Advanced Topics in Cognitive Science- 2018-2019

INFOMATCS

Coordinators

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Context

Machine learning with deep convolutional neural networks (deep learning) is being applied increasingly broadly in computer science, technology and scientific research. This method allows computer systems to perform tasks that have previously been impossible or inaccurate for computers, but typically straightforward for humans. Tasks like visual object identification and natural language processing have traditionally been investigated by cognitive scientists and linguists, but recent applications of deep learning to these tasks also position them at the center of recent artificial intelligence developments. Therefore, it is important for AI students and researchers to understand the links between cognitive science and AI in these fields.

In this course, you will learn the principles behind deep learning, an approach inspired by the structure of the brain. You will learn how these principles are implemented in the brain, focusing on the aspects of visual processing and language (semantic or syntactic) processing. You will build your own deep learning systems for the interpretation of natural images and language, using modern high-level neural network APIs that make implementation of these systems accessible and efficient.

Course goals

At the end of the course, the student will be able to:

- Explain the broad concepts behind deep learning from both computer science and neuroscience perspectives.
- Explain deep learning's advantages and limitations compared to other modelling and machine learning approaches.
- Identify problems that deep learning is suited to addressing in the fields of cognitive (neuro-) science, linguistics and artificial intelligence
- Design and implement deep learning approaches to address some problems in the domain of image and language processing.

You will be able to better understand literature on deep learning and its applications to cognitive science. You will be in a good position to start gaining hands-on experience in a supervised or team setting, such as an internship or Master's thesis project.

Content

Students will attend eight lectures, first introducing the approach taken in deep learning systems and comparing this to how learning is implemented in biological brains. We will then introduce the main applications of deep learning to visual cognitive science. In the second part of the course, we will introduce important concepts and challenges in language processing, and investigate how machine learning networks are used here.

Furthermore, students will work through two lab practical assignments, one on visual processing and one on language processing, in pairs or alone.

Both parts of the course will be supported by reading assignments.

Lectures will cover the following topics:

Lecture 1: Principles of deep learning in artificial networks

Lecture 2: Deep learning in biological neurons and networks

Lecture 3: Early visual processing

Lecture 4: Higher visual processing

Lecture 5: Overview of language processing

Lecture 6: Lexical semantics: representations of word meaning

Lecture 7: Sequence modelling, and hierarchical structure in language

Lecture 8: Metaphors and non-literal language processing

Reading assignments (in recommended order):

Kay KN, Naselaris T, Prenger RJ, Gallant JL (2008) Identifying natural images from human brain activity. Nature, 452 (7185): 352-355.

Huth AG, Nishimoto S, Vu AT, Gallant JL (2012) A continuous semantic space describes the representation of thousands of object and action categories across the human brain. Neuron, 76(6):1210-24.

Yamins DL, DiCarlo JJ (2016) Using goal-driven deep learning models to understand sensory cortex. Nature Neuroscience,19(3): 356-65.

Horikawa T, Tamaki M, Miyawaki Y, Kamitani Y (2013) Neural decoding of visual imagery during sleep. Science, 340 (6132): 639-42.

Huth AG, de Heer WA, Griffiths TL, Theunissen FE, Gallant JL (2016) Natural speech reveals the semantic maps that tile human cerebral cortex. Nature. 532(7600):453-8.

Smaldino PE (2017) Models are stupid, and we need more of them. In: Vallacher RR, Nowak A, Read SJ (Eds) Computational Models in Social Psychology. http://smaldino.com/wp/wp-content/uploads/2017/01/Smaldino2017-ModelsAreStupid.pdf

Jurafsky D, Martin JH (2018) Speech and Language processing. Parts of the following chapters. https://web.stanford.edu/~jurafsky/slp3/

Chapter 6: Vector semantics

Chapter 7: Neural nets and neural language models

Chapter 8: Part-of-speech tagging

Mitchell TM et al (2008) Predicting Human Brain Activity Associated with the Meanings of Nouns. Science, 320: 1191-5.

Pennington J, Socher R, Manning C (2014) GloVe: Global Vectors for Word Representation. In: Proceedings of the 2014 conference on empirical methods in natural language processing (EMNLP): 1532-1543.

Assessment

The course goals will be examined in the following ways:

1) Students' understanding of lectures and reading assignments will be assessed in a final exam that determines 40% of the final grade. You are required to pass this exam to pass the course.
2) Reports from lab assignments will be graded for depth and completion, with each of the two assignments determining 30% of the final grade.

Schedule

Date	Time	Format	Teacher	Room
24/04	15:15-17:00	Lecture 1	Harvey	BBG 214
26/04	09:15-11:00 11:00-12:45	Lecture 2 Lab intro & Lab 1 start	Harvey Overvliet	BBG 001
01/05	15:15-17:00	Lecture 3	Harvey	BBG 214
03/05	09:15-11:00 11:00-12:45	Lecture 4 Lab 1	Harvey Overvliet	BBG 001
08/05	15:15-17:00	Lab 1	Overvliet	BBG 214
10/05	09:15-12:45	Lab 1	None	BBG 001
15/05	15:15-17:00	Lab 1	Overvliet	BBG 214
17/05	09:15-12:45 11:00-12:45	Lab 1 Lecture 5	Overvliet Deoskar	BBG 001
19/05	23:59	Deadline Lab 1		
22/05	15:15-17:00	Lecture 6	Deoskar	BBG 214
24/05	09:15-12:45	Lab 2 intro & Lab 2 start	Deoskar	BBG 001
29/05	15:15-17:00	Lecture 7	Deoskar	BBG 214
05/06	15:15-17:00	Lecture 8	Deoskar	BBG 214
07/06	09:15-12:45	Lab 2	None	BBG 001
12/06	15:15-17:00	Lab 2	Deoskar	BBG 214
14/06	09:15-12:45	Lab 2	Deoskar	BBG 001
19/06	15:15-17:00	Exam question time	Both	BBG 214
21/06	09:00-11:00	EXAM		BBG 201 & 205
26/06	23:59	Deadline Lab 2		