Computational Cognitive Neuroscience ISM

Module 1 - Cognition and Computation: How different are they?

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1. Philosophy of Mind
   Readings:
   - Puzzle of Conscious Experience
   - Searle (417 - 424)

2. Reverse engineering the brain / Comp Model of Mind
   Readings
   - Turing
   - Nillson - Human-Level AI?

   Lecture Slides

3. Theory of Mind
   - Minsky's Society of Mind
   - Our ToM of ChatGPT

4. Later: Subsumption (Perception of Mind)
   - Minsky, Braintenberg's vehicles
   - Cheating Robot
   - Intelligence without reason by Rod Brooks
   - Joanna Joy Bryson's old PhD thesis since it talks super clearly about BoD (Behaviour Oriented Design) and POSH (Parallel-rooted, Ordered, Slip-stack Hierarchical)

Module 2 - Deeper into the Brain

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1. Synaptic plasticity (Learning)
   Readings:
   - Synaptic plasticity: taming the beast- slightly outdated
   - Neuroscience of learning
   - Prof. Bittu recommended: Beyond STDP-towards diverse and functionally relevant plasticity rules

2. Time and space
   Readings:

- Space: A manifold of spatial maps in the brain
  (8 pages, quite neuro heavy, talks about the role of interconnectedness of hippocampal and entorhinal spatial maps in reflecting the complexity of natural environments in dynamic time frames)
- Time: What makes us tick? Functional and neural mechanisms of interval timing
  (9 pages, vv neuro heavy)
  (Suggests that brain represents time in a distributed manner and tells time by detecting the coincidental activation of different neural populations)

Module 3 - Rationality and Decision Making

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1. Neuroeconomics
   Readings:
   - Neuroeconomic foundations of economic choice- Recent advances
     (23 pages, long but does not seem difficult, gives a good overview of the field)
   - https://www.hse.ru/data/2011/12/09/1259101786/Neuroeconomics.pdf (Could possibly do some topics like perceptual vs value-based decision making, social decision making etc.) - **Chapters 3, Estimation and testing of computational psych models (computation stuff), Chapter 7**
   - **Monkey Economy -** https://www.ted.com/talks/laurie_santos_a_monkey_economy_as_irrational_as_ours?language=en
2. Probabilistic Inference Neuroeconomics
   Readings:
   - Basic probability theory (Sections 1 through 4)
   - Generalisation, similarity and Bayesian inference (Griffiths & Tenenbaum) (Read Pages 629-634) (11 pages, seems a bit complex but super interesting, talks about generalization from multiple consequential stimuli and draws parallels between set-theoretic and spatial approaches)
   - Probabilistic brains: Knowns and Unknowns - Difficult, Medium (probabilistic learning, structural learning and approximate inference)
   - Predicting pragmatic reasoning in language games
     (one page, seems nice n fun)
3. Reinforcement learning Readings:
   - Introduction to reinforcement learning: Sutton and Barton (Chp 1 & 14)
   - A neural substrate of prediction and reward
   - Reinforcement learning in the brain

Module 4 - Vision and Language

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1. Vision across modeling approaches (lab)
   Readings:
   - frisby_stone_2010_seeing.pdf (tallinzen.net) - Medium, Lengthy (lots of neuro, super interesting)
   - 1332 1332..1338 (tallinzen.net) - Doable (CS), Small (concept learning, computational)
   - Deep Neural Networks: A New Framework for Modeling Biological Vision and Brain Information Processing (tallinzen.net) - Doable (CS), Lengthy (neural networks psychologically)
2. Language acquisition across modeling approaches
   - alishahi_2010.pdf (tallinzen.net) - Medium-Difficult, Lengthy (whole book) (covers everything - psych + math in language learning and acquisition)
   - PII: S1364-6613(02)01990-3 (tallinzen.net) - Medium-Difficult, Small (theories of language acquisition)

Module 5 - Putting everything together!

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1. Contemporary AI and cognitive science
   Readings:
   - lecun_bengio_hinton_2015.pdf (tallinzen.net) - Easy, Small (review of key architectures in Deep Learning)
   - Why deep-learning AIs are so easy to fool (tallinzen.net) - Easy, Small (delves into drawbacks of DL)
   - Has AI surpassed humans at translation? – Skynet Today (tallinzen.net) - Easy, Small (delves into a human/AI comparison in the context of translation)

2. Modeling Human Cognition
   Lectures:
   - http://www.infocobuild.com/education/audio-video-courses/psychology/res-9-003-summer2015-mitocw.html MIT - Tenebaum 3 part talk

   Readings:
   - Computational Models as Aids to Better Reasoning in Psychology - Medium, Small (talks about modeling cog stuff in general + introduces random walk)
   - The Place of Modeling in Cognitive Science - Medium, Medium (similar but more detailed than above)
   - computing machinery and intelligence - a.m. turing, 1950 (abelard.org) - Easy, Small (cool intro type material)

- 10.1.1.83.5248.pdf (southampton.ac.uk) (similar^)
- The New Turing Omnibus: 66 Excursions In Computer Science - PDF Drive (similar^)

Cool readings

- Where cognitive science went wrong - http://www.naturalthinker.net/trl/texts/Fodor,%20Jerry/Fodor%20-%20Concepts%20-%20Where%20cognitive%20science%20went%20wrong.pdf
- Word learning as Bayesian inference (Tenenbaum and Xu) (Pages 245-253) (Three experiments with adults and children test the Bayesian account's predictions in the context of learning words for object categories at multiple levels of a taxonomic hierarchy)
- Modeling random firing of neurons - pcbi.1002211 1..22 (ucl.ac.uk) - Difficult, Lengthy (lots of probability math)
- Analogues of mental simulation and imagination in deep learning

Course Structure

- 2 Discussion / work sessions per week for students
- 1 Review session per week with Professors

Grading

1. Projects
    a. 3 implementation projects derived from syllabus; computational emphasis
    b. Projects due on on weeks 5, 8, 11
2. Final Presentation - an in-depth review of a topic from the syllabus
3. Course Engagement

Project Ideas

1. Theory of Mind - ChatGPT-4
    a. Literature review
    b. Speak to professors
    c. Design + Perform experiments on GPT-4
    d. Writing the paper
2. Ashoka LLM
    a. Stanford Alpaca model
    b. Literature Review
    c. Use cases
    d. Looking at collaborators
3. Comparing the ways humans and AI solve problems - finding more efficient solutions
    a. Brainstorm
4. *Scraping data and building maps*

All Resources

Courses & Lectures:

1. CCN - Harvard- Taught by Sam Gershman (need Harvard ID for lectures)
   https://cbmm.mit.edu/sites/default/files/courses/syllabus/CCN2016_syllabus_0.pdf

2. Projects to implement in Gershman course
   https://cbmm.mit.edu/learning-hub/course/residential/computational-cognitive-neuroscience-building-models-brain

3. Hopkins- Taught by Tal Linzen
   https://tallinzen.net/media/teaching/intro_ccs_fall_2019.html

4. Intro to Cogsci - Stanford- Taught by Dan Jurafsky (Introduction to CogSci) but in 2005
   https://web.stanford.edu/~jurafsky/symbsys100.2005/
   2008 link: SYMBSYS 100 / LING 144 / PSYCH 130 / PHIL 190 (Stanford University)

5. BMM - MIT OCW (all lectures available)
   http://www.infocobuild.com/education/audio-video-courses/psychology/res-9-003-summer2015-mitocw.html

6. MIT- Infant and Early Childhood Cognition taught by Laura Scultz (can incorporate some topics)
   https://ocw.mit.edu/courses/9-85-infant-and-early-childhood-cognition-fall-2012/pages/syllabus/

Topics & Readings:

Gershman (Harvard):

- Reverse engineering the brain
- Principles of perceptual representation
- Object recognition
- Perceptual decision-making
- Neuroeconomics
- Reinforcement learning
- Computational neuromodulation
- Synaptic plasticity
- Complementing learning systems
- Working memory
- Time and space
- Probabilistic inference in neural circuits
- Computational Psychiatry
- Cognitive control and metareasoning

Linzen (Hopkins):

- Probabilistic inference
- Formal grammars
- Reinforcement learning
- Artificial neural networks
- Language acquisition across modeling approaches
- Vision across modeling approaches
- Contemporary AI and cognitive science

Jurafsky (Stanford) *NOTE: It is old*

- Turing Test - PPT – SYMBOLIC SYSTEMS 100 Introduction to Cognitive Science PowerPoint presentation | free to download - id: 59ea81-ZTE5M (powershow.com)
- Computational Model of the Mind
- Philosophy of Mind
- Bridging Mind and Brain
- Language and Thought
- Vision and Colour Perception
- Perceptual Illusions
- Neuroscience of Awareness
- The Goal of Perception
- Active Vision and Artificial Life
- Language Processing
- Metaphor
- Conversation
- Reasoning and Decision Making - PPT - SYMBOLIC SYSTEMS 100: Introduction to Cognitive Science Dan Jurafsky and Daniel Richardson Stanford University Spring 20 PowerPoint Presentation - ID:1401685 (slideserve.com)
- Cognitive Development
- Machine Learning and Neural Networks- PPT – SYMBOLIC SYSTEMS 100: Introduction to Cognitive Science Dan Jurafsky and Daniel Richardson Stanford University Spring 2005 PowerPoint presentation | free to view - id: 25132f-ZDc1Z (powershow.com)
- Nativism vs Empiricism and Language Learning
- The Evolution of the Mind

Schulz (MIT OCW)