Master 2 Internship

«Information flux in large scale neuronal networks»

Project: Neurons communicate by action potentials (also called spikes). In their simplest expression spikes can be considered as binary events, occurring on a small time window (about 1 ms). It is currently believed that the succession of these spikes convey information (neural code), although there is still no agreement on how to decipher this code. At the level of a neuronal population one expects therefore that there is an information transfer flowing through the neuronal network. This oriented, causal information flux, can be measured by statistical methods. Thanks to the use of Lasso methods for point processes, one can infer a local independence graph, which can be interpreted in neuroscience as functional connectivity [2].

In addition, neuronal networks are able to learn via plasticity mechanisms at the level of synapses (synaptic plasticity). The information flux through the network ought to evolve, in a measurable way, under synaptic plasticity. Up to now, this effect has not been measured though.

The goal of this internship is to measure this effect in a network of conductance based spiking neurons studied mathematically in [1]. Starting from a network randomly connected neurons the aim is to measure how the information flux evolves under synaptic plasticity. In addition, the effect of the network size will be studied. The work consists mainly of large scaled simulations using the spinaker simulator implementing synaptic plasticity [3]. The computational model will map efficiently in real time the causal information flux of spikes propagating through the network [4].

The internship will be done in collaboration between B. Cessac (Biovision, INRIA, Sophia-Antipolis), A. Muzy (MS&N, I3S, Sophia-Antipolis) and P. Reynaud (MS&N, LJAD, University of Nice). The duration is 6 months. The internship will be done at Inria, in the Biovision team headed by B. Cessac.

This master 2 internship could be followed by a PhD, depending how the student performs.

Profile. The project is interdisciplinary, so the candidate is expected to have strong programming skills and a solid background in mathematics or physics.

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Teams
Biovision. The goal of the Biovision team is to investigate new solutions to help vision impaired people. Visual impairment affects some 285 million people in the world, mostly in developed countries: 85% have low vision, i.e., have remaining sight, and 15% are totally blind. It is predicted that the prevalence of visual disabilities will increase markedly during the next 20 years, owing largely to the aging. In this context, Biovision aims at developing fundamental research as well as technology transfer along two axes (i) development of high tech vision aid systems for low vision patients (ii) precise modeling of the visual system for normal and dystrophic conditions, targeting applications for low vision and blind patients. These axes are developed in strong synergy, involving a large network of national and international collaborators with neuroscientists, physicians, and modelers.

MS&N
Modélisation, Simulation & Neurocognition (MS&N) is common to the laboratory of Computer Science, Signals and Systems in Sophia Antipolis (**I3S**) and to the Mathematics laboratory J.-A. Dieudonné (**LJAD**), which belong to both Centre National de la Recherche Scientifique (**CNRS**) and Université Nice Sophia Antipolis (**UNS**).
MS&N aims at integrating models from computer science, mathematics and biology.

The study of neurocognition is characterized by *sparse and small fragments of observations*. Then, the question that cognitivists and neuroscientists ask to modelers is not: how the system behaves *really*? They ask: Is this hypothesis of behavior/structure acceptable or worth? To answer this question, the problem of the modeler is then *how to implement and in/validate an hypothesis?* At MS&N, to solve this problem we provide: *a multilevel methodology from the minimal formal transcription of the biological system to its efficent simulation, using abstraction to validate the links between the different description levels*. Furthermore, to choose and "navigate" between the different abstractions of the systems framed by the hypothesis, our conviction is that *activity* is a good guide.

<u>Research areas</u>

- Probability and statistics: dependence detection, models of interaction graphs, estimation in those models and tests on real biological data (goodness-of-fit)
- Abstract models and formal analysis/synthesis of general, reactive and discrete-event systems, algebraic semantics, category theory
- Formal modeling, formal prototyping using synchronous programming languages
- Computer-aided proofs of behavioral properties
- *In silico* experiments

References

[1] Cessac B, Viéville T. On dynamics of integrate-and-fire neural networks with conductance based synapses. *Front Comput Neurosci*. 2008;2:2. Published 2008 Jul 4. doi:10.3389/neuro.10.002.2008 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2525942/

[2] Lambert, Régis; Tuleau-Malot, Christine; Bessaih, Thomas; Rivoirard, Vincent; Bouret, Yann; Leresche, Nathalie ; Reynaud-Bouret, Patricia *Reconstructing the functional connectivity of multiple spike trains using Hawkes models*, Journal of Neuroscience Methods, 297, 9–21 (2018).

[3] Jin, X., Rast, A., Galluppi, F., Davies, S., & Furber, S. (2010, July). Implementing spike-timing-dependent plasticity on SpiNNaker neuromorphic hardware. In *Neural Networks (IJCNN), The 2010 International Joint Conference on* (pp. 1-8). IEEE.

[4] Zeigler, B. P., Muzy, A., & Kofman, E. (2018). *Theory of Modeling and Simulation: Discrete Event & Iterative System Computational Foundations*. Academic Press.