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Project-Team CORTEX

Neuromimetic intelligence

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RESEARCH CENTER
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THEME
Computational Medicine and Neurosciences

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Project-Team CORTEX

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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

Sensory systems both in the living and in machines have to be optimized with respect to their environmental conditions. The olfactory system of moths is a particularly well-defined example in which rapid variations of odor content in turbulent plumes require fast, concentration-invariant neural representations. Using computational modeling, we show that cellular and network mechanisms in the moth antennal lobe contribute to coding efficiency by implementing a dual latency code for both pheromone identity and intensity. This result was recently published in PNAS [6] and is available at http://www.pnas.org/content/early/2011/11/21/1112367108.abstract.

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 (Mvaspike), 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, Mathieu Lefort, Wahiba Taouali.

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.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. CLONES: Closed-Loop Neural Simulations

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.

CLONES was presented at the Python in Neuroscience Workshop [18].

5.6. 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...)

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.
- 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. 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 [9].
- We have developed several biophysical models of the insect olfactory system to explain the transformation from first-order [10] to second-order neurons [6], [16]. We show in particular how cellular and network mechanisms contribute to coding efficiency.

6.2. Dynamic Neural Fields

Participants: Lucian Aleçu, Frédéric Alexandre, Yann Boniface, Laurent Bougrain, Mauricio Cerda, Georgios Detorakis, Hervé Frezza-Buet, Bernard Girau, 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: 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: 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.
- study of the bridge between an ensemble of spiking neurons and the population firing rate to extend neural fields by shunting inhibition effects. Shunting inhibition is an important effect in real neural systems, e.g. in the context of general anaesthesia. We re-derive the population firing rate well-known in neural fields from the single neuron firing statistics. This derivation assumes McCulloch-Pitts neurons with a trivial f-I curve. Then we exchange the McCulloch-Pitts neurons by more realistic type I-neurons with a non-trivial f-I curve and gain a different, more realistic population firing rate. This formulation allows to consider some shunting inhibition effects [44].

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:

- 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. This work is in preparation for publication.
- In order to clarify the notion of distributed computing, general concepts and definitions in the framework of artificial neural networks have been reviewed, within the scope of dynamic field theory, proposing an unequivocal definition of asynchronous computation. An innovative way to perform such asynchronous computation has been proposed, following theoretical developments in process formalization. Several consequences on both the trajectories and the stability of the whole system have been drawn, including a few practically usable methods and quantitative bounds that can guarantee most of the mesoscopic properties of the system [15].
- Novel numerically efficient algorithm to compute spatio-temporal activity in two-dimensional neural fields involving finite transmission speed.

- Study of the possibility to obtain properties of self-organization with dynamic neural fields and proposition of a new learning rule for self-organization [1], [5].
- We designed a variation of the self-organising map algorithm [14] 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 by adapting the dynamics of the threshold by the use of a feed-back signal generated by a neural field map [22], [39], [45]
- Following [25], we are now studying a computational model of the primary somato-sensory cortex based on the neural field theory where cortical representations develop through the modification of thalamocortical synapses (from thalamus to layer 4), while cortico-cortical synapses (layer 2/3 and 4) provide a distributed competitive mechanism between cortical pyramidal neurons of layer 2/3. Preliminary results explains both the initial development and the self-organization of cortical representations in the primary sensory cortex as well as the dynamic reorganization following a lesion or a sensory deprivation. In this context, the so-called critical period during childhood would correspond to the development and learning of the intra-cortical competitive mechanism that is critical for cortex plasticity.

6.2.2.2. Gaussian mixture based approximation of neural maps

We have studied the advantages of our new implementation of the Continuous Neural Field Theory (CNFT) using a Gaussian mixture based model of the neural field activity, when using high dimensional inputs [40]. 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, that are directly computed in any n-dimensional space, instead of projecting 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.

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. This work has been recently extended to complex movements: to fight, to wave, to clap, using real-world video databases [2], as well as using speech-driven visual animations of faces [28].

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
- Arrangement of several neural fields to model several cortical areas engaged in visual attention

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 [38] 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, Baptiste Payan, Maxime Rio, Carolina Saavedra, Christian Weber.

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 (BCI).

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 [12].

6.3.2. Brain-Computer Interface based on motor imagery to control a robotic arm in 3D

The interface we develop aims to control in 3D a Jaco robotic arm by Kinova, using the Graz Motor Imagery detection paradigm for two or three motor actions in an online situation. The interface is part of the OpenViBE software. The user can switch in different modes to control a specific part of the robotic device (arm, wrist, fingers). We plan to use five different motor imageries: right hand, left hand, foot, rest and both hands. The actions are not available all together for a specific control. The interface is already done. More experiments will be done to adjust the classifier.

6.3.3. Reinforcement learning to better control a robotic arm

The approach we proposed in Cobras is innovative. Many studies attempts improve the recognition rate of a BCI order with new methods for treatment of signal. These studies are placed upstream of the BCI to facilitate the retrieval of information in the signal. However, the signal to noise ratio is so low that the improvements are limited. Rather than improving signal processing upstream, we wanted to improve the recognition rate by adding information in the controlled system. Thus, we placed downstream and added, as inputs of our control system, mechanical data concerning robotic arm. Initially, we validated the possibility of finding -using an inverse algorithm of reinforcement learning- the policy of the expert from a set of trajectories followed in a maze. We defined then a scenario to achieve different trajectories with the robotic arm to reach several buttons. In a third step, we used this algorithm on a maze-type problem but for which we have completed the state vector with the classifier outputs. This study is ongoing.

6.3.4. Mutual influence of firing rates of corticomotoneuronal cells for learning a precision grip task

As a part of a Brain-Machine Interface, we define a model for learning and forecasting muscular activity, given sparse cortical activity in the form of action potential signals (spike trains). We have a collection of experiments in which a trained monkey performs a precision grip. More precisely, its neuronal activity is partially recorded from corticomotoneuron cells of the hand area (area 4) as the monkey clasps two levers between its index finger and thumb. The underlying model parameters are interpreted with respect to the physiological aspects, though the model itself is not bio-physical. The method used is based on a system of first degree linear equations involving the firing rate of the recorded neurons, two sets of thresholds associated to them, and the variation of the global neuronal activity. We build a module to translate the data in the form of spikes trains into the event structure of OpenViBE triggers which is more appropriate than signals. The enslavement of the clamp according to the order generated by OpenViBE was also done. These solutions can demonstrate the capabilities of our algorithms for decoding cortical signals in the task of handling.

6.3.5. Hysteresis thresholding for Wavelet denoising applied to P300 single-trial detection

Template-based analysis techniques are good candidates to robustly detect transient temporal graphic elements (e.g. event-related potential, k-complex, sleep spindles, vertex waves, spikes) in noisy and multi-sources electroencephalographic signals. More specifically, we studied the significant impact on a large dataset of wavelet denoisings to detect evoked potentials in a single-trial P300 speller. We applied the classical thresholds selection rules algorithms and compared them with the hysteresis algorithm by R. Ranta which combine the classical thresholds to detect blocks of significant wavelets coefficients based on the graph structure of the wavelet decomposition.

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 (*cf.* 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?

Our goal is to investigate this question. 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. We have implemented Infotaxis in a robot and shown that it produces trajectories that feature zigzagging and casting behaviours similar to those of moths. This result however should not be interpreted as evidence that the corresponding moth behaviour is driven by Infotaxis. Whether or not moths use infotactic or reactive strategies is still unclear. To compare both strategies, we have developped a cyborg using the antennae of a tethered moth as sensors (no artificial sensor for pheromone molecules is presently known). Experiments are in progress to compare the trajectories of the cyborg controlled by infotactic and reactive search strategies to those obtained with the same cyborg but driven by the moth's brain.

6.4.2.2. How can technology emulate biological olfactory processing?

Glomerular microcircuits in the first stage of the olfactory pathway reformat odor representation. First, many ORNs expressing the same receptor protein, yet presenting heterogeneous dose-response properties, converge onto each glomerulus [10]. Second, onset latency of glomerular activation is believed to play a role in encoding odor quality and quantity in the context of fast information processing [6]. Taking inspiration from biology, we designed a simple yet robust glomerular latency coding scheme for processing gas sensor data [7]. The proposed bio-inspired approach was evaluated using an Sn02 sensor array. Glomerular convergence was achieved by noting the possible analogy between receptor protein expressed in ORNs and metal catalyst used across the fabricated gas sensor array. Ion implantation was another technique used to account both for sensor heterogeneity and enhanced sensitivity. The response of the gas sensor array was mapped into glomerular latency patterns, whose rank order is concentration-invariant.

6.4.3. Hardware implementations of neural models

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, as well as to define hardware-friendly neural models.

- Following our results on the design of spiking models back-engineered from spike recordings, recent works have focused on the analysis of the influence of precision onto asymptotic dynamics of FPGA-embedded integrate-and-fire neural models [13].
- We design hardware-friendly adaptations of dynamic neural fields that use spiking neurons. In this field, we have derived a highly simplified version of such spiking neural fields, and we have experimentally shown that the main properties of standard neural fields are maintained in the context of visual attention [29].
- We currently intend to minimize the topological constraints of FPGA-embedded spiking neural fields using reduced neighborhoods but randomly propagating spikes. A preliminary result has been obtained so as to implement massively distributed pseudo-random number generators based on cellular automata that use minimal areas [21].

6.4.4. Towards 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 current works aim at defining hardware-compatible protocols to assemble various perception-action modalities that are implemented and associated by different bio-inspired neural maps.

6.4.4.1. 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 [23]. This work targets increased robustness and goal-oriented action selection within sensori-motor systems.

6.4.4.2. 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 [39].
- 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 [22].

7. Partnerships and Cooperations

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.

7.2. 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. INRIA ADT project LOIC

Participants: Laurent Bougrain, Baptiste Payan.

This national software collaborative project 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

7.2.3. ANR project KEOPS

Participants: Frédéric Alexandre, Laurent Bougrain, Thierry Viéville.

This «ANR International White Project» involving NEUROMATHCOMP and CORTEX Inria EPI in France with the U. of Valparaiso, U. Tecnica Frederico Santa-Maria, and U. De Chili is a 3 years, 248 person-months, sensory biology, mathematical modeling, computational neuroscience and computer vision, project addressing the integration of non-standard behaviors from retinal neural sensors, dynamically rich, sparse and robust observed in natural conditions, into neural coding models and their translation into real, highly non-linear, bio-engineering artificial solutions. An interdisciplinary platform for translation from neuroscience into bioengineering will seek convergence from experimental and analytical models, with a fine articulation between biologically inspired computation and nervous systems neural signal processing (coding / decoding).

7.2.4. *ANR project PHEROTAXIS*

Participants: Dominique Martinez, Thomas Voegtlin.

How can animals so successfully locate odour sources? This apparently innocuous question reveals on analysis unexpectedly deep issues concerning our understanding of the physical and biological world and offers interesting prospects for future applications. Pherotaxis focuses on communication by sex pheromones in moths. The main aim of the project is to integrate the abundant experimental data on the pheromone plumes, neural networks and search behaviour available in the literature, as well as that collected or being collected by us at the molecular, cellular, systemic and behavioural levels into a comprehensive global model of the pheromonal olfactory processes. To reach this objective, the consortium combines several groups of specialists with different and complementary fields, in physics (Institut Pasteur IP), neurobiology (INRA) and bio-robotics (INRIA).

7.2.5. *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/.

7.2.6. *ANR project MAPS*

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

This collaborative project with INCM (Marseille), UMR Perception and Movement (Marseille) and LIRIS (Lyon) that finished this year aimed 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. Particularly, we focused on the oculomotor function and explored the dynamical and topological representation of information in the superior colliculus.

7.2.7. *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.

7.2.8. *Project CNRS PEPII: A large-scale, robotically embodied decision making model*

Participants: Frédéric Alexandre, Nicolas Rougier, Thierry Viéville.

This project is a collaboration between the “Institut des Maladies neuro-dégénératives” (UMR 5293, team “Approche systémique de la Boucle Extrapyramidale”), Supélec (“Information, Multimodalité, Signal”) and the Cortex team. This project aims at studying the decision making process viewed as a high-level brain function, actioned by a distributed network of cortical and sub-cortical structures, interconnected in positive and negative feedback loops.

7.2.9. Project CNRS PEPII IMAVO

Participants: Nicolas Rougier, Yann Boniface.

This project is a collaboration between the “Institut des Neurosciences Cognitives et Intégratives d’Aquitaine” (UMR 5287), the “Institut des Systèmes Intelligents et de Robotique” (Systèmes Intégrés Mobiles et Autonomes) and the LORIA (Maia and Cortex groups). This project aims at investigating model-free and model-based approaches in the decision process in order to propose a computational model of the decision process in simple tasks.

7.2.10. 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).

7.2.11. 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 in our group.

7.3. European Initiatives

7.3.1. FP7 Projet

7.3.1.1. MathAna

Title: Mathematical Analysis of Anaesthesia

Type: IDEAS ()

Instrument: ERC Starting Grant (Starting)

Duration: January 2011 - December 2016

Coordinator: INRIA (France)

See also: http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&RCN=97256

Abstract: General anaesthesia is an important method in today’s hospital practice and especially in surgery. To supervise the depth of anaesthesia during surgery, the anaesthesist applies electroencephalography (EEG) and monitors the brain activity of the subject on the scalp. The applied monitoring machine calculates the change of the power spectrum of the brain signals to indicate the anaesthetic depth. This procedure is based on the finding that the concentration increase of the anaesthetic drug changes the EEG-power spectrum in a significant way. Although this procedure is applied world-wide, the underlying neural mechanism of the spectrum change is still unknown.

The project aims to elucidate the underlying neural mechanism by a detailed investigating a mathematical model of neural populations. The investigation is based on analytical calculations in a neural population model of the cortex involving intrinsic neural properties of brain areas and feedback loops to other areas, such as the loop between the cortex and the thalamus. Currently, there are two proposed mechanisms for the charactertisic change of the power spectrum: a highly nonlinear jump in the activation (so-called phase transition) and a linear behaviour.

The project mainly focusses on the nonlinear jump to finally rule it out or support it. A subsequent comparison to previous experimenta results aims to fit the physiological parameters. Since the cortex population is embedded into a network of other cortical areas and the thalamus, the corresponding analytical investigations takes into account external stochastic (from other brain areas) and time-periodic (thalamic) forces. To this end it is necessary to develop several novel nonlinear analysis technique of neural populations to derive the power spectrum close to the phase transition and conditions for physiological parameters.

7.3.1.2. 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 Initiatives

7.4.1. INRIA Associate Teams

7.4.1.1. Cortina, associate team with Chile

Participants: Frédéric Alexandre, Thierry Viéville, Laurent Bougrain.

The goal of this associate team 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 spike trains from the retina neural network, an accessible part of the brain, is a difficult task that our partnership can address, what constitute an excellent and unique opportunity to work together sharing our experience and to focus in developing computational tools for methodological innovations.

7.4.2. Visits of International Scientists

7.4.2.1. Internships

NOUHA BOUJELBEN (from Feb 2011 until Jul 2011)

Subject: Information Reduction in the Brain

Institution: Ecole Nationale d'Ingénieurs de Sfax (Tunisia)

Juan Ignacio PORTA (from Mar 2011 until Jul 2011)

Subject: Randomly spiking neural fields

Institution: Universidad Nacional de Rosario (Argentina)

Mouid KESKES (from Feb 2011 until Jul 2011)

Subject: Modeling early vision with artificial neural networks

Institution: Ecole Nationale d'Ingénieurs de Tunis (Tunisia)

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

Participants: Frédéric Alexandre, Thierry Viéville.

This project gathers chilean partners (U de Valparaiso and U Federico Santa-Maria) to french computational neuroscientist (CORTEX and NEUROMATHCOMP EPI). Recording and modeling 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?

8. Dissemination

8.1. Animation of the scientific community

8.1.1. Responsabilities

- Principal Investigator of MATHANA (A. Hutt)
- Member of the Board of Directors in Organization of Computation Neuroscience (A. Hutt)
- Member of the steering committee of the french association for Artificial Intelligence (AFIA) (F. Alexandre)
- Member of the board of directors of the LORIA laboratory (B. Girau).
- Head of the Complex systems and AI department of the LORIA laboratory (B. Girau)
- Member of the scientific culture commission (N. Rougier)
- Elected member of the laboratory council (N. Rougier)
- 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 Neuro-Comp, the initiative to gather the french community in Computational Neuroscience (annual conference and web site: http://www.neurocomp.fr/).

8.1.2. Review activities

- Reviewing for journals: Applied Intelligence, RIA, J. Physiol. (F. Alexandre), Physica A, Physical Review E, Physical Review Letters, Neuroimage, Cognitive Neurodynamics, J. Biological Physics, Mathematical Neuroscience, Philosophical Transactions of the Royal Society A (A. Hutt)
- Member of program committees: International Workshop on Dynamical Olfaction (D. Martinez), TAIMA (F. Alexandre)
- Reviewing (A. Hutt) for the NWO (Science Foundation Netherlands), the ANR and several french regional and territorial agencies (F. Alexandre)

8.1.3. Workshops, conferences and seminars

- Organization of the Neurocomp11 autumn school on Brain-Computer-Interfaces (L. Bougrain responsible; F. Alexandre member of the organizing committee)
- Invited talks: [17], [18]
- Seminars: talk for Cognitive Science Pole in Grenoble (F. Alexandre)

We also have a strong activity for popularization of science:

- The other half-time of Thierry Viéville’s activity is dedicated to popularization of science (http://science-info-lycee.fr, http://www.culture-science-paca.org, http://interstices.info, http://www.fuscia.info) with about 10 conferences and 20 days of scientific animation.
- Participation to a “café des sciences” about brain-computer-interfaces (F. Alexandre)
- 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).

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

Many courses are 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.

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