Internship L3

Research Group

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Title

Simulating noisy neural fields

Context

Knowledge of the mechanisms used by neurons to transmit information is far from being complete. The scientific issues are major, both for a single neuron and for a network of neurons with billions of connections, like in a human brain.

Nowadays, classical deterministic models for neurons are improved upon by the addition of a stochastic component, which attempts to describe one or several sources of noise that exist in the brain. One classical model that has received a lot of attention is the neural field equation (see [3, 6] for a comprehensive review), which models the how macroscopic waves of activity appear and travel across sections of cortex. The addition of spatiotemporal noise to such models is an active and fruitful area of research ([2, 4, 5]).

Subject of the Internship

The classical deterministic neural field equation is an integro-differential equation for the activity $V(t,x)$ of a neuron at time t and position x in a section of cortical tissue $\Omega \subset \mathbb{R}^d$, which has the form

$$\partial_t V(t,x) = -V(t,x) + \int_\Omega w(x,y) S(\lambda V(t,y)) dy + I_{ext}(t,x)$$

where $w(x, y)$ is a neural field kernel describing the connection between neurons located at x and y within Ω, $\lambda > 0$ is some parameter, I_{ext} is the external current input, and $S : \mathbb{R} \to \mathbb{R}$ is typical taken to be a sigmoid function (for example $S(z) = (1 + e^{-z})^{-1}$, $z \in \mathbb{R}$). One particular example of this equation being studied is in [1], where it is used to model the cortical response in the visual region of the cortex to a visual stimulus of a grating orientated at a given angle. The principal idea is that neurons are specific to certain angles, so that for a given grating angle we should only observe activity of those neurons with that particular preference.

The interest in this equation stems form the fact that, depending on the value of λ, the equation exhibits different behavior (it *bifurcates*). Indeed, for certain values of λ the equation may posses multiple stationary solutions. The existence of these multiple solutions has been used to try and explain the phenomenon of optical illusions, whereby we may perceive different things from the same image.

However, a deterministic model does not easily explain why we may jump from one perception to another, since for a given initial condition we always converge to a single stationary solution. However, with the introduction of noise to the system, one may observe random transitions from one stationary solution to another, or become trapped close to one of them, depending on the size of the noise. The aim of the project thus is to investigate numerically using Monte-Carlo methods these transition times, for different intensities of noise.

Advisor

The student will be advised by
Olivier Faugeras (`Olivier.Faugeras@inria.fr`),
James Inglis (`James.Inglis@inria.fr`),
Etienne Tanré (`Etienne.Tanre@inria.fr`,)
Romain Veltz (`Romain.Veltz@inria.fr`),
of the teams Neuromathcomp and Tosca.

Skills and profile

The student will use classical computational tools to approximate stochastic processes and compute probability densities.

References

[1] R. Ben-Yishai, R. Lev Bar-Or, and H. Sompolinsky. Theory of orientation tuning in visual cortex. *Proceedings of the National Academy of Sciences*,

92:3844, 1995.

[2] Paul C. Bressloff. Stochastic neural field theory and the system-size expansion. *SIAM J. Appl. Math.*, 70(5):1488–1521, 2009/10.

[3] Paul C. Bressloff. Spatiotemporal dynamics of continuum neural fields. *J. Phys. A*, 45(3):033001, 109, 2012.

[4] Paul C. Bressloff and Matthew A. Webber. Front propagation in stochastic neural fields. *SIAM J. Appl. Dyn. Syst.*, 11(2):708–740, 2012.

[5] O. Faugeras and J. Inglis. Stochastic neural field equations: A rigorous footing. *http://arxiv.org/pdf/1311.5446.pdf*, 2013.

[6] R. Veltz. Nonlinear analysis methods in neural field models. *PhD thesis*, 2011.