Internship Master 2 subject

Research Center

INRIA Sophia Antipolis - Méditerranée, Equipe-Projet INRIA Neuromathcomp

Localisation

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The master student will be paid by Inria

Title

Two populations model of visual cortex with periodic preferred orientation map.

This internship aims at studying theoretically the dynamics produced by two populations of neurons in a model of visual cortex. The possible extensions are numerous (binocular rivalry, study of propagations waves, effects of delays...) and the subject could possibly be extended to a PhD thesis.

Keywords: oscillations, nonlinear waves, equivariant dynamics, visual hallucinations.

Context

Visual hallucinations (see for example Figure 1) are a privileged road to study, with non invasive methods, the dynamics of our visual system in environments deprived of stimuli. These hallucinations - also called *planforms* - are characterized by the appearance of many simple geometric structures.

In 1979, an elegant theory [3], based on the Turing mechanism, was proposed to explain the different contoured planforms albeit the orientation selectivity of neurons in the primary visual area and the long range connections were neglected. The two basic ingredients of the model were the symmetries of the synaptic connections between neurons and the tuning of the model close to a **static** bifurcation.

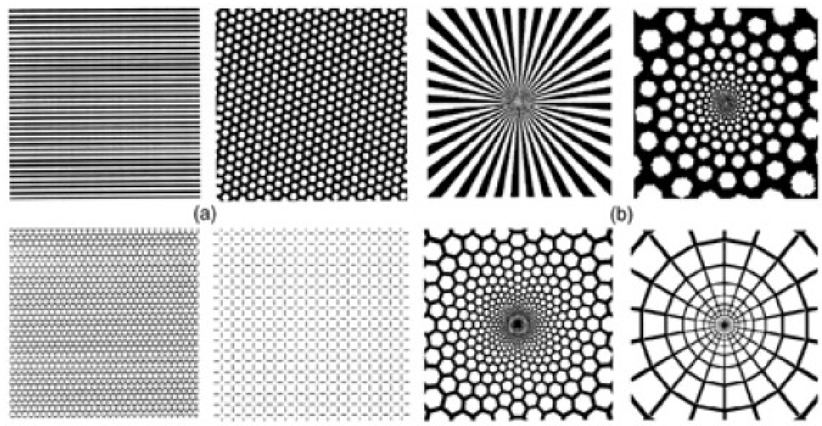

Figure 1: Example of visual hallucinations, from [1].

Almost two decades later, this theory was beautifully extended [1] by taking into account the orientation selectivity of the neurons and the structure of the long range synaptic connections. Doing so, the authors were also able to reproduce the non-contoured planforms. Again, the two main ingredients were a specific symmetry group (the planar shift-twist group, different from [3]) and the tuning of the network close to a static bifurcation.

In a recently submitted paper [6], we improved on the previous work [3, 1] in two major ways. We first assume, unlike [1], that the preferred orientation map (see Figure 2) is composed of a **discrete** lattice of pinwheels whose possible tilings are constrained by the wallpaper groups. The second improvement is that we did not restrict our study to local dynamics *e.g.* working close to a static bifurcation. This allowed us to report new **robust** visual hallucinations (unlike [3, 1]).

There have been recent experimental studies [4, 7] showing that the visual cortex, in awake macaques, produces a lot of oscillations in the 30-80Hz range. Hence, the working regime of the visual cortex is more dynamical than previously thought. This suggests to review the previous work by considering a two populations model (excitatory - inhibitory) that can locally produce oscillations. We expect many interesting results from the dynamics in deprived environments but also when the network is presented a time-varying stimulus.

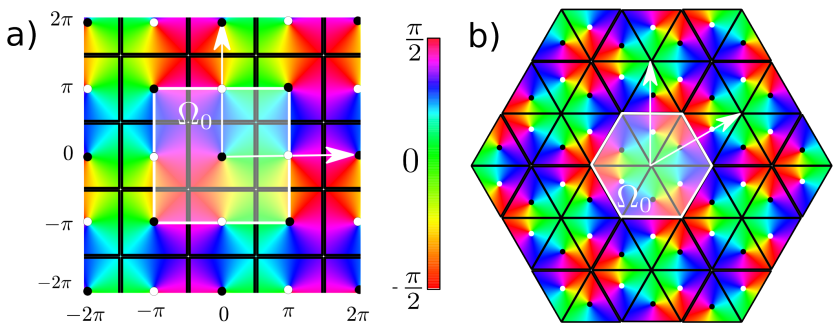

Figure 2: Example of regular tilings of hypercolumns, from [6].

Subject of the internship

The aim of the internship is to study a model that extends the work done in [6] to the case of two populations with long range connections. More precisely, the model reads

$$\tau_E \frac{d}{dt} E(\mathbf{x}, t) + E(\mathbf{x}, t) = \int_\Omega d\mathbf{y} J_{EE}(\mathbf{x}, \mathbf{y}) S(E(\mathbf{y}, t)) - J_{EI}(\mathbf{x}, \mathbf{y}) S(I(\mathbf{y}, t))$$
$$\tau_I \frac{d}{dt} I(\mathbf{x}, t) + I(\mathbf{x}, t) = \int_\Omega d\mathbf{y} J_{II}(\mathbf{x}, \mathbf{y}) S(I(\mathbf{y}, t)) - J_{IE}(\mathbf{x}, \mathbf{y}) S(E(\mathbf{y}, t))$$

where the synaptic connections satisfy $J_{pq}(\mathbf{x}, \mathbf{y}) = J_{pq}^{(loc)}(\mathbf{x}-\mathbf{y}) + \epsilon J_{pq}^{(lat)}(\mathbf{x}, \mathbf{x}-\mathbf{y})$ and ϵ is small. The nonlinearity S represent the $f - I$ curve of the neurons. The internship will start by tuning the local network (case $\epsilon = 0$) close to an (equivariant [2]) Hopf bifurcation to produce oscillations. Some work has already been done [5] in this direction, but the Hopf bifurcation on an hexagonal lattice is not well understood yet. Then, the effect of the perturbation of the dynamics by turning on the long-range connections $\epsilon > 0$ will be studied to predict new visual hallucinations.

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

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