

Simulating the cortical activity evoked by artificial retinal implants

Project: Recent advances in neuroscience and microelectronics opens up the possibility of partially restoring vision to blind patients using retinal prostheses. These are devices capturing the light of a visual scene and converting it to electric impulses sent by a matrix of electrodes chirurgically fixed on the retina. The simulation of an electrode elicits an activation in the visual cortex that evokes a percept similar to a light spot called phosphene. The joint stimulation of electrodes allows to reproduce simple shapes (letters, objects, stairs) and to restore a low resolution vision to blind people (see Fig 1). This domain of research is however at an early stage compared to cochlear implants. Especially, the way an electric stimulation activates the visual cortex is still poorly understood. The group of F. Chavane (NeOpTo team at INT Marseille) has used mesoscopic recordings of cortical activity (optical imaging) to better understand the activity evoked by stimulation of the retina with implanted multi electrodes arrays (Roux et al 2016 eLife). Their results show that local stimulation of the retina evoked a cortical activity that is up to 10 times larger than what is expected based on the activity evoked by visual stimuli. This result is in line with known poor resolutions of percepts evoked by stimulation of artificial retinas implanted in blind patients. This observed spread of evoked cortical activity is now better understood. An important effect, evidenced by Roux et al (2017) <https://elifesciences.org/articles/12687> is the asymmetrical spread of electric activity induced by the direct activation of retinal cells axons away from their somata.

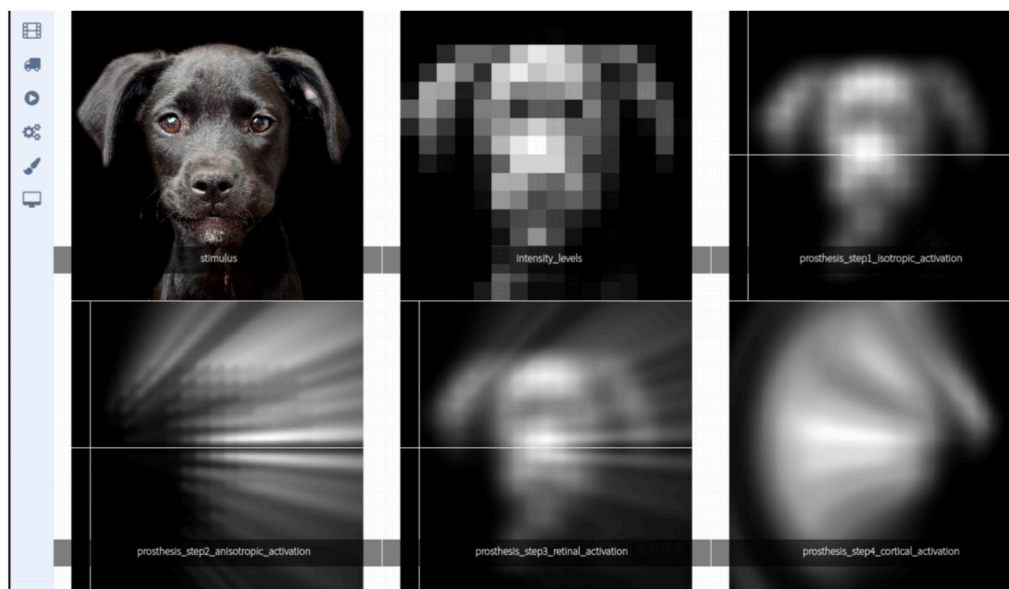


Fig 1 : An image (up-left) is digitalized into small squares (up-left). Each square corresponds to the degree of activation of a corresponding electrode in retinal implant (up-right). The electric stimulation activates neurones en passant of retinal cells leading to non linear diffusion (left bottom) and an effective stimulation pattern (down-middle) which is blurred in comparison to the expected stimulation pattern (up-right). The induced cortical representation is shown in the bottom-right figure

This effect can be modelled at the level of a single electrode with a significant match to experimental measurement. Retinal prostheses integrate hundreds of electrodes and this model can be used to anticipate the simultaneous activation of several electrodes reproducing the shape of an object (Fig 1). This figure has been produced by a retina simulator, called Macular, developed by the Biovision team at Inria, and aiming at reproducing the retina response to stimulation in normal (stimulation by light) and pathological conditions (electric stimulation by prostheses) <https://team.inria.fr/biovision/macular-software/> . In a previous work <https://hal.inria.fr/hal-02292831> we have been able to numerically model the effect of the static joint stimulation of electrodes in retina prostheses on the primary visual cortex (V1) and to compare it to normal vision. However, the stimulation pattern was simplified with respect to reality. Here we want to better understand the spatio-temporal response of the retina and cortex V1 to sequences of images (movies). More precisely, the present internship aims at

- Predicting the dynamics of neuronal activity when the prosthesis emits a spatio-temporal stimulation pattern and compare with visual stimulation ;
- Understanding how retinal circuits and lateral connectivity (horizontal and amacrine cells can improve the activation and resolution ;
- Featuring the difference of activation in the different cells compartment (axone/soma/dendrite).

The internship will be done in collaboration between Bruno Cessac (Biovision, INRIA, Sophia-Antipolis), F. Chavane and S. Roux (INT, CNRS, Marseille). The duration is 6 months. The internship will be done at INRIA with several visits to INT.

Profile. The candidate is expected to have a strong background in programming (C++, git, cmake). He/she must also have a great interest in the field of visual neuroscience, both for fundamental aspects of visual processing and clinical research.

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Teams

- The team **NeOpTo** (Neuronal Operations in Topographic maps) at the Institut des Neurosciences de la Timone (INT-CNRS) aims at elucidating the neural computations that underlies active vision. Vision is a major sensory input for guiding our actions, perceiving our environment and conducting cognitive tasks. Yet the visual inputs that reach the brain represent a computational challenge: they are ambiguous, dynamical, segmented into a myriad of piecewise cues and constantly influenced by eye movements. To overcome this problem, our visual system must link sensory inputs with a priori knowledge at multiple spatial and temporal scales. To investigate how the visual system achieve such challenge, the NeOpTo team combines multiple expertises involving behavioral studies in both humans and monkeys, ophthalmologic clinical approaches, electrophysiological and real-time optical imaging studies in behaving monkeys and Bayesian modeling approaches.
- 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 dystrophic 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.

Application: Interested candidates can find specific application requirements and the online application at: <https://team.inria.fr/biovision/internship-applications>. To ensure full consideration, applications must be completed by December 31, 2019. Late applications will be entertained only if position remains unfilled. Interested applicants are also free to email us directly to discuss potential fit with the lab prior to applying.