M1 internship Neural activity in the retina as a statistical-mechanics problem

Overview

Laboratory name: Institut de la Vision, Sorbonne Université, INSERM, CRNS (UMR S968)
Head of the Institute: Serge Picaud
Advisors: Tobias Kühn and Ulisse Ferrari
Paid internship: Yes
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Studying the brain with physics tools. Modern electrophysiological recording techniques have made it possible to simultaneously measure the activity of hundreds of neurons in the brain. To make sense of these massive recordings, appropriate techniques of data analysis and machine learning are necessary to reveal the relevant information contained therein. Because one of the main challenges of this objective are strong correlations between many interacting units, statistical mechanics is an excellent tool to tackle it, and has in fact been used in the realm of neuroscience for about four decades.

In our work, we use maximum-entropy models [1], and extensions thereof to quantify the information about the stimulus contained in neural activity. This requires the fitting of models faithfully reproducing the statistics of numerous neurons, which is a hard task. We tackle it by adapting methods from statistical physics, notably the theory of inverse problems and diagrammatic perturbation theory [2] to conceive physically sound regularizations of this problem [3].

Objective of the project: extensions in time domain. Maximum entropy models are, by nature, in equilibrium and typically only their stable states are investigated, so they are effectively static. This contrasts with the fundamentally dynamic nature of the stimuli in the real world. The topic of the internship project is therefore to extend the existing models to capture this temporal variability. Under our guidance, the intern will combine concepts stemming from statistical mechanics, information theory and machine learning to understand the data from ex-vivo retinas collected in our team. The task will be to adapt the established techniques to the study of dynamic processes, in order to take into account the increased statistical richness of dynamical processes compared to static setups.

Requirements and possibilities. The candidate we are looking for has basic knowledge in statistical mechanics, enjoys analytical computations, is interested in neuroscientific questions and has solid programming skills (preferentially python or MATLAB, but other languages are welcome as well). We offer a pleasant working environment in a multidisciplinary lab with research topics ranging from electrophysiology and machine-learning to statistical mechanics and information theory.

Contact

Don't hesitate to write us for informal inquiries and further information:
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References

[1] Schneidman E, Berry MJ, Segev R, Bialek W (2006) Weak pairwise correlations imply strongly correlated network states in a neural population. *Nature* 440:1007–1012.

[2] Kühn T, van Wijland F (2023) Diagrammatics for the inverse problem in spin systems and simple liquids. *Journal of Physics A: Mathematical and Theoretical* 56:115001.

[3] Mahuas G, Marre O, Mora T, Ferrari U (2023) Small-correlation expansion to quantify information in noisy sensory systems. *Phys. Rev. E* 108:024406.