TYPE - WORKSHOP • JULY 8 • TUESDAY

W Workshop

JULY 8 • TUESDAY

09:00 – 12:30 W **Advancing Mathematical Methods in Neuroscience Data Analysis** Hall 2B

Speakers: Dave Boothe, Piotr Franaszczuk, Vasileios Maroulas, Ioannis Schizas, Brittany Story

Brief Description: With the ever increasing amount of data acquired in neuroscience applications there is an essential need to develop computationally effective, robust, and interpretable data processing algorithms. Recent advancements in graph inference, topology, information theory and deep learning have shown promising results in analyzing biological/physiological data, as well as datasets acquired by intelligent agents. Combining elements from different disciplines of information theory, mathematics, and machine learning is paramount for developing the next generation of methods that will facilitate big data analysis under the realm of better understanding brain dynamics, as well as neuroinspired system dynamics in general. The goal of the workshop is to bring researchers working in data science, neuroscience, mathematics, and machine learning together to discuss challenges posed by analyzing multimodal data sets in neuroscience along with potential solutions, exchange ideas and present their latest work in designing and analyzing effective data processing algorithms. This workshop will serve as a great opportunity to discuss innovative future directions for neuroinspired processing of large amounts of data, while considering novel mathematical data models and computationally efficient learning algorithms.

Schedule:

9:00 - 9:40: Kathryn Hess, EPFL, Topological perspectives on the connectome

Abstract: Over the past decade or so, tools from algebraic topology have been shown to be very useful for the analysis and characterization of networks, in particular for exploring the relation of structure to function. I will describe some of these tools and illustrate their utility in neuroscience, primarily in the framework of a collaboration with the Blue Brain Project.

9:45 - 10:25: Moo Kyung Chung, University of Wisconsin, Topological Embedding of Dynamically Changing Brain Networks

Abstract: We introduce a novel topological framework for embedding time-varying brain networks into a low-dimensional space. Our Topological Embedding captures the evolving structure of functional connectivity by mapping dynamic birth and death values of topological features (connected components and cycles) into a 2D plane. Unlike traditional analyses that rely on synchronized time-points or direct comparisons of network matrices, our method aligns the dynamic behavior of brain networks through their underlying topological features, thus offering invariance to temporal misalignments and inter-subject variability. Using resting-state functional magnetic resonance images (rs-fMRI), we demonstrate that the topological embedding reveals stable 0D homological structures and fluctuating 1D cycles across time, which are further analyzed in the frequency domain through the Fourier Transform. The resulting topological spectrograms exhibit strong associations with age and cognitive traits, including fluid intelligence. This study establishes a robust and interpretable topological representation for the analysis of dynamically changing brain networks, with broad applicability in neuroscience and neuroimaging-based biomarker discovery. The talk is based on arXiv:2502.05814

10:30 - 11:00: Coffee Break

11:00 - 11:40: Anna Korzeniewska, Johns Hopkins University, From causal interactions among neural networks to significance in imaging brain tumor metabolism.

Abstract: Neural activity propagates swiftly across brain networks, often not providing enough data-points to model its dynamics. This limitation can be overcome by using multiple realizations, or repetitions, of the same process. However, once repetitions have been consumed for modeling, or only one is available, the significance of the neural dynamics cannot be assessed using traditional statistical methods. We propose a new method for assessing statistical confidence using the variance of a smooth estimator and a criterion for the choice of a smooth ratio. We show their applications to event-related neural propagations among eloquent and epileptogenic networks, and to metabolite kinetics in hyperpolarized 13C MRI (hpMRI) of brain tumor. The event-related causality (ERC) method - a multichannel extension of the Granger causality concept – was applied to multi-channel EEG recordings to estimate the direction, intensity, and spectral content of direct causal interactions among brain networks. A two-dimensional (2D) moving average, with a rectangular smooth window, sliding over points in the time-frequency plane, provided the smooth estimator and its error for statistical testing. The smooth size of the 2D moving average was determined by the W-criterion, which combines the *difference* between the smooth estimator and the real values with the *confidence interval*. The same approach was applied to 2D images of hpMRI of pyruvate metabolism of malignant glioma. A newly developed bivariate smoothing model ensured precise embedding of ERC's statistical significance in time-frequency space, revealing complex frequency-dependent dynamics of causal interactions. The strength and pattern of neural propagations among eloquent networks reflected stimulus modality, lexical status, and syllable position in a sequence, uncovering mechanisms

of speech control and modulation. The strength and pattern of high-frequency interactions among epileptogenic networks identified seizure onset zones and unveiled propagations preceding seizure onset. Statistical confidence of the difference between metabolic responses of tumor and normal tissue, obtained through hpMRI, allowed tumor delineation. Moving average provides an efficient smooth estimator and its error (optimal for reducing random noise while retaining sharp step response) and ensures precise embedding of statistical significance in two-dimensional space. The new approach overcomes several limitations of previously used 2D spline interpolation (restraint to a mesh of knots introducing artifactual distributions of variance and significance, and failure to converge in some cases), while W-criterion provides efficient choice of smooth size. The new technique has broad applicability to neuroscientific research and clinical applications, including planning for epilepsy surgery, localizing anatomical targets for responsive neuromodulation, and gauging tumor treatment response.

11:45 - 12:25: Vasileios Maroulas, University of Tennessee Knoxville, The Shape of Uncertainty.

Abstract: How does the brain know where it is and where it is going? Deep within our neural circuits, specialized cells—like head direction and grid cells—fire in intricate patterns to guide spatial awareness and navigation. But decoding these patterns requires tools that can keep up with the brain’s complexity. In this talk, I will share how we wre using topological deep learning to do just that. Our new models tap into higher-dimensional structures to predict direction and position—without relying on hand-crafted similarity measures. But that is just the beginning. I will also introduce a Bayesian framework for learning on graphs using sheaf theory, where uncertainty is not a bug but a feature. By placing probability distributions on the rotation group and learning them through the network, we gain robustness, flexibility, and accuracy—especially when data is scarce. Together, these advances point to a bold new direction: using geometry and topology to unlock the brain’s code and reshape how we learn from complex data.

09:00 – 12:30 W **Brain-Inspired Computing** Room 5

Speakers: Yunliang Zang, Guozhang Chen

Brain-inspired computing looks to mimic how the human brain works to improve artificial intelligence (AI) systems. This area has gained a lot of interest recently because it helps us create stronger and more efficient AI models while tackling challenges faced by current artificial neural networks.

This workshop will cover a range of topics, including biological neural networks, cognitive computing, and biologically-inspired algorithms. We will discuss how learning from the brain's structure and operations can lead to new solutions for complex issues in AI, machine learning, and data processing.

The workshop will include talks from experts in the field and interactive panel discussions. Participants will have the chance to collaborate, share ideas, and connect with others who are excited about using biological principles to advance technology.

Full program in this link.

Schedule

9:00 AM - 9:30 AM Speaker: Rui Ponte Costa, *University of Oxford*
A theory of self-supervised learning in cortical layers
9:30 AM - 10:00 AM Speaker: Guillaume Bellec, *Vienna University of Technology*
Validating biological mechanisms in deep brain models with optogenetic perturbation testing
10:00 AM - 10:30 AM Speaker: Guozhang Chen, *Peking University*
Characteristic differences between computationally relevant features of cortical microcircuits and artificial neural networks
10:30 AM - 11:00 AM Coffee Break
11:00 AM - 11:30 AM Speaker: Robert Legenstein, *Graz University of Technology*
Rapid learning with phase-change memory-based neuromorphic hardware through learning-to-learn
11:30 AM - 12:00 PM Speaker: Shogo Ohmae, *Chinese Institute for Brain Researc*
World-model-based versatile computations in the neocortex and the cerebellum
12:00 PM - 12:30 PM Speaker: Yuliang Zang, *Tianjin University*
Biological strategies for efficient learning in cerebellum-like circuits
12:30 End of Workshop and Lunch Break

Full program in this link.

09:00 – 12:30 W **Enabling synaptic plasticity, structural plasticity, and mutil-scale modeling with morphologically detailed neurons using Arbor** Belvedere room

Speakers: Thorsten Hater, Han Lu

Current computational neuroscience studies are often limited to a single scale or simulator, with many still relying on standalone simulation code due to computational power and technology constraints. Simulations incorporating biophysical properties and neural morphology typically focus on single neurons or small networks, while large-scale neural network simulations often resort to point neurons as a compromise to incorporate plasticity and cell diversity. Whole-brain simulations, on the other hand, frequently sacrifice details at the individual neuron and network composition levels.

This workshop introduces recent advances leveraging the next-generation simulator Arbor, designed to overcome these challenges. Arbor enables seamless conversion from the widely used NEURON simulator, facilitates the study of functional and structural plasticity in large neural networks with detailed morphology, and supports multi-scale modeling through co-simulation, integrating microscopic and macroscopic levels of simulation.

Arbor is a library optimized for efficient, scalable neural simulations by utilizing both GPU and CPU resources. It supports the simulation of both individual neurons and large-scale networks while maintaining detailed biophysical properties and morphological complexity. The workshop will feature presentations covering key aspects:

Effortless Transition from NEURON to Arbor - Dr. Beatriz Herrera - Allen Brain Institute, USA
Introducing to the SONATA format, which simplifies the migration process and enables cross-simulator validation, ensuring a smooth transition to Arbor for researchers familiar with NEURON.

Structural Plasticity Simulations - Marvin Kaster - TU Darmstadt, Germany
Presenting ReLEARN and Arbor's capabilities in modeling distance-dependent structural plasticity, providing insights into structural changes.

Synaptic Plasticity - Dr. Jannik Luboeinski - University of Göttingen, Germany
Showcasing Arbor's capabilities in modeling calcium-based functional plasticity.

Multi-Scale Co-Simulation with TVB - Dr. Juliette Courson - CY Cergy-Paris University, France
Demonstrating Arbor's co-simulation with The Virtual Brain (TVB) platform, illustrating the study of epilepsy propagation as an example of multi-scale modeling.

The workshop will conclude with an interactive coding session, offering participants hands-on experience with Arbor and an opportunity to apply the presented concepts.

09:00 – 12:30 W **Inference Methods for Neuronal Models: from Network Activity to Cognition** Hall 2A

Speakers: Matthieu Gilson, Meysam Hahsemi

CAREFUL ABOUT THE NEW ROOM: HALL 2A IN ENTRANCE BUILDING 2ND FLOOR

Workshop description:

The development of models for neuronal systems have matured in recent years and they exhibit increasing complexity thanks to computer resources for simulation. In parallel, the increasing availability of data poses the challenge to quantitatively related those models to data, going beyond reproducing qualitative activity patterns and behavior. Model inference is thus becoming an indispensable tool for unraveling the mechanisms underlying brain dynamics, behavior, and (dys)function. A critical aspect of this endeavor is the ability to infer changes across multiple scales, from neurotransmitters and synaptic interactions to neural circuits and whole-brain networks. Recent approaches that have been adopted by the neuroscience community include methods for directed effective connectivity (e.g. dynamical causal modeling), simulation-based inference on whole-brain models, and active inference for understanding perception, action and behavior. They have significantly enhanced our ability to interpret data by modeling underlying mechanisms and neuronal processes. This workshop will bring together experts from diverse fields to explore the state-of-the-art methodologies, taking specific applications as examples to compare them and highlight remaining challenges.

Detailed program with abstract: https://matthieugilson.eu/events/workshop_inference_CNS2025.pdf

Schedule:

• **9:00-9:20 Matthieu GILSON** *Institut de Neurosciences de la Timone, CNRS & Aix-Marseille University, France* (email: matthieu.gilson@univ-amu.fr)
Intro & **"Effective connectivity in "large" networks from fMRI signals as tested for estimation methods"**

• **9:20-9:45 Nina BALDY** *Institut de Neurosciences des Systèmes, INSERM, Aix-Marseille University, France (nina.baldy@univ-amu.fr)*
"Dynamic Causal Modeling in Probabilistic Programming Languages"

• **9:45-10:10 Cyprien DAUTREVAUX** *Institut de Neurosciences des Systèmes &* Institut de Neurosciences de la Timone, INSERM & CNRS, Aix-Marseille University, France (email: cyprien.dautrevaux@univ-amu.fr)
"Bayesian Inference of cortico-cortical effective connectivity in networks of neural mass models with neuroanatomical prior"

• **10:10-10:35 Richard ROSCH** Department for Basic and Clinical Neuroscience, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, UK (email: richard.rosch@kcl.ac.uk)
"Integrating multimodal data through Bayesian Inference"

• **10:35-11:00** coffee break

• **11:00-11:25 Meysam HASHEMI** *Institut de Neurosciences des Systèmes, INSERM, Aix-Marseille University, France (nina.baldy@univ-amu.fr)*
"Simulation-based inference on virtual brain models of disorders"

• **11:25-11:50 Levin KUHLMANN** *Monash University, Melbourne, Australia (email: levin.kuhlmann@monash.edu)*
"Bayesian vs Simulation Based Inference for neural population models"

• **11:50-12:15 Ivilin Peev STOIANOV** *National Research Council (CNR), Institute of Cognitive Sciences and Technologies (ISTC), Padova, Italy (email: ivilinpeev.stoianov@cnr.it)*
"Active inference: From Cortical Control to Neural Decoding"

09:00 – 12:30 W **Mechanisms for Oscillatory Neural Synchrony** Room 6

Speakers: Carmen Canavier

Here is the website: https://www.medschool.lsuhsc.edu/cell_biology/cns_2025.aspx

We have added a zoom link: https://lsuhsc.zoom.us/j/93759703592?from=addon
Meeting ID: 937 5970 3592

CNS*2025 in Florence, Italy on July 08, 2025
From 9:00 to 12:30
This workshop will bring together researchers who have recently published on synchronization networks of coupled oscillators, with a mix of approaches but an emphasis on phase response curve (PRC) theory. The researchers come from both theoretical and experimental backgrounds. Topics include synchronization mechanisms for theta nested gamma in the medial entorhinal cortex, mean-field pulsatile coupling methods for fast oscillations in inhibitory networks, beta oscillations in parkinsonian basal ganglia, the relative contributions of synaptic and ultra-fast non-synaptic ephaptic coupling to the inhibition of cerebellar Purkinje cells by basket cells, infinitesimal macroscopic PRC (imPRC) within the exact mean-field theory applied to ING and PING, and robustness in a neuromechanical model of motor pattern generation.
9:00-9:30 Carmen Canavier, LSU Health Sciences Center New Orleans: “A Mean Field Theory for Pulse-Coupled Oscillators based on the Spike Time Response Curve”
9:30- 10:00 Dimitri M Kullmann, University College London: “Phase response curves in the hippocampus and cerebellar cortex ”
10:00-10:30 Hermann Rieke, Northwestern University**: “**Paradoxical phase response of gamma rhythms facilitates their entrainment in heterogeneous networks”
10:30-11:00 am Coffee Break
11:00- 11:30 am Yangyang Wang, Brandeis University: “Variational and phase response analysis for limit cycles with hard boundaries, with applications to neuromechanical control problems”
11:30-12:00 Brandon Williams, Boston University: “Fast spiking interneurons generate high frequency gamma oscillations in the medial entorhinal cortex”
12:00 -12:30 Joshua A Goldberg, Hebrew University of Jerusalem**: "**Empirical Study of dendritic integration and entrainment of basal ganglia pacemakers**"**

09:00 – 12:30 W **Multiscale Modeling of Electromagnetic Field Perturbations on Neural Activity** Hall 3B

Speakers: Claudia Casellato, Alberto Arturo Vergani

Rational

Electromagnetic (EM) perturbations in silico are increasingly recognized as a promising approach in neuroscience, enabling the study of stimulation effects on brain models and providing insight into neural dynamics across temporal and spatial scales. This computational methodology serves both technological and clinical challenges, requiring multidisciplinary expertise to model EM perturbations and simulate their impact on the brain. In silico evaluations using advanced estimators to capture propagation dynamics remain at the forefront of contemporary research. This workshop provides a comprehensive overview of the computational workflow for EM perturbation modeling, covering key steps: (i) EM field generation, (ii) coupling across brain scales (from morphological models to large-scale systems), and (iii) evaluation of perturbative effects using quantitative measures. The program follows a progressive structure. It begins with foundational talks on theoretical and computational models of EM perturbations, establishing the framework to understand their mechanisms. Mid-stage talks make the transition toward applications, exploring how EM perturbations influence neural dynamics in mice and humans across brain states (from health to disease). Final talks address evaluation criteria, focusing on effectiveness, reproducibility, and translational relevance, emphasizing their role in both clinical and computational neuroscience. By integrating these elements, the program offers a cohesive narrative, illustrating how EM perturbation research evolves from theoretical models to real-world applications in neuroscience and medicine.

Timeline [slots of 25mins: 20 talk + 5 Q/A]

[9:00 – 9:05] Introduction by organizers

[9:05 – 9:30] *Whole-Brain Connectome-Based Modeling of Brain Stimulation and Network Dynamics*
Davide Momi, Post-doctoral Research Fellow, Stanford University

[9:30 – 9:55] *Quantifying Neural Complexity of Evoked Activities in Brain Recordings and Computational Models*
Gianluca Gaglioti, PhD student, University of Milan

[9:55 – 10:20] *Modeling EM-neuromodulation Across Scales: Mechanisms, Precision Medicine, and Model-Predictive Control*
Esra Neufeld, Head Computational Life Sciences, Associate Director, Foundation for Research on Information Technologies in Society (IT'IS), Zurich, CH

[10:20 – 10:45] *Whole-Brain Simulations of TMS-evoked Potentials in Major Depression*
Marius Pille, PhD student, Universitätsmedizin Berlin

[10:45-11:10] Time Break

[11:10 – 11:35] *Numerical Modeling of EM Fields and Dosimetric Assessment on Virtual Models*
Micol Colella, Postdoctoral Research Fellow, Sapienza University

[11:35 – 12:00] *EM Field Coupling on Virtual Mouse Brain*
Marialaura De Grazia, PhD student, University of Pavia

[12:00 – 12:25] *EM Field Coupling on Multicompartmental Neuronal Models*
Daniele Linaro, Associate Professor, Polytechnic of Milan

[12:25 – 12:30] Closing remarks or extra Q/A

09:00 – 12:30 W **Neuromodulation, sleep-dependent brain dynamics and information processing** Room 9

Speakers: Michal Zochowski, Sara Aton

Organizers: Sara J. Aton1, Michal Zochowski2

1. Department of Molecular, Cellular and Developmental Biology, University of Michigan, Ann Arbor, Mi, USA

2. Department of Physics and Biophysics Program, University of Michigan, Ann Arbor, Mi, USA

Introduction

State-dependent neural network dynamics have been proposed as an essential component of memory consolidation. Sleep and wake states drive changes in network-wide behavior and brain physiology, including state-specific network oscillations, synaptic plasticity profiles, excitatory-inhibitory balance, and neuronal activity levels. These changes are often mediated via release of neuromodulators that affect different features of network-wide dynamics, Those neuromodulators (that include but are not limited to acetylcholine, serotonin, norepinephrine and dopamine) on one hand target specific cell populations that express required receptor types, while on the other act as "global regulators" by influencing large neural networks and different brain modalities, adjusting their activity levels and changing computational properties of these networks.

Here, we will bring together an interdisciplinary group of experts whose research focuses on elucidating the role of state dependent neuromodulatory effects on network plasticity, dynamics and overall information processing. The workshop will bring together researchers using experimental as well as theoretical/computational approaches, while the presentations will bridge the scales from molecular and cellular to network effects.

Specific questions that we are aiming to be addressed are:

- How state specific changes in neuromodulatory milieu affect neuronal dynamics and network plasticity,
- How does neural network dynamics change during sleep?
- How are memories transformed during the sleep consolidation process?
- How state-dependent neuromodulatory processes interact with memory consolidation?
- What is the role of REM vs SWS sleep for various forms of memory?
- Can effects of state-dependent memory consolidation be successfully incorporated into AI models for improved performance?

Schedule:

Time	Speaker	Title
9:00 - 9:05	Sara Aton / Michal Zochowski	Introduction
9:05 - 9:30	Maksim Bazhenov	Interleaved Replay of Novel and Familiar Memory Traces During Slow-Wave Sleep Prevents Catastrophic Forgetting
9:30 - 9:55	Cecilia Diniz Behn	Mathematical modeling of noradrenaline dynamics across behavioral states
9:54 - 10:20	Victoria Booth	Modeling infraslow oscillatory brainstem dynamics during NREM-REM sleep cycles
10:25 - 10:50	Niels Niethard	VIP interneuron activity during sleep – conveying the cortical infraslow oscillation
10:50 - 11:15	Abdelrahman Rayan	Latent Dimensions of Rodent Sleep: A Deep Learning Approach

11:15 - 11:40	Penny Lewis (virtual)	Detecting memory reactivation in REM and NREM sleep - towards a generalisable EEG classifier
11:40 - 12:30	All	Questions and Debate
12:30		End of Workshop and Lunch Break

Talk Summaries:

Interleaved Replay of Novel and Familiar Memory Traces During Slow-Wave Sleep Prevents Catastrophic Forgetting

Maksim Bazhenov
Department of Medicine, University of California at San Diego, San Diego, CA, USA

Abstract

Humans and animals can learn continuously, acquiring new knowledge and integrating it into the pool of lifelong memories. Sleep replay has been proposed as a powerful mechanism contributing to interference-free new learning. In contrast, artificial systems suffer from a problem called catastrophic forgetting, where new training damages existing memories. This issue can be mitigated by interleaving training on new tasks with past data; however, whether the brain employs this strategy remains unknown. In this work, we show that slow-wave sleep (SWS) employs an interleaved replay of familiar cortical and novel hippocampal memory traces within individual Up states of the sleep slow oscillation (SO), allowing new memories to be embedded into the existing pool of cortical memories without interference. Using a combination of biophysical modeling and analyses of single-unit activity from the mouse retrosplenial cortex, we found that hippocampal ripples arriving near the Down-to-Up or Up-to-Down transitions of the sleep SO entrain novel memory replay, while the middle phase of the Up state always replays familiar cortical memories. This strategy ensures the consolidation of novel cortical memory traces into long-term storage while minimizing damage to familiar ones. This study presents a novel theory of how the replay of familiar and novel memory traces is organized during SWS to enable continual learning.

Mathematical modeling of noradrenaline dynamics across behavioral states

Cecilia Diniz Behn
Department of Applied Math & Statistics, Colorado School of Mines, Golden, CO, USA

Abstract

Wake, rapid eye movement (REM) sleep, and non-REM (NREM) sleep are characterized by differential release of neuromodulators such as noradrenaline (NE). The noradrenergic locus coeruleus (LC) promotes wakefulness and exhibits state-dependent changes in neuronal activity and NE release. Recent experimental advancements have described the LC-NE system with high temporal resolution and refined our understanding of how LC activity changes with behavioral state. Specifically, LC activity and NE release are highest during wakefulness, but they vary with attention and activity level. In NREM sleep, LC activity is phasic and drives infraslow extracellular oscillations in NE. During REM sleep, LC activity ceases, and extracellular NE decays slowly. However, at the offset of REM sleep, extracellular NE increases rapidly suggesting that there is an asymmetry in the dynamics of NE rise and fall. We previously developed a firing rate model formalism that describes both firing rate and associated neurotransmitter rel

09:00 – 12:30 W **NeuroXAI: Explainable AI for Understanding Biological Brains** Onice Room

Speakers: Jie Mei, Nina Hubig, Subham Dey, Claudia Plant

Full program

Join us online! https://it-u-at.zoom.us/j/96126010931?pwd=e1OBQaSLpNcghm96sq8qBMapfFLcTy.1

Overview

In evolutionarily advanced species, from rodents to humans, the biological brain orchestrates computations performed by hundreds of millions to billions of neurons, giving rise to behaviors emerging from this highly parallelized system. To model neural activities efficiently, down-sampling of the neuronal density is often required. Meanwhile, models inspired by neural computation can scale up to millions or even billions of parameters. While the interpretability of neuro-inspired artificial neural networks (ANNs) is essential for evaluating their reliability, robustness, biological plausibility, and trustworthiness, their structural complexity often makes them difficult to interpret.

This workshop will begin with an overview of interpretability challenges in modeling the nervous system, highlighting solutions from the perspective of explainable AI (XAI). We will examine the obstacles faced by the experimental and computational neuroscience communities in data analysis, model development, and dataset integration. Through these examples, we will explore how XAI methods can be used to probe the inner workings of neuro-inspired ANNs.

Furthermore, this OCNS workshop provides a unique platform to bring together neuroscience and AI researchers working on XAI for neuroscience (NeuroXAI) and other relevant areas of research. Topics of interest include machine learning and data mining models for neuroscience, XAI methods to address challenges in neuroscience data analysis and modeling, neuro-inspired models, and topics of high societal relevance (e.g., open science practices and reproducibility). By fostering the exchange of ideas and collaborations, the workshop aims to shape future research directions and advance the development and testing of robust, reliable, and reproducible models, methods, and frameworks.

Talks

Parsimonious and Tractable RNNs for Dynamical Systems Reconstruction
Daniel Durstewitz (Central Institute of Mental Health Mannheim and Interdisciplinary Center for Scientific Computing at Heidelberg University)

Leveraging Latent Space Models for Biomarker Discovery in Deep Brain Stimulation
Sankar Alagapan (Georgia Institute of Technology)

Explainable AI for neuroimaging in psychiatry: evaluation and cellular-to-network investigation of E/I imbalance in autism
Trang-Anh Nghiem (Stanford University/Hertie Institute for AI in Brain Health)

Neural dynamics of reversal learning in the prefrontal cortex and recurrent neural networks
Christopher Kim (Howard University)

What can artificial neural networks learn from biological neuromodulatory systems?
Srikanth Ramaswamy (Newcastle University/MIT)

09:00 – 13:00 W **Cross-species modeling of brain structure and dynamics** Auditorium

Speakers: Eli Justin Muller, James Pang

A central challenge in neuroscience is understanding the organizational principles that govern brain structure and dynamics, particularly those features of the human brain that underpin our unique cognitive abilities. To unravel these principles, it is essential to consider brain evolution and the diversity of neural architectures across species, as this comparative approach offers the most comprehensive insights. This workshop brings together leading experts who employ a combination of experimental and computational methods to explore brain structure and dynamics in both humans and a variety of non-human species (e.g., chimpanzee, macaque, mouse, c. elegans).

Schedule:

- 09:00 - 09:30 **Eli Muller**, University of Sydney, Australia (**Evolutions attractors: From cells to systems, theory to application**)
- 09:30 - 10:00 **Petra Vertes**, University of Cambridge, UK (**Networks in action: The crucial role of dynamics in network neuroscience**)
- 10:00 - 10:30 **Giovanni Rabuffo**, Aix Marseille University, France (**Multiscale mapping between local neuronal activity and global brain dynamics (and back)**)

- 10:30 - 11:00 BREAK

- 11:00 - 11:30 **James Pang,** Monash University, Australia (**Geometric influences on mammalian brain organization and dynamics**)
- 11:30 - 12:00 **Mengsen Zhang**, Michigan State University, USA (**A topological link between models of brain-behavior dynamics**)
- 12:00 - 12:30 **Sean Froudist-Walsh**, University of Bristol, UK (**Comparative computational neuroscience of working memory mechanisms in mice, marmosets, and macaque monkeys**)

09:00 – 12:30 W **Linking structure, dynamics, and function in neuronal networks: old challenges and new directions**

Speakers: Wilhelm Braun, Kayson Fakhar, Claus C Hilgetag Room 101

The full program including abstracts can be found here

https://sites.google.com/view/cns2025workshop-strudynfun/

We are looking forward to seeing you at the workshop.

Wilhelm Braun, Kayson Fakhar and Claus C. Hilgetag

09:00 – 17:30 W **Computational strategies in epilepsy modelling and seizure control** Room 202

Speakers: Isa Dallmer-Zerbe, Guillaume Girier, Jaroslav Hlinka, Helmut Schmidt

The event schedule and abstracts are available here: https://brady.cs.cas.cz/ocns-epilepsy-workshop

Epilepsy remains a complex neurological condition, necessitating innovative approaches to understanding and mitigating seizure activity. This workshop is designed to bring together computational neuroscientists and researchers with experimental and clinical background to explore cutting-edge strategies in epilepsy modeling and seizure control. For the general content structure, we plan to start from a modeler's perspective and then progressively move towards more data-driven approaches.

The first session will explore seizure mechanisms through biophysical and neural mass models at different temporal and spatial scales, investigating, among others, ionic dynamics and network plasticity. It aims to understand seizure initiation, progression, and duration.

The second session will focus on the application of computational models to EEG data recorded in epileptic patients. First, it will discuss advanced parameter inference methods to tailor models to individual data samples to provide mechanistic insight. It then moves on to issues of seizure monitoring using wearable devices and long-term EEG recordings, and in particular the use of data features inspired by concepts derived from mathematical modeling in epilepsy.

The third session will examine stimulation-based strategies to terminate or prevent seizures. There will be a focus on recent advancements in closed-loop and low-frequency electrical stimulation to control seizures. On top of model-based approaches, this session will also include the clinical perspective on stimulation treatment and data-driven studies.

09:00 – 17:30 W **Population activity: the influence of cell-class identity, synaptic dynamics, plasticity and adaptation** Room 4
Speakers: Michele GIUGLIANO, Simona OLMI, Alessandro TORCINI

WEB PAGE of the WORKSHOP

Title: Population activity : the influence of cell-class identity, synaptic dynamics, plasticity and adaptation.

The workshop will take place on 8th July (9:00-12:30) in Room 4 and on 9th July (9:30-12:30 - - 14;00-17:30) in Room Hall 1A

Organizers:

Michele GIUGLIANO (co-organizer)
Università degli Studi di Modena e Reggio Emilia - Dipartimento di Scienze Biomediche, Metaboliche e Neuroscienze sede ex-Sc. Biomediche - Italy
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Alessandro TORCINI (co-organizer)
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Abstract:
In recent years tremendous developments have been achieved in the comprehension of neural activity at the population level. This has been possible on one side thanks to the new investigation methods recently developed (e.g. the neuropixels probes and large-scale imaging) that allows for the contemporary registration of the activity of (tens/hundreds of) thousands of neurons in alive and behaving mice as well as established dynamic-clamp protocols.
On the other side by the elaboration of extremely refined mean field models able to describe the population activity of spiking neural networks encompassing realistic biological features, from different forms of synaptic dynamics to plastic and adaptive aspects present at the neural level.
The aim of this workshop is to gather neuroscientists, mathematicians, engineers, and physicists all working on the characterization of the population activity from different point of views, ranging from data analysis of experimental results to simulations of large ensembles of neurons, from next generation neural mass models to dynamical mean field theories. This workshop will favour the exchanges and the discussion on extremely recent developments in this extremely fluorishing field.

Key Words : Neuropixels probes; neural mass models; Fokker Planck formulation; dynamical mean field theory; short- term and long-term plasticity; excitatory and inhibitory balanced networks; spike frequency adaptation

Program:
July 8th -- Room 4

9:15-9:30 Opening
9:30-10:00 **Anna Levina** (University of Tübingen, Germany)
Talk title: "Balancing Excitation and Inhibition in connectivity and synaptic strength"
10:00-10:30 **Giacomo Barzon** (Padova Neuroscience Center, University of Padova, Italy)
Talk title: "Optimal control of neural activity in circuits with excitatory-inhibitory balance"

10:30-11:00 Coffee break

11:00-11:30 **Eleonora Russo** (Scuola Superiore Sant'Anna, The BioRobotics Institute, Italy)
Talk title “Integration of rate and phase codes by hippocampal cell-assemblies supports flexible encoding of spatiotemporal context”

11:30-12:00 **Tobias Kühn** (University of Bern, Switzerland)
Talk title: "Discrete and continuous neuron models united in field theory: statistics, dynamics and computation"
12:00-12:30 **Gianluigi Mongillo** (Sorbonne Université, INSERM, CNRS, Institut de la Vision, F-75012 Paris, France)
Talk title: “Synaptic encoding of time in working memory”

July 9th -- Room Hall 1A

9:30 - 10:00 **Magnus J.E. Richardson** (Warwick Mathematics Institute, UK)
Talk title: "Spatiotemporal integration of stochastic synaptic drive within neurons and across networks"
10:00-10:30 **Gianni Valerio Vinci** (Istituto Superiore di Sanita’, Rome, Italy)
Talk title: "Noise induced phase transition in cortical neural field: the role of finite-size fluctuations"

10:30-11:00 Coffee break

11:00-11:30 **Simona Olmi** (Institute for Complex Systems - National Research Council - Italy)
Talk title: “Relaxation oscillations in next-generation neural masses with spike-frequency adaptation”
11:30-12:00 **Ferdinand Tixidre** (CY Cergy Paris University, France)
Talk title: "Is the cortical dynamics ergodic? A numerical study in partially-symmetric networks of spiking neurons"
12:00-12:30 **Letizia Allegra Mascaro** (Neuroscience Institute, National Research Council, Italy)
Talk title: "State-Dependent Large-Scale Cortical Dynamics in Neurotypical and Autistic Mice"

12:30-14:00 Lunch break

14:00-14:30 **Alessandro Torcini** (CY Cergy Paris Université- Cergy-Pontoise, France)
Talk title : “Discrete synaptic events induce global oscillations in balanced neural networks"
14:30-15:00 **Rainer Engelken** (Columbia University, NY, United States)
Talk title:"Sparse Chaos in Cortical Circuits: Linking Single-Neuron Biophysics to Population Dynamics"
15:00-15:30 **Tilo Schwalger** (Technische Universität Berlin, Institut für Mathematik, Germany)
Talk title: "A low-dimensional neural-mass model for population activities capturing fluctuations, refractoriness and adaptation"

15:30-16:00 Coffee break

16:00-16:30 **Giancarlo La Camera** (Stony Brook University, NY, United States)
Talk title: “Prefrontal population activity during strategic behavior in context-dependent tasks”
16:30-17:00 **Gorka Zamora-López** (Universitat Pompeu Fabra, Barcelona, Spain)
Talk title: "Emergence and maintenance of modular hierarchy in neural networks driven by external stimuli"
17:00-17:30 **Sacha van Albada** (Research Center Juelich and University of Cologne, Germany)
Talk title: "Determinants of population activity in full-density spiking models of cerebral cortex"

Abstracts of the Talks ----------

The Complete list of abstracts is attached below as a PDF file, due to the lack of space and they can be found also in the

OFFICIAL WEB PAGE of the WORKSHOP

09:00 – 17:30 W **Workshop on Methods of Information Theory in Computational Neuroscience** Room 203

Speakers: Marilyn Gatica, Joseph T. Lizier, Abdullah Makkeh, Pedro A.M. Mediano, Michael Wibral

Workshop website: https://kgatica.github.io/CNS2025-InfoTeory-W.io/

Methods originally developed in Information Theory have found wide applicability in computational neuroscience. Beyond these original methods there is a need to develop novel tools and approaches that are driven by problems arising in neuroscience. A number of researchers in computational/systems neuroscience and in information/communication theory are investigating problems of information representation and processing. While the goals are often the same, these researchers bring different perspectives and points of view to a common set of neuroscience problems. Often they participate in different fora and their interaction is limited. The goal of the workshop is to bring some of these researchers together to discuss challenges posed by neuroscience and to exchange ideas and present their latest work. The workshop is targeted towards computational and systems neuroscientists with interest in methods of information theory as well as information/communication theorists with interest in neuroscience.

This is the 20th iteration of this workshop at CNS --join us to celebrate!

W Workshop

JULY 9 • WEDNESDAY

09:00 – 12:30 W **Linking structure, dynamics, and function in neuronal networks: old challenges and new directions**

Speakers: Wilhelm Braun, Kayson Fakhar, Claus C Hilgetag

Room 101

The full program including abstracts can be found here

https://sites.google.com/view/cns2025workshop-strudynfun/

We are looking forward to seeing you at the workshop.

Wilhelm Braun, Kayson Fakhar and Claus C. Hilgetag

09:00 – 17:30 W **Brain Digital Twins: from Multiscale Modeling to Precision Medicine**

Belvedere room

Speakers: Lorenzo Gaetano Amato, Alberto Mazzoni

This workshop will explore how brain digital twins are revolutionizing research into pathological brain conditions and transforming the landscape of precision medicine. Participants will learn how these models work and how they integrate data and tools from different fields, such as molecular neuroscience, network theory and dynamical systems. We will discuss how digital twins can help identify early biomarkers able to characterize pathological states and predict disease progression. Another key topic will be the use of digital twins as in silico environments for testing potential treatments before applying them in clinical scenarios.
Through real-world examples and interactive sessions, we will tackle some of the challenges that come with this innovative approach, such as achieving anatomical precision, handling large datasets, and ensuring ethical use in patient care. The focus will be on making these cutting-edge tools accessible and impactful, not just for researchers but also for clinicians aiming to deliver more effective, tailored care to their patients.

Schedule:
9:00 - 9:45. Prof. Petra Ritter, Charité Berlin, Berlin, Germany:
"*Digital Brain Twins: from Theory to Clinical Applications"*

9:45 – 10:30. Michelangelo Fabbrizzi, Sant'Anna School of Advanced Studies, Pisa, Italy:
"*Integrative Personalized Models for Reconstructing Brain Anatomy and Dynamics"*

10:30 – 11:00. Coffee Break
11:00 – 11:45. Claudia Casellato, University of Pavia, Pavia, Italy:
"*Cerebellar Neuromodulation in Ataxia: Digital Cerebellar Twin to Predict the Movement Rescue"*

11:45 – 12:30. Lorenzo Gaetano Amato, Sant'Anna School of Advanced Studies, Pisa, Italy:
"*Digital Brain Twins for the Derivation of Personalized Biomarkers"*

12:30 – 14:00. Lunch Break
14:00 – 14:45. Pierpaolo Sorrentino, Aix-Marseille University, Marseille, France:
"*Digital Patients in Parkinson's Disease and Multiple Sclerosis"*

14:45 – 15:30. Jesùs Cabrera-Alvarez, Complutense University of Madrid, Madrid, Spain:
"*Integrative Biophysical Modelling of the Progression of Alzheimer's Disease: Mechanisms and Applications"*

15:30 – 16:00. Coffee Break

16:00 – 16:45. Leanne Rokos, Rotman Research Institute, Baycrest Health Sciences, Toronto, ON, Canada:
"Modeling Brain Network Dynamics in Early Development with The Virtual Brain"

16:45 – 17:30. Jyotika Bahuguna, University of Strasbourg, Strasbourg, France:
"Energy landscape analysis for characterizing neural dynamics in neuropathologies"

09:00 – 17:30 W **Brains and AI** Room 4

Speakers: Thomas Nowotny, Maksim Bazhenov, Vassilis Cutsuridis

Full workshop program

Schedule

9:00-9:30 Andreas Tolias

Foundation models and digital twins of the brain (online)

9:30-10:00 Vassilis Cutsuridis

Synapse strengthening in bistratified cells leads to super memory retrieval in the hippocampus

10:00-10:30 Spyridon Chavlis

Dendrites as nature's blueprint for a more efficient AI

10:30-11:00 Coffee Break

11:00-11:30 Fleur Zeldenrust

Heterogeneity, non-linearity and dimensionality: how neuron and network properties shape computation

11:30-12:00 Robert Legenstein

Spatio-Temporal Processing with Dynamics-enhanced Spiking Neural Networks

12:00-12:30 Max Garagnani

Concept superposition and learning in standard and brain-constrained deep neural networks

12:30-14:00 Lunch

14:00-14:30 Martin Trefzer

Motifs, Modules, and Mutations: Building Brain-like Networks

14:30-15:00 Julian Göltz

From biology to silicon substrates: neural computation with physics

15:00-15:30 Maxim Bazhenov

Do Neural Networks Dream of Electric Sheep?

15:30-16:00 Coffee Break

16:00-16:30 Dhireesha Kudithipudi

Temporal Chunking Enhances Recognition of Implicit Sequential Patterns

16:30-17:00 Thomas Nowotny

Auto-adjoint method for gradient descent in spiking neural networks

17:00-18:00 Questions and Debate

18:00 End of Workshop

Full workshop program

09:00 – 17:30 W **Computational strategies in epilepsy modelling and seizure control** Room 202

Speakers: Helmut Schmidt, Jaroslav Hlinka, Guillaume Girier, Isa Dallmer-Zerbe

The event schedule and abstracts are available here: https://brady.cs.cas.cz/ocns-epilepsy-workshop

Epilepsy remains a complex neurological condition, necessitating innovative approaches to understanding and mitigating seizure activity. This workshop is designed to bring together computational neuroscientists and researchers with experimental and clinical background to explore cutting-edge strategies in epilepsy modeling and seizure control. For the general content structure, we plan to start from a modeler's perspective and then progressively move towards more data-driven approaches.

The first session will explore seizure mechanisms through biophysical and neural mass models at different temporal and spatial scales, investigating, among others, ionic dynamics and network plasticity. It aims to understand seizure initiation, progression, and duration.

The second session will focus on the application of computational models to EEG data recorded in epileptic patients. First, it will discuss advanced parameter inference methods to tailor models to individual data samples to provide mechanistic insight. It then moves on to issues of seizure monitoring using wearable devices and long-term EEG recordings, and in particular the use of data features inspired by concepts derived from mathematical modeling in epilepsy.

The third session will examine stimulation-based strategies to terminate or prevent seizures. There will be a focus on recent advancements in closed-loop and low-frequency electrical stimulation to control seizures. On top of model-based approaches, this session will also include the clinical perspective on stimulation treatment and data-driven studies.

09:00 – 17:30 W **Emerging Research Topics in NeuroAI** Onice Room

Speakers: Zhe Sage Chen, Michael Halassa

This workshop is inspired by the goal of the NIH BRAIN (*Brain Research Through Advancing Innovative Neurotechnologies)* Initiative to develop theories, models, and methods to understand brain functions and their causal links to behaviors. The modern advances in neuroscience and AI have generated growing interests in NeuroAI, as witnessed by the feedback from the recent NIH BRAIN NeuroAI workshop (Nov. 12-13, 2024). Briefly, NeuroAI is aimed to, first, use AI to understand and improve the brain and behaviors, and second, to develop brain-inspired AI systems for robust, faster and more efficient operations and performances. Motivated by the new wave and developments in NeuroAI, this workshop invites leading experts and new investigators from various research backgrounds to discuss many emerging research topics. The goal of this full-day workshop is to focus on building the bridge between AI and neuroscience, to discuss new research directions and outstanding questions, and to foster team collaborations and open science. Research topics of interest include but not limited to neural transformers and foundation models, new neural network architectures, distributional or meta reinforcement learning, structural reasoning and inference, large language models (LLMs), and digital twins brain. The format of the workshop will consist of both overview-like and research-oriented lecture presentations as well as panel discussions.

Confirmed speakers (in alphabetical order) include:

Z. Sage Chen (NYU), *Multiplicative couplings facilitate learning and flexibility in recurrent neural circuits*

Rui Ponte Costa (Oxford), *Learning across the brain: a NeuroAI perspective*

Tatiana Engel (Princeton), *Closing the discovery loop with digital twins and causal perturbations*

Michael M. Halassa (Tufts)*, Thalamocortical architectures for cognitive control and flexibility*

Daniel Levenstein (Mila/McGill), *NeuroAI as a platform for theory development: lessons from hippocampal representation and replay*

Kevin Miller (Google Deepmind), *Automatically discovering neuroscience theories from data*

Gaspard Oliviers (Oxford)*, Bidirectional predictive coding: Towards robust inference and versatile learning in the brain*

Seng Song (Tsinghua), *Brain inspired learning rules and evolutionary computing*

Naoshige Uchida (Harvard)*, Distributional reinforcement learning in the brain*

This session is neither sponsored by nor affiliated with the NIH BRAIN Initiative.

09:00 – 17:30 W **Modeling extracellular potentials: principles, methods, and applications** Room 5

Speakers: Nicolo Meneghetti, Eleonora Russo

Please visit the dedicated website for full details: https://nicolomeneghetti.github.io/ECP_CNS2025_Wshop/

Simulating large-scale neural activity is essential for understanding brain dynamics and linking in silico models to experimentally measurable signals like LFP, EEG, and MEG. These simulations, ranging from detailed biophysical models to simplified proxies, bridge microscale neural dynamics with meso- and macro-scale recordings, offering powerful tools to interpret data, refine analyses, and explore brain function. Recent advances have demonstrated the clinical and theoretical value of such models, shedding light on oscillations, excitation-inhibition balance, and biomarkers of neurological disorders like epilepsy, Alzheimer's, and Parkinson's disease. This workshop will cover the latest methodologies, hybrid modeling approaches, and applications of brain signal simulations.

09:15 – 09:50
Dominik Peter Koller, *Berlin Institute of Health (BIH) at Charité – Universitätsmedizin Berlin, Berlin, Germany*
Title: "**How structural connectivity directs cortical traveling waves and shapes frequency gradients**"

09:50 – 10:25
Gaute T. Einevoll, *Department of Physics, University of Oslo, Oslo, Norway*
Title: "**Modeling electric brain signals and stimulation**"

10:30 – 11:00
Coffee Break

11:00 – 11:35
Johanna Senk, *Institute for Advanced Simulation (IAS-6), Jülich Research Centre, Jülich, Germany*
Title: **"Large-scale modeling of mesoscopic networks at single-neuron resolution"**

11:35 – 12:10
Pablo Martínez Cañada, *Research Centre for Information and Communications Technologies (CITIC), University of Granada, Granada*
Title: "**Inverse Modelling of Field Potentials from Simulations of Spiking Network Models: Applications in Neuroscience Research and Clinical Settings**"

12:10 – 12:40
Nicolò Meneghetti, *The Biorobotics Institute, Sant'Anna School of Advanced Studies, Pisa, Italy*
Title**: "From microcircuits to mesoscopic signals: a kernel approach to efficient and interpretable LFP estimation"**

12:45 - 14.00
Lunch Break

14:15 – 14:50
Emily Patricia Stephen, *Department of Math and Statistics, Boston University, Boston, MA, United States of America*
Title: **"Connecting biophysical models to empirical power spectra using Filtered Point Processes"**

14:50 - 15:25
Madeleine Lowery, *School of Electrical and Electronic Engineering, University College Dublin, Dublin, Ireland*
Title: **"Modelling Neural Activity During Adaptive Deep Brain Stimulation for Parkinson's Disease"**

15:30 - 16:00
Coffee Break

16:00 – 16:35
Meysam Hashemi, *Aix Marseille University INSERM, INS, Institute for Systems Neuroscience, Marseille, France*
Title: **"Principles and Operation of Virtual Brain Twins"**

16:35 - 17:10
Katharina Duecker, *Brown University and University of Birmingham, USA/UK*

Title: "**The Human Neocortical Neurosolver as an interactive modeling tool to study the multi-scale mechanisms of human EEG/MEG signals**"

09:00 – 17:30 W **NEW VISTAS IN MULTISCALE BRAIN MODELLING AND APPLICATIONS** Hall 3B

Speakers: Sergio Mauro Solinas, Egidio D'Angelo, Rosanna Migliore, Paolo Massobrio, Alessia Bonafede

EBRAINS-Italy MNESYS Workshop

This conjoint EBRAINS-MNESYS workshop will address the pillars of multiscale brain modelling by presenting and discussing front-end research topics in Computational Neuroscience. This event will offer the attendees the opportunity to explore multiscale modelling workflows, digital computation tools, data-based validation workflows, data analysis pipelines, and several applications to neurophysiology, neuropathology, and neurotechnology. The workshop also aims to foster collaboration and drive innovation within the field of Computational Neuroscience, contributing to the establishment of the EBRAINS-Italy research infrastructure and partnership.

9th July 2025 Hall 3B Palazzo dei Congressi

8:45 Welcome and Introduction

9:00-10.30 Introductory concepts

9:00 Michele Migliore (CNR)
The EBRAINS-Italy ecosystem of workflows and pipelines for computational neuroscience research

9:30 Egidio D'angelo (Univ. of Pavia)
Brain modelling toward the generation of digital twins

10:00 Sergio Martinoia (Univ. of Genoa)
In-vitro and in-silico brain models: toward hybrid biological-digital twins

10:30 Coffee Break

11.00-11.30 Theoretical models

11:30 Cosimo Lupo (Istituto Nazionale di Fisica Nucleare INFN)
Dendritic integration and neuromodulation in biologically-inspired multi-compartment neuron models

11.30-12:30 Computational modeling and hands-on (cells and circuits)

11:30 Jonathan Mapelli (Univ. of Modena and Reggio Emilia)
Multiscale modeling of the hippocampus: "embedding microcircuits into whole-brain models"

12:00 Claudia Casellato (Univ. of Pavia)
Multiscale cerebellar circuit models

12:30 Lunch Break

14.00-15.30 Computational modelling of systems and whole brain

14:00 Paolo Massobrio (Univ. of Genoa)
Model fusion: experimental and mathematical approaches to decoding neuronal ensembles in physiological and pathological conditions

14:30 Alberto Mazzoni (School of Adv. Studies Pisa)
From silico to clinics: network models of neurodegeneration for early diagnosis and personalized treatments

15:00 Alberto Antonietti (Polytechnic University of Milan)
Multiscale models for Parkinson's disease and neuromodulation

15:30 Coffee Break

16.00-17.00 Theoretical models

16:00 Dora Marasco (Univ. of Federico II Naples)
The A-GLIF model in action: data-driven modelling and neuron copy generation for heterogeneous large-scale network implementations

16:30 Maurizio Mattia (Istituto Superiore di Sanità Rome)
Recurrent neural networks as digital twins of brain activity

17.00-17:30 Computational modeling and hands-on (cells and circuits)

17:00 Sergio Solinas (Univ. of Sassari)
Modelling and visualisation of the CA1 region of the Human Hippocampus

17.30 - 18:00 Discussion and Final Remarks

09:00 – 17:30 W **Population activity: the influence of cell-class identity, synaptic dynamics, plasticity and adaptation** Hall 1A
Speakers: Michele GIUGLIANO, Simona OLMI, Alessandro TORCINI

WEB PAGE of the WORKSHOP

Title: Population activity : the influence of cell-class identity, synaptic dynamics, plasticity and adaptation.

The workshop will take place on 8th July (9:00-12:30) in Room 4 and on 9th July (9:30-12:30 - - 14;00-17:30) in Room Hall 1A

Organizers:

Michele GIUGLIANO (co-organizer)
Università degli Studi di Modena e Reggio Emilia - Dipartimento di Scienze Biomediche, Metaboliche e Neuroscienze sede ex-Sc. Biomediche - Italy
michele.giugliano@unimore.it

Simona OLMI (co-organizer)
Institute for Complex Systems - National Research Council - Italy
simona.olmi@fi.isc.cnr.it

Alessandro TORCINI (co-organizer)
Laboratoire de Physique Théorique et Modélisation - CY Cergy Paris Université- Cergy-Pontoise, France
alessandro.torcini@cyu.fr

Abstract:
In recent years tremendous developments have been achieved in the comprehension of neural activity at the population level. This has been possible on one side thanks to the new investigation methods recently developed (e.g. the neuropixels probes and large-scale imaging) that allows for the contemporary registration of the activity of (tens/hundreds of) thousands of neurons in alive and behaving mice as well as established dynamic-clamp protocols.
On the other side by the elaboration of extremely refined mean field models able to describe the population activity of spiking neural networks encompassing realistic biological features, from different forms of synaptic dynamics to plastic and adaptive aspects present at the neural level.
The aim of this workshop is to gather neuroscientists, mathematicians, engineers, and physicists all working on the characterization of the population activity from different point of views, ranging from data analysis of experimental results to simulations of large ensembles of neurons, from next generation neural mass models to dynamical mean field theories. This workshop will favour the exchanges and the discussion on extremely recent developments in this extremely fluorishing field.

Key Words : Neuropixels probes; neural mass models; Fokker Planck formulation; dynamical mean field theory; short- term and long-term plasticity; excitatory and inhibitory balanced networks; spike frequency adaptation

Program:
July 8th -- Room 4

9:15-9:30 Opening
9:30-10:00 **Anna Levina** (University of Tübingen, Germany)
Talk title: "Balancing Excitation and Inhibition in connectivity and synaptic strength"
10:00-10:30 **Giacomo Barzon** (Padova Neuroscience Center, University of Padova, Italy)
Talk title: "Optimal control of neural activity in circuits with excitatory-inhibitory balance"

10:30-11:00 Coffee break

11:00-11:30 **Eleonora Russo** (Scuola Superiore Sant'Anna, The BioRobotics Institute, Italy)
Talk title “Integration of rate and phase codes by hippocampal cell-assemblies supports flexible encoding of spatiotemporal context”

11:30-12:00 **Tobias Kühn** (University of Bern, Switzerland)
Talk title: "Discrete and continuous neuron models united in field theory: statistics, dynamics and computation"
12:00-12:30 **Gianluigi Mongillo** (Sorbonne Université, INSERM, CNRS, Institut de la Vision, F-75012 Paris, France)
Talk title: “Synaptic encoding of time in working memory”

July 9th -- Room Hall 1A

9:30 - 10:00 **Magnus J.E. Richardson** (Warwick Mathematics Institute, UK)
Talk title: "Spatiotemporal integration of stochastic synaptic drive within neurons and across networks"
10:00-10:30 **Gianni Valerio Vinci** (Istituto Superiore di Sanita’, Rome, Italy)
Talk title: "Noise induced phase transition in cortical neural field: the role of finite-size fluctuations"

10:30-11:00 Coffee break

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12:00-12:30 **Letizia Allegra Mascaro** (Neuroscience Institute, National Research Council, Italy)
Talk title: "State-Dependent Large-Scale Cortical Dynamics in Neurotypical and Autistic Mice"

12:30-14:00 Lunch break

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Talk title : “Discrete synaptic events induce global oscillations in balanced neural networks"
14:30-15:00 **Rainer Engelken** (Columbia University, NY, United States)
Talk title:"Sparse Chaos in Cortical Circuits: Linking Single-Neuron Biophysics to Population Dynamics"
15:00-15:30 **Tilo Schwalger** (Technische Universität Berlin, Institut für Mathematik, Germany)
Talk title: "A low-dimensional neural-mass model for population activities capturing fluctuations, refractoriness and adaptation"

15:30-16:00 Coffee break

16:00-16:30 **Giancarlo La Camera** (Stony Brook University, NY, United States)
Talk title: “Prefrontal population activity during strategic behavior in context-dependent tasks”
16:30-17:00 **Gorka Zamora-López** (Universitat Pompeu Fabra, Barcelona, Spain)
Talk title: "Emergence and maintenance of modular hierarchy in neural networks driven by external stimuli"
17:00-17:30 **Sacha van Albada** (Research Center Juelich and University of Cologne, Germany)
Talk title: "Determinants of population activity in full-density spiking models of cerebral cortex"

Abstracts of the Talks ----------

The Complete list of abstracts is attached below as a PDF file, due to the lack of space and they can be found also in the

OFFICIAL WEB PAGE of the WORKSHOP

09:00 – 17:30 W **Theoretical and experimental approaches towards understanding brain state transitions** Room 6

Speakers: Andre Peterson, Nima Dehghani

This workshop aims to assemble computational and experimental neuroscientists to focus on the state dynamics and modulation of transitions in collective neuronal activity. Participants will discuss theoretical models and experimental approaches that both describe and influence state transitions, particularly highlighting ensemble activity and other spatiotemporal signatures of population dynamics such as oscillatory rhythms. This forum will engage the mathematical, computational and experimental challenges essential for capturing and modulating these transitions *in silico* and *in vivo*. Ultimately, the workshop seeks to catalyze a robust exchange of relevant ideas and concepts, identifying key challenges and opportunities for future research into the modulation and understanding of brain state transitions.

Schedule

9:00 Introduction: *Peterson/Dehghani*

9:05-9:30 ***Maria V. Sanchez-Vives***, ICREA, Barcelona
"Switching brain states and cortical dynamics by acting on ionic channels"

9:30-9:55 ***Michael Okun***, University of Nottingham, UK
"Brain state transitions primarily impact the spontaneous rate of slow-firing neurons"

9:55-10:20 ***Christian Meisel***, Charite, Berlin
"Critical dynamics predicts cognitive performance and provides a common framework for heterogeneous mechanisms impacting cognition"

10:20 – 10:30 Wrap-up and general comments and questions

10:30-11 Coffee break

11:00 Introduction: Peterson/Dehghani

11:05-11:30 ***Richard Rosch***, King's College, UK
"Modelling seizure state transitions using DCM"

11:30-11:55 ***Brian Lundstrom***, Mayo Clinic, USA
"Time-varying estimates of cortical excitability"

11:55-12:30 *Extended Morning Panel discussion involving all 5 speakers*

12:30-14:00 Lunch

14:00 Introduction: Peterson/Dehghani

14:05-14:30 ***Nima Dehghani***, MIT, USA.
"Network balance as an order parameter for brain state transitions"

14:30-14:55 ***Anna Levina***, University of Tubingen, Germany
"Footprints of state-transitions in timescales of neuronal dynamics"

14:55-15:20 **Andre Peterson**, University of Melbourne, Australia.
"Network connectivity and brain state transitions"

15:20-15:30 Wrap-up and general comments and questions

15:30-16:00 Coffee break

16:00 Introduction: *Peterson/Dehghani*

16:05-16:30 **Rainer Engelken**, University of Columbia, USA.
"Lyapunov Spectra of Recurrent Neural Networks: Implications for Temporal Learning"

16:30-16:55 ***Marisa Saggio***, Universite Aix Marseille, France.
"Mechanisms for transitions in dynamical systems and application to depolarization block "

16:55-17:30 *Extended panel discussion with all 5 speakers in the afternoon sessions.*

09:00 – 17:30 W **Understanding the Computational Logic of Predictive Processing: A 25-year Perspective** Room 9

Speakers: Aurelio Cortese, Abhishek Banerjee, Erin Rich, Silvia Maggi

Aims and topic

Predictive processes are ubiquitous in the brain and thought to be critical for adaptive behaviours, such as rapid learning and generalisation of tasks and rules. Early works such as the model proposed by Rao and Ballard (1999) have inspired over two decades of theoretical, computational, and experimental research about predictive neural processing. Stemming from these early works, ongoing investigations provide a rich ecosystem extending beyond the notion of predictive coding. Further, thanks to rapidly developing neural recording technologies, large datasets at multiple scales of granularity and resolution are becoming increasingly available. New computational models enable us to gain a mechanistic understanding of how neural circuits learn to implement and deploy predictive computations. Yet, a full understanding of the underlying computational logic remains fleeting because different aspects are often studied in separate research programs (e.g., layer circuits vs whole-brain neuroimaging), with little cross-pollination. This symposium will look at predictive processes in the context of modern computational neuroscience. Speakers will discuss new work across species (humans, monkeys, rodents), focusing on high-level, flexible behaviours (reasoning, context changes, learning). The topic addressed in this symposium is central to diverse streams of research in computational neuroscience, e.g., perception, decision-making, learning and memory. Our aspiration is to stimulate interaction among researchers working in different disciplines and highlight the open questions that will shape future research.

Speakers (alphabetical order)
Abhishek Banerjee (Oxford University / Queen Mary University of London, UK)
Andrea Benucci (Queen Mary University of London, UK)
Aurelio Cortese (ATR Institute International, Japan)
Armin Lak (Oxford University, UK)
Silvia Maggi (University of Nottingham, UK)
Rohan Rao (Newcastle University / Oxford University, UK)
Erin Rich (New York University, USA)
Matthias Tsai (Bern University, Switzerland)

Schedule
09:30 - 09:45 Opening remarks by Abhi Banerjee
09:45 - 10:15 Rohan Rao [Diverse frontal cortical predictive strategy codes underlie diversity in adaptive learning]
10:15 - 10:45 Aurelio Cortese [Time-dependent transformation of fear memories]
10:45 - 11:15 Coffee break
11:15 - 12:00 Erin Rich [Effects of value predictions on motivated behaviour]
Break
14:00 - 14:30 Matthias Tsai [Unsigned reward prediction errors inform apical amplification]
14:30 - 15:15 Silvia Maggi [A computational perspective on predictive error processing]
15:30 - 16:00 Coffee break
16:00 - 16:45 Andrea Benucci [Unifying Sensory, Cognitive, and Motor Processing Through Hierarchical Predictive Coding in the Mouse Posterior Cortex]
16:45 - 17:30 Armin Lak [Dopaminergic computations shaping individual long-term learning trajectories]
17:30 ~ Closing remarks/discussion

Full program with abstracts is available here.

09:00 – 17:30 W **Workshop on Methods of Information Theory in Computational Neuroscience** Room 203

Speakers: Joseph T. Lizier, Abdullah Makkeh, Pedro A.M. Mediano, Marilyn Gatica, Michael Wibral

Workshop website: https://kgatica.github.io/CNS2025-InfoTeory-W.io/

Methods originally developed in Information Theory have found wide applicability in computational neuroscience. Beyond these original methods there is a need to develop novel tools and approaches that are driven by problems arising in neuroscience. A number of researchers in computational/systems neuroscience and in information/communication theory are investigating problems of information representation and processing. While the goals are often the same, these researchers bring different perspectives and points of view to a common set of neuroscience problems. Often they participate in different fora and their interaction is limited. The goal of the workshop is to bring some of these researchers together to discuss challenges posed by neuroscience and to exchange ideas and present their latest work. The workshop is targeted towards computational and systems neuroscientists with interest in methods of information theory as well as information/communication theorists with interest in neuroscience.

This is the 20th iteration of this workshop at CNS --join us to celebrate!

PINNED
14:00 – 17:30

W **Bridging Complexity and Abstraction: Large-Scale Mechanistic Models of Brain Circuits from Biophysically Detailed to Simplified Representations** Room 101

Speakers: Athanasia Papoutsi, Beatriz Herrera, William W Lytton, Michele Migliore, Erik De Schutter, Srikanth Ramaswamy, Michael Reimann

Large-scale biophysically detailed models of microcircuits and mesocircuits have provided unprecedented insights into cellular diversity, synaptic connectivity and network activity. However, their computational demands limit their use for studying emergent properties at the network and behavioural levels. Conversely, simplified models, such as mean-field, population-based, or rate-based representations, enable efficient large-scale simulations but often sacrifice biological realism. Bridging these approaches is crucial to building models which are both mechanistically grounded and computationally scalable.

This workshop will explore the integration of biophysically and morphologically detailed models with simplified representations to advance our understanding of brain dynamics. By bringing together leading experts in computational neuroscience, this workshop will discuss state-of-the-art methodologies, trade-offs between different modelling approaches, and how these models can be leveraged to gain mechanistic insights into learning, memory, and cognition.

By attending this workshop, participants will:

1. Gain an understanding of the advantages and limitations of biophysically detailed versus simplified models
2. Learn about cutting-edge techniques for integrating multiple modelling scales
3. Explore real-world applications of these models in studying cognitive functions and brain disorders
4. Engage with experts on future directions for large-scale computational neuroscience

This workshop will, therefore, provide a unique platform to discuss strategies for advancing mechanistic models while ensuring they remain scalable, interpretable, and biologically meaningful.

Confirmed speakers:

1. Athanasia Papoutsi, Institute of Molecular Biology and Biotechnology, FORTH, Crete, Greece
“Neurophysiological mechanisms supporting flexible computations and functions”.

2. Erik De Schutter, Okinawa Institute of Science and Technology, Japan
“Evolution towards higher BK channel unitary conductance in mammals enables more efficient use of calcium and increases precision of neuron spike timing”.

3. Michele Migliore, Institute of Biophysics, CNR, Palermo, Italy
"Spiking neuron full-scale computational model of Mouse and Human Hippocampus CA1 networks”.

4. Michael Reimann, Open Brain Institute, Lausanne, Switzerland
“Morphology is the key to all of this – An intuitive explanation how neuron morphology generates non-random networks and how you as well can model this”.

5. Beatriz Herrera, Allen Institute, Seattle, USA
“Multi-Scale Modeling of Mouse Primary Visual Cortex”.

6. Bill Lytton, SUNY Downstate Medical Center, USA
"Solving nonlocal calculations by encapsulating ANN in the neuron”.

Organizers:

Srikanth Ramaswamy, Newcastle University/MIT
Michael Reimann, Open Brain Institute