for AI that exist today were all rooted, at some point in the past, in the use of neuroscience and psychology insights. This course will provide you with a historical overview of the influence of neuroscience and psychology ideas on AI. We will cover the earliest days of this interdisciplinary interaction, up through to today's state-of-the-art. You will learn both the basic brain facts required to understand the theory behind this work, as well as the mathematical details of the models. The specific learning objectives for the course are:

1. Students will understand broadly what computation is and what algorithms are. They will also understand how computations are implemented by algorithms, and in turn, how algorithms can be implemented by brain-like structures.
2. Students will become familiar with parallel distributed processing and neural network models, their advantages and disadvantages, and how they are used in AI.
3. Students will understand the core ideas of supervised learning, auto-associative memories, unsupervised learning, reinforcement learning, and their use in AI.
4. Students will understand the relationship between learning and optimization, and be able to identify at least two brain-inspired learning algorithms for neural networks.
5. Students will understand what an inductive bias is, this idea's place in the history of deep learning, and how it is related to neuroscience knowledge.
6. Students will be able to explain more sophisticated brain-inspired techniques, including convolution, attention, and memory augmentation.
7. Students will be able to program simple neural network models from scratch.
8. Students will be able to discuss scientific papers from the area of brain-inspired AI.

These objectives will provide the foundation for any future work in academia or industry related to neural information processing, brain machine interfaces or AI. There are many jobs in these areas at this point in history, and a lot of active research. Now is the right time to gain an education in this area!

But, doing well in this course will require keeping up with the material and pushing yourself out of your comfort zone, especially if you are completely unfamiliar with neuroscience or psychology and have never programmed a neural network before. As well, the readings are probably different from what many students in computer science are used to. A few important tips:

- There are a fair number of readings (available for free on *myCourses*), at various levels of difficulty. You may not understand everything you read, but it is important that you understand the basic concepts. Discuss the readings with other students in the class. Discussion will help you to understand things you struggle with on your own.
- If you are struggling with any of the neuroscience or psychology concepts, come to office hours. I am here to help you understand these things.
- Get started on the programming assignments as soon as they are released, especially if you are new to programming neural networks.

Asking questions

Please ask questions! As many as possible! However, please post your out of class questions to *myCourses* so everyone can see the answer and the TA and I do not have to repeat ourselves. **We will not answer course content questions sent to us by email.** Only email questions to us if they are of a personal or specific-to-you administrative nature.

Course requirements and evaluation

The final grade is based on two assignments, a midterm test, a final exam, and a mark for participation in the post-lecture discussions. Here is the specific break-down of the marking scheme:

Item	Percentage	Date
Programming assignment 1	25%	Due on February 17th
Midterm test – Feb. 6th	20%	February 6th
Programming assignment 2	25%	Due on March 23rd
Final exam – April 2nd	25%	April 2nd
Participation in discussion	5%	NA

Note: The midterm and final will take place in class on the indicated days.

Programming assignments

As stated above, there will be two programming assignments, the first of which will be released during the week of January 13th, the second of which will be released the week of February 24th. For both assignments, you will receive a backbone of Python code that you will use to build the models. The first assignment will have you program a Boltzmann machine for modelling images of hand-written digits. The second assignment will have you program an actor-critic network for a spatial navigation task. For both assignments you will **not** be allowed to use modern machine learning libraries that provide autograd capabilities. You will be doing it old school! In both assignments there will be a few questions to answer and some additional tasks for the graduate students.

Exams and tests

Both the midterm and final will consist of short-answer questions that may include small proofs or derivations. A few practice questions will be sent out the week before.

Lecture and readings schedule

Week	Dates	Subject	Required readings
1	Jan. 7, 9	What is artificial intelligence?	Richards (2018) Turing (1950)
2	Jan. 14, 16	Parallel distributed processing 1	PDP Chapter 1 Marr & Poggio (1976)
3	Jan. 21, 23	Parallel distributed processing 2	PDP Chapter 2 PDP Chapter 3
4	Jan. 28, 30	Unsupervised learning	Rumelhart and Zipser (1985) PDP Chapter 7
5	Feb. 6	NA – Midterm	NA - **No class on the 4th**
6	Feb. 11, 13	Supervised & auto-assoc. learning	PDP Chapter 8 Hopfield (1982)
7	Feb. 18, 20	Reinforcement learning	Sutton & Barto (1981) RL Chapters 1 & 6
8	Feb. 25, 27	Deep learning and inductive biases	Bengio and LeCun (2007) Hassabis et al. (2017)
9	Mar. 10, 12	Models of spatial invariance	Fukushima (1980) LeCun (1989)
10	Mar. 17, 19	Memory networks	Hochreiter & Schmidhuber (1997) Pritzel et al. (2017)
11	Mar. 24, 26	Attention networks	Xu et al. (2015) Vaswani et al. (2017)
12	Mar. 31, Apr. 2	Summary and final exam	NA – final exam

Language of submissions

In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded. This does not apply to courses in which acquiring proficiency in a language is one of the objectives.

Conformément à la Charte des droits de l'étudiant de l'Université McGill, chaque étudiant a le droit de soumettre en français ou en anglais tout travail écrit devant être noté (sauf dans le cas des cours dont l'un des objets est la maîtrise d'une langue).

Academic integrity

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures" (see McGill's guide to academic honesty for more information).

L'université McGill attache une haute importance à l'honnêteté académique. Il incombe par conséquent à tous les étudiants de comprendre ce que l'on entend par tricherie, plagiat et autres infractions académiques, ainsi que les conséquences que peuvent avoir de telles actions, selon le Code de conduite de l'étudiant et des procédures disciplinaires (pour de plus amples renseignements, veuillez consulter le guide pour l'honnêteté académique de McGill).

Additional statements regarding evaluation

The University Student Assessment Policy exists to ensure fair and equitable academic assessment for all students and to protect students from excessive workloads. All students and instructors are encouraged to review this Policy, which addresses multiple aspects and methods of student assessment, e.g. the timing of evaluation due dates and weighting of final examinations.

Note that to support academic integrity, your assignments may be submitted to text-matching or other appropriate software (e.g., formula-, equation-, and graph-matching).

Accessibility

As the instructor of this course I endeavor to provide an inclusive learning environment. However, if you experience barriers to learning in this course, do not hesitate to discuss them with me and the Office for Students with Disabilities, 514-398-6009.

Course evaluations

End-of-course evaluations are one of the ways that McGill works towards maintaining and improving the quality of courses and the student's learning experience. You will be notified by e-mail when the evaluations are available. Please note that a minimum number of responses must be received for results to be available to students.

Land acknowledgement statement

McGill University is on land which has long served as a site of meeting and exchange amongst Indigenous peoples, including the Haudenosaunee and Anishinabeg nations. We acknowledge and thank the diverse Indigenous people whose footsteps have marked this territory on which peoples of the world now gather.

L'Université McGill est sur un emplacement qui a longtemps servi de lieu de rencontre et d'échange entre les peuples autochtones, y compris les nations Haudenosaunee et Anishinabeg. Nous reconnaissons et remercions les divers peuples autochtones dont les pas ont marqué ce territoire sur lequel les peuples du monde entier se réunissent maintenant.

Note: *In the event of extraordinary circumstances beyond the University's control, the content and/or evaluation scheme in this course is subject to change.*