Activity Report 2019

Project-Team BIOVISION

Biologically plausible Integrative mOdels of the Visual system : towards synergIstic Solutions for visually-Impaired people and artificial visiON

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Computational Neuroscience and Medicine

Table of contents

Project-Team BIOVISION

Creation of the Team: 2016 January 01, updated into Project-Team: 2018 August 01

Keywords:

Computer Science and Digital Science:

A5.3. - Image processing and analysis
A5.4. - Computer vision
A5.6. - Virtual reality, augmented reality
A6.1.1. - Continuous Modeling (PDE, ODE)
A6.1.4. - Multiscale modeling
A6.1.5. - Multiphysics modeling
A6.2.4. - Statistical methods

Other Research Topics and Application Domains:

B1.1.8. - Mathematical biology
B1.2.1. - Understanding and simulation of the brain and the nervous system
B2.1. - Well being
B2.5.1. - Sensorimotor disabilities
B9.5.2. - Mathematics
B9.5.3. - Physics

1. Team, Visitors, External Collaborators

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Aurelie Calabrèse [Inria, Starting Research Position, from Nov 2019]
Pierre Kornprobst [Inria, Senior Researcher, HDR]

Post-Doctoral Fellow

Hui-Yin Wu [Inria, Post-Doctoral Fellow, from Mar 2019]

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2. Overall Objectives

2.1. Overall Objectives

Vision is a key function to sense the world and perform complex tasks. It has a high sensitivity and a strong reliability, given that most of its input is noisy, changing and ambiguous. Better understanding biological vision will have a strong scientific, medical, societal and technological impact in the near future. In this context, Biovision aims at developing fundamental research as well as technological transfer along two axes: (i) developing of high tech vision aid-systems for low-vision patients and (ii) 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.

3. Research Program

3.1. Introduction

The Biovision team has started on January 1st, 2016 and became an Equipe Projet Inria on August 1st, 2018 . It aims at developing fundamental research as well as technological developments along two axes.

3.1.1. Axis 1: High tech vision aid-systems for low-vision patients

Visual impairment, also known as vision loss, is a decreased ability to see to a degree that causes problems not fixable by usual means, such as glasses or lenses. Low-vision is a condition caused by eye disease, in which visual acuity is 20/70, meaning that the person is able to see, at 20 meters from a chart, what a normal person would see at 70 meters. Visual impairment affects some 285 million humans in the world, mostly in developed countries where this number is going to increase rapidly due to aging. 85% have low-vision or poorer. [1] There is a strong need to conceive new aid-systems to help these people in their daily living activities. Such systems already exist and can be divided into two categories according to their function. The first category concerns aids that translate visual information into alternative sensory information, such as touch or sound, called Sensory Substitution Devices (SSDs) [45], [40]. The second category concerns aids that adapt visual information to render it more visible to the patients, using scene processing methods and suitable devices. These are based on technological and algorithmic solutions that enhance salient scene characteristics [60], [56]. In Biovision team, we focus on this second category by targeting new vision aid-systems helping patients in their daily life, adapting to their own pathology.

We have strong contacts and collaborations with low-vision centers and associations in order to better understand low-vision patients needs, and have feedback on our prototypes aimed to be distributed to patients via transfer or company creation (startup). With the fast-growing number of incurable eye diseases, crucial steps must be taken to increase visual accessibility by:

- Designing solutions for earlier and more decisive detection of visual pathologies,
- Developing efficient rehabilitation protocols, and,
- Designing innovative vision-aid systems to empower patients with improved perceptual capacities.

To do this, we need to work in synergy with patients to assess their needs, understand their pathologies at a perceptual level and design personalized solutions to create change and adoption. This will require developing state-of-the-art methods in computer science, necessitating skills from many areas such as artificial intelligence, virtual and augmented reality, human-machine interface, multimedia systems, etc. By doing so, we will leverage new technologies to offer life-changing solutions for people with visual impairment [12], [15].

[1] Source: VisionAware

3.1.2. Axis 2: Human vision understanding through joint experimental and modeling studies, for normal and distrophic retinas

A holistic point of view is emerging in neuroscience where one can observe simultaneously how vision works at different levels of the hierarchy in the visual system. Multiple scales functional analysis and connectomics are also exploding in brain science, and studies of visual systems are upfront on this fast move. These integrated studies call for new classes of theoretical and integrated models where the goal is the modeling of visual functions such as motion integration.

In Biovision we contribute to a better understanding of the visual system with those main goals:

1. Proposing simplified mathematical models characterizing how the retina converts a visual scene into **spike population coding**, in normal and under specific pathological conditions.
2. Designing biophysical models allowing to better understand the **multiscale dynamics** of the retina, from dynamics of individual cells to their collective activity, and how changes in biophysical parameters (development, pharmacology, pathology) impacts this dynamics.
3. Elaborating an **integrated mathematical and numerical model** of the visual stream, with a focus on motion integration, from retina to early visual cortex (V1).
4. Developing a **simulation platform** emulating the retinal response to visual and prosthetic simulations, enabling us to test hypotheses about the functioning of the early visual system, in normal, pharmacological or pathological conditions.

Finally, although this is not the main goal of our team, two other natural avenues of our research are (i) to develop novel synergistic solutions to solve computer vision tasks based on bio-inspired mechanisms [7]; (ii) collaborate with neuroscientists and neuronal modellers to address mathematical problems outside the scope of the retina or the early visual system.

3.2. Scientific methodology

In this section we briefly describe the scientific methods we use to achieve our research goals.

3.2.1. Adaptive image enhancement

Image enhancement is a natural type of image processing method to help low-vision people better understand visual scenes. An impressive number of techniques have been developed in the fields of computer vision and computer graphics to manipulate image content for a variety of applications. Some of these methods have a direct interest in the design of vision aid-systems. Only a few of them have been carefully evaluated with patients [36], [49], [50], [41], [37]. Our objective is to further exploit and evaluate them with patients, considering dedicated use-cases, using virtual and augmented reality technology (Sec. 3.2.2). We consider not only classical brightness manipulations (e.g., equalization, gamma correction, tone mapping, edge enhancement, image decomposition and cartoonization) but also more sophisticated approaches which can change the geometric information of the scene to highlight the most relevant information (e.g., scene retargeting and seam carving). In addition, we investigate how image enhancements could be adapted to patients needs by relating tuning parameters to the patient pathology.

3.2.2. Virtual, mixed and augmented reality

Virtual, mixed and augmented reality technology (VR/MR/AR) is based on the idea of combining digital worlds with physical realities in different ways. It encompasses a wide spectrum of hardware. It is our conviction that this technology will play a major role in the domain of low-vision. Not only can this technology be useful to design novel vision aid-systems and rehabilitation programs, but also it has the potential to revolutionize how we study the behaviour of low-vision people (controlled condition, free head, eye tracking, possibilities for large scale studies). These projects require a constant interaction with psychophysicists and ophtalmologists so as to design our solutions based on patients needs and capabilities.

3.2.3. Biophysical modeling

Modeling in neuroscience has to cope with several competing objectives. On one hand, describing the biological realm as close as possible, and, on the other hand, providing tractable equations at least at the descriptive level (simulation, qualitative description) and, when possible, at the mathematical level (i.e., affording a rigorous description). These objectives are rarely achieved simultaneously and most of the time one has to make compromises. In the Biovision team we adopt the point of view of a physicist: try to capture the phenomenological description of a biophysical mechanism, removing irrelevant details in the description, and try to have a qualitative description of equations behaviour at least at the numerical simulation level, and, when possible, obtain analytical results. We insist on the quality of the model in predicting and proposing new experiments. This requires a constant interaction with neuroscientists so as to keep the model on the tracks, warning of too crude approximation, still trying to construct equations from canonical principles [1], [2], [6].

3.2.4. Methods from theoretical physics

Biophysical models mainly consist of differential equations (ODEs or PDEs) or integro-differential equations (neural fields). We study them using dynamical systems and bifurcation theory as well as techniques coming from nonlinear physics (amplitude equations, stability analysis, Lyapunov spectrum, correlation analysis, multi-scales methods) [23].

For the study of large scale populations (e.g., when studying population coding) we use methods coming from statistical physics. This branch of physics gave birth to mean-field methods as well statistical methods for large population analysis. We use both of them. Mean-field methods are applied for large scale activity in the retina and in the cortex [4], [8], [39].

For the study of retina population coding we use the so-called Gibbs distribution, initially introduced by Boltzmann and Gibbs. This concept includes, but *is not limited to*, maximum entropy models [55] used by numerous authors in the context of the retina (see, e.g., [57], [59], [52], [51], [61]). These papers were restricted to a statistical description without memory neither causality: the time correlations between successive times is not considered. However, maximum entropy extends to spatio-temporal correlations as we have shown in, e.g., [2] [62], [43]. In this context, we study how the retina respond to transient stimuli (moving objects), i.e. how spatio-temporal correlations are modified when a moving object crosses the receptive fields of ganglion cells, taking into account the lateral connectivity due to amacrine cells [42], [20], [11], [21].

4. Application Domains

4.1. Applications of virtual/augmented reality for low-vision

- **Rehabilitation**: Serious games are games designed for a primary purpose which is not pure entertainment. In our context, we think about serious games as a way to help low-vision patients in performing rehabilitation exercises. Virtual/augmented reality technology is a promising platform to develop such rehabilitation exercises targeted to specific pathologies. For example, with Age Macular Degeneration (AMD), our objective is to propose solutions allowing rehabilitation of visuo-perceptual-motor functions to optimally use residual portions of the peripheral retina and obtain efficient eccentric viewing.
- **Vision aid-systems**: A variety of aids for low-vision people are already on the market using different kinds of virtual/augmented reality platforms (dedicated or large public ones). They offer different functionalities (magnification, image enhancement, text to speech, face and object recognition). Our goal is to design new solutions allowing autonomous interaction in mixed reality environments, and take advantage of the improvement of functions obtained via rehabilitation protocols.
- **Cognitive research**: Virtual/augmented reality technology represents a new opportunity to conduct cognitive and behavioural research using virtual environments where all parameters can be psychophysically controlled. Our objective is to re-assess common theories by allowing patients to freely explore their environment in more ecological conditions.

4.2. Applications of vision modeling studies

- **Neuroscience research.** Making in-silico experiments is a way to reduce the experimental costs, to test hypotheses and design models, and to test algorithms. Our goal is to develop a large-scale simulations platform of impaired retinas, called Macular, allowing to mimic specific degeneracies or pharmacologically induced impairments, as well as to emulate electric stimulation by prostheses. In addition, the platform provides a realistic entry to models or simulators of the thalamus or the visual cortex, in contrast to the entries usually considered in modelling studies.
- **Education.** Macular is also targeted as a useful tool for educational purposes, illustrating for students how the retina works and responds to visual stimuli.

5. Highlights of the Year

5.1. Highlights of the Year

In November 2019, the Biovision project team recruited Dr. Aurelie Calabrèse as a "Starting Research Position" for a 3-year period. A. Calabrèse is a psychophysicist specialized in visual neuroscience with a strong clinical expertise. She has done extensive work on enhancing further the methods to detect and measure reading deficit in low-vision populations. She has extensive practice in experimenting with visually impaired individuals and will be a great asset to bridge the gap between development and validation of assistive technology solutions.

6. New Software and Platforms

6.1. Virtual Retina

A biological retina model with contrast gain control for large scale simulations

KEYWORDS: Neurosciences - Simulation - Biology - Health

SCIENTIFIC DESCRIPTION: Virtual Retina has a variety of biological features implemented such as (i) spatio-temporal linear filter implementing the basic center/surround organization of retinal filtering, (ii) non-linear contrast gain control mechanism providing instantaneous adaptation to the local level of contrast, (iii) spike generation by one or several layers of ganglion cells paving the visual field.

FUNCTIONAL DESCRIPTION: Virtual Retina is a simulation software that allows large-scale simulations of biologically-plausible retinas.

- Participants: Adrien Wohrer, Pierre Kornprobst, Bruno Cessac, Maria-Jose Escobar and Thierry Viéville
- Contact: Pierre Kornprobst
- Publication: Virtual Retina: A biological retina model and simulator, with contrast gain control
- URL: https://team.inria.fr/biovision/virtualretina/

6.2. PRANAS

Platform for Retinal ANalysis And Simulation

KEYWORDS: Retina - Neural Code - Data management - Statistics - Modeling - Vision

SCIENTIFIC DESCRIPTION: PRANAS was designed as a user-friendly tool dedicated to the neuroscientist community in a large sense, i.e., not only experienced computational neuroscientists. It has two main goals : (i) to analyze retina data, especially spatio-temporal correlations, at single cell but also population levels, (ii) to simulate the spike response of the retina to a visual flow with a customizable retina simulator which evolves in synergy with experimental data analysis. In general, PRANAS allows us to explore several aspects of retinal image processing such as understanding how to reproduce accurately the statistics of the spiking activity at the population level, or reconciling connectomics and simple computational rules for visual motion detection. This makes this tool a unique platform to better understand how the retina works.

FUNCTIONAL DESCRIPTION: The retina encodes a visual scene by trains of action potentials sent to the brain via the optic nerve. PRANAS brings to neuroscientists and modelers tools to better understand this coding. It integrates a retina simulator allowing large scale simulations while keeping a strong biological plausibility and a toolbox for the analysis of spike trains population statistics. The statistical method (entropy maximization under constraints) takes into account both spatial and temporal correlations as constraints, allowing to analyze the effects of memory on statistics. PRANAS also integrates a tool computing and representing in 3D (time-space) receptive fields. All these tools are accessible through a friendly graphical user interface. The most CPU-costly of them has been implemented to run in parallel. The actual version simulates healty retinas but the long term goal is to study retinas with a pathology (DMLA, Retinitis Pigmentosa, Glaucoma).

- Authors: Bruno Cessac, Pierre Kornprobst, Sélim Kraria, Hassan Nasser, Daniela Pamplona, Geoffrey Portelli and Adrien Wohrer
- Contact: Bruno Cessac
- Publication: PRANAS: A New Platform for Retinal Analysis and Simulation
- URL: https://team.inria.fr/biovision/pranas-software/

6.3. Platforms

6.3.1. Macular

Macular https://team.inria.fr/biovision/macular-software/ is a platform for the numerical simulation of the retina and primary visual cortex. It aims to reproduce the response of the retina to visual or electrical stimulation – produced by retinal prostheses – under normal or pathological conditions. The objective is to develop a tool that can be used by neuroscience researchers to reproduce experimental results, but also to guide their experiments through hypotheses that can be tested in the simulator. This can save a considerable amount of experimental resources. Macular is based on the central idea that its use and its graphic interface can evolve according to the objective of the user. It can be used in several cases, such as the simulation of retinal waves, the simulation of retinal and cortical responses to electrosurgical stimulation, the study of the contribution of specific classes of retinal cells in the encoding of visual scenes. Macular's modular architecture makes it flexible and makes it easy to implement new features. It also includes a scripting option, which offers the user the ability to decode his own model, with a given set of equations, variables and parameters, without having to program a code. Finally, thanks to a highly parallelizable architecture, Macular makes it possible to simulate a large number of cells of different classes (see Fig. 1).

7. New Results

7.1. High tech vision aid-systems for low-vision patients

7.1.1. Multilayered Analysis of Newspaper Structure and Design

Participants: Hui-Yin Wu, Pierre Kornprobst.

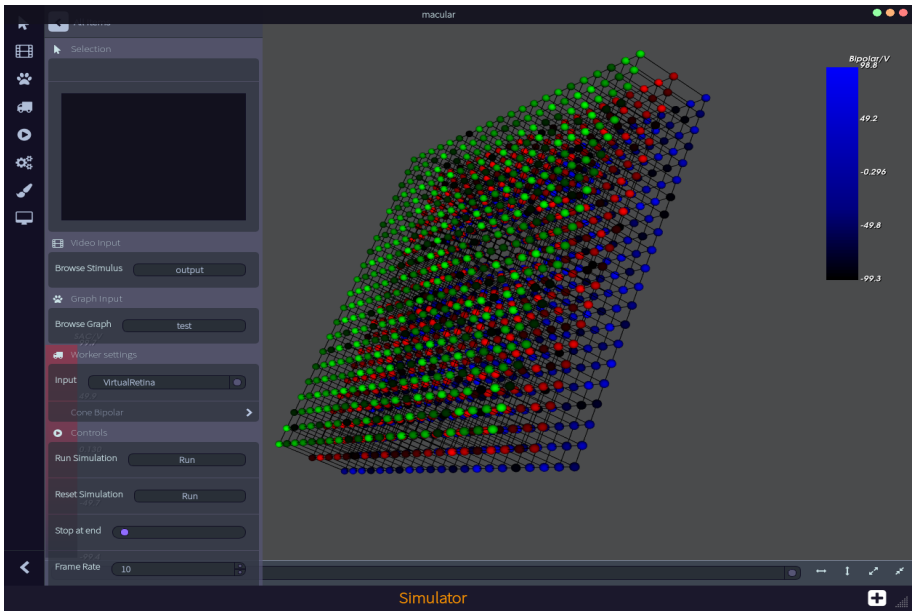

Figure 1. The Macular software. Here we see a three dimensional view of three retinal cells layers.

The understanding of newspaper document structure can help in the adaptation of text and visual content for different devices and media [53], as well as, in the context of low vision, to enhance accessibility by combining magnification and text-to-speech aids. However, automated segmentation of complex document structures like newspapers remains an ongoing challenge due its dense layout with numerous visual and textual design elements [38], [44].

To address this challenge, we propose a multi-layered analysis of structure and design, presented in [27]. Taking images of newspaper front pages as input, our approach uses a combination of computer vision techniques to segment newspapers with complex layouts into meaningful blocks of varying degrees of granularity, and convolutional neural network (CNN) to classify each block. The final output presents a visualization of the various design elements present in the newspaper such as in Figure 2. Compared to previous approaches, our method introduces a much larger set of design-related labels (23 labels against less than 10 before) resulting in a very fine description of the pages, with high accuracy (83%), as shown in Figure 3.

This work is presented in [27].

7.1.2. Towards accessible news reading design in virtual reality for low vision

Participants: Hui-Yin Wu, Aurélie Calabrèse, Pierre Kornprobst.

Low-vision conditions resulting in partial loss of the visual field strongly affect patients' daily tasks and routines, and none more prominently than the ability to access text. Though vision aids such as magnifiers, digital screens, and text-to-speech devices can improve overall accessibility to text, news media, which is non-linear and has complex and volatile formatting, bars low-vision patients from easy access to essential news content [54].

Our aim is to position virtual reality as the next step towards accessible and enjoyable news reading for the low vision. Our ongoing work, which we present in [26], consists of an extensive review into existing research on low-vision reading technologies and accessibility for modern news media. From previous research and

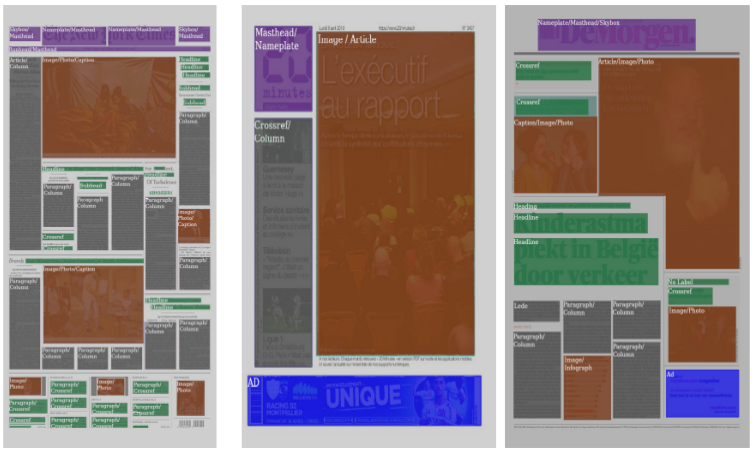

Figure 2. Visualization of the classification results on three different newspapers in our test set. Colors indicate primary categories as masthead elements (purple), text column (gray), ads (blue), images (brown) and minor text elements (green). Original images copyright of (from left to right) New York Times, 20 Minutes, and DeMorgan, courtesy of Newseum.

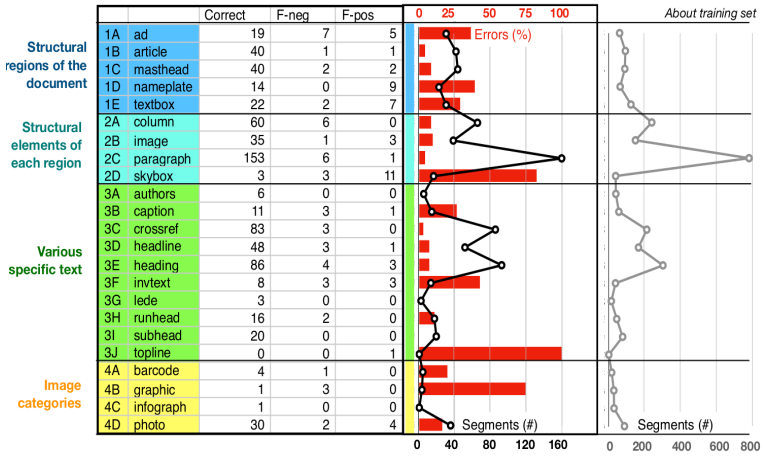

Figure 3. Classification result per categories. Results are presented in the table, showing the number of design elements that are correctly classified, false-negative (i.e. missing label), and false-positive (i.e. wrongly assigned label). Then a red chart shows the errors together with the number of segments (black line) used for the test dataset. To the right, the grey curve indicates the number of segments which were available in the training set.

studies, we then conduct an analysis into the advantages of virtual reality for low-vision reading and propose comprehensive guidelines for visual accessibility design in virtual reality, with a focus on reading. This is coupled with a hands-on study of eight reading applications in virtual reality to evaluate how accessibility design is currently implemented in existing products. Finally, we present a framework that integrates the design principles resulting from our analysis and study, and implement a proof-of-concept for this framework using browser-based graphics (Figure 4 and 5) to demonstrate the feasibility of our proposal with modern virtual reality technology.

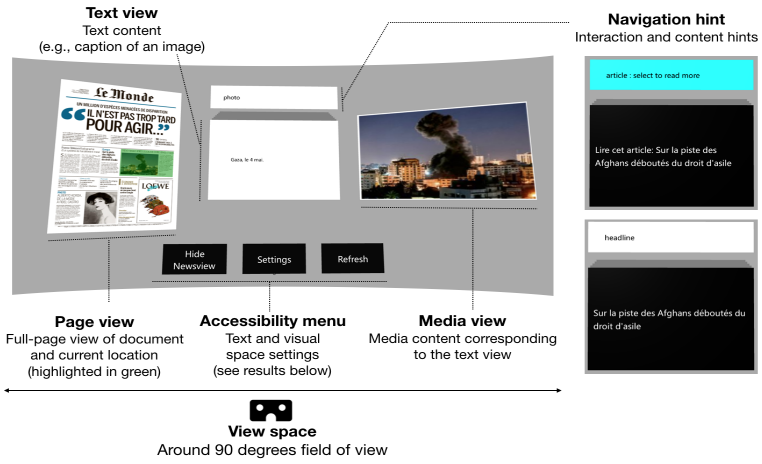

Figure 4. Application prototype: The global overview of the newspaper page is shown side-by-side with the enlarged text and images of the highlighted region. Navigation hints above the card show what type of content is displayed (e.g. photo, heading, paragraph) and whether the card can be selected (i.e. highlighted in light blue) to reveal further content. Text and images of the newspaper are purely for demonstrating a proof-of-concept. Excerpted from 7 May 2019 issue of ©Le Monde.

This work is presented in [26].

7.2. Human vision understanding through joint experimental and modeling studies, for normal and distrophic vision

7.2.1. From micro- to macroscopic description of the retina

7.2.1.1. Retinal Waves

Participants: Dora Matzakos-Karvouniari [Laboratoire Jean-Alexandre Dieudonné, (LJAD), Nice, France], Bruno Cessac, Lionel Gil [Institut de Physique de Nice (InPhyNi), France].

Retinal waves are bursts of activity occurring spontaneously in the developing retina of vertebrate species, contributing to the shaping of the visual system organization: retina circuitry shaping, retinotopy, eye segregation [63], [47], [58], [48]. They stop a few weeks after birth. Wave activity begins in the early development, long before the retina is responsive to light. It was recently found that they can be reinitiated pharmacologically in the adult mammalian retina [46]. This could have deep consequences on therapy for several degenerative retinal diseases. The mechanism of their generation, in developing, or adult retinas, remains however incompletely understood [64].

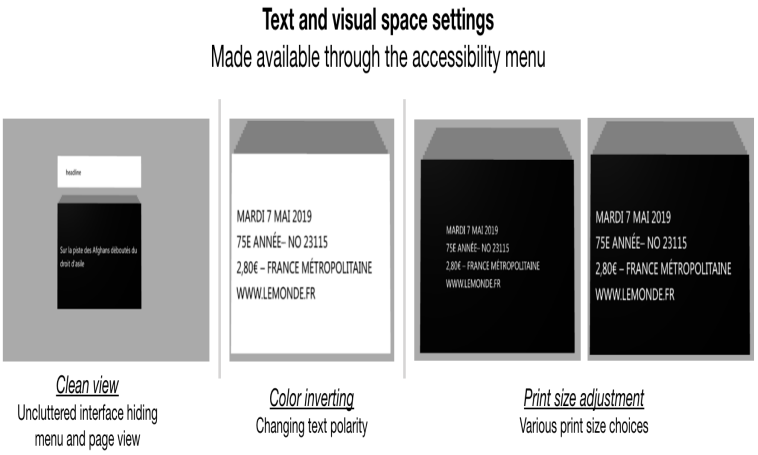

Figure 5. The accessibility menu provides a number of functions including (1) showing/hiding the page and menu view to personalize the view space, (2) invert foreground and background color only for text content, and (3) change the print size. Text on the cards excerpted from 7 May 2019 issue of ©Le Monde

We have proposed a model for stage II retinal waves - induced by bursting Starburst Amacrine Cells (SACs) coupled by acetylcholine - with two objectives: (i) being sufficiently close to biophysics to explain and propose experiments and (ii) affording a mathematical analysis [14], [34]. From a bifurcations analysis we have highlighted several relevant biophysical parameters controlling waves generation, mainly regulating potassium and calcium dynamics. We thus explain how SACs in different species exhibit a large variability in their bursting periods with a common mechanism.

Based on this biophysical model we have analysed here the dynamics of retinal waves and their statistics. We show that, despite the acetylcholine coupling intensity has been experimentally observed to change during development, SACs retinal waves can nevertheless stay in a regime with power law distributions, reminiscent of a critical regime. Thus, this regime occurs on a range of coupling parameters instead of a single point as in usual phase transitions. We explain this phenomenon thanks to a coherence-resonance mechanism, where noise is responsible for the broadening of the critical coupling strength range. This work has been presented in [14], [16], [25]

7.2.1.2. Anticipation in the retina and the visual cortex V1

Participants: Bruno Cessac, Frédéric Chavane [Institut de Neurosciences de la Timone (CNRS and Aix-Marseille Université, France)], Alain Destexhe [Institute de Neuroscience Paris-Saclay (UNIC)], Sandrine Chemla [Institut de Neurosciences de la Timone (CNRS and Aix-Marseille Université, France)], Selma Souihel, Matteo Di Volo [Institute de Neuroscience Paris-Saclay (UNIC)].

This work has been done in the context of the ANR Trajectory and Selma Souihel Thesis [11].

Vision is initiated in the retina, where light is converted into electrical signals by photoreceptors, sent to bipolar cells then ganglion cells, generating spike trains. Visual information is then transmitted to the thalamus via the optic nerve which in turn transmits it to the visual cortex. The retinal processing alone takes time, up to 150 ms, not to mention the time lags introduced by synaptic transmissions between the three processing units. This shows that the existence of compensatory mechanisms to reduce processing delays is absolutely essential. These compensatory mechanisms are known as anticipation. Anticipation first occurs at the level of the retina and is further carried out by the primary visual cortex. In its first occurrence, anticipation is either characterized by a shift in the the peak response, or a short range wave of activation. In the second case, it is characterized by a wider range wave of activation.

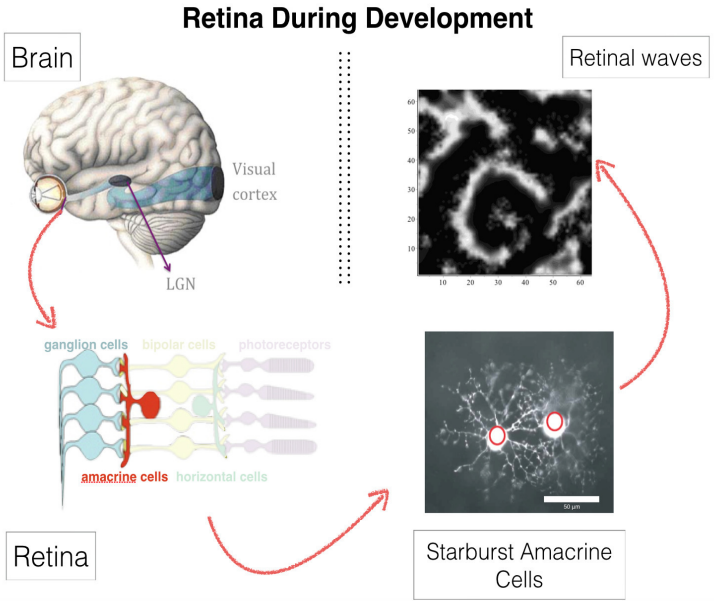

Figure 6. Top left. View of the human visual system. Bottom left. Right after birth the retina is not fully developed (shadowed parts). The retinal waves (top right) contributes to this development. They are mediated by specific cells (Starburst Amacrine Cells in stage II, bottom right).

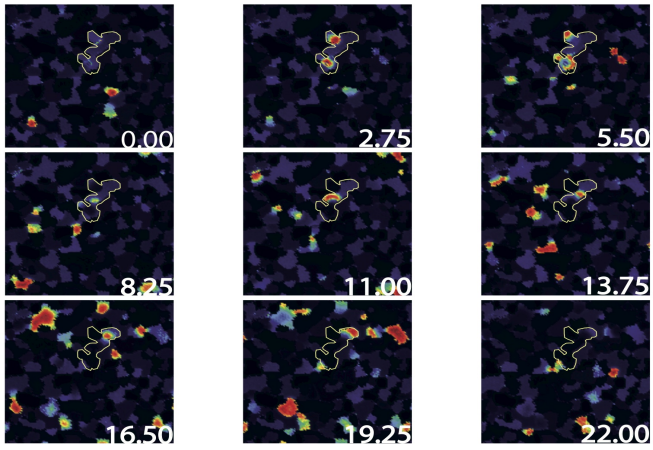

Figure 7. Example of the two dimensional time evolution of the calcium concentration C. Dark regions correspond to low calcium concentration while red corresponds to high concentration (wave). The time (in s) is displayed in the bottom right corner. The same thin white line in the center of each image, delimits a closed domain where wave propagates almost periodically. Hence, after the sequence shown above which correspond to a single period, a new one takes place a time later with a new wave following almost the same trajectory. The domain delimited by the white line is circled with high sAHP regions and therefore slowly evolves with time. A numerical movie is available on the website : https://www.youtube.com/watch?v=shMR3NMCBDE

The first contribution of this work is the development of a generalized 2D model of the retina, mimicking three types of ganglion cells : Fast OFF cells with gain control, direction selective cells with gap junction connectivity, and differential motion cells connected through an upstream amacrine circuit, able of anticipating different kinds of moving stimuli. The second contribution is to use our retina model as an input to a mean field cortical model to reproduce motion anticipation as observed in voltage sensitive dye imaging recordings. Throughout our work, we will study the effect of non linear phenomena involved in anticipation, as well as connectivity, both at the level of the retina and the primary visual cortex. The integrated retino-cortical model allowed us to study the effects of anticipation on two-dimensional stimuli, and to highlight the collaborative aspect of anticipation mechanisms in the retina and the cortex.

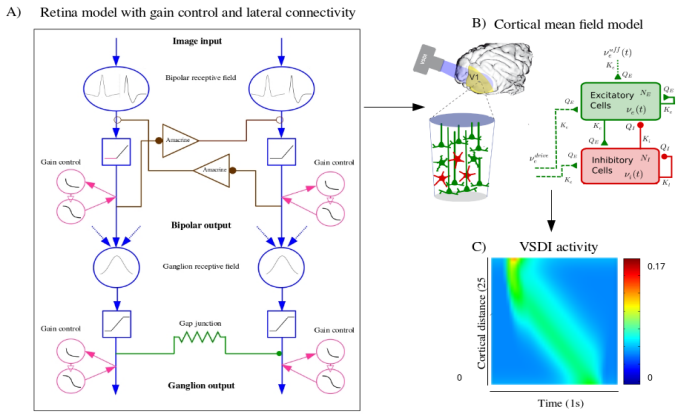

Figure 8. Schematic of our retino cortical model for anticipation. Left. Structure of the retinal model with 3 pathways: Blue: Gain control. Green: Gap junctions laterally connecting Ganglion Cells. Brown. Amacrine cells lateral connectivity. Right top. Cortical model (from Destexhe-Boustani 2009). Bottom. Simulation of VSDI activity in response to a moving bar.

This work has been presented in [17], [22], [20], [34], [21], [11]

7.2.1.3. Dynamical synapse in the retina

Participants: Bruno Cessac, Simone Ebert, Olivier Marre [Institut de la Vision (IdV), Paris, France], Romain Veltz [MathNeuro].

A very sophisticated example of the computations within the retina is observed when the visual system is exposed to a periodic stimulus, such as a regular series of flashes. If the retina would simply respond proportionally to the stimulus input, one might expect that ganglion cells would become entrained into aperiodic activity, responding to each flash. When the stimulus sequence ends,the activity would end as well. However, ganglion cells can exhibit various different kinds of response patterns to this form of stimulation shown in Figure 3. At the beginning of the stimulus, cells typically respond to the first flash of this new stimulus with a peak of activity, but then very rapidly decay in the amplitude of their response to the following flashes. Most remarkably, when the flash sequence ends ganglion cells do not just stop to respond, but in fact may generate a pulse of activity signalling the missing stimulus. This property of indicating a deviation from an expected pattern has been termed the Omitted Stimulus Response (OSR) (Schwartz, Harris, Shrom, Berry, 2007). The aim of this study was to implement and compare the two existing models of Omitted Stimulus Response in the retina, as well as exploring potential mechanisms that may be involved in generating it. Especially synaptic mechanisms may provide an explanation here, but the integration of such a mechanism into

an OSR model has not been explored yet. A potential synaptic property that provides an interesting candidate to test here would be short-term plasticity (STP), which modulates synaptic efficacy depending on the previous activity in a short time interval (Blitz, Foster, Regehr, 2004). STP thus modulates signal transmission and a consecutive spike pattern and has been found to take place within the retina (Dunn, Rieke, 2008). Examining the models' underlying mechanisms, advantages and disadvantages as well as similarities and differences will provide a good foundation to modify existing models by adding potential mechanisms and exploring their effect on a ganglion cell response to a periodic stimulus. Ultimately, this may help shedding light on cellular properties in a neuronal circuit as of as few as 3 cells can contribute to already interpreting information from the environment.

This work has been presented in [32]. It has lead to experiments done in the Institut de la Vision by S. Ebert (internship Biovision) and O. Marre (Institut de la Vision (IdV), Paris, France) in November 2019.

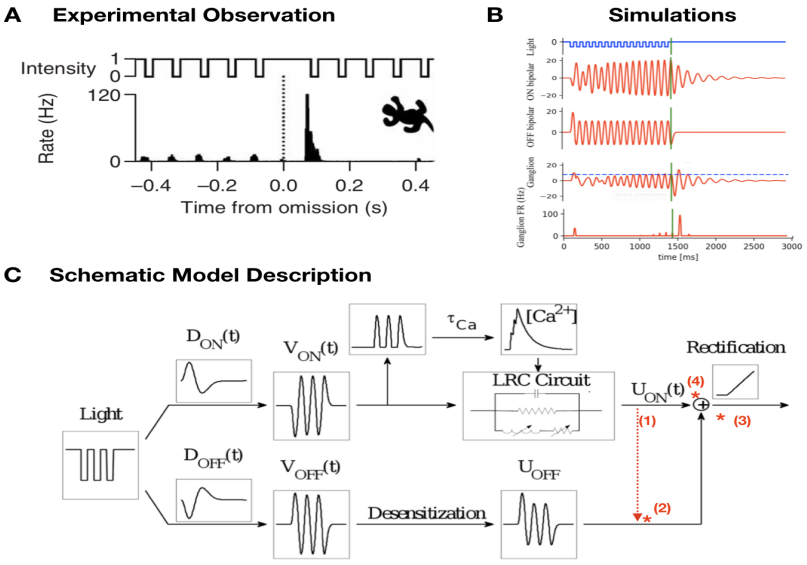

Figure 9. A. Experimentally observed Omitted Stimulus Response (OSR) to a periodic flash sequence. B. Simulations performed with an existing Model from Gao et al., 2009. C. Schematic description of the used 'Calcium-tuned Oscillator' Model from Gao et al., 2009. It is based on a feedforward circuit consisting of two different pathways with different intrinsic processing steps. Both pathways are combined to represent the synaptic input ganglion cells, who's activity with generate an Omitted Stimulus Response. Planned modifications planned are marked in red. (1) a presynaptic connection before summation of both pathways. (2),(3),(4) are synapses where short term synaptic plasticity could occur.

7.2.2. Numerical modelling of the retina in normal and pathological conditions

7.2.2.1. Probing retinal function with a multi-layered simulator

Participants: Bruno Cessac, Gerrit Hilgen [Institute of Neuroscience (ION), Newcastle, UK], Evgenia Kartsaki, Evelyne Sernagor [Institute of Neuroscience (ION), Newcastle, UK].

Our brain can recreate images from interpreting a stream of information emitted by one million parallel channels in the retina. This ability is partly due to the astonishing functional and anatomical diversity of the retinal ganglion cells (RGCs), each interpreting a different feature of the visual scene. How precisely

this complexity is encoded in the spike trains produced by the population of RGCs is, however, largely unknown. Adding to the complexity, RGCs "speak" to each other during complex tasks (especially motion handling), via amacrine cells (ACs - lateral connectivity). To decipher their role, we study an experimental setting where neurons co-express the genes Grik4 or Scnn1a and excitatory or inhibitory DREADDs (Designer Receptors Exclusively Activated by Designer Drugs), activated by the designer drug CNO. Switching on or off RGCs and/or ACs cells may not only impact the RGCs individual response but also their concerted activity to different stimuli, thus allowing us to understand how they contribute to the encoding of complex visual scenes. However, it is difficult to distinguish on pure experimental grounds the effect of CNO when both cell types express DREADDs, as these cells "antagonise" each other. Contrarily, numerical simulation can afford it. Here, we propose a novel simulation platform that can reflect normal and impaired retinal function (from single-cell to large-scale level). It is able to handle different visual processing circuits and allows us to visualise responses to visual scenes (movies). In addition, the platform allows simulation of retinal responses when DREADD-expressing cell subclasses are either silenced or excited with CNO. To demonstrate how our simulator works, we deploy a circuit that handles motion on a large-scale level and study how the retina responds to visual scenes by visualising retinal processing at each level. The simulator also provides a tunable parameter to control the CNO effect (excitation or inhibition). Consequently, it facilitates the disentanglement of the effect of CNO on ACs and RGCs. Nevertheless, simulations and experiments are widely complementary. Experiments are necessary to constrain the numerical model and check its validity (especially, its predictions), while the computational approach affords to explore aspects that cannot be easily achieved experimentally.

This work has been presented in [24], [19], [33]

7.2.2.2. Simulating the cortical activity evoked by artificial retinal implants

Participants: Teva Andréoletti, Bruno Cessac, Frédéric Chavane [Institut de Neurosciences de la Timone (CNRS and Aix-Marseille Université, France)], Sébastien Roux [Institut de Neurosciences de la Timone (CNRS and Aix-Marseille Université, France)].

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.

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 [28], [29] 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.

This work has been presented in [28], [29]

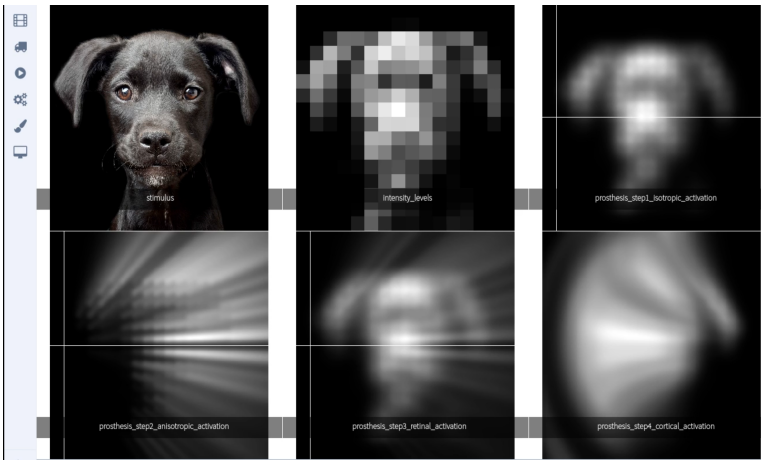

Figure 10. Simulation of the retinal and cortical response to a prosthesis simulation. An image (up-left) is digitalized into small squares (up-left). Each square corresponds to the degree of activation of a corresponding electrode in retinal implant (up-right). The electric stimulation activates neurones 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.

7.3. Neuronal modelling

7.3.1. Linear response in neuronal networks: from neurons dynamics to collective responses

Participant: Bruno Cessac.

We have reviewed two examples where the linear response of a neuronal network submitted to an external stimulus can be derived explicitly, including network parameters dependence. This is done in a statistical physics-like approach where one associates to the spontaneous dynamics of the model a natural notion of Gibbs distribution inherited from ergodic theory or stochastic processes. These two examples are the Amari-Wilson-Cowan mode and a conductance based Integrate and Fire model

This work has been published in [13], [31], [18].

7.3.2. On the role of Nav1.7 sodium channels in chronic pain: an experimental and computational study

Participants: Lyle Armstrong [Institute of Neuroscience (ION), Newcastle, UK], Alberto Capurro [Institute of Neuroscience (ION), Newcastle, UK], Bruno Cessac, Jack Thornton [Institute of Neuroscience (ION), Newcastle, UK], Evelyne Sernagor [Institute of Neuroscience (ION), Newcastle, UK].

Chronic pain is a global healthcare problem with a huge societal impact. Its management remains generally unsatisfactory, with no single treatment clinically approved in most cases. In this study we use an in vitro model of erythromelalgia consisting of dorsal root ganglion neurons derived from human induced pluripotent stem cells obtained from a patient (carrying the mutation F1449V) and a control subject. We combine neurophysiology and computational modelling to focus on the Nav1.7 voltage gated sodium channel, which acts as an amplifier of the receptor potential in nociceptive neurons and plays a critical role in erythromelalgia due to gain of function mutations causing the channel to open with smaller depolarisations. Using extracellular recordings, we found that the scorpion toxin OD1 (a Nav1.7 channel opener) increases dorsal root ganglion cell excitability in cultures obtained from the control donor, evidenced by an increase in spontaneous discharges,

firing rate and spike amplitude. In addition, we confirmed previous reports of voltage clamp experiments concerning an increase in spontaneous discharge in the patient cell cultures and the analgesic effects of the Nav1.7 blocker PF-05089771. Our findings are explained with a conductance-based model of the dorsal root ganglion neuron, exploring its behaviour for different values of half activation voltage and inactivation removal rate of the Nav1.7 current. Erythromelalgia was simulated through a decrease of the Nav1.7 half activation voltage, turning previously subthreshold stimuli to pain-inducing, and successfully counteracted with the channel blocker. The painful effects of OD1 were simulated through a quicker removal of Nav1.7 inactivation that reproduced the effects of the toxin not only on the spike frequency but also on its amplitude. This work has been submitted to J. Neuroscience. [30].

7.3.3. Ghost attractors in spontaneous brain activity: wandering in a repertoire of functionally relevant BOLD phaselocking solutions

Participants: Joana Cabral [Department of Psychiatry, Medical Sciences Division, University of Oxford,UK], Bruno Cessac, Gustavo Deco [Catalan Institute for Research and Advance Studies (ICREA), Spain], Morten L. Kringelbach [University of Oxford, UK], Jakube Vohryzek [Center for Music in the Brain, Department of Clinical Medicine, Aarhus University, Denmark].

Functionally relevant network patterns form transiently in brain activity during rest, where a given subset of brain areas exhibits temporally synchronized BOLD signals. To adequately assess the biophysical mechanisms governing intrinsic brain activity, a detailed characterization of the dynamical features of functional networks is needed from the experimental side to inform theoretical models. In this work, we use an open-source fMRI dataset from 100 unrelated participants from the Human Connectome Project and analyse whole-brain activity using Leading Eigenvector Dynamics Analysis, which focuses on the detection of recurrent phase-locking patterns in the BOLD signal. Borrowing tools from dynamical systems theory, we characterise spontaneous brain activity in the form of trajectories within a low-dimensional phase space. Decomposing the phase space into Voronoi-like cells using k-means clustering algorithm, we demonstrate that the cluster centroids (representing recurrent BOLD phase-locking patterns) closely overlap with previously identified resting-state networks. We further demonstrate that the metric associated with the phase-locking patterns shows moderate reliability across recordings indicating potential existence of subject specific dynamical landscapes. Our results point to the hypothesis that functional brain networks behave as ghost attractor states in a low-dimensional phase space, providing insights into the evolutionary rules governing brain activity in the spontaneous state and reinforcing the importance of addressing brain function within the framework of dynamical systems theory. This work has been submitted to Frontiers in Systems Neuroscience.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. Helping visually impaired employees to follow presentations in the company: Towards a mixed reality solution

Participants: Riham Nehmeh [InriaTech], Carlos Zubiaga [InriaTech], Julia-Elizabeth Luna [InriaTech], Arnaud Mas [EDF], Alain Schmid [EDF], Aurélie Calabrèse, Pierre Kornprobst

Duration: 2 months

The objective of the work is to develop a first proof-of-concept (PoC) targeting a precise use-case scenario defined by EDF (contract with InriaTech, supervised by Pierre Kornprobst). The use-case is one of an employee with visual impairment willing to follow a presentation. The idea of the PoC is a vision-aid system based on a mixed-reality solution. This work aims at (1) estimating the feasibility and interest of such kind of solution and (2) identifying research questions that could be jointly addressed in a future partnership.

APP Deposit (on-going)

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

9.1.1.1. Trajectory

Title: Encoding and predicting motion trajectories in early visual networks

Programme: ANR

Duration: October 2015 - September 2020

Coordinator: Invibe Team, Institut des Neurosciences de la Timone, Frédéric Chavane,

Partners:

Institut de Neurosciences de la Timone (CNRS and Aix-Marseille Université, France)

Institut de la Vision (IdV), Paris, France

Universidad Tecnico Federico Santa María (Electronics Engineering Department, Valparaíso, Chile)

Inria contact: Bruno Cessac

Global motion processing is a major computational task of biological visual systems. When an object moves across the visual field, the sequence of visited positions is strongly correlated in space and time, forming a trajectory. These correlated images generate a sequence of local activation of the feed-forward stream. Local properties such as position, direction and orientation can be extracted at each time step by a feed-forward cascade of linear filters and static non-linearities. However such local, piecewise, analysis ignores the recent history of motion and faces several difficulties, such as systematic delays, ambiguous information processing (e.g., aperture and correspondence problems) high sensitivity to noise and segmentation problems when several objects are present. Indeed, two main aspects of visual processing have been largely ignored by the dominant, classical feed-forward scheme. First, natural inputs are often ambiguous, dynamic and non-stationary as, e.g., objects moving along complex trajectories. To process them, the visual system must segment them from the scene, estimate their position and direction over time and predict their future location and velocity. Second, each of these processing steps, from the retina to the highest cortical areas, is implemented by an intricate interplay of feed-forward, feedback and horizontal interactions. Thus, at each stage, a moving object will not only be processed locally, but also generate a lateral propagation of information. Despite decades of motion processing research, it is still unclear how the early visual system processes motion trajectories. We, among others, have proposed that anisotropic diffusion of motion information in retinotopic maps can contribute resolving many of these difficulties. Under this perspective, motion integration, anticipation and prediction would be jointly achieved through the interactions between feed-forward, lateral and feedback propagations within a common spatial reference frame, the retinotopic maps. Addressing this question is particularly challenging, as it requires to probe these sequences of events at multi-scale (from individual cells to large networks) and multiple stages (retina, primary visual cortex (V1)). “TRAJECTORY” proposes such an integrated approach. Using state-of-the-art micro- and mesoscopic recording techniques combined with modeling approaches, we aim at dissecting, for the first time, the population responses at two key stages of visual motion encoding: the retina and V1. Preliminary experiments and previous computational studies demonstrate the feasibility of our work. We plan three coordinated physiology and modeling work-packages aimed to explore two crucial early visual stages in order to answer the following questions: How is a translating bar represented and encoded within a hierarchy of visual networks and for which condition does it elicit anticipatory responses? How is visual processing shaped by the recent history of motion along a more or less predictable trajectory? How much processing happens in V1 as opposed to simply reflecting

transformations occurring already in the retina? The project is timely because partners master new tools such as multi-electrode arrays and voltage-sensitive dye imaging for investigating the dynamics of neuronal populations covering a large segment of the motion trajectory, both in retina and V1. Second, it is strategic: motion trajectories are a fundamental aspect of visual processing that is also a technological obstacle in computer vision and neuroprostheses design. Third, this project is unique by proposing to jointly investigate retinal and V1 levels within a single experimental and theoretical framework. Lastly, it is mature being grounded on (i) preliminary data paving the way of the three different aims and (ii) a history of strong interactions between the different groups that have decided to join their efforts.

9.2. European Initiatives

9.2.1. Collaborations in European Programs, Except FP7 & H2020

- Program: Leverhulme Trust
- Project acronym:
- Project title: A novel approach to functional classification of retinal ganglion cells
- Duration: 2017-2020
- Coordinator: Evelyne Sernagor, Institute of Neuroscience (ION), Newcastle, UK
- Inria contact: Bruno Cessac
- Other partners:

  Melissa Bateson Institute of Neuroscience (ION), Newcastle, UK

  Matthias Hennig Institute for Adaptive and Neural Computation (ANC, School of Informatics University of Edinburgh, UK)

  Gerrit HilgenInstitute of Neuroscience (ION), Newcastle, UK
- Abstract: Vision begins with photoreceptors converting light from different parts of the visual scene into electrical signals, compressing our visual world into a parsimonious code of impulses at the retinal output level, the retinal ganglion cells (RGCs). This information is sent to the brain via only $\approx$1m RGCs (45,000 in mouse). Amazingly, the brain can recreate images from interpreting these "barcodes" or trains of impulses. This ability is partly due to the astonishing functional diversity of RGCs, each interpreting a different feature of the visual scene. It is all these parallel streams of information that impart the complexity of visual scenes to our brain visual areas. At present, at least 30 RGC subtypes have been identified. Classification is typically based on common anatomical features, or on basic functions (e.g. whether cells respond to the onset or offset of the light, or whether they are sensitive to motion direction) and it has recently progressed to include molecular markers. Recent studies have successfully characterised common physiological properties between RGCs sharing gene expression, suggesting that their molecular signature may indeed be a good indicator of function. However, according to mouse genetics repositories (e.g., the Allen Brain Project) many genes are expressed in subpopulations of RGCs for which we have no phenotype yet. Genes that are expressed in most RGCs probably do not reflect specific functional populations, but some other genes are expressed only in sparse RGC groups. Each gene-specific class exhibits a distinct spatial mosaic pattern across the retina, suggesting that the cells belong to a common group. Many classes, even sparse, exhibit asymmetric distributions across the retina, e.g., with larger numbers on the ventral or dorsal side, suggesting specific roles in ecological vision, e.g., specialised in detecting moving objects in the sky (ventral) or on the ground (dorsal).

  We propose to develop a multidisciplinary approach to functionally phenotype new RGC subclasses sharing gene expression. Rather than inferring knowledge about the entire population from studying individual cells, we will take a global approach based on large-scale, high-density pan-retinal recordings, pharmacogenetics (allowing us to selectively silence defined cell populations at will) and high-resolution imaging combined with computational approaches and behaviour. This novel

approach necessitates collaboration between retinal neurophysiologists, animal behaviour specialists (Newcastle) and modellers (Inria) who specialise in visual processing and have sophisticated mathematical tools and software to handle and interpret the encoding of visual information at the pan-retinal level.

9.3. International Initiatives

9.3.1. Inria International Labs

Inria Chile

Associate Team involved in the International Lab:

9.3.1.1. MAGMA

Title: Modelling And understandinG Motion Anticipation in the retina

International Partner (Institution - Laboratory - Researcher):

Universidad Técnica Federico Santa Marı´a, Valparaiso (Chile) - Department of Electric Engineering - Maria-José Escobar

Start year: 2019

See also: https://team.inria.fr/biovision/associated-team-magma/.

Motion processing represents a fundamental visual computation ruling many visuomotor features such as motion anticipation which compensates the transmission delays between retina and cortex, and is fundamental for survival. We want to strengthen an existing collaborative network between the Universidad de Valparaiso in Chile and the Biovision team, gathering together skills related with physiological recording in the retina, data analysis numerical platforms and theoretical tools to implement functional and biophysical models aiming at understanding the mechanisms underlying anticipatory response and the predictive coding observed in the mammalian retina, with a special emphasis on the role of lateral connectivity (amacrine cells and gap junctions).

9.4. International Research Visitors

9.4.1. Visits of International Scientists

Helene Schreyer (University of Göttingen, Germany)

Dr Cyril Eleftheriou (IIT, Genova)

R. Cofré (Universidad Valparaíso, Chile).

9.4.1.1. Internships

- **September-November 2019 (M1).** Ignacio Ampuero, Université de Valparaiso.
- **March-August 2019 (M1).** Min-Toan Nguyen, Cycle Ingénieur Polytechnicien 3A. (co-direction with A. Muzy (I3S) et P. Reynaud-Bourret (LJAD)).
- **March-May 2019 (M1)** Safia Mensor, Master Mod4NeuCog (co-direction with A. Guyon (IPMC)) [35].
- **March-May 2019 (M1) et September 2019 - February 2020 (M2)** Simone Ebert, Master Mod4NeuCog (Co-direction with O. Marre Institut de la Vision (IdV), Paris, France et R. Veltz (Mathneuro)).
- **March-August 2019 (M2)** Téva Andreoletti, ENSEA Cergy.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events

- Bruno Cessac was a member of the Local Committee of the Conference NeuroFrance 2019 https://www.neurosciences.asso.fr/V2/colloques/SN19/ (22-24 May 2019) one of the most important congress organised by the Société des Neurosciences with 1260 registrations: researchers, medical doctors, students, industrials, from France and from 26 foreign countries.
- Bruno Cessac has co-organized the parallel topical meetings and plenary sessions "Nonlinear waves in biology" in the international conference "Waves Cote d'Azur" http://wavescotedazur.org/ Nice, France, 4-7 June 2019.
- Hui-Yin Wu was in the Program Chair of the 8th Eurographics Workshop on Intelligent Cinematography and Editing, Genoa, Italy
- Hui-Yin Wu was member of the conference program committees IEEE Conference on Games, London, UK
- Hui-Yin Wu was member of the 3rd Conference on Computing Systems and Applications, Algiers, Algeria
- Bruno Cessac has co-organized the 1st meeting of the NeuroMod Institute, Frejus, 1-2 july 2019

10.1.2. Scientific Events: Organisation

- MOMI 2019 (Le MOnde des Mathématiques Industrielles) was a two-day workshop on applied and industrial mathematics. The workshop took place on the 25th and 26th of February, 2019 at the Inria Sophia Antipolis-Mediteranée research center with a focus on Big Data and Machine Learning. It was supported and financed by Inria, by the Maison de la Modélisation, de la Simulation et des Interactions – MSI of Université Côte d'Azur, by the Graduate School "Digital Systems for Humans" (EUR project ANR-17-EURE-004 from the "Programme Investissements d'Avenir"), by the Agence pour les Mathématiques en Interaction avec l'Entreprise et la Société (AMIES) and by the companies OLEA Medical, Thales Alenia Space and Wildmoka. In total, 3 keynote speakers, 7 industrial speakers and 90 participants (researchers, PhDs , postdocs and engineers) attended MOMI 2019. Finally, a company fair was organized to promote networking and identify future opportunities and collaborations. Selma Souihel and Evgenia Kartsaki have actively participated to the organizing committee. Their duties involved writing funding proposals, budget handling, communication and traveling arrangements for the keynote speakers, company fair and social event organization.
- E. Kartsaki and S. Souihel are participating to the organization of the PhD Seminars of Inria Sophia Antipolis - Méditerranée, organized and held by PhD candidates every two weeks and aim to share knowledge, and to promote collaborations, all in a friendly and interactive way. Selma Souihel and Evgenia Kartsaki have been members of the organizing committee during the academic year 2018/2019 (Evgenia Kartsaki is still an ongoing member). Both have been involved in the scheduling, communication and diffusion of the seminars. These tasks include calls for presentations, calendar planning and promotion of each seminar. Finally, they were also involved in the organization of the MOMI 2019 conference.

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

Pierre Kornprobst has been associate editor for the Computer Vision and Image Understanding Journal (CVIU) since Jul 2016.

10.1.3.2. Reviewer - Reviewing Activities

- A. Calabrèse has served as a peer-reviewer for the following international journals (IF):
  - Scientific Reports (4.644)
  - Investigative Ophthalmology and Vision Science (3.683)
  - PLoS ONE (3.344)
  - Acta Ophthalmologica (3.206)

  - Translational Vision Science and Technology (2.399)
  - Journal of Vision (2.141)
- Bruno Cessac has been reviewer for J. Math. Neuro (IF 2.091)
- Hui-Yin Wu has been reviewer for Multimedia Tools and Applications. (IF: 2.101)

10.1.4. Invited Talks

- E. Karstaki, The Rank Prize Funds - Symposium on The retinal processing of natural signals, Jun 2019, Grasmere, United Kingdom. Probing retinal function with a multi-layered simulator.
- E. Karstaki, First meeting of the NeuroMod Institute, Jul 2019, Fréjus, France. Probing retinal function with a multi-layered simulator.
- B. Cessac, D. Karvouniari, L. Gil, O. Marre,, Multiscale dynamics in retinal waves,LACONEU 2019 Conference, Valparaiso, Chile, January 18th, 2019.
- B. Cessac, S. Souihel, "Anticipation in the retina and the primary visual cortex : towards an integrated retino-cortical model for motion processing", Workshop on Visuo-motor Integration, EITN, Paris, 6-7 Jun 2019. https://visuomotor.sciencesconf.org/.
- B. Cessac, M. Mantegazza (IPMC) "Modelling of physiological and pathological states in neuroscience: exchanges among theoreticians and experimentalists", First meeting of the NeuroMod Institute 1-2 July 2019, Fréjus.
- B. Cessac, S. Souihel,"Motion anticipation in the retina", Neurostic Conférence, Sophia Antipolis, 14-15 October 2019, http://www.gdr-isis.fr/neurostic/?p=452.
- Hui-Yin Wu, "Thinking Like a Director: Film Editing Patterns for Virtual Cinematographic Storytelling", 8th Eurographics Workshop on Intelligent Cinematography and Editing, Genoa, Italy. May 2019.
- Hui-Yin Wu, "Interactive and Multimedia Storytelling", PhD Seminars, UCA Inria. November 2019.

10.1.5. Research Administration

Bruno Cessac is a member of the scientific council of the Institut NeuroMod de "Modélisation en Neurosciences et Cognition".

Bruno Cessac is a member of the "Bureau" of the Institut NeuroMod de "Modélisation en Neurosciences et Cognition".

Bruno Cessac was a member of the Groupe de Travail for the creation of the Inria project team FACTAS.

Bruno Cessac was a member of the Groupe de Travail for the creation of the Inria project team ATLANTIS.

Pierre Kornprobst has been an elected member of the Academic Board of UCA (*Conseil Académique*, from Nov. 2015 to Aug. 2019).

Pierre Kornprobst has been a member of the Comité de Suivi Doctoral (CSD) since March 2017.

Pierre Kornprobst has been an elected member of the Academic Council of UCA (*Conseil d'Administration*, since Dec. 2019).

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Licence :

- Selma Souihel "Advanced network administration and security: architecture of a company network, services installation and configuration, users management, system and network security, cryptography, virtual private networks and secured protocols, and supervision tools, Numeric transmission : data acquisition, satellite and cable transmission, numeric modulation", 1ere année de l'IUT, Département Réseaux et Télécommunications, 64h/year, 50 students.

Master 1: Bruno Cessac (with F. Lavigne), *Introduction to Modelling in Neuroscience*, 40 hours, Master Mod4NeuCog, Université Nice Sophia Antipolis, France.

10.2.2. Supervision

- PhD defended on December 18th, 2019. Selma Souihel, "Generic and specific computational principles for the visual anticipation of motion trajectories". Started in November 2016. Supervisor B. Cessac
- PhD in progress: Evgenia Kartsaki. "How Specific Classes of Retinal Cells Contribute to Vision: a Computational Model", Started in October 2017. Supervisor B. Cessac codirection with E. Sernagor, ION.

10.2.3. Juries

Pierre Kornprobst was member of the Comité de suivi de thèse of Alexandre Montlibert, from CERCO, Toulouse, France.

Pierre Kornprobst was reviewer of the PhD of Erwan David, entitled “L’impact des troubles du champ visuel sur les dynamiques spatio-temporelles de l’observation de sce`nes naturelles”, from Université de Nantes, France.

Bruno Cessac was member of the Comité de suivi de thèse of Matthieu Sarazin from Paris VI and Halgurd Taher from EDSFA Nice.

11. Bibliography

Major publications by the team in recent years

[1] R. COFRÉ, B. CESSAC. *Dynamics and spike trains statistics in conductance-based integrate-and-fire neural networks with chemical and electric synapses*, in "Chaos, Solitons & Fractals", 2013, vol. 50, n^{o} 13, 3 p.

[2] R. COFRÉ, B. CESSAC. *Exact computation of the maximum-entropy potential of spiking neural-network models*, in "Phys. Rev. E", 2014, vol. 89, n^{o} 052117

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