Internship Master 2 subject

Research Center

INRIA Sophia Antipolis - Méditerranée, Equipe-Projet INRIA Neuromathcomp

Localisation

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Financial Support

The master student will be paid by Inria

Title

PERIODIC FORCING OF NEURAL FIELDS MODELS.

This internship aims at studying theoretically the dynamics produced by a periodic stimulus on a spatiality extended neural network.

Keywords: oscillations, nonlinear waves, equivariant dynamics.

Context

Neural fields models are an efficient description of neural dynamics at a mesoscopic scale when the spatial position of neural populations is taken into account. These models are also appealing from an experimental point of view as they yield predictions for optical imaging experiments that images the activity of the (visual) cortex.

Most neural fields models [3] have been used in the context of a static stimulus or in deprived environments because it eases a lot their mathematical study. These models have nevertheless been successful in accounting for visual hallucinations [4] and for orientation selectivity [1] for example.

A natural generalization is to suppose that the stimulus has a either a specific spatial structure (e.g. symmetries) or temporal structure (periodic or quasi-periodic). A periodic stimulus with simple spatial structure is called a flickering stimulus and it can produce visual hallucinations [2] that have yet to find a satisfactory model (see for example Figure 1).

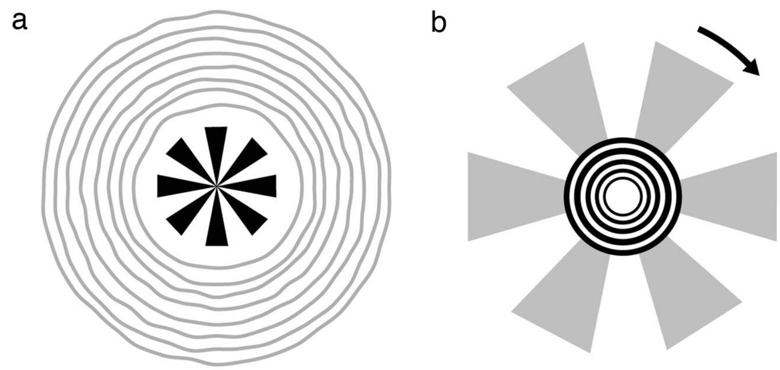

Figure 1: Two examples of hallucinatory percepts. Physical biasing patterns are shown in black, and hallucinations are shown in gray (depicting the shadowy nature of the percepts). (a) If the area around a small fan shape is flickered, subjects report seeing illusory circular patterns. (b) If the area around a circular pattern is flickered, all subjects report seeing an illusory rotating fan shape. From [2].

Subject of the internship

The aim of the internship is to study a model that extends the work [7] to explain some of the flickering stimuli seen in [2]. We will start with a single population and describe the effect of a periodic stimulus on the global dynamics. We will study the existence, number and period of periodic solutions of (1) using tools from functional analysis, see for example [8] in the case of equilibria. An alternative method could be to define Poincaré sections and study the discrete maps associated to them.

More precisely, we study

$$\tau \frac{d}{dt} V(\mathbf{x}, t) + V(\mathbf{x}, t) = \int_{\Omega} J(\mathbf{x}, \mathbf{y}) S(V(\mathbf{y}, t)) d\mathbf{y} + I_{ext}(\mathbf{x}, t) \tag{1}$$

where J are the synaptic connections and the nonlinearity S represent the $f - I$ curve of the neurons. The stimulus I_{ext}, seen here as an external input, is time periodic.

The extension to two populations will then be considered. This case is much richer and more relevant from a biological point of view. This case was numerically explored in [7] and will be studied mathematically with the theory of dynamical systems with symmetries [5]. The study is very likely to lead to the study of quasipatterns [6] which are yet to be predicted in neural systems.

Advisor

The student will be advised by Romain Veltz (`Romain.Veltz@inria.fr`), Pascal Chossat (`pascal.chossat@inria.fr`) and Olivier Faugeras (`olivier.faugeras@inria.fr`).

Skills and profile

The student will use standard tools issued from dynamical system and numerical calculus.

References

[1] R. Ben-Yishai, R. L. Bar-Or, and H. Sompolinsky. Theory of orientation tuning in visual cortex. *Proceedings of the National Academy of Sciences*, 92(9):3844–3848, April 1995.

[2] Vincent A. Billock and Brian H. Tsou. Neural interactions between flicker-induced self-organized visual hallucinations and physical stimuli. *Proceedings of the National Academy of Sciences*, 104(20):8490–8495, 2007.

[3] Paul C Bressloff. Spatiotemporal dynamics of continuum neural fields. *Journal of Physics A: Mathematical and Theoretical*, 45(3):033001, January 2012.

[4] Paul C. Bressloff, Jack D. Cowan, Martin Golubitsky, Peter J. Thomas, and Matthew C. Wiener. Geometric visual hallucinations, euclidean symmetry and the functional architecture of striate cortex. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 356(1407):299–330, March 2001.

[5] Pascal Chossat and Reiner Lauterbach. *Methods in Equivariant Bifurcations and Dynamical Systems*. World Scientific, 2000.

[6] A. M. Rucklidge and M. Silber. Quasipatterns in parametrically forced systems. *Physical Review E*, 75(5):055203, May 2007.

[7] Michael Rule, Matthew Stoffregen, and Bard Ermentrout. A model for the origin and properties of flicker-induced geometric phosphenes. *PLoS Comput Biol*, 7(9):e1002158, 2011.

[8] Romain Veltz and Olivier Faugeras. Local/global analysis of the stationary solutions of some neural field equations. *SIAM Journal on Applied Dynamical Systems*, 9(3):954, 2010.