M2 Internship Project:

Dynamical study of a mean-field model of neural network activity driven by biophysical ion exchange mechanisms

Project description. In neuroscience the question of scales is central, ranging from the molecule to the whole brain. In theoretical and computational neuroscience, it is possible to model these different scales and to build the link between them [1]. In particular to describe the activity on the scale of a population of neurons by a mean-field approach, capturing some aspects of the corresponding spiking network. A recently derived mean-field model of a biophysical description of neuronal excitability shows abilities to capture synchronized activities observed in pathological states, such as seizures [2]. The system obtained is a compound of coupled differential equations which can be studied by applying timescale separation methods [3, 4]. This model is a candidate to be used within The Virtual Brain [5] for clinical applications. A detailed characterization is therefore essential.

Main objectives. **1.** To identify the different dynamical regimes of this model, in particular in a parameter configuration corresponding to a healthy state; **2.** To determine the different timescales involved in this system; (and possibly) **3.** To start a bifurcation study for identified biophysical parameters of interest.

Period. Some time in 2023, in accordance with the schedule of the candidate's courses.

Location. One or both of the following addresses:

Institut de Neurosciences des Systèmes
AMU Faculty of Medicine
27, Boulevard Jean Moulin
13005 Marseille, France

Inria centre at Université Côte d'Azur
MathNeuro Project team
2004 route des Lucioles - BP 93
06902 Sophia Antipolis, France

Supervisors. **Damien Depannemaecker** (Aix-Marseille Université) and **Mathieu Desroches** (Inria).

How to apply. Interested candidates should send a CV and a short motivation letter expressing your interest and skills for this project to: mathieu.desroches@inria.fr and damien.depannemaecker@univ-amu.fr. Selected candidates will be invited to an interview, which may take place online. For candidates requiring a visa for the EU, a period of at least three months is necessary to obtain the documents.

Candidate profile. The candidate from an MSc (M2) or an engineering school must have an interest and skills in dynamical systems as well as for neuroscience. Having at least basic programming knowledge (e.g. `python` or `matlab`) is necessary for this internship. The involvement and motivation of the candidate, as well as the ability to be organized and proactive, are essential criteria in the selection of the candidate. *There could be perspectives of following up with a PhD.*

References

[1] Depannemaecker D, Destexhe A, Jirsa V, Bernard C. Modeling seizures: From single neurons to networks. Seizure. 2021 Aug;90:4–8. Available from: http://dx.doi.org/10.1016/j.seizure.2021.06.015.

[2] Bandyopadhyay A, Rabuffo G, Calabrese C, Gudibanda K, Depannemaecker D, Ivanov A, et al. Mean-field approximation of network of biophysical neurons driven by conductance-based ion exchange. bioRxiv. 2022. Available from: https://www.biorxiv.org/content/early/2022/12/03/2021.10.29.466427.

[3] Desroches M, Rinzel J, Rodrigues S. Classification of bursting patterns: A tale of two ducks. PLoS Computational Biology. 2022;18(2):e1009752. Available from: https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1009752.

[4] Saggio ML, Spiegler A, Bernard C, Jirsa VK. Fast–Slow Bursters in the Unfolding of a High Codimension Singularity and the Ultra-slow Transitions of Classes. The Journal of Mathematical Neuroscience. 2017 Jul;7(1). Available from: http://dx.doi.org/10.1186/s13408-017-0050-8.

[5] The Virtual Brain;. Available from: https://www.thevirtualbrain.org/.