Computational Neuroscience

• Introduction
  • About me: Olivier Manette
Dreamspeed Project

www.flod.aero
Some recent bibliography

30 Janvier 2014
Livre, Presse Académique Francophone
Codage spatio-temporel des neurones cortico-motoneuronaux: ou comment le cerveau parle à nos muscles?
Février 2009
Chapitre dans Livre, Theory and Novel Applications of Machine Learning, I-Tech, Vienna
TempUnit: A bio-inspired spiking Neural Network?
Aout 2013
Proceeding of: Neuroinformatics 2013, At Stockholm, Sweden
HELMHOLTZ: A CUSTOMIZABLE FRAMEWORK FOR NEUROPHYSIOLOGY DATA MANAGEMENT
• Andrew P. Davison, Thierry Brizzi, Domenico Guarino, Olivier F. Manette, Cyril Monier, Gerard Sadoc, Yves Fregnac
Juillet 2011
International Joint Conference on Neural Networks, San Jose 2011
TEMPORAL AND RATE DECODING IN SPIKING NEURONS WITH DENDRITES
• Olivier F. Manette
Juillet 2011
International Joint Conference on Neural Networks, San Jose 2011
LOCAL LEARNING RULES FOR SPIKING NEURONS WITH DENDRITE
• Olivier F. Manette
Juin 2011
International Neuroinformatics Coordinating Facility, Stockholm, 2011
SPEEDING 100 FOLD NEURAL NETWORK SIMULATIONS WITH GPU PROCESSING
• Olivier F. Manette, German Hernandez
What is Computational Neuroscience?

Computational Neuroscience is the theoretical study of the brain to uncover the principles and mechanisms that guide the development, organization, information processing and mental abilities of the nervous system.
Computational/theoretical tools in context
EEG and fMRI
Optical Imaging techniques
Another way of experimenting
Phineas Cage

- Frontal Lobe amazing recovery
- Antonio Damasio: *Descartes' Error*
- Only positive rewards
Drugs effects

What is freedom?
Other cases

- What/Where pathways
- Prehension syndrome (inhibition problem)

- Olivers Sacks books

*The Man with the Shattered World*

Alexander Luria

⇒ The unity of the world is an illusion
Levels of organization in the nervous system
What is a model?

Models are abstractions of real world systems or implementations of hypothesis to investigate particular questions about, or to demonstrate particular features of, a system or hypothesis.
What, How and Why

The questions, what, how, and why are addressed by descriptive, mechanistic, and interpretative models. Descriptive models summarize large amounts of experimental data that shows What neurons do.

https://www.youtube.com/watch?v=KE952yueVLA
Lateral Geniculate Nucleus
dark stimulus
activates OFF channels

light stimulus
activates ON channels

lateral inhibition

centre-surround

on centre cells - respond optimally to central light/peripheral dark stimuli

on centre cells - suppressed if only periphery is stimulated

off centre cells - respond optimally to central dark/peripheral light stimuli
What, **How** and Why

Mechanistic Models address the question of how nervous systems operate on the basis of known anatomy, physiology, and circuitry. Such models often form a bridge between descriptive models couched at different levels.
Example of models

http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/V1/Lgn-V1.html
Visual Pathways & Primary Visual Cortex

Fig. 1.1. A drawing of a section through the human eye with a schematic enlargement of the retina.
Interpretive models

Interpretative models use computational and information-theoretic principles to explore the behavioral and cognitive significance of various aspects of nervous system function, addressing the question of why nervous systems operate as they do.
Towards a Brain Theory

- Reverse Engineering
- What level of description is the most appropriate?
- Hardware implemented or simulated on software? ➔ highly parallel distributed processing
- What is emergence?
- Bottom-up or Top-down approach?
- Why do we need a brain?
Marr’s approach

1. Computational theory: What is the goal of the computation, why is it appropriate, and what is the logic of the strategy by which it can be carried out?

2. Representation and algorithm: How can this computational theory be implemented? In particular, what is the representation for the input and output, and what is the algorithm for the transformation?

3. Hardware implementation: How can the representation and algorithm be realized physically?

Marr puts great importance to the first level:
"To phrase the matter in another way, an algorithm is likely to be understood more readily by understanding the nature of the problem being solved than by examining the mechanism (and hardware) in which it is embodied."
The brain is an anticipating memory system. It learns to represent the world, or more specifically, expectations of the world, which can be used to generate goal directed behavior.
Outline

Basic neurons
Lecture 2: Membrane potentials and spikes
Lecture 3: Simplified neurons and population nodes
Lecture 4: Synaptic plasticity

Basic networks
Lecture 5: Random networks
Lecture 6: Feedforward network
Lecture 7: Competitive networks
Lecture 8: Point attractor networks

System-level models
Lecture 9: Modular models
Lecture 10: Hierarchical models
Read from the mind
Lecture 11: Information theory and Neural Decoding
Some applications of Comp. Neuro

- [https://www.youtube.com/watch?v=UUcubnQML9s](https://www.youtube.com/watch?v=UUcubnQML9s) : EEG
- Cyborg : [https://www.youtube.com/watch?v=9NOncx2jU0Q](https://www.youtube.com/watch?v=9NOncx2jU0Q)
- [https://www.youtube.com/watch?v=szd33v89CDo](https://www.youtube.com/watch?v=szd33v89CDo) : cochlear implant
- Mind Reading with fMRI : [https://www.youtube.com/watch?v=wwK6zdedUjM](https://www.youtube.com/watch?v=wwK6zdedUjM)
If you are interested in

• working in comp-neuro in an academical environment
  • Comp-neuro mailing list :
    • http://www.neuroinf.org/mailman/listinfo/comp-neuro

• Further reading :
  • Peter Dayan and Laurence F. Abbott 2001, Theoretical Neuroscience, MIT Press

• Other resource ➔ Coursera:
  https://class.coursera.org/compneuro-001
Questions

What is a model?

What is emergence?