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FOUNDATION FOR RESEARCH AND TECHNOLOGY - HELLAS

Network Analysis in Neocortex during Passive & Active Learning

neuronsXnets

NeuronsXnets Analysis

Workshop 2024

July 1st and 2nd, 2024

Foundation for Research and Technology-Hellas

Agenda

July 1, 2024

15.00-15.15 **Welcome & Brief Introduction of the MSCA NeuronsXnets Project**

15.15 - 16.15 *Volatile Working Memory Representations Crystalize with Practice*, Golshani Peyman (Department of Neurology, UCLA)

Abstract: Working memory (WM), the capacity to temporarily store and manipulate information, is essential for most cognitive functions and fails in several neurological and psychiatric disorders. The mechanism of generation and maintenance of WM-related neural representations during learning and their evolution with continued expert performance remains unclear. A key challenge has been to record and manipulate the same neuronal populations over a long period of time while the animal learns and becomes expert in the task performance. In this presentation, we will address two critical questions: How stable are the WM representations across time as the animal learns the task and practices performing the task as an expert? Are these representations critical for task performance? We will compare the emergence of cortical and hippocampal representations and through voltage imaging, ask how interneuron function also evolves with learning and practice. In the last part of the talk, we will review new open-source optical imaging tools (including two-photon miniaturized microscopes) that we have created and are sharing with the community for recording large scale activity patterns in freely behaving animals.

Short bio: Peyman Golshani, MD/PhD obtained his MD/PhD from UC Irvine where he trained with the late great Edward G. Jones on the development of corticothalamic function. He completed his neurology residency at UCLA after which he was appointed Assistant Professor. He is now a Professor in Residence in the Department of Neurology and Semel Institute at UCLA. His laboratory focuses on understanding large scale neural dynamics in cortex, hippocampus and striatum in cognitive and social tasks as well as understanding how these patterns go awry in model of neuropsychiatric disease. He is also developing new tools for recording neuronal activity in freely behaving animals.

16.20 - 17.20 ***Lessons from a Mouse Model of Bistable Perception,*** **Anna Palagina and Stelios Smirnakis (Harvard Medical School, Brigham & Women's Hospital)**

Abstract: Mouse V1 is thought to respond chiefly to local orientation and visual motion elements rather than to global patterns of motion, similar to V1 in higher mammals. We used type I plaids formed by the additive superposition of moving gratings to investigate this question and found that mouse V1 contains a considerably smaller fraction of component-motion selective neurons (17% vs 84%), and a larger fraction of pattern-motion selective neurons (10% vs 1.3%) compared to primate or cat V1. Measurement of optokinetic responses to plaid stimuli revealed that mice demonstrate bistable perception, sometimes tracking individual stimulus components and others the global pattern of motion. Moreover, bistable optokinetic responses cannot be entirely attributed to subcortical circuitry as V1 lesions alter the fraction of responses occurring along pattern versus component motion. These observations suggest that area V1 input contributes to complex motion perception in the mouse and establish the bistable visual motion paradigm in the mouse as a potentially powerful way to study neuronal circuits underlying perception as well as perceptual flexibility. Using this paradigm, we found that the rate of perceptual reversals between global and local motion interpretations is reduced in the methyl-CpG-binding protein 2 duplication syndrome (MECP2-duplication) mouse model of autism. Moreover, the stability of local motion percepts is greatly increased in MECP2-duplication mice at the expense of global motion percepts. This is consistent with features seen in human autism, namely reduced rate of visual rivalry and atypical perception of visual motion. Preliminary results on the elements of neuronal circuitry that underly bistable perceptual transitions will be discussed.

Short bio: Stelios Smirnakis received a PhD in Physics and an MD from Harvard University. He did graduate work on retinal physiology under professor Markus Meister and postgraduate work on primate electrophysiology and functional magnetic resonance imaging at the Max Planck Institute for Biological Cybernetics under director Nikos Logothetis. In parallel, he trained in Vascular Neurology and Neurological Critical Care at Massachusetts General Hospital and Brigham & Women's Hospital, joining the faculty at Harvard Medical School in 2003. In 2008 he moved to Baylor College of Medicine, where he received tenure in 2015. He returned to Harvard Medical School in 2015 as an Associate Professor of Neurology, clinically affiliated with Brigham and Women's Hospital and Jamaica Plain Veterans Administration Hospital. His laboratory focuses on the study of multi-neuronal mechanisms of visual processing, learning and perception as well as mechanisms of neural circuit dysfunction in mouse models of disease such as epilepsy, autism, ischemic stroke and Alzheimer's.

Short bio: Dr. Ganna Palagina is an Instructor at Harvard Medical School. She is interested in circuits behind conscious experience, visual perception and interaction between low-level sensory processing and higher-order decision making. She is now working on paradigms for studying bistable visual perception in animals, including animal models of psychiatric diseases.

17.20 - 17.30 Coffee Break

17.30 - 18.30 Poster Session

July 2, 2024

10.00 - 11.00 ***Do AI Machines See the World the Way Animals Do?*** **Gabriel Kreiman (Harvard Medical School and Children's Hospital),**

Abstract: There has been rapid progress in artificial vision algorithms during the last decade, with headlines announcing that vision is solved and computer vision systems that can match or even surpass human performance in narrow domains. At the same time, AI machines remain fragile as demonstrated by adversarial attacks, fail to generalize as demonstrated by lack of extrapolation to novel scenarios, and provide only a minimal account of the mechanisms underlying visual processing. In this talk, I will introduce some of the accomplishments of neural network models of vision and how they can sometimes match animal behavior and neurophysiological responses. Next, I will discuss many of the failure modes and lack of alignment between AI and biological networks, both at the behavioral level and at the neuronal level. Finally, I will end with a more speculative discussion of what's missing in the field and the next steps towards building computational models of visual processing that better capture biological mechanisms.

Short bio: Gabriel Kreiman is a Professor at Children's Hospital, Harvard Medical School. He obtained his Ph.D. from Caltech, working with Professor Christof Koch, and subsequently trained with Prof. Tomaso Poggio at MIT. The Kreiman lab is interested in the intersection of neuroscience and Artificial Intelligence, using AI as potential models of neural circuit function and using insights from neuroscience to develop better AI algorithms. The Kreiman lab has contributed to our understanding of vision, learning and memory. For more information about the lab, please visit https://kreiman.hms.harvard.edu

11.00- 12.00 ***An Orchestra in the Brain: Identifying Communication Modules from the Functional Architecture of Primary Visual Cortex*****, Maria Papadopouli (University of Crete, FORTH, Archimedes R.U.)**

Abstract: How does the brain perform the complicated computations that allow us to learn about and interact with the environment? The rapid advances in optical imaging, machine learning, and the availability of computational resources, provide a unique opportunity to decipher this fundamental question. Although much has been learned about the computational properties of single neurons, we remain far from understanding how networks of cortical cells coordinate and interact with each other in order to process information. Several pioneering works have proposed theories regarding how the configuration of neuronal ensembles encode information in the cortex. Ensembles of neurons that fire in synchrony are likely to be more efficient at relaying shared information to downstream targets as well as more likely to belong to networks of neurons subserving similar functions. Spontaneous patterns of activity reflect the intrinsic dynamics of the brain in the absence of external stimulation or task performance. The following questions shape this research: What is the architecture of the functional connectivity of the primary visual cortex and how is information relayed across layers? How are these information streams modulated by different behavioral states and internal neuronal dynamics? The talk aims to shed light on the structure of spontaneous activity and what it tells us about computational processing in the brain.

Short Bio: Maria Papadopouli (Ph.D. Columbia University, 2002) is a Professor of Computer Science at the University of Crete, a Research Associate at the Institute of Computer Science, FORTH, a Lead Researcher at the Archimedes Research Unit, Athena Research Center, and a Fulbright Scholar. She has been a visiting Professor at the Brigham and Women's Hospital, Harvard Medical School (2022-2025), Fulbright Scholar at the Computer Science and Artificial Intelligence Laboratory (CSAIL), MIT (2017), and at the School of Electrical Engineering, KTH Royal Institute of Technology in Stockholm. From July 2002 until June 2006, she was a tenure-track Assistant Professor at the University of North Carolina at Chapel Hill (UNC), on leave from July 2004 until June 2006. Her research has been supported by several awards (e.g., IBM Faculty Awards, Google Faculty Award, Comcast Innovation Fund) and competitive national, EU, and international grants. Her research interests extend from the Internet of Things to network neuroscience and AI, focusing on analyzing complex networks.

12.00-12.20 Coffee Break

12.20-13.20 ***Neuronal Activity Transmission from Mice V1 Layer 4 to Layers 2/3,*** **Ioannis Smyrnakis (Hellenic Mediterranean University)**

Abstract: The mode of transmission of activity in mice V1, from layer 4 to layers 23 is examined. Artificial data are generated that preserve the average firing rates of the individual neurons as well as the population firing rate in every frame. The hypothesis that activity transmission is carried out through statistically significant cofirings on specific groups of layer 4 neurons is examined. The effect on the whole of layers 23 of these significant cofirings is examined, as well as their temporal distribution over the spike trains. There appears to be short 'talks' among neurons followed by large periods of silence. Temporal aspects of the significant cofirings appearance in relation to population firing are examined. Advantages of transmission of activity through significant cofirings, most

notably its relative independence on the internal fluctuations in the V1 layer 4 activity are discussed.

Short Bio:Ioannis Smyrnakis is an Associate Professor in Applied Mathematics at the Hellenic Mediterranean University. He obtained his first degree from Cambridge University, England and his Ph.D. from Columbia University, New York, on Mathematical Physics. He has worked on mathematical modeling in Particle Physics, Solid State Physics, Quantum Information Theory, Random walks and Neuroscience. Also he has worked on the characterization of dyslexia through eye tracking data while reading, for Emmetropia, a private sector company.

13.20-14.30 Lunch Break

14.30 - 15.30 ***Towards next-generation AI with neuro-inspired computing*****, Angeliki Pantazi (IBM Research – Zurich)**

Abstract: The recent advances in AI show that models only remotely inspired by biology can achieve impressive results on human-like tasks. These AI capabilities are achieved using the latest generations of Large Language Models (LLMs), enabled by their powerful transformer architecture. However, the operational principles of these systems have little similarity to the substantially more evolved network designs that the brain employs. Contrary to humans, the AI models operate with enormous energy and area consumption and their learning mechanism requires a large amount of data for training. A computational model inspired by the principles and mechanisms of biological systems is likely to provide more efficient innovative AI solutions due to its inherent conception idea. For example, the sparse neural activity, the neural coding strategies, the efficient neuronal dynamics, and the local plasticity mechanisms are potential key enablers for the astounding energy efficiency of the brain that can be integrated in AI systems. In this talk, I will provide an overview of our research on neuro-inspired models and learning algorithms that aim to address the sustainability concerns of current AI models. I will also showcase the efficiency of neuro-inspired computing concepts in several AI applications. Finally, I will present how neuro-inspired models could further leverage the acceleration provided by analog AI hardware.

Short Bio: Angeliki Pantazi is a Principal Research Staff Member and a Research Manager at the IBM Research – Zurich. She received her Diploma and Ph.D. degrees in Electrical Engineering and Computer Technology from the University of Patras, Greece. Since 2006, she has been a Research Staff Member in IBM Research – Zurich, where she has contributed to several projects in the area of data storage systems. Currently, she leads the research on neuro-inspired computing in the Emerging Computing and Circuits group. She was named IBM Master Inventor in 2014 and became a senior member of the IEEE in 2015 and a Fellow of IFAC in 2019. She was a co-recipient of the 2009 IEEE Control Systems Technology Award, the 2009 IEEE Transactions on Control Systems Technology Outstanding Paper Award and the 2014 IFAC Industrial Achievement Award. In 2017, she received an IBM Corporate Award and the IEEE Control Systems Society Transition to Practice Award. She has published over 100 refereed articles and holds over 50 granted patents.

15.30- 16.30 ***Challenges in Machine Learning for Big Scientific Data Analysis,*** **Greg Tsagkatakis (University of Crete, FORTH)**

Abstract:A wealth of scientific instruments, from microscopes monitoring the neuronal activity of the brain to orbiting telescopes trying to estimate the distribution of dark matter in the universe, is offering unprecedented views of our cosmos. Understanding the massive amounts of data and observations requires a rethinking of traditional scientific data analysis approaches, through the introduction of Big Science Data analytics. At the same time, the past ten years have witnessed a revolution in how to understand and infer meaningful patterns from massive amounts of data through the introduction of data-driven machine learning models. The aim of this talk is to present a number of challenges associated with introducing (deep) machine learning approaches for analyzing massive scientific data including topics like handling high dimensional observations, quantifying uncertainties, and dealing with data-related issues like class imbalance or missing observations. Approaches for addressing these challenges will be discussed in the context of different scientific domains including Neuroscience, Earth Observation, and Astrophysics.

Short Bio: Dr. Grigorios Tsagkatakis is an Assistant Professor at the Department of Computer Science of the University of Crete and an affiliated researcher with the Institute of Computer Science of FORTH. He received his BEng and MS degrees in Electronics and Computer Engineering from the Technical University of Crete, Greece in 2005 and 2007 respectively, and his Ph.D. in Imaging Science from the Rochester Institute of Technology, New York, in 2011. His work has been funded by different agencies including a European Commission Marie Skłodowska-Curie fellowship with the Department of Electrical and Computer Engineering at the University of Southern California, as well as projects with ESA and NASA. His research focuses on topics related to signal/image processing and machine learning with applications in remote sensing, astrophysics, and biology.

16.30-17.00: Coffee Break

17.00 - 18.00 ***Open Discussion on Neurocentric AI***

REGISTRATION

The registration is ***free***. However you need to indicate your participation in the following link:

https://forms.gle/jxbXy5TQ7Kbsvj699