# Master 2 Internship

## « A computational model of the retino-thalamo-cortical pathway»

**Project:** The natural visual environments in which we have evolved have shaped and constrained the neural mechanisms of vision. Rapid progress has been made in recent years in understanding how the retina, thalamus, and visual cortex are specifically adapted to processing natural scenes. Over the past several years it has in particular become clear that cortical and retinal responses to dynamic visual stimuli are themselves dynamic. For example, the response in primary visual cortex to a sudden onset is not a static activation, but rather a propagating wave. Probably the most common motions on the retina are image shifts due to our own eye movements: in free viewing in humans, ocular saccades occur about three times every second, shifting the retinal image at speeds of 100-500 degrees of visual angle per second. How these very fast shifts are suppressed, leading to clear, accurate and stable representations of the visual scene, is an fundamental unsolved problem in visual neuroscience known as saccadic suppression. The new Agence Nationale de la Recherche (ANR) project "ShootingStar" aims at studying the unexplored neuroscience and psychophysics of the visual perception of fast (over 100 deg/s) motion, and incorporating these results into models of the early visual system.

In this master, which can be followed by a PhD funded by the ANR ShootingStar, we will develop a retino-thalamico-cortical mean-field model based on the previous work of Zerlaut et al (horizontal connectivity in V1), Souihel et al (integrated model of the retina and V1). Most excitatory synapses in thalamus are of cortical origin, and thus the cortico-thalamic feedback is determinant. In addition, thalamic neurons have very complex intrinsic firing properties, and can generate bursts of action potentials, so they are also not a simple relay. We will integrate these properties by using a previously proposed model of the thalamus using AdEx neurons (Destexhe, 2009), which will be formulated in mean-field terms. This will result in a retino-thalamo-cortical model, where every cell population is represented as mean fields. We will test the role of the corticothalamic feedback in refining the feedforward response in the response to fast stimuli,like saccades.

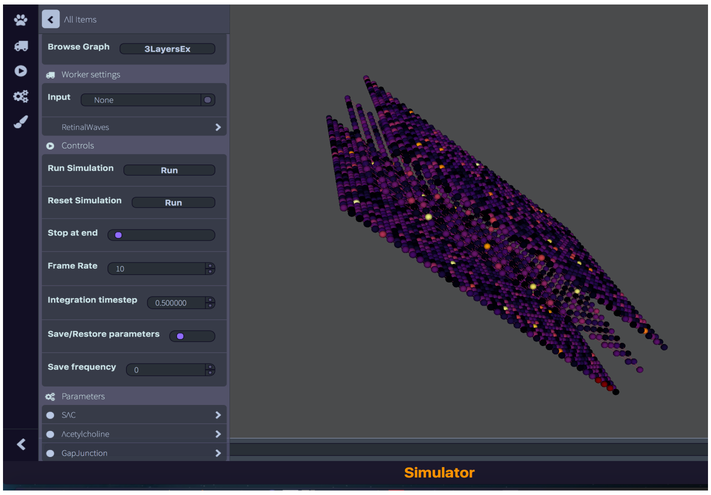


***Figure 3.*** *MACULAR - A retina simulation platform. 3 dimensional view of a simulation with 3 layers of cells with intra layer and inter layers synapses.*

The model will be implemented in Macular, a platform developed at INRIA (Fig. 1), aiming to emulate the response of the early visual system to visual inputs which can be any movie, featuring any type of stimulus. Macular will be used to reproduce the retino-thalamico-cortical activity observed in experiments: rapid motions compared to the same motions preceded and followed by still images, role of refresh rates. It will also be used to simulate the role of the thalamo-cortical loop. Therefore, in the model, we should be capable of simulating the response to the different types of stimuli used in experiments as well as more general types of stimuli.

**Profile**

The master will be done under the co-supervision of B. Cessac (INRIA Biovision, Sophia-Anitpolis) and A. Destexhe (CNRS-NeuroPSI, Paris). The student will be mainly based in Sophia with frequent travels to A. Destexhe's lab. We are seeking a student either with a physicist or computer scientist profile, with strong interests in neuroscience, and solid skills in programming (C++ and Python).

**References**


Zerlaut, Y., Chemla, S., Chavane, F. & Destexhe, A. Modeling mesoscopic cortical dynamics using a mean-field model of conductance-based networks of adaptive exponential integrate-and-fire neurons. J. Comput. Neurosci. 44, 45–61 (2018).

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**Teams**

The goal of the Biovision team is to investigate new solutions to help vision impaired people. Visual impairment affects some 285 million people in the world, mostly in developed countries: 85% have low vision, i.e., have remaining sight, and 15% are totally blind. It is predicted that the prevalence of visual disabilities will increase markedly during the next 20 years, owing largely to the aging. In this context, Biovision aims at developing fundamental research as well as technological transfer along two axes (i) development of high tech vision aid systems for low vision patients (ii) precise modeling of the visual system for normal and distrophic conditions, targeting applications for low vision and blind patients. These axes are developed in strong synergy, involving a large network of national and international collaborators with neuroscientists, physicians, and modellers. Bruno Cessac, the head of the Biovision team, is a theoretical physicist, research director at INRIA, specialized in the modelling and analysis of neuronal models, especially, the retina.

Alain Destexhe's research team investigates the genesis and role of different brain states from a biophysical point of view. The team comprises 1 Professor, 8 postdocs, 2 PhD students, and 3 staff members. Alain Destexhe is Adjunct Director of the Paris-Saclay Institute of Neuroscience (NeuroPSI), a CNRS Institute devoted to the study of brain function from molecules to behavior. NeuroPSI comprises 22 research teams, of which 20 are experimental and 2 theoretical. It also hosts the European Institute of Theoretical Neuroscienc (EITN), where Destexhe of director Alain Destexhe is also an active member of the Human Brain Project (HBP), where his team contributes the bridging between cellular scale (neurons) to large scales (populations) using mean-field models. These mean-fields are used to simulate entire brain regions such as primary visual cortex (V1). The numerous collaborations (in part through HBP and the EITN) and the proximity to experiments, makes Destexhe's team ideal for physicists, mathematicians of engineers interested to participate to neuroscience projects.