COMPUTATIONAL ANALYSIS OF PRIMATE VISION

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DO BRAINS COMPUTE?

WHY BIOLOGICAL REALISM?

WHY COMPUTATION?
Felleman & Van Essen, Cerebral Cortex 1991
Markov et al., Cerebral Cortex 2014
PRIMATES AND MICE

- Mice are accessible to molecular methods and genetic engineering
- Retina, fovea, visual cortical organization and visual behavior very different
- Primate CX hierarchy still better understood
What I cannot create, I do not understand.

Know how to solve every problem that has been solved.

\[ f = \langle V, a \rangle \]

\[ s = \frac{1}{2} at^2 \]

\[ f = \frac{1}{2} \left[ v_f + v_0 \right] \frac{t}{2} \]

\[ f = \frac{1}{2} \left[ v_f^2 - v_0^2 \right] \]

What I cannot
Create
I do not
Understand

- Richard Feynman
from __future__ import division
import numpy as np
import matplotlib.pyplot as plt
import pdb
pi = np.pi
x = np.arange(-pi, pi, pi/100)
y = np.exp(1j*x)

# pdb.set_trace()
fig, ax = plt.subplots()
ax.fill(np.real(y), np.imag(y), 'orange')
ax.fill(np.real(y)/20, 19/20+np.imag(y)/25, 'black')
ax.axis('equal')
plt.fill(' Griff')
plt.show()
COMPLEX CODE HINDER DEVELOPMENT
CXSYSTEM2

Design principles: Flexibility, Simplicity

Built on top of Brian2
CSV FILE INTERFACE TO SIMULATION

Andalibi et al., Neural Computation 2019
PYTHON, C++, GENN AND CLUSTER OPTIONS

Andalibi et al., Neural Computation 2019
SUPPORT FOR OLIGOCOMPARTMENTAL MODELS

Hokkanen et al., Neural Computation 2019
NEURODYNLIB USE CASES

- Analyze experimental traces (eFel, BluePyOpt)
- Import existing models

igraph image of experimental traces and text block:

CRH modulates excitatory transmission and network physiology in hippocampus (Gunn et al. 2017)
Anatomy and Physiology of Macaque Visual Cortical Areas V1, V2, and V5/MT: Bases for Biologically Realistic Models

Simo Vanni¹,², Henri Hokkanen¹,², Francesca Werner¹,²,³, and Alessandra Angelucci⁴
INTERAREAL CONNECTIVITY
MAJOR PATHWAYS ARE WELL-KNOWN

Vanni et al., Cerebral Cortex 2020
LOCAL CONNECTIVITY
KNOWN ONLY FOR V1, LESS SO FOR INHIBITORY CELL TYPES, V2 AND V5

Vanni et al., Cerebral Cortex 2020
INTRICATE PARALLEL PATHWAYS

LGN => V1

Vanni et al., Cerebral Cortex 2020
HORIZONTAL, PATCHY CONNECTIONS EXTEND LONGER DISTANCES IN HIGHER AREAS

Vanni et al., Cerebral Cortex 2020
SOME VISUAL STIMULUS TUNING PARAMETERS CLEARLY DISCRIMINATE THE V1, V2 AND V5

Vanni et al., Cerebral Cortex 2020
Retina Model

Visual stimuli need reasonable prefilter
ELLIPSOID AND TEMPORAL KERNEL FITTING TO SPIKE-TRIGGERED DATA FROM CHICHILNISKY LAB

Hokkanen & Vanni, in preparation
FOUR GANGLION CELL (GC) TYPES COVERS 96% OF FOVEAL AND 88% OF PERIPHERAL GC:S

Hokkanen & Vanni, in preparation
SELECTION OF INTERNAL MODEL USE LESS ENERGY THAN ACCURATE REPRESENTATION

POSSIBLE ECOLOGICAL REASON FOR PREDICTIVE CODING

Artiñano et al., under review
SIMPLE SPIKING NETWORK MODEL FOLLOWING BRENDEL ET AL PLOS COMPUT BIOL 2020

Artiñano et al., under review
NETWORK FIRST LEARNS TO REPLICATE THE 3 INPUT CHANNEL AMPLITUDES AT THE 3 OUTPUT UNIT MEMBRANE VOLTAGES

Artiñano et al., under review
HOW BIOPHYSICAL PARAMETER VARIATIONS AFFECT INFORMATION TRANSFER?

Artiñano et al., under review
FOUR DISTINCT METRICS SHOW HIGHER INFORMATION TRANSFER WITH HIGHER FIRING RATE

Artiñano et al., under review
ACCURATE REPRESENTATION IS EXPENSIVE
ONLY SPECIAL PARAMETER COMBINATIONS, HIGH FIRING RATES, AND
OUTPUT UNITS WITH SHORT MEMORY FOLLOW THE FAST INPUT TRANSIENTS

Artiñano et al., under review
INPUT => OUTPUT CLASSIFICATION ACCORDING TO TRANSMITTED INFORMATION

Coherence

Input to output pairing

10 replications for 30 pairs

Confusion matrix
CLASSIFICATION SURVIVES VERY LOW FIRING RATES

Artiñano et al., under review
ACCURACY SCORES DIP WHEN CELLS EITHER CEASE FIRING OR SATURATE

3 by 3

6 by 6

Artiñano et al., under review
IF TRANSMITTED INFORMATION CAN BE TURNED INTO MODEL SELECTION, ACTIVATING AN INTERNAL MODEL WOULD BE AN ECONOMICAL WAY OF REPRESENTING THE ENVIRONMENT.
ACKNOWLEDGEMENTS

∞ Vafa Andalibi ................................................................. Programming Cxsystem
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∞ Tomás Garnier Artiñano ........................................... Simulations for Infometrics
∞ Iiris Atula ........................................................................ Math for Infometrics
∞ Margaux Calice ................................................................. Thalamocortical system
∞ Hanna Heikkinen ................................................................. Program preceding CxSystem
∞ Henri Hokkanen .............. Retina, Modeling, Programming, Neuroinformatics
∞ Matteo Maestri ................................................................. Control Simulations for Infometrics
∞ Francesca Werner .............. Digitizing data for Neuroinformatics
1) **What was the scientific question?**
   - Biologically and computationally meaningful models of macaque monkey visual cortical areas V1, V2 and V5

2) **How did you/project partners address it?**
   - Neuroinformatics, High-level tool dev, simulations, information metrics

3) **What are the main outcomes of the project?**
   - Publications, GitHub repo

4) **What are the next steps of the project?**
   - After retina model, work towards V1 model using Grossberg ART model as a scaffold