COLIN MCDONNELL
LEARNING
LEARNING

THE PAPERS

- Innate attentional biases and associated effects
- Thalamocortical loops for prediction learning
- Method of comparing human classification capability to neural networks

how the brain learns and how it informs machine learning and vice versa with no pretensions of completeness
LEARNING

STRUCTURE OF TALK

- What is learning
- Neuroscience inspires machine learning
- Machine learning guides neuroscience
SOME DEFINITIONS

what do I mean neuroscience?
Affective neuroscience
Behavioral neuroscience
Cellular neuroscience
Clinical neuroscience
Cognitive neuroscience
Computational neuroscience
Cultural neuroscience
Developmental neuroscience
Evolutionary neuroscience
Molecular neuroscience
Neuroengineering
Neuroethology
Neuroheuristics
Neuroimaging
Neuroinformatics
Neurolinguistics
Neurophysics
Neuropsychology
Paleoneurology
Social neuroscience
Systems neuroscience

what do I mean ML?
WHAT IS LEARNING

- pattern recognition
- finding an efficient encoding
- discovering beneficial behavior based on past observations
- abstraction

Australian or European?
NEUROSCIENCE INSPIRES MACHINE LEARNING
Hebbian learning
spike timing dependent plasticity
synaptic re-wiring

sort of a 404, but...

sparsity

winner-take-all learning

ReLU?
many excitatory synapses (for temporal learning?)

neurons that remember window of past inputs/firings
dendritic computation

layers collapse to neurons
mathematically equivalent
reflection of action potential into input dendrites  

gradient learning
WHAT IS LEARNING > NEURO INSPIRES ML > ML GUIDES NEURO

going smaller...

molecular diffusion
neuromodulators
neuropeptides
nitrous oxide

message-passing networks

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A synthetic genetic edge detection program.
Tabor JJ, Salis HM, Simpson ZB, Chevalier AA, Levskaya A, Marcotte EM, Voigt CA, Ellington AD.
What is learning: retrograde chemical signaling and reverse connections
attractor circuits should arise organically...

(later: LeabraTI)
communicating brain regions

top-down feedback [Ullman 2015]

basal ganglia for decisions

multi-sensory learning

deprecated learning

eventually, interacting networks:

deep reinforcement learning

variable binding

information routing
innate biases

attention mechanisms

“feature weights”
bias network towards “mover events”

first pass:
  - high precision, low recall

second pass:
  - tracking/continuity
  - body context

third pass:
  - gaze

fourth pass
  - mirroring
  - own-hands

comparison

but was it necessary?

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From simple innate biases to complex visual concepts

Shimon Ullman¹², Daniel Harari¹, and Nimrod Dorfman¹

Department of Mathematics and Computer Science, Weizmann Institute of Science, Rehovot 76100, Israel
implicit labeling/\nsensorimotor proto-concepts
[Ullman 2012]  

semi-supervised labeling  
basins of attraction as reward signal generator
supervised learning
supervised learning

error-driven backpropagation

problems
- requires transmission of exact derivatives over distance
- neurons communicate through (stochastic?) spikes
- temporal synchronicity
- what are the targets?
supervised learning

derivative backpropagation

hyper polarization of dendrites
+ reverse action potential
supervised learning

training epochs

hippocampus-mediated replay
supervised learning

momentum gradient descent  plasticity modulation
supervised learning

dropout

stochastic models of neural spiking
supervised learning

layer-by-layer training

developmental drop-off in cortical plasticity
unsupervised learning
unsupervised learning

auto-encoders

layer-size bottleneck

lateral inhibition
unsupervised learning

predictive learning

babies understand spatiotemporal coherence thalamocortical loops!

[O’Reilly 2014]
unsupervised learning

prediction learning

babies understand spatiotemporal coherence thalamocortical loops! [O’Reilly 2014]
Learning

Inter-Discipline Comparisons

Atoms of recognition in human and computer vision.

Ullman S¹, Assif L², Fetaya E², Harari D³.