COG403(**W21**): Seminar in Cognitive Science

Yang Xu

Day/Time/Location: **Wednesday 14pm–17pm ET**

Lecture times: **14–15:10pm ET and 16–17pm ET**

In-class lab time: **15:15–15:55pm ET**

Instructor: Yang Xu

Contact: yangxu@cs.toronto.edu

Office Hours: **Friday 14:15–15:15pm ET**

Syllabus might be adjusted as the course progresses.

Description

This course is a sequel to COG260: Data, Computation, and The Mind. It provides advanced treatment of cognitive science topics by focusing on computational tools for research in this field. The course is organized roughly into four related topics: a) a bootcamp that discusses the mathematical and computational basics; b) neural networks and paradigms of learning; c) probabilistic inference and its links to optimal behaviour under uncertainty; d) efficient communication and the evolution of language. We will discuss classic and recent papers on these topics. All students are expected to take the initiative in leading the paper discussions. Students will also build and evaluate computational models with real-world data in a project. *Prerequisites:* COG260, CSC148H1, (MAT135H1, MAT136H1)/ MAT137Y1, 0.5 FCE in statistics.

Objectives

1. Introduce common tools for computational approaches to cognition.
2. Develop skills in computational thinking and modelling.
3. Build experience in scientific presentation and writing.

Recommended References

Minsky, M. (1986). *The society of mind*. New York: Simon & Schuster.
McClelland, J. L., Rumelhart, D. E., and PDP Research Group. (1987). *Parallel distributed processing (Vol. 1)*. Cambridge, MA: MIT press.

Bishop, C. M. (2006). *Pattern recognition and machine learning.* New York: Springer.

Deliverables and Assessments

Paper presentation (including slides)	20%
Paper summary	15% (∼1% per paper)
Labs 1-2	30%
Project proposal	5%
Project report	15%
Project presentation (including slides)	10%
Code repository	5%

Grading Scale

90 - 100%	A+	77 - 79%	B+	67 - 69%	C+	57 - 59%	D+
85 - 89%	A	73 - 76%	B	63 - 66%	C	53 - 56%	D
80 - 84%	A-	70 - 72%	B-	60 - 62%	C-	50 - 52%	D-
						0 - 49%	Fail

Policies and guidelines

- Students are expected to attend the lectures and labs.
- Students should complete the labs individually and collaborate in pairs on the projects. Plagiarism is strictly forbidden and any such case if identified will be reported according to the university guidelines (see http://www.governingcouncil.utoronto.ca/Assets/Governing+Council+Digital+Assets/Policies/PDF/ppjun011995.pdf).
- Every student is expected to present. PDF slides should be emailed to the instructor at least two days prior to the presentation.
- Every non-presenting student is expected to raise one non-clarification question related to the paper presented.
- Critical summary (including one summary paragraph and one non-clarification question) of each paper should be submitted online at least one day prior to the class in which the paper will be presented.
- Programming tasks from the lab and project assignments should be completed in Python or Python Jupyter Notebooks.
- Late deliverables, labs, or written assignments will be discredited at 1 point per delayed hour based on the time stamps of submission. Exceptional circumstances should be explained in writing to the course instructor, at least three days prior to the due date.

Schedules and Readings (due/required items are highlighted)

- **Jan 13 (Wed)** Cognition and Computation

  Course overview

  Background readings for this and the following weeks:

  – Shannon, C.E. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, 27, 379-423, 623-656.

  – Turing, A. M. (1950). Computing machinery and intelligence. *Mind*, 49, 433–460.

  – Chomsky, N. (1956). Three models for the description of language. *IRE Transactions on information theory*, 2(3), 113–124.

  – Rosenblatt, F. (1958). The perceptron: A probabilistic model for information storage and organization in the brain. *Psychological Review*, 65(6), 386–408.

  – Chapter 1 in Marr, D. (1982). *Vision: A computational investigation into the human representation and processing of visual information.* San Francisco: Freeman.

  Assignment: Email the TA *prior to the class next week* 3 preferred paper choices for presentation; choose numerically indexed papers from the following Readings and Presentations sections.

- **Jan 20 (Wed)** Computational Basics

  In-class lab on probabilities

- **Jan 27 (Wed)** Connectionism and Neural Networks

  Readings and Presentations (summary due 1 day before):

  1 Rumelhart, D. E., Hinton, G., E., and Williams, R. J. (1986). Learning representations by back-propagating errors. *Nature*, 323, 533–536.

  – In-class lab on distributions

  2 Elman, J. L. (1990). Finding structure in time. *Cognitive Science*, 14(2), 179–211.

  Background readings:

  – McClelland, J. L., Rumelhart, D. E., and Hinton, G. E. (1988). The appeal of parallel distributed processing. In A. M. Collins and E. E. Smith (Eds.), *Readings in cognitive science: A perspective from psychology and artificial intelligence* (pp. 52-72). Morgan Kaufmann.

  – McClelland, J. L., and Rogers, T. T. (2003). The parallel distributed processing approach to semantic cognition. *Nature Reviews Neuroscience*, 4(4), 310–322.

  Lab 1 out

- **Feb 3 (Wed)** Deep Learning

  Readings and Presentations (summary due 1 day before):

3 LeCun, Y., Boser, B., Denker, J. S., Henderson, D., Howard, R. E., Hubbard, W., and Jackel, L. D. (1989). Backpropagation applied to handwritten zip code recognition. *Neural Computation*, 1(4), 541–551.

– In-class lab on maximum likelihood estimation

4 Hinton, G., E. and Salakhutdinov, R. R. (2006). Reducing the dimensionality of data with neural networks. *Science*, 313, 504–507.

Background readings:

– Hinton, G. E. (2007). Learning multiple layers of representation. *Trends in Cognitive Sciences*, 11(10), 428-434.

– LeCun, Y., Bengio, Y., and Hinton, G. (2015). Deep learning. *Nature*, 521(7553), 436–444.

Project announcement

- **Feb 10 (Wed)** Bayesian Inference

Readings and Presentations (summary due 1 day before):

5 Xu, F. and Tenenbaum, J. B. (2007). Word learning as Bayesian inference. *Psychological Review*, 114(2), 245–272.

– In-class lab on Bayes theorem

6 Kemp, C. and Tenenbaum, J. B. (2008). The discovery of structural form. *Proceedings of the National Academy of Sciences*, 105(31), 10687–10692.

Background readings:

– Anderson, J. R. (1991). The adaptive nature of human categorization. *Psychological Review*, 98(3), 409–429.

– Griffiths, T. L., Kemp, C., and Tenenbaum, J. B. (2008). Bayesian models of cognition. In Ron Sun (ed.), *The Cambridge handbook of computational cognitive modeling*. Cambridge University Press.

Lab 1 due; Lab 2 out

- **Feb 24 (Wed)** Probabilistic Graphical Models

Readings and Presentations (summary due 1 day before):

7 Pearl, J. (1985). Bayesian networks: A model of self-activated memory for evidential reasoning. In *Proceedings of the 7th Conference of the Cognitive Science Society*.

– In-class lab on entropy

8 Blei, D., Ng, A., and Jordan, M. (2001). Latent Dirichlet allocation. *Advances in neural information processing systems*, 14, 601–608.

Background readings:

- Landauer, T. K. and Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, 104(2), 211240.
- Griffiths, T. L., Steyvers, M., and Tenenbaum, J. B. (2007). Topics in semantic representation. *Psychological Review*, 114(2), 211-244.

  Project proposal due

- **Mar 3 (Wed)** Optimal Cue Integration

  Readings and Presentations (summary due 1 day before):

  9 Ernst, M. O. and Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, 415(6870), 429–433.

- In-class lab on mutual information

  10 Körding, K. P., and Wolpert, D. M. (2004). Bayesian integration in sensorimotor learning. *Nature*, 427(6971), 244–247.

  Background readings:

- Oaksford, M. and Chater, N. (1994). A rational analysis of the selection task as optimal data selection. *Psychological Review*, 101(4), 608–631.
- Chater, N., and Oaksford, M. (1999). Ten years of the rational analysis of cognition. *Trends in Cognitive Sciences*, 3(2), 57–65.

  Lab 2 due

- **Mar 10 (Wed)** Efficient Communication

  Readings and Presentations (summary due 1 day before):

  11 Piantadosi, S. T., Tily, H., and Gibson, E. (2011). Word lengths are optimized for efficient communication. *Proceedings of the National Academy of Sciences*, 108(9), 3526–3529.

- In-class lab on principle of maximum entropy

  12 Kemp, C. and Regier, T. (2012). Kinship categories across languages reflect general communicative principles. *Science*, 336(6084), 1049–1054.

  Background readings:

- Kemp, C., Xu, Y., and Regier, T. (2018). Semantic typology and efficient communication. *Annual Review of Linguistics*, 4, 109–128.
- Gibson, E., Futrell, R., Piandadosi, S. T., Dautriche, I., Mahowald, K., Bergen, L., and Levy, R. (2019). How efficiency shapes human language. *Trends in Cognitive Sciences*, 23(5), 389–407.

- **Mar 17 (Wed)** Semantic Universals

  Readings and Presentations (summary due 1 day before):

13 Youn, H., Sutton, L., Smith, E., Moore, C., Wilkins, J.F., Maddieson, I., Croft, W., and Bhattacharya, T. (2016). Universal structure of human lexical semantics. *Proceedings of the National Academy of Sciences*, 113(7), 1766–1771.

- In-class lab on clustering

14 Xu, Y., Duong, K., Malt, B.C., Jiang, S., and Srinivasan, M. (2020) Conceptual relations predict colexification across languages. *Cognition*, 201, 104280.

Background readings:

- François, A. (2008). Semantic maps and the typology of colexication: Intertwining polysemy networks across languages. In M. Vanhove (Ed.), *From polysemy to semantic change: Towards a typology of lexical semantic associations*, (pp. 163–215). Amsterdam: John Benjamins.
- Evans, N. and Levinson, S. C. (2009). The myth of language universals: Language diversity and its importance for cognitive science. *Behavioral and Brain Sciences*, 32(5), 429–448.

- **Mar 24 (Wed)** Semantic Variation

15 Thompson, B., Roberts, S. G., and Lupyan, G. (2020). Cultural influences on word meanings revealed through large-scale semantic alignment. *Nature Human Behaviour*, 4(10), 1029–1038.

- Research talk

Background readings:

- Regier, T., Carstensen, A., and Kemp, C. (2016). Languages support efficient communication about the environment: Words for snow revisited. *PLOS ONE*, 11(4), e0151138.

- **Mar 31 (Wed)** Guest Lecture
  - Research talk
  - Project presentation and report requirements
- **Apr 7 (Wed)** Student Project Presentations

Project report due Monday the following week (10am ET) after presentation

Paper–Project Presentation Guidelines

- Paper presentations should take about 25-30 minutes, allowing time for question and answering. Project presentation duration will be announced in due time.
- Joint presentations should distribute the labour evenly between the presenters.
- Presenters in a joint presentation will be assessed individually.
- Presentation structure should be roughly as follows:

  Motivation - Background - Materials and Methods - Results - Limitations and Extensions - Conclusion.

- *Background* should provide sufficient context by a brief discussion of 2-3 prior work relevant to the paper, e.g., drawn from *Background readings* or elsewhere.
- Presenters should emphasize clarity and encourage class participation.
- Whiteboard may be used to facilitate the presentation.
- Slides should be submitted as a single PDF to the instructor, with name(s) on the front page.
- Tips for presenting: https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1005373.

Project Report Guidelines

- Report should be 5-6 pages long with 1 additional page of references.
- Report should follow the LaTex template here: https://github.com/rlevy/cogsci-template.
- Report should be structured as follows:

  Abstract - Introduction - Materials and Methods - Results - Discussion.

- *Materials and Methods* should provide GitHub (https://github.com/) or OSF (https://osf.io/) link to code/data.
- Report not conforming to the above standards will not receive any credit.
- Reporting style should support replication of the analyses and results described.
- Report and appendix should be submitted as a single PDF, with name(s) on page 1.
- Tips for writing: https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1005619.