Random Graphs in the Brain

Workshop

NeuroMat - November 23-27, 2015/ São Paulo, Brazil

Detailed Program

Initial Address: NeuroMat Questions

Antonio Galves

(University of São Paulo, Brazil)

Date: Monday 23, 11h00-12h00.

Lectures

Almut Schüz

(Max Planck Institute for Biological Cybernetics, Germany)

Dates: Tuesday 24,11h00-12h00; Wednesday 25, 11h00-12h00;Thursday 26, 11h00-12h00; Friday 27, 11h00-12h00.

Lecture 1) "Quantitative neuroanatomy as a tool to understand cortical function. Part 1: methodological aspects"

In the first lecture I will talk about neuroanatomical methods and, based on those, about approaches for quantification of anatomical aspects, such as cell density, synaptic densities, lengths and densities of cell processes, or density of dendritic spines and synapses along dendrites.

Lecture 2) "Quantitative neuroanatomy as a tool to understand cortical function. Part 2: network structure and functional conclusions"

In the second lecture I will present results of such measurements and what they tell us about the network properties of the cerebral cortex, as well as its basic function. Both lectures are based on the book *Braitenberg and Schüz, Cortex: Statistics and geometry of neuronal connectivity (1998), Springer.*

Lecture 3) "Cortico-cortical long- and middle-range connectivity: anatomical data from mouse and monkey"
Here I will briefly introduce into the field of tracer methods and then report about global connectivity in the mouse cortex, such as the arrangement and extension of terminal fields, as well as density of projections to distant places. I will then move on to the monkey brain and the phenomenon of patchy connections.
Schüz et al. (2006), Quantitative Aspects of Corticocortical Connections: A Tracer Study in the Mouse. *Cerebral Cortex 16:1474-1486*;
Voges et al. (2010) *A modeler's view on the spatial structure of intrinsic horizontal connectivity in the neocortex Progress in Neurobiol. 92: 277-292*
Lecture 4) "Cortico-cortical long-range connectivity: anatomical data from the human cortical white matter"
This last lecture will deal with cortico-cortical fibers in the white matter of the human brain, such as the number of fibers connecting the various cortical lobes, as well as axon diameters and their role for cortical function.
Schüz and Braitenberg (2002) The human cortical white matter: Quantitative aspects of cortico-cortical long-range connectivity. In: Cortical Areas: Unity and Diversity. Schüz and Miller (eds). Taylor and Francis.
Liewald et al. (2014) Distribution of axon diameters in cortical white matter:an electron-microscopic study on three human brains and a macaque. Biological Cybernetics, Biol Cybern 108(5) 541-557.

Audrey Mercer

(University College London, United Kingdom)

Dates: Monday 23, 14h00-15h00; Tuesday 24, 9h30-10h30; Wednesday 25, 9h30-10h30.

Lecture 1) "Combined electrophysiological and anatomical studies: Methodological aspects"
In this lecture, I will review the different types of recordings techniques (extracellular, intracellular, patch recordings, MEA), the different stimulation methods (electrical vs optogenetics) and the associated anatomical techniques (Biocytin, EM, etc...).
Lecture 2) "Combined electrophysiological and anatomical studies: Quantitative analysis"
In this lecture, I will talk about the different types of preparations that can be used (cultures, slices and in-vivo) and review the type of information/measurements that can be drawn from such studies including EPSC, IPSC, EPSP, IPSC, synaptic strength, binomial measurements, anatomical data, synaptic contacts, etc...
Lecture 3) "Selectivity and specificity in cortical circuits"
Finally, in the last lecture, I will summarise the properties of synaptic connections in the cortex and hippocampus and the precision with which they select their targets.
Bibliographic References
Thomson et al. (2002) Target and temporal pattern selection at neocortical synapses. Phil Trans R Soc Lond B Biol Sci. 357(1428), 1781-91.
Thomson & Armstrong (2011) Biocytin-labelling and its impact on late 20th century studies of cortical circuitry. Brain Res Rev 66(1-2): 43–53.
Mercer et al. (2012) Local circuitry involving parvalbumin-positive basket cells in the CA2 region of the hippocampus. Hippocampus 22(1): 43-56.
Fuchs al., (2013) $GABA_A$ receptors can initiate the formation of functional inhibitory GABAergic synapses. Eur J Neurosci 38(8):3146-3158.

Remco van der Hofstad and Sándor Kolumbán

(Eindhoven University of Technology, The Netherlands)

Dates: Monday 23, 15h15-16h15; Thursday 26, 9h30-10h30; Friday 27, 9h30-10h30.

"Modeling structure and function of complex networks and the brain"

Often, random graph models are used to model the topology of brain networks, while stochastic processes living on these networks are used to describe their functionality. This tutorial focusses on random graph models for the brain and its functionality, and consists of two main parts.

The first part is called `Modeling structure of complex networks and the brain'. In it, we will describe random graph models used to model complex networks, and how these might apply to the brain. Here we can think of the Erdoes-Renyi random graph, models where the number of connections per network element are fixed, as well as several models that incorporate geometry. We also discuss some models that have been proposed particularly for the brain, with their properties, as well as our view on how they fit the purpose.

The second part is called `Modeling function of complex networks and the brain'. In it, we will describe some stochastic processes that are used to model the functionality of the brain, or data that has been obtained from the brain. Examples include bootstrap percolation, the Ising model, and stochastic pro"esses including inhibitory behavior as present in the brain.

We will also include a more speculative part, where we look ahead and discuss some more realistic settings, for example to include learning and/or pruning as present in real brain function.

Bibliographic references:

HOFSTAD, Remo van der. Random graphs and complex networks. (available from http://www.win.tue.nl/~rhofstad/NotesRGCN.html).

http://www.scholarpedia.org/article/Neuropercolation

Papers:

(1) Complex brain networks: graph theoretical analysis of structural and functional systems
Ed Bullmore and Olaf Sporns
Nature Reviews 10: 186-198, (2009).

(2) Generative models of the human connectome<">
RF Betzel, A Avena-Koenigsberger, J Goñi, Y He, MA de Reus, A Griffa, et al
NeuroImage (to appear 2015).

(3) Bootstrap percolation with inhibition
Hafsteinn Einarsson<http://arxiv.org/find/math/1/au:+Einarsson_H/0/1/0/all/0/1>, Johannes Lengler<http://arxiv.org/find/math/1/au:+Lengler_J/0/1/0/all/0/1>, Konstantinos Panagiotou<http://arxiv.org/find/math/1/au:+Panagiotou_K/0/1/0/all/0/1>, Frank Mousset<http://arxiv.org/find/math/1/au:+Mousset_F/0/1/0/all/0/1>, Angelika Steger<http://arxiv.org/find/math/1/au:+Steger_A/0/1/0/all/0/1>
Preprint (2015)

(4) Ising models for networks of real neurons
Gasper Tkacik, Lead Schneidman, Michael J. Berry II, and William Bialek
Preprint (2006).

(5) Neuropercolation: A Random Cellular Automata Approach to Spatio-temporal Neurodynamics
Robert Kozma, Mark" Puljic, Paul Balister, Bela Bollobas, Walter J. Freeman
Springer Berlin Heidelberg Lecture Notes in Computer Science (vol. 3305 Cellular Automata), 2004, pages 435-443.

Open Questions Session

Chair: Christophe Pouzat (Université Paris Descartes, France)

Date: Monday 23, 17h30-19h00.

What are the mechanisms responsible for the origin and characteristics of the ongoing activity of the brain at rest?
Antonio C. Roque (University of São Paulo, Brazil)

How can we infer interactions/causality when we observe only part of the entire system?
Daniel Yasumasa Takahashi (Princeton University, USA)

Presentation: "Memory formation, consolidation and restructuring"

Sidarta Ribeiro

(Federal University of Rio Grande do Norte, Brazil)

Date: Wednesday 25, 14h00-15h00.

In this talk I will review the mechanisms underlying the acquisition of memories and their storage for long-term retrieval. I will review important aspects of memory formation, such as the fact that different kinds of memories depend on distinct brain circuits. The electrophysiological and molecular aspects of memory formation will be addressed, including a review of memory consolidation during sleep, memory reconsolidation during waking, and memory restructuring.

Guest Talk: “Emerging frontiers of Science of Information”

Wojciech Szpankowski

(Purdue University)

Date: Wednesday 25, 18h00-19h00.

Information is one of the defining aspects of our era, permeating every facet of our lives. Our ability to extract and effectively utilize information from various processes has the potential for significant advances in our day-to-day lives. Our current understanding of information dates back to Claude Shannon's revolutionary work in 1948, resulting in a general mathematical theory of reliable communication, which formalized modern digital communication and storage principles, paved the way for the Internet, DVDs and iPods of today. Shannon's focus on what is fundamental, and his precise quantitative analyses, continue to motivate and inspire.

However, in the current world, information is not merely communicated; it is also acquired, curated, suitably abstracted and represented, aggregated, analyzed, retrieved, inferred, secured, and used in various scientific, engineering, and socio-economic processes. A comprehensive Science of Information that fundamentally builds on Shannon's basic principles, to address key challenges in transforming data to information to knowledge is critically needed.

The National Science Foundation has established a flagship Science & Technology Center on the Science of Information (CSoI) to meet the new challenges posed by the rapid advances in basic and social sciences, economics and commerce, and engineering, coupled with the ability to collect, communicate, and analyze large amounts of data. Its mission is to advance science and technology through a new quantitative understanding of the representation, communication, and processing of information. Led by Purdue, Center member institutions include Berkeley, Bryn Mawr, Howard, MIT, Princeton, Stanford, Texas A&M, UCSD, UIUC, U. Hawaii. Other institutions (e.g., Rutgers, ETH, and LINCS, Paris) are affiliated with the Center in various roles.

In this talk, after briefly reviewing some of Shannon accomplishments, we proceed to explain novel challenges in analyzing multi-modal data, present representative results from our approach in provable security in networks, algorithms for classifying tweets through joint string complexity, and offer some interesting information-theoretic models for biological systems.

Presentation: “Measuring and comparing brain cortical surface area and other areal quantities”

Anderson Winkler

(University of Oxford, United Kingdom)

Date: Thursday 26, 14h00-15h00.

Structural analysis of MRI data on the cortical surface usually focuses on cortical thickness. Cortical surface area, when considered, has been measured only over gross regions or approached indirectly via comparisons with a standard brain. In this presentation I will show that direct measurement and comparison of the surface area of the cerebral cortex at a fine scale is possible using mass conservative interpolation methods. I will present a framework for analyses of the cortical surface area, also applicable to any other measurement distributed across the cortex that is areal by nature. The method consists of the construction of a mesh representation of the cortex, registration to a common coordinate system and, crucially, interpolation using a pycnophylactic method. Statistical analysis of surface area is done with power-transformed data to address lognormality, and inference is done with permutation methods. I will discuss the concept of facewise analysis, its interpretation, and potential applications.

Tutorial: "Stochastics systems with a large number of interacting components"

Pablo Ferrari

(Universidad de Buenos Aires, Argentina)

Date: Thursday 26, 18h00-19h00.

TBC

Working Groups

Dates: Wednesday 25, 15h15-17h30; Thursday 26, 15h15-17h30.