PhD opportunity on sequential learning and neuronal modeling and simulation (2018-2021)

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Start: From September 2017 to January 2018.

Net salary: 2078 Euros/month.

Competences expected: Discuss with specialists from other disciplines (cognition, biology, etc.) Acquire or have competences in: mathematics (mainly set theory and probabilities) and computer science (programming).

Place and environment: The phd student will work at I3S laboratory in Sophia Antipolis, France (http://www.i3s.unice.fr/) but will regularly collaborate with mathematicians at LJAD laboratory (http://math.unice.fr/), cognitivists (http://bcl.cnrs.fr), and biologists (https://www.ipmc.cnrs.fr). At I3S, he will be part of the team MS&N (http://msn.unice.fr/). This team is already a fertile place for discussion because it is constituted of programmers, computer scientists, mathematicians and biologists. Usual work: The student will work with computer scientists and formalize its models in collaboration with mathematicians (statisticians) and biologists. He will implement these learning models and collect the results to be compared with biological experiments. The student should be able to acquire new competences (in mathematics and computer science). Competences : Computer science and/or mathematics.

Topic: Being able to emulate the human brain (or approximations or parts of it) is one of the next major biological/technological breakthroughs that will have impacts in our daily life (health, autonomous machines, artificial intelligence, etc.). If recent progresses in machine learning have roots in bio-inspired techniques, mostly dated from the 70's, they usually represent very simple and specific structures without catching the essence of structure-function brain mechanisms. In machine learning, computer scientists build usually bio-inspired algorithms (such as sequence learning) but not transdisciplinary biocognitive algorithms. In biology, researches on sequence learning are limited by the lack of experimental data (only lacunar biological data can be collected on animals and even less on humans). In cognition, sequence learning is studied in relation to prediction processes, but the link with the neuronal substrate is still unclear.

Our main goal is to develop a computational brain tool as an intermediate layer between high-level features (behavioral and cognitive functions at the human level) and low-level features (biological layers studied in mice, i.e., an animal brain that can be a model of human brain, as well as modifications observed in pathologies). To achieve this goal, we will focus on the hippocampus and the cortex, two brain structures highly implicated in learning. Here, learning is identified as the core integrative concept of the brain in sequence learning and prediction, but its complex processing within neuronal networks is still little understood. Using previous data obtained by biologists in this consortium and new biological data specifically obtained during this project, learning rules will be mathematized and implemented from synapses to behavioral and cognitive functions. In the long term, the computational brain can be conceived as a new local research tool providing *in silico* experiments to complete brain biocognitive data providing insights in neuronal learning modeling. In particular, this new tool will be used to study corresponding diseases (Alzheimer and epilepsy), to foster pedagogical innovation, and to develop new machine learning algorithms and artificial intelligence.

In cooperation with the matematics laboratory from Nice (LJAD), the PhD student will be co-supervised by Alexandre Muzy (AM) and Fredéric Lavigne (FL). Recently, *learning of probability in sequences and its effects on behavior have been studied in human and have been addressed in computational models of the cortex (Lavigne et al., 2014)*. Sequential machines theory has been used in AM's team to find simulation-based conjectures of activity-based learning of parallel and series structures (Muzy & Zeigler, 2014a) or more complex structures (Muzy & Zeigler, 2014b). The student will have to extend these conjectures and proofs to sequential learning (in collaboration with LJAD). To achieve this goal, simple directed graphs of neurons or actions will be incrementally formalized in more and more complicated (recursive) structures. Furthermore, the major scientific challenge encountered by the PhD student will be to finally link neuronal levels to actions at cognitive and behavioral levels (developed by FL in (Lavigne, 2014)) accounting for measurement errors (all the neurons cannot be measured) using abstraction (Zeigler et al., 2000).

References

Lavigne F, Avnaïm F and Dumercy L (2014) Inter-synaptic learning of combination rules in a cortical network model. Front. Psychol. 5 :842. doi : 10.3389/fpsyg.2014.00842.

Muzy, A., Zeigler, B.P. (2014a) Activity-based credit assignment heuristic for simulation-based stochastic search in a hierarchical model base of systems, IEEE Systems Journal, vol.PP, no.99, 1-12.

Muzy, A., Zeigler, B.P. (2014b) A conjecture from learning simulations of series and parallel connections of components, the 26 th European Modeling and Simulation Symposium, Sept. 2014, Bordeaux, France, 550-557.

Zeigler, B.P., Kim, T., Praehofer, H. (2000) Theory of Modeling and Simulation, 2nd Edition, Elsevier.