Postdoctoral position

From computer vision to the salamander retina: How to interpret the neural code to identify image categories?

Image **classification** has become a very important working area in the **computer vision** community. As it can observed in the literature, lots of efforts have been made to extract "the best" **features**, giving the best results for state-of-the-art benchmarks. For example, the notion of local descriptors (or patches) has been very much developed recently, combined with methods to analyze the distributions of theses patches in the scene (e.g., using histograms or bag-of-words). But two problems remain: finding these features is still an open challenge if we consider the classification task in the general setting, when robustness is considered. In many cases, the methods employed disregard the information about the spatial distribution of the features (their relative positions in the scene).

Meanwhile, **neuroscience** is also making lots of progress in understanding the visual system and how the visual content is translated and transmitted to the brain. The first major processing occurs at the **retina** level, where the visual stream is converted at the ganglionic level by as series of electric impulses called spikes. But interestingly, the retina is far to be a simple linear analogue to digital converter: Not only the retina allows to capture a variety of rich behaviors [3] but also the information encoded in the spike trains cannot simply be interpreted by just counting the spikes. For example, it has been proposed in [5] and latter confirmed by [2] that the visual information is efficiently encoded by the order in which neurons are activated. So, with only the first wave of spikes, one is able to capture the main visual information and recognize image content within very short periods of time. Of course, refinements will come after and based on other spike train statistics.

From this brief presentation of the retina, two key elements have appeared: The first is the notion of **features** which naturally emerges from the retinal functional architecture. The ganglion cells will be excited according to a given visual content which can be easily interpreted as spatio-temporal features. The second is the notion of **coding**, which is not considered in classical computer vision. The response of ganglion cells is not a simple scalar value indicating if the cell is excited or not; It is a temporal succession of spikes which is much harder to analyze.

The goal of this postdoctoral research is to investigate how to perform image classification directly from spike trains recordings coming from a salamander retina. To do so, the candidate will benefit from the expertise, data and mathematical results of the partners involved in the project. The candidate will have the possibility to study **real cells recordings** coming from **multi-electrode arrays (MEA)** and associated to state-of-the-art computer vision database. The first step will be consider the first wave of spikes corresponding to flashed images and to evaluated the performance that can be reached in term on image classification. Also, further analysis will be conducted to understand, among the excited cells, what kinds of cells are the most important for the classification of certain scenes. The second step will be to consider higher order statistics on the spike trains to investigate the level of performance that can be reached. All this work will also be possibly supported by simulations with the retinal simulator **Virtual Retina** [7].

Candidates should have a strong experience in machine learning and pattern recognition, and desire to carry out interdisciplinary research combining mathematical and computational modeling with connections between computer science and computational neuroscience.

References

[1] T. André, M. Antonini, M. Barlaud, and R.M. Gray. Entropy-based distortion measure and bit allocation for wavelet image compression. *IEEE Transactions on Image Processing*, 16(12):3058–3064, Dec. 2007.

[2] T. Gollisch and M. Meister. Rapid neural coding in the retina with relative spike latencies. *Science*, 319:11081111, 2008. DOI: 10.1126/science.1149639.

[3] T. Gollisch and M. Meister. Eye smarter than scientists believed: neural computations in circuits of the retina. *Neuron*, 65(2):150–164, January 2010.

[4] R. Segev, J. Goodhouse, J. Puchalla, and MJ. Berry II. Recording spikes from a large fraction of the ganglion cells in a retinal patch. *Nature Neuroscience*, 7:1154–1161, 2004.

[5] SJ. Thorpe. Spike arrival times: A highly efficient coding scheme for neural networks. *Parallel processing in neural systems and computers*, page 9194, 1990.

[6] J.C. Vasquez, A. Palacios, O. Marre, M.J. Berry II, and B. Cessac. Gibbs distribution analysis of temporal correlation structure on multicell spike trains from retina ganglion cells. *J. Physiol. Paris (submitted)*.

[7] A. Wohrer and P. Kornprobst. Virtual retina : A biological retina model and simulator, with contrast gain control. *Journal of Computational Neuroscience*, 26(2):219, 2009. DOI 10.1007/s10827-008-0108-4.

Location: Sophia Antipolis, between Nice and Cannes on the French Riviera

Two research labs involved:

- I3S (University of Nice-Sophia Antipolis and CNRS)
- Neuromathcomp project team (INRIA) located in Sophia-Antipolis .

Partners involved with main skills related to this project: This project focuses on new paradigms of information processing suggesting a potential break with the state-of-the-art, which will be made possible by the expertise of different partners:

- Marc Antonini (CNRS, I3S): image and video compression, information theory (see, e.g., [1])
- Bruno Cessac (INRIA, EPI Neuromathcomp): spike train statistics analysis (see, e.g., [6])
- Pierre Kornprobst (INRIA, EPI Neuromathcomp): retina modeling (see, e.g., [7])
- Olivier Marre (Princeton University): MEA recording, spike train statistics analysis (see, e.g., [4])

How to apply? Applications must include

- Cover letter
- CV
- List of publications
- Reprints of 1 to 3 major publications
- Document (one or two pages in A4 or letter size) describing:
  - Summary of your previous research
  - Interests and proposal for research
  - Additional research skills not directly foreseeable from publications
- Contact information of 2 referees

Application material should be sent in electronic format to neuromathcomp.application-s1@inria.fr