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Project-Team cortex

Neuromimetic intelligence

Nancy - Grand Est

Theme : Computational Medicine and Neurosciences

Activity Report

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2. Overall Objectives

2.1. Introduction

The goal of our research is to study the properties and computational capacities of distributed, numerical and adaptative networks, as observed in neuronal systems. In this context, we aim to understand how complex high level properties may emerge from such complex systems including their dynamical aspects. In close reference to our domain of inspiration, Neuroscience, this study is carried out at three scales, namely neurons, population and behavior.

1. **Neurons:** At the microscopic level, our approach relies on precise and realistic models of neurons and of the related dynamics, analyzing the neural code in small networks of spiking neurons (*cf.* § 3.2).
2. **Population of neurons:** At the mesoscopic level, the characteristics of a local circuit are integrated in a high level unit of computation, i.e. a dynamic neural field (*cf.* § 3.3). This level of description allows us to study larger neuronal systems, such as cerebral maps, as observed in sensori-motor loops.
3. **Higher level functions:** At the macroscopic level, the analysis of physiological signals and psychometric data is to be linked to more cognitive and behavioral hints. This is for instance the case with electroencephalographic (EEG) recordings, allowing to measure brain activity, including in brain computer interface paradigms (*cf.* § 3.4).

Very importantly, these levels are not studied independently and we target progresses at the interface between levels. The microscopic/mesoscopic interface is the place to consider both the analog and asynchronous/event-based mechanisms and derive computational principles coherent across scales. The mesoscopic/macroscopic interface is the place to understand the emergence of functions from local computations, by means of information flow analysis and study of interactions.

Learning is a central issue at each level. At the microscopic level, the pre/post synaptic interactions are studied in, e.g., the framework of Spike Time Dependent Plasticity (STDP). At the mesoscopic level, spatial and temporal patterns of activity in neural population are the cues to be memorized (e.g. via the BCM rule). At the macroscopic level, behavioral skills are acquired along time, through incremental strategies, e.g. using conditioning, unsupervised or reinforcement learning.

Our research is linked to several scientific domains (*cf.* § 3.1). In the domain of computer science, we generate novel paradigms of distributed spatial computation and we aim at explaining their properties, intrinsic (e.g. robustness) as well as functional (e.g. self-organization). In the domain of cognitive science, our models are used to emulate various functions (e.g. attention, memory, sensori-motor coordination) which are consequently fully explained by purely distributed asynchronous computations. In the domain of neuroscience, we share with biologists, not only data analysis, but also frameworks for the validation of biological and computational assumptions in order to validate or falsify existing models. This is the best way to increase knowledge and improve methods in both fields.

In order to really explore such bio-inspired computations, the key point is to remain consistent with biological and ecological constraints. Among computational constraints, computations have to be really distributed, without central clock or common memory. The emerging cognition has to be situated (*cf.* § 3.6), i.e. resulting from a real interaction in the long term with the environment. As a consequence, our models are particularly well validated with parallel architectures of computations (e.g. FPGA, clusters, *cf.* § 3.5) and embodied in systems (robots) that interact with their environment (*cf.* § 3.6).

Accordingly, four topics of research have been carried out this year.

- Microscopic level (*cf.* § 6.1): neural code; time coding and synchronization; simulation; application to olfaction.
- Mesoscopic level (*cf.* § 6.2): motion perception; visual attention; motor anticipation; neural field implementation.
- Macroscopic level (*cf.* § 6.3): neural information processing; brain computer interface.

with a transversal topic related to:

- Embodied and embedded systems (*cf.* § 6.4): dedicated architectures.

2.2. Highlights

Our colleague, Axel Hutt, has obtained an ERC Starting Grant for the project MATHANA that will study mathematically the neural activity during general anaesthesia and will compare the gained results to experimental data.

3. Scientific Foundations

3.1. Computational neuroscience

With regards to the progress that has been made in anatomy, neurobiology, physiology, imaging, and behavioral studies, computational neuroscience offers a unique interdisciplinary cooperation between experimental and clinical neuroscientists, physicists, mathematicians and computer scientists. It combines experiments with data analysis and functional models with computer simulation on the basis of strong theoretical concepts and aims at understanding mechanisms that underlie neural processes such as perception, action, learning, memory or cognition.

Today, computational models are able to offer new approaches for the understanding of the complex relations between the structural and the functional level of the brain, thanks to models built at several levels of description. In very precise models, a neuron can be divided in several compartments and its dynamics can be described by a system of differential equations. The spiking neuron approach (*cf.* § 3.2) proposes to define simpler models concentrated on the prediction of the most important events for neurons, the emission of spikes. This allows to compute networks of neurons and to study the neural code with event-driven computations.

Larger neuronal systems are considered when the unit of computation is defined at the level of the population of neurons and when rate coding and/or correlations are supposed to bring enough information. Studying Dynamic Neural Fields (*cf.* § 3.3) consequently lays emphasis on information flows between populations of neurons (feed-forward, feed-back, lateral connectivity) and is well adapted to defining high-level behavioral capabilities related for example to visuomotor coordination.

Furthermore, these computational models and methods have strong implications for other sciences (e.g. computer science, cognitive science, neuroscience) and applications (e.g. robots, cognitive prosthesis) as well (*cf.* § 4.1). In computer science, they promote original modes of distributed computation (*cf.* § 3.5); in cognitive science, they have to be related to current theories of cognition (*cf.* § 3.6); in neuroscience, their predictions have to be related to observed behaviors and measured brain signals (*cf.* § 3.4).

3.2. Computational neuroscience at the microscopic level: spiking neurons and networks

Computational neuroscience is also interested in having more precise and realistic models of the neuron and especially of its dynamics. We consider that the latter aspect cannot be treated at the single unit level only; it is also necessary to consider interactions between neurons at the microscopic scale.

On one hand, compartmental models describe the neuron at the inner scale, through various compartments (axon, synapse, cellular body) and coupled differential equations, allowing to numerically predict the neural activity at a high degree of accuracy. This, however, is intractable if analytic properties are to be derived, or if neural assemblies are considered. We thus focus on phenomenological punctual models of spiking neurons, in order to capture the dynamic behavior of the neuron isolated or inside a network. Generalized conductance based leaky integrate and fire neurons (emitting action potential, i.e. spike, from input integration) or simplified instantiations are considered in our group.

On the other hand, one central issue is to better understand the precise nature of the neural code. From rate coding (the classical assumption that information is mainly conveyed by the firing frequency of neurons) to less explored assumptions such as high-order statistics, time coding (the idea that information is encoded in the firing time of neurons) or synchronization aspects. At the biological level, a fundamental example is the synchronization of neural activities, which seems to play a role in, e.g., olfactory perception: it has been observed that abolishing synchronization suppresses the odor discrimination capability. At the computational level, recent theoretical results show that the neural code is embedded in periodic firing patterns, while, more generally, we focus on tractable mathematical analysis methods coming from the theory of nonlinear dynamical systems.

For both biological simulations and computer science emerging paradigms, the rigorous simulation of large neural assemblies is a central issue. Our group is at the origin, up to our best knowledge, of the most efficient event-based neural network simulator, based on well-founded discrete event dynamic systems theory, and now extended to other simulation paradigms, thus offering the capability to push the state of the art on this topic.

3.3. Computational neuroscience at the mesoscopic level: dynamic neural field

Our research activities in the domain of computational neurosciences are also interested in the understanding of higher brain functions using both computational models and robotics. These models are grounded on a computational paradigm that is directly inspired by several brain studies converging on a distributed, asynchronous, numerical and adaptive processing of information and the continuum neural field theory (CNFT) provides the theoretical framework to design models of population of neurons.

This mesoscopic approach underlines the fact that the number of neurons is very high, even in a small part of tissue, and proposes to study neuronal models in a continuum limit where space is continuous and main variables correspond to synaptic activity or firing rates in population of neurons. This formalism is particularly interesting because the dynamic behavior of a large piece of neuronal tissue can be studied with differential equations that can integrate spatial (lateral connectivity) and temporal (speed of propagation) characteristics and display such interesting behavior as pattern formation, travelling waves, bumps, etc.

The main cognitive tasks we are currently interested in are related to sensorimotor systems in interaction with the environment (perception, coordination, planning). The corresponding neuronal structures we are modeling are part of the cortex (perceptive, associative, frontal maps) and the limbic system (hippocampus, amygdala, basal ganglia). Corresponding models of these neuronal structures are defined at the level of the population of neurons and functioning and learning rules are built from neuroscience data to emulate the corresponding information processing (filtering in perceptive maps, multimodal association in associative maps, temporal organization of behavior in frontal maps, episodic memory in hippocampus, emotional conditioning in amygdala, selection of action in basal ganglia). Our aim is to iteratively refine these models, implement them on autonomous robots and make them cooperate and exchange information, toward a completely adaptive, integrated and autonomous behavior.

3.4. Brain Signal Processing

The observation of brain activity and its analysis with appropriate data analysis techniques allow to extract properties of underlying neural activity and to better understand high level functions. This study needs to investigate and integrate, in a single trial, information spread in several cortical areas and available at different scales (MUA, LFP, ECoG, EEG).

One major problem is how to be able to deal with the variability between trials. Thus, it is necessary to develop robust techniques based on stable features. Specific modeling techniques should be able to extract features investigating the time domain and the frequency domain. In the time domain, template-based unsupervised models allows to extract graphic-elements. Both the average technique to obtain the templates and the distance used to match the signal with the templates are important, even when the signal has a strong distorted shape. The study of spike synchrony is also an important challenge. In the frequency domain, features such as phases, frequency bands and amplitudes contain different pieces of information that should be properly identified using variable selection techniques. In both cases, compression techniques such as PCA or ICA can reduce the fluctuations of the cortical signal. Then, the designed models have to be able to track the dynamic evolution of these features over the time.

Another problem is how to integrate information spreading in different areas and relate this information in a proper time window of synchronization to behavior. For example, feedbacks are known to be very important to better understand the closed-loop control of a hand grasping movement. However, from the preparatory signal and the execution of the movement to the visual and somatosensory feedbacks, there is a delay. It is thus necessary to use stable features to build a mapping between areas using supervised models taking into account a time window shift.

Several recoding techniques are taken into account, providing different kinds of information. Some of them provide very local information such as multiunit activities (MUA) and local field potential (LFP) in one or several well-chosen cortical areas. Other ones provide global information about close regions such as electrocorticography (ECoG) or the whole scalp such as electroencephalography (EEG). If surface electrodes allow to easily obtain brain imaging, it is more and more necessary to better investigate the neural code.

3.5. Connectionist parallelism

Connectionist models, such as neural networks, are among the first models of parallel computing. Artificial neural networks now stand as a possible alternative with respect to the standard computing model of current computers. The computing power of these connectionist models is based on their distributed properties: a very fine-grain massive parallelism with densely interconnected computation units.

The connectionist paradigm is the foundation of the robust, adaptive, embeddable and autonomous processings that we aim at developing in our team. Therefore their specific massive parallelism has to be fully exploited. Furthermore, we use this intrinsic parallelism as a guideline to develop new models and algorithms for which parallel implementations are naturally made easier.

Our approach claims that the parallelism of connectionist models makes them able to deal with strong implementation and application constraints. This claim is based on both theoretical and practical properties of neural networks. It is related to a very fine parallelism grain that fits parallel hardware devices, as well as to the emergence of very large reconfigurable systems that become able to handle both adaptability and massive parallelism of neural networks. More particularly, digital reconfigurable circuits (e.g. FPGA, Field Programmable Gate Arrays) stand as the most suitable and flexible device for low cost fully parallel implementations of neural models, according to numerous recent studies in the connectionist community. We carry out various arithmetical and topological studies that are required by the implementation of several neural models onto FPGAs, as well as the definition of hardware-targetted neural models of parallel computation.

This research field has evolved within our team by merging with our activities in behavioral computational neuroscience. Taking advantage of the ability of the neural paradigm to cope with strong constraints, as well as taking advantage of the highly complex cognitive tasks that our behavioral models may perform, a new research line has emerged that aims at defining a specific kind of brain-inspired hardware based on modular and extensive resources that are capable of self-organization and self-recruitment through learning when they are assembled within a perception-action loop.

3.6. The embodiment of cognition

Recent theories from cognitive science stress that human cognition emerges from the interactions of the body with the surrounding world. Through motor actions, the body can orient toward objects to better perceive and analyze them. The analysis is performed on the basis of physical measurements and more or less elaborated emotional reactions of the body, generated by the stimuli. This elicits other orientation activities of the body (approach and grasping or avoidance). This elementary behavior is made possible by the capacity, at the cerebral level, to coordinate the perceptive representation of the outer world (including the perception of the body itself) with the behavioral repertoire that it generates either on the physical body (external actions) or on a more internal aspect (emotions, motivations, decisions). In both cases, this capacity of coordination is acquired from experience and interaction with the environment.

The theory of the situatedness of cognition proposes to minimize representational contents (opposite to complex and hierarchical representations) and privileges simple strategies, more directly coupling perception and action and more efficient to react quickly in the changing environment.

A key aspect of this theory of intelligence is the Gibsonian notion of affordance: perception is not a passive process and, depending on the current task, objects are discriminated as possible “tools” that could be used to interact and act in the environment. Whereas a scene full of details can be memorized in very different and costly ways, a task-dependent description is a very economical way that implies minimal storage requirements. Hence, remembering becomes a constructive process.

For example with such a strategy, the organism can keep track of relevant visual targets in the environment by only storing the movement of the eye necessary to foveate them. We do not memorize details of the objects but we know which eye movement to perform to get them: The world itself is considered as an external memory.

Our agreement to this theory has several implications for our methodology of work. In this view, learning emerges from sensorimotor loops and a real body interacting with a real environment are important characteristics for a learning protocol. Also, in this view, the quality of memory (a flexible representation) is preferred to the quantity of memory.

4. Application Domains

4.1. Overview

Our application domain is twofold:

On one hand, neuro-scientists are end-users of our researches. Data analysis is one issue, but the main outcomes concern modeling, namely the validation of biological assumptions either at a theoretical level or via numerical experiments and simulation of bio-processes. This includes algorithmic expertises and dedicated softwares.

On the other hand, science and technology of information processing is impacted. This concerns embedded systems such as in-silico implementations of bio-inspired processes, focusing on spatial and distributed computing. This also concerns embodied systems such as robotic implementation of sensori-motor loops, the bio-inspiration yielding such interesting properties as adaptivity and robustness.

5. Software

5.1. Spiking neural networks simulation

Participants: Mohamed-Ghaïth Kaabi, Dominique Martinez.

A spiking neuron is usually modeled as a differential equation describing the evolution over time of its membrane potential. Each time the voltage reaches a given threshold, a spike is sent to other neurons depending on the connectivity. A spiking neural network is then described as a system of coupled differential equations. For the simulation of such a network we have written two simulation engines : (i) mvaspike based on an event-driven approach and (ii) sirene based on a time-driven approach.

- Mvaspike : The event-driven simulation engine was developed in C++ and is available on http://mvaspike.gforge.inria.fr. Mvaspike is a general event-driven purpose tool aimed at modeling and simulating large, complex networks of biological neural networks. It allows to achieve good performance in the simulation phase while maintaining a high level of flexibility and programmability in the modeling phase. A large class of spiking neurons can be used ranging from standard leaky integrate-and-fire neurons to more abstract neurons, e.g. defined as complex finite state machines.
- Sirene : The time-driven simulator engine was written in C and is available on http://sirene.gforge.inria.fr. It has been developed for the simulation of biologically detailed models of neurons —such as conductance-based neurons— and synapses. Its high flexibility allows the user to implement easily any type of neuronal or synaptic model and use the appropriate numerical integration routine (e.g. Runge-Kutta at given order).

5.2. DANA: Implementation of computational neuroscience mechanisms

Participants: Nicolas Rougier, Thomas Girod, Mathieu Lefort.

Computational neuroscience is a vast domain of research going from the very precise modeling of a single spiking neuron, taking into account ion channels and/or dendrites spatial geometry up to the modeling of very large assemblies of simplified neurons that are able to give account of complex cognitive functions. DANA attempts to address this latter modeling activity by offering a python computing framework for the design of very large assemblies of neurons using numerical and distributed computations. However, there does not exist something as a unified model of neuron: if the formal neuron has been established some sixty years ago, there exists today a myriad of different neuron models that can be used within an architecture. Some of them are very close to the original definition while some others tend to refine it by providing extra parameters or variables to the model in order to take into account the great variability of biological neurons. DANA makes the assumption that a neuron is essentially a set of numerical values that can vary over time due to the influence of other neurons and learning. DANA aims at providing a constrained and consistent python framework that guarantee this definition to be enforced anywhere in the model, i.e., no symbol, no homonculus, no central executive.

5.3. ENAS: Event Neural Assembly Simulation

Participants: Frédéric Alexandre, Axel Hutt, Nicolas Rougier, Thierry Viéville.

EnaS (that stands for “Event Neural Assembly Simulation”) is a middleware implementing our last numerical and theoretical developments, allowing to simulate and analyze so called "event neural assemblies". The recent achievements include (in collaboration with the Neuromathcomp EPI): spike trains statistical analysis via Gibbs distributions, spiking network programing for exact event’s sequence restitution, discrete neural field parameters algorithmic adjustments and time-constrained event-based network simulation reconciling clock and event based simulation methods. It has been designed as plug-in for our simulators (e.g. DANA or MVASpike) as other existing simulators (via the NeuralEnsemble meta-simulation platform) and additional modules for computations with neural unit assembly on standard platforms (e.g. Python or the Scilab platform).

5.4. OpenViBE

Participants: Laurent Bougrain, Baptiste Payan.

OpenViBE is a C++ open-source software devoted to the design, test and use of Brain-Computer Interfaces. The OpenViBE platform consists of a set of software modules that can be integrated easily and efficiently to design BCI applications. Key features of the platform are its modularity, its high-performance, its portability, its multiple-users facilities and its connection with high-end/Virtual Reality displays. The ?designer? of the platform enables to build complete scenarios based on existing software modules using a dedicated graphical language and a simple Graphical User Interface (GUI). This software is available on the INRIA Forge under the terms of the LGPL-V2 license (http://openvibe.inria.fr). The development of OpenVibe is done in association with the INRIA research team BUNRAKU for the national INRIA project: ADT LOIC (*cf.* § 7.2).

5.5. GINNet-DynNet: Decision-making platform

Participants: Laurent Bougrain, Marie Tonnelier.

GINNet (Graphical Interface for Neural Networks) is a decision-aid platform written in Java, intended to make neural network teaching, use and evaluation easier, by offering various parametrizations and several data pre-treatments. GINNet is based upon a local library for dynamic neural network developments called DynNet. DynNet (Dynamic Networks) is an object-oriented library, written in Java and containing base elements to build neural networks with dynamic architecture such as Optimal Cell Damage and Growing Neural Gas. Classical models are also already available (multi-layer Perceptron, Kohonen self-organizing maps, ...). Variable selection methods and aggregation methods (bagging, boosting, arcing) are implemented too.

The characteristics of GINNet are the following: Portable (100% Java), accessible (model creation in few clicks), complete platform (data importation and pre-treatments, parametrization of every models, result and performance visualization). The characteristics of DynNet are the following: Portable (100% Java), extensible (generic), independent from GINNet, persistent (results are saved in HML), rich (several models are already implemented), documented.

This platform is composed of several parts:

1. Data manipulation: Selection (variables, patterns), descriptive analysis (stat., PCA..), detection of missing, redundant data.
2. Corpus manipulation: Variable recoding, permutation, splitting (learning, validation, test sets).
3. Supervised networks: Simple and multi-layer perceptron.
4. Competitive networks: Kohonen maps, Neural Gas, Growing Neural Gas.
5. Metalearning: Arcing, bagging, boosting.
6. Results: Error curves, confusion matrix, confidence interval.

DynNet and GINNet are free softwares, registrated to the APP and distributed under CeCILL license, Java 1.4 compatible (http://ginnet.gforge.inria.fr). GINNet is available as an applet. For further information, see http://gforge.inria.fr/projects/ginnet (news, documentations, forums, bug tracking, feature requests, new releases...)

5.6. Interface between Sofa and Brian

Participant: Thomas Voegtlin.

The goal of this work is to provide an easy-to-use framework for closed-loop simulations, where interactions between the brain and body of an agent are simulated.

We developed an interface between the Sofa physics engine, (http://www.sofa-framework.org) and the Brian neural simulator (http://www.briansimulator.org). The interface consists in a Sofa plugin and a python module for Brian. Sofa and Brian use different system processes, and communicate via shared memory. Synchronization between processes is achieved through semaphores.

As a demonstration of this interface, a physical model of undulatory locomotion in the nematode *c. elegans* was implemented, based on the PhD work of Jordan H. Boyle.

6. New Results

6.1. Spiking neurons

Participants: Hana Belmabrouk, Yann Boniface, Mohamed-Ghaïth Kaabi, Dominique Martinez, Horacio Rostro, Thierry Viéville, Thomas Voegtlin.

6.1.1. Mathematical modeling

- We demystify some aspects of coding with spike-timing, through a simple review of well-understood technical facts regarding spike coding, allowing to better understand to which extent computing and modeling with spiking neuron networks might be biologically plausible and computationally efficient. Considering a deterministic implementation of spiking neuron networks, we are able to propose results, formula and concrete numerical values, on several topics: (i) general time constraints, (ii) links between continuous signals and spike trains, (iii) spiking neuron networks parameter adjustment. This should prevent one from implementing mechanisms that would be meaningless relative to obvious time constraints, or from artificially introducing spikes when continuous calculations would be sufficient and more simple [3].

- We propose a generalization of the existing maximum entropy models used for spike train statistics analysis, bringing a simple method to estimate statistics and generalizing existing approaches based on Ising model or one step Markov chains to arbitrary parametric potentials. Our method enables one to take into account memory effects in dynamics. It provides directly the “free-energy” density and the Kullback-Leibler divergence between the empirical statistics and the statistical model. Furthermore, it allows the comparison of different statistical models and offers a control of finite-size sampling effects, inherent to empirical statistics, by using large deviations results [50]. This work is submitted for publication.
- Following some theoretical work about back-engineering from spike recordings, we study the possibility to design an artificial vision system based on spiking neurons, for which neural connections and synaptic weights are directly derived from recordings of spiking activities in the human visual system through a back-engineering approach. A specific simple spiking model has been defined that mathematically enables this back-engineering process from biological data. From a hardware point of view, this model results in an efficient implementation on FPGAs

6.1.2. Biophysical modeling

Our understanding of the computations that take place in the human brain is limited by the extreme complexity of the cortex, and by the difficulty of experimentally recording neural activities, for practical and ethical reasons. The Human Genome Project was preceded by the sequencing of smaller but complete genomes. Similarly, it is likely that future breakthroughs in neuroscience will result from the study of smaller but complete nervous systems, such as the insect brain or the rat olfactory bulb. These relatively small nervous systems exhibit general properties that are also present in humans, such as neural synchronization and network oscillations. Our goal is therefore to understand the role of these phenomena by combining biophysical modelling and experimental recordings, before we can apply this knowledge to humans. In the last year, we obtained the following results :

- We have explored the role of subthreshold membrane potential oscillations in stabilizing the oscillation frequency in a model of the olfactory bulb. [42]
- We developed a biophysical neuron model capable of reproducing and explaining the stereotyped multiphasic response observed in pheromone-sensitive antennal lobe neurons.

6.2. Dynamic Neural Fields

Participants: Lucian Aleçu, Frédéric Alexandre, Yann Boniface, Laurent Bougrain, Mauricio Cerda, Hervé Frezza-Buet, Bernard Girau, Thomas Girod, Axel Hutt, Mathieu Lefort, Jean-Charles Quinton, Nicolas Rougier, Wahiba Taouali, Thierry Viéville, Thomas Voegtlin.

The work reported this year represents both extensions of previous works and new results linked to the notion of neural population, considered at (i) a formal level (theorical studies of neural fields), (ii) a numerical level (study of functioning and learning rules) and (iii) a more embodied one (implementations of specific functions).

6.2.1. Formal Level

- study of the differences between synchronous and asynchronous (without a central clock) evaluation [10], [41]: The hallmark of most artificial neural networks is their supposed intrinsic parallelism where each unit is evaluated concurrently to other units in a distributed way. However, if one gives a closer look under the hood, one can soon realize that such a parallelism is an illusion since most implementations use what is referred to as synchronous evaluation, or using a central clock. Here we propose to consider different evaluation methods (namely asynchronous and event based evaluation methods) and study their properties in some restricted but illustrative cases. This work is also in preparation for publication.

- taking into account transmission speed between units in a neural field [6]: Neurons in populations are connected to each other by axonal branches sending electric pulses. The pulse propagation with finite speed delays the neuron interactions. The developed numerical algorithm illustrates how to simulate neural fields in two spatial dimensions involving finite axonal transmission speeds. The algorithm is derived analytically shows how to implement a Fast Fourier Transform in the computation scheme.

6.2.2. Numerical Level

6.2.2.1. Numerical studies of DNF and related mechanisms

At the numerical level, specific developments were carried out to assess our software platform, to master functioning rules and to study the performances of new learning rules:

- Presentation of the DANA computing framework to implement neural fields [30]
- The problem of adjusting the parameters of a mesoscopic event and valued neural field with delayed connections is addressed here at the programmatic level. An effective computational framework, with the implementation of a general algorithm is developed allowing us to effectively design non-trivial input/output transformations of events and values, using a class of biologically plausible distributed functional models [44]. This work is in preparation for publication.
- Novel numerically efficient algorithm to compute spatio-temporal activity in two-dimensional neural fields involving finite transmission speed [6].
- Study of the possibility to obtain properties of self-organization with dynamic neural fields [2] and proposition of a new learning rule for self-organization [9]
- We designed a variation of the self-organising map algorithm [9] where the original time-dependent (learning rate and neighbourhood) learning function has been replaced by a time-invariant one. This allows for on-line and continuous learning on both static and dynamic data distributions. One of the property of the newly proposed algorithm is that it does not fit the magnification law and the achieved vector density is not directly proportional to the density of the distribution as found in most vector quantisation algorithms. From a biological point of view, this algorithm sheds light on cortical plasticity seen as a dynamic and tight coupling between the environment and the model.
- Adaptation of the BCM rule to multi-modality [1], [47]
- To compare various implementations on a fair basis, it was necessary to find the optimal parameters for each implementation and set of tasks to perform. Optimal parameters may indeed differ due to adaptations in the differential equations or numerical method used, for instance temporal integration techniques used for rate-coding vs spiking neurons, or spatial integration techniques used for discrete units vs extended Gaussian fields. A genetic algorithm approach was chosen and led us to explore the relationships between the various parameters and their impact on the overall dynamics [28].

6.2.2.2. Gaussian mixture based approximation of neural maps

We also developed a new implementation of the Continuous Neural Field Theory (CNFT) using a Gaussian mixture based model of the neural field activity. It exploits the rapid convergence of the activity to a reduced set of localized bubbles when competition occurs. These bubbles of activity can be accurately approximated by Gaussian distributions. The goal of this model is twofold:

- The manipulation of a reduced set of components after a few iterations drastically reduces the amount of computations to be performed, and thus allows the fast simulation of complex competition dynamics (up to a hundred fold speedup) [27].
- This model also alleviates several constraints of classical neural maps, the most important being the need to project high dimensional inputs onto 2D maps (which generally leads to topological distortions).

This implementation is thus used to evaluate the possibilities of sensorimotor or multimodal associations without prior self-organization on 2D cortical maps, and could be directly interfaced with high dimensional artificial systems [47].

6.2.3. Embodied Level

6.2.3.1. Motion detection

We develop bio-inspired neural architectures to extract and segment the direction and speed components of the optical flow from sequences of images. Following this line, we have recently built additional models to code and distinguish different visual sequences. The structure of these models takes inspiration from the course of visual movement processing in the human brain, such as in area MT (middle temporal) that detects patterns of movement, or area FBA where neurons have been found to be sensitive to single spatio-temporal patterns, e.g. one clapping person or animal movement.

Recent works have been focused on two aspects of our models.

- To validate our bio-inspired model to distinguish visual sequences using synthetic data, we compare our work with other approaches in computer vision algorithms and computational neuroscience [18]. In this work we discuss the idea of a global comparison at each time instant (template), and show how local features may account for the visual discrimination process.
- Lately, we have extended the theoretical analysis of the neuron population model, showing that for simple patterns it is possible to consider cumulative/total activation of the population to distinguish different patterns in the framework of 2D asymmetric neural fields. Jointly, we have explored the performance of our classification model with realistic data using 3D sequences captured by a Vicon setup, considering properties such as rotation invariance and time-warping. This work is currently being extended to an other set of more complex movements: to fight, to wave, to clap.

6.2.3.2. Modeling the superior colliculus by mean of a neural field.

In the context of the ANR MAPS project (cf. § 7.2), we have been studying the superior colliculus in tight collaboration with Laurent Goffart from the Institut de Neurosciences Cognitives de la Méditerranée. Considering the cortical magnification induced by the non homogeneous distribution of retina rods and cones on the retina surface, we modeled the superior colliculus using a dynamic neural field that may explain the stereotyped nature of colliculus activity. This year, we have extended this approach to wider contexts:

- Using Neural Fields to model the Superior Colliculus in a task of saccade generation [32]
- Arrangement of several neural fields to model several cortical areas engaged in visual attention [5]

6.2.3.3. Modeling of neural activity during anaesthesia.

Anaesthesia plays an important role in medical surgery though its neural mechanism is still poorly understood. Besides several different molecular and behavioral phenomena, the administration of anaesthetic agents affects the power spectrum of electro-encephalographic activity (EEG) in a characteristic way. The theoretical study aims to model the power spectrum changes in EEG subject to the concentration of the specific anaesthetic agent propofol. The work developed a neural model involving two neuron types and synapse types while taking into account the synaptic effect of propofol. The mathematical derivation of the power spectrum allows for the investigation of suitable physiological parameters which reproduce the experimental effect of propofol. Several mathematical conditions on physiological parameters have been derived and the EEG-power spectrum during the administration of different concentration levels of propofol has been modeled successfully.

6.3. Higher level functions

Participants: Frédéric Alexandre, Laurent Bougrain, Octave Boussaton, Axel Hutt, Maxime Rio, Carolina Saavedra.

Our activities concerned information analysis and interpretation and the design of numerical distributed and adaptive algorithms in interaction with biology and medical science. To better understand cortical signals, we choose a top-down approach for which data analysis techniques extract properties of underlying neural activity. To this end several unsupervised methods and supervised methods are investigated and integrated to extract features in measured brain signals. More specifically, we worked on Brain-Computer Interfaces [45].

6.3.1. Detection of partial amplitude synchronization in multivariate data

To gain information on the interactions between neural structures, several electrodes may be implanted in cortical areas to measure Local Field Potentials. The developed method aims to extract time windows in which a subset of measured time series exhibit an amplitude synchronization in certain frequency bands [38].

6.3.2. Wavelet denoising for evoked potentials

Machine learning techniques are an efficient way to deal with a large amount of noisy data. Nevertheless, processing data at various scales and in real time needs more advanced methods. We develop neural networks techniques able to deal with multiscale analysis of electrophysiological signals. Some pieces of information are only available at a microscopic scale (spikes, evoked potentials), others at a macroscopic scale (frequency band energies...). The main difficulty is to be able to deal with these different elements not scanning them systematically but only when needed. A hierarchical clustering approach can be used keeping a coherent general framework of analysis with template-based algorithms [40].

We studied signal processing and data-mining techniques dedicated to brain signal analysis. More precisely, we studied wavelet denoising in collaboration with Radu Ranta (CRAN/Nancy university) to improve the detection of evoked potentials in a single trial. We proposed to apply a new threshold combining hard and soft approaches to detect P300 waves for brain-computer interfaces. We also evaluated the impact of several classifiers (Linear Discriminant Analysis, Support Vector Machines. . .) on a large database for a speller in collaboration with the Universidad Autonoma Metropolitana (UAM, Mexico) [46]. Using wavelet families with a waveform close to the evoked potential waveform does not improve the denosing compared to standard wavelet families. Indeed, to compare both signals the denoising produces a very small number of coefficients that cannot be discriminant enough for the classifier.

6.3.3. OpenViBE: interoperability and design of new scenarios.

OpenViBE is a free opensource software for Brain-Computer Interfaces (*cf.* § 5.4). This year, we integrated two new EEG drivers for Micromed and TMSi amplifiers. We developed a Quizz based on P300 wave for the rehabilitation center for children of Flavigny. We started to integrate a hybrid BCI based on P300 wave and steady-State Visual Evoked Potential. We added Support Vector Machine as a possible classifier. We also updated the online documentation and proposed a tutorial at the BCI meeting [43]. We proposed a demonstration in several exhibitions. The development of OpenVibe is done in association with the INRIA research team BUNRAKU for the national INRIA project: ADT LOIC (*cf.* § 7.2).

6.3.4. Spike sorting

We also studied spike sorting (threshold and clustering techniques) because another neuronal graphic-elements, the spike, has to be detected (before to sorting it). We did it for two collaborations : i) CNRS NeuroInformatics program on cortical signals to control a two-finger robotic hand driven by artificial muscles (*cf.* § 7.2) and ii) Algorithms for modeling the visual system : From natural vision to numerical applications with Adrian Palacios (Centro Interdisciplinario de Neurociencia de Valparaiso, Chile) (*cf.* § 7.4).

6.3.5. Decoding cortical signals to control a two-finger robotic hand

Over the last two decades, major advances in both multi-electrode recording techniques and the development of decoding algorithms have provided new tools for brain-machine interfaces (BMIs). We developed data analysis techniques to extract properties of underlying neural activity from multi-electrode recordings for direct BMIs for the control of a skilled hand movement. Last year, we won the international BCI competition IV, datasets 4, on the prediction of individual finger flexion from electro-corticogram (ECoG) using amplitude modulation in specific bands. This year, in Brain-Machine Interfaces (BMI), we built a linear model with interdependencies between spike trains to improve the prediction of the position (and the strength) of a finger during a precision grip.

6.4. Embodied and embedded systems

Participants: Yann Boniface, Hervé Frezza-Buet, Bernard Girau, Mathieu Lefort, Dominique Martinez, Jean-Charles Quinton, Nicolas Rougier.

6.4.1. InterCell

Our research in the field of dedicated architectures and connectionist parallelism mostly focuses on embedded systems (*cf.* §3.5). Nevertheless we are also involved in a project that considers coarse-grain parallel machines as implementation devices. The core idea of this InterCell project (part of the MIS axis of the CPER (*cf.* §7.1); *cf.* also http://intercell.metz.supelec.fr) is to map fine grain computation (cells) to the actual structure of PC clusters. The latter rather fit coarse grain processing, using relatively few packed communication, which a priori contradicts neural computing. Another fundamental feature of the InterCell project is to promote interaction between the parallel process and the external world. Both features, cellular computing and interaction, allow to consider the use of neural architectures on the cluster on-line, for the control of situated systems, as robots.

6.4.2. Embodied/embedded olfactory systems

6.4.2.1. How can animals successfully locate odour sources?

Two different classes of strategies are possible for olfactory searches: those based on a spatial map, e.g. Infotaxis, and those where the casting-and-zigzagging behaviour observed in insects is purely reactive, without any need for an internal memory, representation of the environment, or inference. Our goal is to investigate this question by implementing infotactic and reactive search strategies in a robot and test them in real environmental conditions. In [8], we have shown that robot Infotaxis produces trajectories that feature zigzagging and casting behaviours similar to those of moths, is robust and allows for rapid and reliable search processes. We are now implementing infotactic and reactive search strategies in a cyborg using the antennae of a tethered moth as sensors (no artificial sensor for pheromone molecules is presently known). The resulting trajectories will be compared to those obtained with the same cyborg but driven by the moth?s brain and to those obtained with flying moths.

6.4.2.2. How can technology emulate biological olfactory processing?

In the framework of the associate team BioSens, we constructed a micro-electronic nose model which incorporates spiking neurons. The outputs of a microhotplate gas sensor array (16 sensors) are encoded as a spike train insensitive to changes in gas concentration [4]. The properties of this device (compactness, low power consumption) make it suitable for embedded gas sensor applications (smellphone). This work pioneers the translation of neurophysiological findings into hardware for the processing of electronic noses.

6.4.3. Specific hardware implementations

In the field of dedicated embeddable neural implementations, we use our expertise in both neural networks and FPGAs so as to propose efficient implementations of applied neural networks on FPGAs.

Recent works in this axis have focused on the efficient implementation of a specific spiking neural model that allows back-engineering of its synaptic weights from biological spike recordings [39]. This work has been carried out within the activities of the CorTexMex associate team (*cf.* §7.4).

6.4.4. Multimodal learning through joint dynamic neural fields

This work relates to the development of a coherent multimodal learning for a system with multiple sensory inputs.

- We have modified the BCM synaptic rule, a local learning rule, to obtain the self organization of our neuronal inputs maps and we use a CNFT based competition to drive the BCM rule. In practice, we introduce a feedback modulation of the learning rule, representing multimodal constraints of the environment [36], [25].
- We have introduced an unlearning term in the BCM equation to solve the problem of the different temporalities between the raise of the activity within modal maps and the multimodal learning of the organization of the maps [37].

6.4.5. Anticipatory mechanisms in neural fields

We have defined first models of neural fields that include anticipatory mechanisms through the integration of spatiotemporal representations into the lateral interactions of a dynamic neural field. This work targets increased robustness and goal-oriented action selection within sensori-motor systems. This approach is related to previous work on how competition and learning could be performed on future-oriented representations in a computationally efficient but distributed manner [49].

6.4.6. Brain-inspired hardware

Our activities on dedicated architectures have strongly evolved in the last years. We now focus on the definition of brain-inspired hardware-adapted frameworks of neural computation.

Our above work about “Multimodal learning” is fully part of this project, since our aim is to define hardware-compatible protocols to assemble various perception-action modalities that are implemented and associated by different bio-inspired neural maps.

At a lower-level, we study the elemental reflex processes and their relationship with higher multimodal levels. In particular we are interested in the generation of rhythmic locomotion patterns by Central Pattern Generators (CPGs). We have designed a flexible implementation of CPGs, as well as an embedded adaptation of the parameters that tune the rythmic patterns to enable different gaits for the locomotion of a robot [14], [15]. This work has been carried out within the activities of the CorTexMex associate team (*cf.* §7.4).

7. Other Grants and Activities

7.1. Regional initiatives

7.1.1. Action Situated Informatics of the CPER

Participants: Laurent Bougrain, Octave Boussaton, Thierry Viéville.

In the framework of the Contrat de Projet État Région, we are contributing to the axis IS (Informatique Située) through the project CoBras whose goal is to study reinforcement learning to better control a robotic arm in a Brain-Machine interface. We bought a JACO robotic arm for wheelchair by Kinova.

7.1.2. Action Modeling, Simulation and Interaction of the CPER

Participants: Frédéric Alexandre, Hervé Frezza-Buet, Nicolas Rougier.

In the framework of the Contrat de Projet État Région, we are contributing to the axis MIS (Modeling, Interaction and Simulation) through the project InterCell whose goal is to study massive cellular computations in an interactive framework (*cf.* § 6.4).

7.2. National initiatives

7.2.1. DGE Ministry grant COMAC “Optimized multitechnique control of aeronautic composite structures”

Participants: Laurent Bougrain, Octave Boussaton, Marie Tonnelier.

The goal of this three-years project is to develop a powerful system of control on site, in production and in exploitation, of aeronautical pieces made of composite. It takes up the challenge of the precise, fast and local inspection on composite pieces of aeronautical structures new or in service by using techniques of non-destructive control more effective and faster to increase the lifespans of the structures of planes. This project requires a decision-making system including fast methods of diagnostic based on several optical technics as non-destructive control.

7.2.2. Bio-inspired spatial computing: ARC Amybia

Participant: Bernard Girau.

Our regular collaborations with researchers from the Maia team has shown that we share common computation paradigms based on massively distributed and local models that are inspired by biological systems. This has led us to join our efforts in an original collaboration within the Amybia project led by Nazim Fatès (ARC INRIA), together with Hugues Berry (Combining team) who works on similar models by exploring a bio-inspired approach to propose challenging paradigms for spatial computing. This collaboration is also linked with our hardware implementation activities, since it has resulted in an embedded implementation of a biological inspired model for the decentralized gathering of computing agents. Though this ARC ended in 2009, we still collaborate in 2010 within this framework, thanks to the presence of a postdoctoral fellow whose grant was obtained through the Amybia project. The main result is an asymptotical study of the phase transitions of the stochastic Greenberg-Hastings cellular automata that has been made possible thanks to fast FPGA implementations [34].

7.2.3. INRIA ADT project LOIC

Participants: Laurent Bougrain, Baptiste Payan.

This national software collaborative project (http://openvibe.inria.fr/related/adt-loic/) with the INRIA research team BUNRAKU (Rennes) is devoted to OpenViBE (*cf.* § 5.4). The objectives of the project are:

- Software enhancement:
  - Make the software compatible with new devices
  - Create new BCI scenarios (e.g. SSVEP, hybrid BCI...)
  - Create new 3D visualization
  - Create bridges to other softwares (e.g. MATLAB, TurboFieldTrip, BCI 2000)
  - Enhance global computation performance
- Software dissemination:
  - Gforge, website, support management...
  - Create new demos and tutorials
  - Organise training sessions
- Explore new research topics:
  - Hybrid BCI (e.g. visual and auditory, visual and tactile)
  - Immersive neurofeedback

7.2.4. ANR project PHEROSYS

Participants: Dominique Martinez, Hana Belmabrouk.

This collaborative project in systems Biology (ANR-BBSRC SysBio) with INRA (Paris, FR) and the University of Sussex (UK) explores olfactory coding in the insect pheromone pathway through models and experiments. More information available at http://www.informatics.sussex.ac.uk/research/projects/PheroSys/index.php/.

7.2.5. ANR project MAPS

Participants: Frédéric Alexandre, Yann Boniface, Elham Ghassemi, Nicolas Rougier, Wahiba Taouali, Thierry Viéville.

This collaborative project with INCM (Marseille), UMR Perception and Movement (Marseille) and LIRIS (Lyon) aims at re-examining the relationship between structure and function in the brain, taking into account the topological (spatial aspects) and hodological (connectivity) constraints of the neuronal substrate. We think that those constraints are fundamental for the understanding of integrative processes, from the perception level to the motor level and the initiation of coordinated actions.

7.2.6. *Project of the CNRS NeuroInformatics program on olfaction*

Participants: Hana Belmabrouk, Mohamed-Ghaïth Kaabi, Dominique Martinez.

The project "Olfactory coding" (2008-2009) from the CNRS program "Neuroinformatics" with the CNRS UMR5020 (Lyon) explores the role of spike timing in olfactory coding.

7.2.7. *Project of the CNRS NeuroInformatics program on neural coding in the retina*

Participants: Frédéric Alexandre, Laurent Bougrain, Axel Hutt, Thierry Viéville.

The new project "Sensory Transduction to Perception " (2009-2010) from the CNRS program "Neuroinformatics" aims to initiate the research cooperation of groups at the University of Nice, the University of Santiago de Chile and the University of Valparaiso in Chile. The aim of the project is the better understanding of the neural coding in the retina in the presence of natural stimuli. To this end, in-vivo experiments are performed in the Chilean laboratories and the French groups analyse and model the data obtained.

7.2.8. *Project of the CNRS NeuroInformatics program on cortical signals to control a two-finger robotic hand (CorticoRobot)*

Participants: Laurent Bougrain, Thierry Viéville.

Nowadays, the understanding of the control of manual dexterity in primates can be reached. Over the last twenty years, thanks to improved techniques for intra-cranial recordings, several advances have been obtained in particular to predict the direction of movement of the upper limb. Recent work has shown that it is possible to predict from brain data the flexion and the strength of fingers. The main objective of this project is to study the control of two anthropomorphic fingers (index finger and thumb) through intra-cortical signals recorded in the monkey during grasping movements (precision grip), forecasting both the finger position and the electromyographic activity (EMG) of the muscles involved in the movements of these two fingers. The project aims at (i) acquiring high-quality recordings using an array of 96 micro-electrodes, (ii) improving our experimental site for the grasping, and (iii) evaluating new modelings. This project is a cooperation between the University of Paris V, the Mediterranean Institute for Cognitive Neuroscience (INCM) and the EPI CORTEX.

7.2.9. *Project of the CNRS NeuroInformatics program on oscillations in the rat olfactory bulb*

Participants: Axel Hutt, Dominique Martinez, Thomas Voegtlin.

This project is a collaboration between the CORTEX group and the "Neurosciences et Systèmes sensoriels" group (CNRS UMR 5020) at University of Lyon 1. The goal of the project is to understand why the frequency of LFP oscillations in the olfactory bulb changes during the respiratory cycle (alternance beta/gamma). The project combines experimental (in-vivo experiments) and theoretical work (computer simulations).

7.2.10. *Project INRA-INRIA*

Participants: Dominique Martinez, Thomas Voegtlin.

This project is a collaboration between the CORTEX group at INRIA and the PISC group at INRA. This project aims at reconstructing and explaining the encoding of the pheromone stimulus in the early neural pathway of the moth olfactory system. Models of single neurons based on Hodgkin-Huxley formalism are being developed to incorporate the ionic conductances found in experiments and to account for the overall properties of the cells. A network model is also built to account for the different response types in the moth olfactory system with respect to the temporal structure of the stimulus. The simulations are performed with the Sirene and Mvaspike softwares developed at Loria.

7.3. European initiatives

7.3.1. *FP7-ICT project NEUROCHEM*

Participant: Dominique Martinez.

The european project NEUROCHEM explores biologically inspired computation for chemical sensing, in collaboration with the University of Barcelona, the royal institute of technology (Sweden), INRA (Paris), the university of Manchester, the university Pompeu Fabra (Spain), CNR-IMM (Italy) and the university of Leicester. More information is available at http://www.neurochem-project.org/

7.4. International cooperation

7.4.1. INRIA associate team CorTexMex

Participants: Bernard Girau, Yann Boniface, Mauricio Cerda, Nicolas Rougier.

We are working with the Computer science department of the INAOEP (national institute of astrophysics, optics and electronics of Puebla) and the Cinvestav Tamaulipas research center (both in Mexico) on massively distributed connectionist models for embedded perception-action, within the INRIA associate team CorTexMex led by Bernard Girau. The main goal is to provide methods able to handle the massive distribution and the connection complexity of bio-inspired neural models, as well as their specific recurrent differential computations. Another goal is to provide bio-inspired connectionist processing models to be embedded and directly integrated in perception-action loops.

This year, two main subjects have been addressed: biologically inspired visual perception on FPGAs (based on spiking neural fields), and bio-inspired models on-chip for the perception-action loop (based on Central pattern generators and multimodal neural maps). All these activities are strongly linked with §6.4.

7.4.2. CONICYT-INRIA Program of Cooperation with Chile: AMVIS

Participants: Frédéric Alexandre, Thierry Viéville.

The goal of this AMVIS (Algorithm for Modeling the VIsual System) project is to combine our complementary expertise, from experimental biology and mathematical models (U de Valparaiso and U Federico Santa-Maria) to computational neuroscience (CORTEX and NEUROMATHCOMP), in order to develop common tools for the analysis and formalization of neural coding and related sensory-motor loops. Recording and modeling on non-standard retina neural network involved in sensori-motor perceptual tasks is targeted here: How visual signals are coded at earlier steps in the case of natural vision? What are their functions? What are the computational ?coding? principles explaining (in artificial or biological system) the statistical properties of natural images? As a consequence of this collaboration and of the CNRS support in the Neuroinformatics program mentionned above, we have recently obtained a large ANR support (KEOpS international project with Chile), to begin next year.

7.4.3. STIC-AmSud project BAVI

Participants: Bernard Girau, Mauricio Cerda.

This collaboration with the Computer science department of the University of Santiago (Chile) and the Laboratory for System Dynamics and Signal Processing of the National University of Rosario (Argentina), lies in the field of audio-visual information integration. The approach is based on the derivation of distributed models from neurophysiologic studies of motion perception in the human brain, and takes advantage of advanced methods for audio-visual information integration and visual animation. In this collaboration, we have jointly developed a face animation technique with our Chilean partner able to deliver animations of any model (subject) using the data of our Argentinian partner [19]. Now, we are showing that our classification model for motion patterns can be used in a different context such as digit classification from video (different face movements).

7.4.4. STIC-AmSud project BCI

Participants: Frédéric Alexandre, Laurent Bougrain, Carolina Saavedra.

The STIC Amsud project (2009-2010) BCI "Robust single-trial evoked potential detection for brain-computer interfaces using computational intelligence techniques" aims to develop computational intelligence techniques for pattern recognition of graphic elements (e.g. event-related potential, auditory evoked potential, k-complex, spindle) included in electro-encephalographic signals. More precisely, we want to develop adaptive computational intelligence techniques based on artificial neural networks, support vector machines and classical data analysis techniques to robustly detect evoked potentials in a single trial from noisy and multi-sources electro-encephalographic signals. The participants are: the Laboratory of Engineering Rehabilitation and Neuromuscular and Sensorial Research (L.I.R.I.N.S), Facultad de Ingeniería, Universidad Nacional de Entre Ríos, Argentina ; The Department of Biomedical Engineering, Valparaíso University, Valparaiso, Chile ; The Computer Science Department, Federico Santa María University, Valparaiso, Chile ; The Laboratory of Neuro Imaging Research, Autonomous Metropolitan University, Mexico DF, Mexico.

7.4.5. Common project with United Kingdom

Participant: Axel Hutt.

The project partner is the Herriot-Watts University of Edinburgh and the project aims to study stochastic effects in neural networks. To this end the Royal Society of Scotland supported the initial visit in Edinburgh to discuss first mathematical details and software implementations besides a schedule for future common activities.

8. Dissemination

8.1. Animation of the scientific community

8.1.1. Responsabilities

- Responsible for the axis MIS "Modeling, Interaction Simulation", of the CPER with the Lorraine Region (until June 2010, F. Alexandre).
- Head of the Network Grand-Est for Cognitive Science (F. Alexandre)
- Member of the steering committee of the ARP PIRSTEC (Prospective on cognitive science and technology for the ANR) (F. Alexandre)
- Member of the steering committee of the french association for Artificial Intelligence (AFIA) (F. Alexandre)
- Member of the Board of Directors in Organization of Computation Neuroscience (A. Hutt)
- Member of the board of directors of the LORIA laboratory (B. Girau).
- Thierry Viéville is a member of the Scientific Committee of the University of Nice Sophia-Antipolis;
- Member of the "Bureau du Comité de Projets" (Steering Committee of the Project-Team Committee) (F. Alexandre)
- F. Alexandre and T. Viéville are members (and moderators) of the scientific committee of NeuroComp, the initiative to gather the french community in Computational Neuroscience (annual conference and web site: http://www.neurocomp.fr/). They were in the scientific committee of Neurocomp'10.

8.1.2. Review activities

- Reviewing for journals: Journal of Mathematical Neuroscience, New Journal of Physics, Biological Cybernetics, Physical Review E, Philosophical Transactions of the Royal Society A, Cognitive Neurodynamics, Nonlinearity, SIAM Journal of Dynamical Systems, Journal of Physics A (A. Hutt); Frontiers in Computational Neuroscience, Neurocomputing (T. Viéville);
- Member of program committees: BioMed'10, CAP'10, SAB'10 (F. Alexandre); AMINA'10, RECONFIG'10 (B. Girau);

8.1.3. Workshops, conferences and seminars

- Organization of the Latin American Summer School in Computational Neuroscience and Biomedical Applications, Valparaiso, Chile, January 11-29, 2010 (F. Alexandre and T. Viéville). http://lascn.risc.cnrs.fr/
- Invited talks: Seminar talk at Department of Mathematics, University of Augsburg, Germany, June 2010 (A. Hutt)
- International lecture series, National Institute of Informatics, Tokyo, Japan (N. Rougier)
- Seminars: talk at the Cinvestav research center, Ciudad Victoria, Mexico.(B. Girau); talk for the team Multimodal Information Processing, Supelec (F. Alexandre)

8.1.4. International cooperations

- in neurophysiology with MPI for Biological Cybernetics (Tubingen)
- in general anaesthesia with University of Auckland (New Zealand)
- on modeling visual attention with university of Chemnitz (Germany)
- in brain-computer interface with the Universidad Autónoma Metropolitana (UAM, Mexico)
- in spike sorting with university of Princeton (USA)

8.2. Teaching

- Courses given in universities and schools of engineers at different levels (LMD) by most team members, in computer science, in applied mathematics and in cognitive science;
- T. Viéville: 20h of teaching about Computer Science in sessions of permanent formation of 2ndary schools teachers.
- Teaching at the Latin American Summer School in Computational Neuroscience and Biomedical Applications, Valparaiso, Chile, January 11-29, 2010 (F. Alexandre, L. Bougrain, A. Hutt and T. Viéville).
- B. Girau is the head of one of the three specialities (RAR, recognition, learning, reasoning) of the second year of the Master in Computer Science of Nancy University.
- Member of PhD and HDR defense committees (F. Alexandre, B. Girau, T. Viéville);

8.3. Miscellaneous

- The other half-time of Thierry Viéville's activity is dedicated to popularization of science (http://interstices.info (scientific animation from the creation to 2007), http://www.fuscia.info (scientific co-editor)) [11].
- Adapted teaching in secondary schools, to present our activity of researchers (F. Alexandre, N. Rougier, T. Viéville).
- Participation to a show, organized by the teachers of a secondary school in Lunéville, about Neuroscience and Cognitive Science (3 stands organized by F. Alexandre, L. Bougrain, N. Rougier).
- Recording and broadcasting of scientific spots on the Radio France Bleu (F. Alexandre, L. Bougrain)
- Our PhD student Wahiba Taouali attended the highly selective Okinawa computational neuroscience summer school.
- Organization of a talk serie on Image, Perception, Action & Cognition on a montly basis at the INRIA-Nancy Grand Est laboratory (http://ipac.loria.fr/).
- Participation in the "Cordée de la réussite" between Henri-Poincaré University (Nancy), INRIA Nancy-Grand Est, Lycée Poincaré (Nancy) and Collège Bichat (Lunéville) (N. Rougier, F. Alexandre).

- Talk to the Forum for Cognitive Sciences, University Nancy 2 (F. Alexandre, L. Bougrain, B. Payan)
- articles in Interstices, the web site for scientific large public dissemination http://interstices.info/ (F. Alexandre, T. Viéville)

9. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] T. GIROD. *Un modèle d'apprentissage multimodal pour un substrat distribué d'inspiration corticale*, Université Henri Poincaré - Nancy I, November 2010, http://hal.inria.fr/tel-00547941/en.

Articles in International Peer-Reviewed Journal

[2] L. ALECU, H. FREZZA-BUET, F. ALEXANDRE. *Can Self-Organization Emerge through Dynamic Neural Fields Computation?*, in "Connection Science", September 2010, http://hal.inria.fr/inria-00537799/en.

[3] B. CESSAC, H. PAUGAM-MOISY, T. VIÉVILLE. *Overview of facts and issues about neural coding by spikes*, in "Journal of Physiology-Paris", 2010, vol. 104, n^O 1-2, p. 5-18 [*DOI :* 10.1016/J.JPHYSPARIS.2009.11.002], http://hal.inria.fr/inria-00407915/en.

[4] H. T. CHEN, K. T. NG, A. BERMAK, M. K. LAW, D. MARTINEZ. *Spike latency coding in a biologically inspired micro-electronic nose*, in "IEEE Transactions on Biomedical Circuits and Systems", 2010, http://hal.inria.fr/inria-00543031/en.

[5] J. FIX, N. P. ROUGIER, F. ALEXANDRE. *A dynamic neural field approach to the covert and overt deployment of spatial attention*, in "Cognitive Computation", 2010 [*DOI :* 10.1007/S12559-010-9083-Y], http://hal.inria.fr/inria-00536374/en.

[6] A. HUTT, N. P. ROUGIER. *Activity spread and breathers induced by finite transmission speeds in two-dimensional neural fields*, in "Physical Review E: Statistical, Nonlinear, and Soft Matter Physics", 2010, vol. 82, R055701, http://hal.inria.fr/inria-00533067/en.

[7] M. G. KAABI, A. TONNELIER, D. MARTINEZ. *On the performance of voltage-stepping for the simulation of adaptive, nonlinear, integrate-and-fire neuronal networks*, in "Neural Computation", 2010, http://hal.inria.fr/inria-00543030/en.

[8] E. MARTIN MORAUD, D. MARTINEZ. *Effectiveness and robustness of robot infotaxis for searching in dilute conditions*, in "Frontiers in neurorobotics", 2010, vol. 4, n^O 1, p. 1-8, http://hal.inria.fr/inria-00467858/en.

[9] N. P. ROUGIER, Y. BONIFACE. *Dynamic Self-Organising Map*, in "Neurocomputing", 2010, http://hal.inria.fr/inria-00495827/en.

[10] N. P. ROUGIER, A. HUTT. *Synchronous and Asynchronous Evaluation of Dynamic Neural Fields*, in "The Journal of Difference Equations and Applications", 2010, vol. In press, n^O In press [*DOI :* 10.1080/10236190903051575], http://hal.inria.fr/inria-00403107/en.

Articles in Non Peer-Reviewed Journal

[11] F. ÉLIE, B. GUERRY, D. LACROIX, P. LUCAUD, C. NESTEL, C. PICARD-LIMPENS, T. VIÉVILLE. *Est-il besoin de savoir programmer pour comprendre les fondements de l'informatique ou utiliser les logiciels ?*, in "EPINet - La revue électronique de l'EPI", December 2010, 11, http://hal.inria.fr/inria-00546150/en.

Invited Conferences

[12] D. MARTINEZ, A. CHAFFIOL, H. BELMABROUK, Y. GU, S. ANTON, P. LUCAS, J.-P. ROSPARS. *Stereotyped firing response patterns in moth antennal lobe neurons: experiments and models*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543044/en.

[13] D. MARTINEZ, A. CHAFFIOL, Y. GU, S. ANTON, J.-P. ROSPARS. *Stereotyped firing response patterns in moth antennal lobe neurons: from experiments to models*, in "European Chemoreception Research Organization (ECRO)", France Avignon, 2010, http://hal.inria.fr/inria-00543034/en.

International Peer-Reviewed Conference/Proceedings

[14] H. BARRON-ZAMBRANO, C. TORRES-HUITZIL, B. GIRAU. *FPGA-based Circuit for Central Pattern Generator in Quadruped Locomotion*, in "17th International Conference on Neural Information Processing – ICONIP", Australia Sydney, 2010, http://hal.inria.fr/inria-00522194/en.

[15] H. BARRON-ZAMBRANO, C. TORRES-HUITZIL, B. GIRAU. *Hardware Implementation of a CPG-Based Locomotion Control for Quadruped Robots*, in "20th International Conference on Artificial Neural Networks - ICANN 2010", Greece Thessaloniki, K. DIAMANTARAS, W. DUCH, L. S. ILIADIS (editors), Lecture Notes in Computer Science, Springer-Verlag, 2010, vol. 6353, p. 276-285 [*DOI :* 10.1007/978-3-642-15822-3_35], http://hal.inria.fr/inria-00522186/en.

[16] H. BELMABROUK, Y. GU, T. NOWOTNY, J.-P. ROSPARS, D. MARTINEZ. *A model of the moth macroglomerular complex: interplay between interglomerular inhibition and neuronal intrinsic properties*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543048/en.

[17] L. BUCKLEY, D. MARTINEZ, J.-P. ROSPARS, A. CHAFFIOL, T. NOWOTNY. *Critical Rate Dynamics Explain the Dynamic Range of the Moth Pheromone System*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543042/en.

[18] M. CERDA, B. GIRAU. *Bio-inspired visual sequences classification*, in "Brain Inspired Cognitive Systems 2010 - BICS 2010", Spain Madrid, July 2010, pp. 20, http://hal.inria.fr/hal-00504090/en.

[19] M. CERDA, R. VALENZUELA, N. HITSCHFELD-KAHLER, L. TERISSI, J. C. GOMEZ. *Generic Face Animation*, in "XXIX International Conference of the Chilean Computer Society", Chile Antofagasta, November 2010, http://hal.inria.fr/inria-00536958/en.

[20] A. GRÉMIAUX, D. JARRIAULT, A. CHAFFIOL, S. ANTON, D. MARTINEZ, J.-P. ROSPARS. *Signal transformation from olfactory receptor neurons to central neurons*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543050/en.

[21] A. GRÉMIAUX, D. JARRIAULT, A. CHAFFIOL, Y. GU, S. ANTON, D. MARTINEZ, J.-P. ROSPARS. *Analysis of the Signal Transformation From First- to Second-order Neurons in the Moth Sex-Pheromone Olfactory*

System, in "9th international workshop Neural Coding - NC 2010", Cyprus Limassol, 2010, http://hal.inria.fr/inria-00543037/en.

[22] Y. GU, H. BELMABROUK, A. CHAFFIOL, J.-P. ROSPARS, D. MARTINEZ. *Modelling the cellular mechanisms underlying the multiphasic response of moth pheromone-sensitive projection neurons*, in "European Chemoreception Research Organization (ECRO)", France Avignon, 2010, http://hal.inria.fr/inria-00543035/en.

[23] Y. GU, H. BELMABROUK, J.-P. ROSPARS, A. CHAFFIOL, D. MARTINEZ. *A biophysical model reproduces the multiphasic firing patterns observed in moth antennal lobe neurons*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543046/en.

[24] M. LECHON, D. MARTINEZ, P. F. VERSCHURE, S. BERMUDEZ I BADIA. *The role of neural synchrony and rate in high-dimensional input systems. The Antennal Lobe: a case study*, in "International Joint Conference on Neural Networks - IJCNN 2010", Spain Barcelone, IEEE, 2010, http://hal.inria.fr/inria-00543033/en.

[25] M. LEFORT, Y. BONIFACE, B. GIRAU. *Self-organization of neural maps using a modulated BCM rule within a multimodal architecture*, in "Brain Inspired Cognitive Systems 2010", Spain Madrid, July 2010, 26, http://hal.inria.fr/hal-00480028/en.

[26] E. MARTIN MORAUD, D. MARTINEZ. *Scent-tracking by autonomous robots: Infotaxis and beyond*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543045/en.

[27] J.-C. QUINTON, B. GIRAU. *A sparse implementation of dynamic competition in continuous neural fields*, in "Brain Inspired Cognitive Systems 2010 - BICS 2010", Spain Madrid, July 2010, http://hal.inria.fr/inria-00488888/en.

[28] J.-C. QUINTON. *Exploring and Optimizing Dynamic Neural Fields Parameters Using Genetic Algorithms*, in "IEEE World Congress on Computational Intelligence 2010 - WCCI 2010", Spain Barcelona, July 2010, http://hal.inria.fr/inria-00488914/en.

[29] J.-P. ROSPARS, A. GRÉMIAUX, Y. GU, D. JARRIAULT, L. KOSTAL, P. LANSKY, S. ANTON, T. NOWOTNY, P. LUCAS, D. MARTINEZ. *Olfactory receptor neurons: A comparative analysis of their response properties with diverse stimuli in different species*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543041/en.

[30] N. P. ROUGIER. *DANA, Distributed (Asynchronous) Numerical & Adaptive computing framework*, in "3rd European meeting on Python in Science - EuroScipy 2010", France Paris, Ecole Normale Supérieure, 2010, http://hal.inria.fr/inria-00536385/en.

[31] N. P. ROUGIER. *From Computational Neuroscience to Cellular Automata*, in "16th International Workshop on Cellular Automata- AUTOMATA 2010", France Nancy, INRIA, June 2010, http://hal.inria.fr/inria-00536408/en.

[32] W. TAOUALI, N. P. ROUGIER, F. ALEXANDRE. *Saccades generation : from the visual input to the superior colliculus*, in "International Conference on Neural Computation ICNC 2010", Spain Valence, 2010, http://hal.inria.fr/inria-00506397/en.

[33] M. TARZAN-LORENTE, A. GUTIERREZ-GALVEZ, D. MARTINEZ, S. MARCO. *A Biologically Inspired Associative Memory for Artificial Olfaction*, in "International Joint Conference on Neural Networks - IJCNN 2010", Spain Barcelone, IEEE, 2010, http://hal.inria.fr/inria-00543032/en.

[34] N. VLASSOPOULOS, N. FATÈS, H. BERRY, B. GIRAU. *An FPGA Design for the Stochastic Greenberg-Hastings Cellular Automata*, in "International Conference on High Performance Computing & Simulation - HPCS 2010", France Caen, 2010, p. 565-574, http://hal.inria.fr/inria-00522193/en.

[35] A. ZAVADA, L. BUCKLEY, D. MARTINEZ, J.-P. ROSPARS, T. NOWOTNY. *Minimal model of blend recognition in the moth pheromone system*, in "Dynamical olfaction workshop", United Kingdom Brighton, 2010, http://hal.inria.fr/inria-00543038/en.

National Peer-Reviewed Conference/Proceedings

[36] M. LEFORT, Y. BONIFACE, B. GIRAU. *Auto organisation d'une carte de neurones par modulation de la règle BCM dans un cadre multimodal*, in "17e congrès francophone AFRIF-AFIA Reconnaissance des Formes et Intelligence Artificielle - RFIA 2010", France Caen, January 2010, p. 423-430, http://hal.inria.fr/hal-00434530/en.

[37] M. LEFORT, Y. BONIFACE, B. GIRAU. *Auto-organisation d'une carte de neurones BCM sous contrainte multimodale*, in "5ème Conférence française de Neurosciences Computationnelles - Neurocomp 2010", France Lyon, October 2010, http://hal.inria.fr/inria-00512658/en.

[38] M. RIO, A. HUTT, B. GIRAU. *Partial amplitude synchronization detection in brain signals using Bayesian Gaussian mixture models*, in "Cinquième conférence plénière française de Neurosciences Computationnelles, "Neurocomp'10"", France Lyon, Neurocomp, October 2010, p. 109 – 113, http://hal.inria.fr/hal-00534076/en.

[39] H. ROSTRO-GONZALEZ, H. BARRON-ZAMBRANO, C. TORRES-HUITZIL, B. GIRAU. *Low-cost hardware implementations for discrete-time spiking neural networks*, in "Cinquième conférence française de Neurosciences Computationnelles - NeuroComp'10", France Lyon, 2010, http://hal.inria.fr/inria-00522180/en.

[40] C. SAAVEDRA, L. BOUGRAIN. *Wavelet denoising for P300 single-trial detection*, in "Proccedings of the 5th french conference on computational neuroscience - Neurocomp'10", France Lyon, October 2010, p. 227-231, http://hal.inria.fr/inria-00549218/en.

[41] W. TAOUALI, T. VIÉVILLE, N. P. ROUGIER, F. ALEXANDRE. *On asynchronous dynamic neural field computation*, in "Cinquième conférence plénière française de Neurosciences Computationnelles (Neurocomp 10)", France Lyon, 2010, http://hal.inria.fr/inria-00506401/en.

[42] T. VOEGTLIN, C. AMAT, V. BRIFFAUD, N. BUONVISO, E. COURTIOL, N. FOURCAUD-TROCMÉ. *Stable frequency response to varying stimulus intensity in a model of the rat olfactory bulb.*, in "5ème Conférence Française de Neurosciences Computationnelles - Neurocomp10", France Lyon, 2010, http://hal.inria.fr/inria-00542330/en.

Workshops without Proceedings

[43] Y. RENARD, L. BONNET, B. PAYAN, L. BOUGRAIN, A. LÉCUYER. *OpenViBE Tutorial: A Novel Open-Source Software to Design, Test and Use Brain-Computer Interfaces*, in "BCI Meeting 2010", United States Asilomar, May 2010, http://hal.inria.fr/inria-00551379/en.

Research Reports

[44] H. ROSTRO-GONZALEZ, J.-C. VASQUEZ, B. CESSAC, T. VIÉVILLE. *Reverse-engineering in spiking neural networks parameters: exact deterministic parameters estimation*, INRIA, February 2010, n$^{\mathrm{o}}$ RR-7199, http://hal.inria.fr/inria-00455415/en.

Scientific Popularization

[45] L. BOUGRAIN, C. SAAVEDRA, B. PAYAN, A. HUTT, M. RIO, F. ALEXANDRE. *INRIA's project-team Cortex : Computational Neuroscience*, May 2010, Type : Poster, http://hal.inria.fr/inria-00549246/en.

[46] C. LEDESMA-RAMIREZ, E. BOJORGES-VALDEZ, O. YÁÑEZ-SUAREZ, C. SAAVEDRA, L. BOUGRAIN, G. G. GENTILETTI. *An Open-Access P300 Speller Database*, May 2010, Type : Poster, http://hal.inria.fr/inria-00549242/en.

Other Publications

[47] T. GIROD, M. LEFORT, J.-C. QUINTON. *Cortically-inspired Computational Models for Multimodality*, October 2010, Type : Poster, http://hal.inria.fr/inria-00536869/en.

[48] M. LEFORT, Y. BONIFACE, B. GIRAU. *Multi-sensory integration by constrained self-organization*, October 2010, Type : Poster, http://hal.inria.fr/inria-00536933/en.

[49] J.-C. QUINTON. *Sensorimotor Exploration/Exploitation with Coordinating Local Predictions*, January 2010, Type : Poster, http://hal.inria.fr/inria-00536870/en.

[50] J.-C. VASQUEZ, T. VIÉVILLE, B. CESSAC. *Entropy-based parametric estimation of spike train statistics*, 2010, 37 pages, 8 figures, http://hal.inria.fr/inria-00534847/en.