Colloque ANR ChaMaNe : interaction biologistes-mathématiciens 21-22 mars 2023

salle 201 tour 23-24, Sorbonne Université

Mardi 21 mars 2023

10h-10h45 : Vincent Rivoirard, Université Paris Dauphine

Titre : Estimation bayésienne variationnelle de graphes de connectivité fonctionnelle modélisés par des processus de Hawkes non-linéaires.

Résumé : Les processus de Hawkes constituent une classe particulière de processus ponctuels qui permet de modéliser la probabilité d'occurence d'un événement à l'aide d'occurrences passées. Ils sont donc naturellement utilisés lorsque l'on s'intéresse à l'inférence de graphes de connectivité fonctionnelle neuronale. Dans le cadre linéaire, l'inférence statistique des processus de Hawkes est à présent bien connue. Nous nous intéresserons donc plus spécifiquement à la classe des processus de Hawkes non-linéaires multivariés qui permettent de modéliser à la fois les phénomènes d'excitation et d'inhibition.
L'estimation statistique considérée dans cet exposé se placera dans le cadre de l'approche bayésienne non-paramétrique. Cependant les lois a posteriori pouvant être difficilement accessibles, en particulier dans le cadre mutlivarié, nous utiliserons plus spécifiquement l'approche bayésienne variationnelle qui fournit un calcul direct et rapide d'une approximation déterministe des lois a posteriori. L'objectif de cet exposé sera de présenter différents algorithmes en lien avec cette méthodologie permettant le passage à l'échelle et l'analyse en temps raisonnable de graphes comportant plusieurs dizaines de neurones.
Travail en collaboration avec Déborah Sulem et Judith Rousseau

11h00-11h45 : Mangin, Sorbonne Université, IBPS

Titre : Large-scale functional imaging of the neuro-glial network initiating fetal motor behavior.

Résumé : In vertebrates including humans, the embryonic development of the neuromuscular and musculo-skeletal systems depends on the activation of spinal motoneurons during spontaneous neural activity (SNA). Spinal SNA initiates the first fetal motor behavior characterized by rhythmic and patterned waves of muscle contractions. Despite its crucial role during neuromuscular development, the spinal neural network responsible for patterning muscle activation during this fetal behavior remains obscure. More particularly, it remains unclear how such an extensive and coordinated motor behavior can already arise

when spinal neurons have just started to form synapses. We also recently demonstrated that radial glial cells are depolarized during episodes of SNA1. This glial depolarization result from the unique capability of radial glia located at the ventral midline to spontaneously generate mixed Ca2+/Na+ action potentials (AP). These glial APs primarily rely on T-type calcium channels which are predominantly expressed in midline radial glia. APs sequentially propagate between midline radial glial cells along the entire rostro-caudal extent of the spinal cord via direct electrical coupling by gap junctions. They also propagate medio-laterally into non-excitable radial glial cells via gap junctions. We hypothesized that this novel form of electrical activity in glial cells is responsible for initiating and patterning motoneuron activity and trigger the first motor behavior at fetal stages. In order to study how the propagation of radial glia APs participate to pattern motoneuron activity, we developed a calcium imaging technique using cell permeant Rhod2-AM which loads radial glial cells as well as motoneurons. We discovered that waves of SNA not only propagate along a rostro-caudal sequence as previously described, but are also along a slower medio-lateral sequence starting from the midline. Application of T-type calcium channel or gap-junction blockers both abolish SNA propagation. By using a transgenic line that expresses the genetically encoded calcium indicator GCaMP6f specifically in the motoneurons, we discovered that motoneuron columns controlling distinct muscles are sequentially activated during SNA. This sequence was abolished by pharmacological blockage of radial glia APs. By contrast, we found that specific activation of midline radial glia via electrical or optogenetic stimulation was sufficient to trigger motoneuron activation along the same sequence. Finally, we developed a fetal slice preparation preserving connectivity between radial glia, motoneuron and muscles and found that activation of midline radial glia led to the sequential contraction of developing muscles. Taken together, our results demonstrate that action potentials generated by midline radial glia can initiate and pattern motor activity at fetal stages.

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1. Arulkandarajah, K.H., Osterstock, G., Lafont, A., Le Corronc, H., Escalas, N., Corsini, S., Le Bras, B., Chenane, L., Boeri, J., Czarnecki, A., et al. (2021). Neuroepithelial progenitors generate and propagate non-neuronal action potentials across the spinal cord. Curr. Biol. 31, 4584-4595.e4.

Buffet et discussions

14h00 à 14h45 : Romain Brette, Institut de la vision

Titre :

Résumé : TBA

15h00 à 15h45 : Romain Veltz, Université Côte d'Azur

Titre : Quelques résultats sur un champ moyen d'un réseau de neurones à spike.

Résumé : Dans cet exposé, je présenterai quelques résultats concernant la dynamique d'un réseau de neurones à spike stochastiques apparentés au "modèle linéaire généralisé". Ce réseau est une élaboration de celui introduit dans [De Masi et al. 2014] en généralisant la dynamique des neurones individuels qui devient 2d. Cela permet de capter la plupart des comportements neuronaux intrinsèques connus, comme le bursting par exemple, et ainsi d'étudier l'effet de la dynamique neuronale sur la dynamique macroscopique.

Le modèle présente quelques défis. Il s'agit d'un processus de Markov déterministe par morceaux non linéaire avec un flot explosif et une fonction de tau de transition non bornée. Je présenterai quelques résultats théoriques concernant l'équation linéarisée (bien posée, ergodicité, ...) et l'équation non linéaire.

16h15 à 17h00 : Daniele Avitabile, Université d'Amsterdam,

Titre :

Résumé : TBA

Mercredi 22 mars 2023

9h30 à 10h15 : Sylvia Soares, Sorbonne Université (IBPS)

Titre : Molecular and cellular mechanism of axon fate post-injury.

Résumé : TBA

10h45-11h30 : Hermine Biermé, Université de Poitiers

Titre : Spike detection for calcium activity

Résumé : We present a global methodology for the spike detection in a biological context of fluorescence recording of GnRH-neurons calcium activity. For this purpose we first propose a simple stochastic model that could mimic experimental time series by considering

an autoregressive AR(1) process with a linear trend and specific innovations involving spiking times. Estimators of parameters with asymptotic normality are established and used to set up a statistical test on estimated innovations in order to detect spikes. We compare several procedures and illustrate on biological data the performance of our procedure.

11h45-12h30 : Stefano Spaziani, Université Côte d'Azur

Titre : Estimating the functional connectivity in the brain via a multiscale spike-LFP autoregressive model

Résumé : It is well known that the analysis of the rhythmic activity of individual and aggregated neurons can be a powerful tool to decode high cognitive processes such as learning (Benchenane et al, Neuron 2010; Colgin Current opinion in Neurobiology 2011 ....) . However, many publications have reported that the LFP drives spike trains, but fewer studies have investigated the impact of spikes on the various LFP rythms. Here we want to develop a generic model and adequate corresponding statistical tool to extract these relationships out of the data and ultimately to understand more the links between LFP and spikes, especially during learning.

Our work is divided into three parts. First, we developed the model equations, which explicitly link the neuron spiking probabilities with themselves and the different LFPs rhythms. Similarly, the local field potentials depend on themselves and on the spiking neurons. We examined the conditions under which there exists a weak-stationary solution of this model. Secondly, a LASSO algorithm has also been developed in order to assess these dependencies and create a sparse directed connectivity graph, which can be a useful and easily interpretable instrument for the understanding of the underlying biological process. We have proved that this method satisfies an oracle inequality and that our method is able to retrieve various well known phenomena . Lastly, we validated our model on simulated processes and then on real data coming from a context-dependent emotional memory experiment. (data published by Girardeau, Inema and Buzsáki, Nat Neurosci 2017 "Reactivations of emotional memory in the hippocampus–amygdala system during sleep")

Buffet et discussions

14h00 à 14h45 : Nicolás Vattuone, Université Côte d'Azur

Titre : Sparse Networks: A local solution for stochastic linearly interacting particles on an infinite regular tree.

Résumé : The problem of characterizing marginal distributions for large stochastic system on sparse networks remains as a hard challenge to tackle since Mean-Field models are known to work only for dense graphs. Recently, a method has been proposed by Lacker et al. [1] to obtain a set of local equations for diffusive systems of particles on trees. Nonetheless, these equations involve the conditional law of a particle given the observation of the full trajectory on a subset of neighbors. This makes the equations hard to treat in general and computationally expensive to simulate due to exponential growth in time. Therefore, finding simple systems in which the equations can be explicitly computed can provide an insight on how to deal with them. In this work, we study linear stochastic differential equations of particles interacting on a infinite regular tree. For this system, we find explicit equations for the conditional expectation mentioned above and we prove existence and uniqueness of the solution. Through this procedure, we obtain the local dynamics for the marginal distribution of the root of the tree and the first generation. The equations obtained take then the form of a Stochastic Volterra equation for which tools to solve are already known. Finally, we discuss qualitatively on how this approach can be extended to random trees and how could be used as an approximation for non-linear system. This work was done in collaboration with Etienne Tanré and Romain Veltz (Université Côte d'Azur, Inria). This work was supported by the Human Brain Project (HBPSGA3-14870 / WP1 HBP SGA 3).

[1] D. Lacker, K. Ramanan, and R. Wu. Marginal dynamics of interacting diffusions on unimodular galton-watson trees, 2020.

15h00 à 15h45 : Adeline Leclercq Samson, Université de Grenoble

Titre : Analysis and estimation for hypoelliptic stochastic neural models

Résumé : Stochastic differential equations (SDEs) are used to model neural dynamics. We can cite among others the stochastic FitzhHugh-Nagumo model describing the intracellular behavior of a single-neuron, or the Jansen and Rit neural mass model describing neural population dynamics of a local cortical circuit. These SDEs are hypoelliptic, meaning that the diffusion coefficient of the SDE is degenerate. Hypoellipticity is a big challenge from a statistical point of view. We will discuss in this talk several issues: numerical approximation schemes, contrat estimation and estimation rates of convergence.