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Project-Team CORTEX

Neuromimetic Intelligence

Lorraine

THEME COG

Activity Report

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1. Team

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2. Overall Objectives

2.1. Overall Objectives

The goal of our research is to study the properties and capacities of distributed, numerical and adaptive automated information processing and to show that that kind of processing may allow to build "intelligent" systems, i.e. able to extract knowledge from data and to manipulate that knowledge to solve problems. More precisely, these studies rely on the elaboration and analysis of neuromimetic connectionist models (*cf.* § 3.1), developed along two sources of inspiration, computational neuroscience and machine learning.

Both sources of inspiration are studied together because they are interested in better understanding how such distributed models can learn internal representations, and manipulate knowledge and both propose complementary approaches allowing cross-fertilization. Machine learning proposes connectionist numerical models for information processing in a statistical framework, to extract knowledge from data (*cf.* § 3.2). Computational neuroscience proposes distributed theoretical models and elementary mechanisms that aim at explaining how the human or animal nervous system processes information at various levels, from neuronal mechanisms (*cf.* § 3.4) to behaviour (*cf.* § 3.3).

Complementarily to our multidisciplinary domains of inspiration, our research is applied in domains like data and signal interpretation, intelligent sensors, robotics, and computer-aided decision. More generally, our models are dedicated to monitoring complex, multimodal processes, perceiving and acting on their environment (*cf.* § 4.1).

These models are firstly implemented on classical computers, but other architectures are also explored, namely parallel machines, autonomous robots, and more generally specialized circuits for embedded systems, as suggested by our applications (*cf.* § 3.5).

Accordingly, four topics of research are currently carried out. (i) In computational neuroscience, at a behavioral level, we are developing models of cerebral neuronal structures (*cf.* § 6.1), to allow the navigation of autonomous robots. (ii) In computational neuroscience, at the neuronal level, we are modeling spiking neurons (*cf.* § 6.2), seen as dynamic systems with temporal behavior, allowing synchronization within populations of neurons. (iii) From a more statistical point of view, we are studying how classical continuous neuronal models can be adapted to database and signal interpretation, for knowledge extraction (*cf.* § 6.3). (iv) From a more technological point of view, all the above-mentioned models are adapted to allow implementations on dedicated architectures (*cf.* § 6.4).

3. Scientific Foundations

3.1. Connectionism

Keywords: *artificial neural network*, *connectionism*, *multi-layer perceptron*, *perceptron*, *self-organizing map*.

Connectionism can be defined as the study of graphs of simple interconnected units, performing elementary numerical computations, derived from their input and internal parameters. In particular, neuro-inspired connectionism is interested in artificial neural networks, like perceptrons or self-organizing maps. These models have been thoroughly studied in the domain of machine learning for their properties of learning and approximation and their links with other statistical tools.

Artificial neural networks have been successfully applied to a variety of tasks (pattern matching, prediction, control) in a variety of domains (signal processing, industrial processes, medicine). Beyond computing statistics on databases from such domains, one can also wonder about using such capabilities on databases including an important temporal dimension and on more cognitive tasks like interpretation and knowledge extraction. Both characteristics are not classical properties of artificial neural networks, but are fundamental from an expertise point of view. Current research aims at extending their capabilities to these tasks (*cf.* § 3.2).

Other connectionist approaches aim at going back to the basis of connectionism and look for a tighter inspiration from neuroscience. The inspiration can be local and look for more realistic models of neuronal functioning and particularly of its dynamical aspect (*cf.* § 3.4). It can be global with the goal of implementing tasks related to the modeling of integrated behavior (*cf.* § 3.3). Both biologically inspired approaches are refered to as computational neuroscience. They are multidisciplinary and aim at a better understanding of brain function (biological aspect) and of neuronal computation, seen as a new paradigm of computation (computer science aspect).

Another important issue in connectionism is to take benefit from the parallel distributed nature of its computation and to develop implementations that exploit those characteristics. As such implementations lead to cope with the real nature of neural computation, they may improve the performance of algorithms and be embedded in electronic devices (*cf.* § 3.5).

3.2. Intelligent information processing

Keywords: *data analysis*, *knowledge extraction*, *neuro-symbolic integration*, *pre-processing*, *visualization*.

Artificial neural networks are information processing systems that can be widely applied to data mining. They have a lot of capabilities for analyzing and pre-processing data, as well as visualizing and extracting knowledge. These capabilities can be developed through unsupervised and supervised networks or by combining them to obtain data analysis and forecasting models close to the ones performed by statistical methods but with other interesting properties.

To improve the performance of such information processing systems, several approaches can be followed depending of the prior knowledge available. Indeed, depending on additional labels (class or continuous value) which can be used (or available) on none of the patterns, on a subset of the patterns or on all of them, unsupervised or supervised learning can be sequentially performed. When there is no prior knowledge on the problem to be solved, knowledge extraction may use an unsupervised neural network as a front-end for forecasting applications or extracting rules. Because of its synthesis capabilities, an unsupervised neural network can be used both for limiting the computation complexity and for extracting the most significant knowledge. Moreover, knowledge extraction is facilitated as soon as multi-viewpoint unsupervised neural network model is used. This kind of methods also allows using in a second step additional information when it is available for optimizing a forecasting problem. However, for a forecasting problem where all patterns are labelled, classical networks using supervised learning can be successfully improved by finding the minimal architecture using pruning algorithms. The pruning methods consist in removing, during learning, the connections or neurons, or both, that have the least influence on the system's performance. Reducing the complexity of the networks prevents overtraining and allows easier implementation and knowledge extraction (variable selection, rule extraction). In any case, combining several models into a committee helps to improve the quality of the knowledge extracted or the forecasting and the proposed methods must be efficient for typical real-world in our domain, dealing with large amount of noisy and temporal data. Both topics are recently developed in the project.

Whenever they can be associated to such information processing techniques, new visualization techniques represent high added value as soon as their original processing results are mostly represented in high dimensional space.

3.3. Computational neuroscience: behavioral approach

Keywords: *behavioral model*, *computational neuroscience*, *cortical column*, *cortical model*, *population of neurons*.

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 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 of the complex relations between the structural and the functional level of the brain thanks to realistic models. Furthermore, these computational models and methods have strong implications for other sciences (e.g. psychology, biology) and applications (e.g. robots, cognitive prosthesis) as well.

Our research activities in the domain of computational neurosciences are centered around 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 provides the theoretical framework to design models of population of neurons.

The main cognitive tasks we are currently interested in are related to the autonomous navigation of a robot in an unknown environment (perception, sensorimotor 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 goal 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. Computational neuroscience: spiking neurons

Keywords: *computational neuroscience*, *neural code*, *olfaction*, *spiking neurons*, *synchronization of activity*.

Computational neuroscience is also interested in having more precise and realistic models of the neuron and especially of its dynamics. Compartmental models describe the neuron through various compartments (axon, synapse, cellular body) and coupled differential equations. Such models describe the activity of real neurons to a high degree of accuracy. However, because of their complexity, these models are difficult to understand and to analyze. For this reason our work focuses on the use of simplified models, i.e. simple phenomenological models of spiking neurons, that try to capture the dynamic behavior of the neuron in leaky integrators that explain how spikes can be emitted through time from input integration.

These models are interesting for several reasons. From a neuroscience point of view, they allow a better understanding of neuronal functioning. Indeed, although it is well known that real neurons communicate with spikes, i.e. a short electrical pulse also called action potential, the precise nature of the neural code is a topic of intense debate. The firing-rate coding hypothesis stating that the firing frequency of a neuron estimated by temporal averaging encodes information is now challenged by a number of recent studies showing that precise spike timing is a significant element in neural encoding. In particular, stimulus-induced synchronization and oscillatory patterning of spike trains have been experimentally observed in perceptive systems like in vision or olfaction. Moreover, synchronization of neural activities seems to play a role in olfactory perception; for example, when the synchronization is pharmacologically abolished, honeybees do not discriminate anymore between similar odors.

From a computer science point of view, we investigate the spatio-temporal dynamics of simplified models of spiking networks using both mathematical analysis and numerical simulations. Therefore, we have to define (i) a tractable mathematical analysis with methods coming from the theory of nonlinear dynamical systems and (ii) an efficient computing scheme with either event-driven or time-driven simulation engines. These models can also be applied to difficult coding tasks for machine perception like vision and olfaction, and can help to understand how sensory information is encoded and processed by biological neural networks.

3.5. Connectionist parallelism

Keywords: *FPGA*, *connectionism*, *digital circuits*, *parallelism*.

Connectionist models, such as neural networks, are 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 develop 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 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.

4. Application Domains

4.1. Overview

Keywords: *database interpretation*, *multidisciplinary applications*, *perception/action interaction*, *robotics*, *signal interpretation*.

Our connectionist models are applied to two kinds of tasks. From a machine learning point of view, the idea is to combine the statistical exploration of databases with knowledge extraction from these databases. From a computational neuroscience point of view, we are interested in modeling various aspects of intelligent behavior. Domains of application are thus very wide since they include domains where databases have to be structured and interpreted and domains where perception-action loops have to be elaborated from the exploration of an unknown world.

Beyond the good performances of the neuronal paradigm on these tasks, these applications are also interesting for several reasons. From an expertise point of view, they allow to extract knowledge from databases including geographical and geological data (*cf.* § 7.2), industrial data (*cf.* § 7.3), bibliographical data (*cf.* § 7.3) or EEG signals (*cf.* § 7.3).

From a technological point of view, they allow to define a methodology for using artificial neural networks (*cf.* § 5.) and they can lead to hardware implementation (*cf.* § 5.5). From a multidisciplinary point of view, they lead to projects (*cf.* § 7.2 and § 7.3) including partners from different domains and working together for a better understanding of the brain (neuroscientists, ethologists, physicians).

5. Software

5.1. Spiking neural networks simulation

Keywords: *event-driven simulator*, *spiking neurons*.

Participant: 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 using either (i) an event-driven approach or (ii) a time-driven approach. They are respectively more dedicated to the simulation of integrate-and-fire neurons or Hodgkin-Huxley neurons.

- The event-driven simulation engine was developed in C++ by O. Rochel during his PhD thesis. 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.
- The time-driven simulator engine called SIRENE was written in C and developed for the simulation of a model of the antennal lobe, the first structure of the insect olfactory system. This simulator engine can simulate any type of spiking neural network and is indeed more dedicated to 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). In the context of an application to large networks (*cf.* § 7.2), we have developed a graphical interface to visualize the spikes and the evolution of our networks.

5.2. Implementation of computational neuroscience mechanisms

Keywords: *computational neuroscience*.

Participants: Nicolas Rougier, Julien Vitay, Jérémy Fix, Zhor Ramdane-Cherif.

Most of our models are based on the Continuum Neural Field Theory (CNFT) which requires heavy processing power and memory since most interesting properties emerge from the interaction of many processing units. To cope with this problem we had to design efficient management of both CPU and memory together with an ease of use when designing simulations. The resulting software is core/plugin architecture where the core has been designed in C++ and the plugins in python which offers a very flexible way of manipulating models via scripts. For example, a user can view or modify any variables or objects using either a console or a graphical interface. Furthermore, a graphical display of the network has been designed using OpenGL that allows an easy debugging using visual 3D manipulations of the network. Finally, resulting models are running in real-time and can be used on the PeopleBot Robot to perform tasks such as target tracking or attention shifting among moving targets.

5.3. Decision-making platform

Keywords: *decision-making*.

Participants: Laurent Bougrain, Nizar Kerkeni, 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 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...)

5.4. MicroNOMAD-MultiSOM

Keywords: *documentary database*, *knowledge discovery*.

Participants: Shadi Al Shehabi, Jean-Charles Lamirel.

The MicroNOMAD-MultiSOM software mainly focuses on the automatic extraction and organization of knowledge that is embedded in documentary databases. The basic principle of this software is to provide users with interactive and interconnected cartographies of knowledge materializing several different syntheses of the content of a given documentary database. The underlying model of the MicroNOMAD-MultiSOM software represents an extension of Kohonen's SOM model to a multi-maps (i.e. multi-viewpoints) context. Due to the flexibility of this extension, the resulting maps can both play the role of elaborated browsing tools, data mining tools, as well as tools for assisting users in querying the documentary database. The model allows users to exploit dynamic exchange between the multiple viewpoints for highlighting correlations between the different views on the same data. It also permits the use of partial or incomplete descriptions of the data and accepts simultaneous representations of the same data with regard to different media.

The MicroNOMAD-MultiSOM software has been used on different operational applications of data mining. The versions 1 and 2 of this software have been patented by INRIA. The version 3 offers numerous extensions for analyzing non structured data as well as numerous functions for the automation of analysis.

5.5. Neural network synthesis on FPGA

Keywords: *FPGA*, *digital circuits*, *parallelism*.

Participant: Bernard Girau.

To date the majority of neural network implementations have been in software. Despite their generally recognised performances, the high cost of developing ASICs (Application Specific Integrated Circuits) has meant that only a small number of hardware neural-computing devices has gone beyond the research-prototype stage in the past. With the appearance of large, dense, highly parallel FPGA circuits, it has now become possible to realize large-scale neural networks in hardware, with the flexibility and low cost of software implementations.

Though easier than ASIC development, implementations on FPGAs still require a significant amount of work, especially for connectionists who are not very familiar with such tools as the VHDL language, synthesis tools, etc. Therefore, we have initiated a software project that aims at developing a generic methodology to fully automatically specify, parametrize and implement neural networks according to various application and technological constraints (e.g. area of targeted FPGAs, required precision, etc).

This project implies that we handle very different aspects: numerous different technological choices to fit the implementation constraints, genericity and modularity of solutions, precise analysis of the relations between application data, device specifications, and performances, for each valid technological solution.

This work has led to a software platform that handles both FPGA boards and neural implementations. Multilayer neural networks and graphically designed networks of neurons are automatically "compiled" onto FPGA by this tool. Communications between the FPGA, the host and the memory slots are also taken into account. The second version of this software has been developed this year. Major changes have been made in the graphical user interface, in the memory management and dialog with the FPGA board, and in the test benches and results generation. The software now fully implements a functional chain from the creation of a network to the visualisation of results produced in the board. Moreover, part of the software has been dedicated to vision applications, with specific data management. Numerous technological solutions still have to be included, as well as advanced neural mapping methods. Current efforts focus on extensions to recurrent networks, spiking networks [27], as well as on precision study and serial arithmetics.

6. New Results

6.1. Behavioral computational neuroscience

Participants: Frédéric Alexandre, Yann Boniface, Laurent Bougrain, Jérémy Fix, Hervé Frezza-Buet, Bernard Girau, Thomas Girod, Olivier Ménard, Zhor Ramdane-Cherif, Nicolas Rougier, Julien Vitay, Thomas Voegtlin.

The works reported this year are mostly concerned with modeling several parts of the visual path in the cortex, from the most elementary to the most integrated (motion detection, attention and active vision, anticipation) and also with the better understanding of the computational paradigms we use to model populations of neurons. We have tried to extend their use and relate them to a solid mathematical formalism [16]. We have also explored ways to reconciliate models using the frequency rate code at the level of the population of neurons, with our spiking models.

6.1.1. Motion detection

Visual perception of motion is a major challenge in machine perception research, since it constitutes an important parameter in a wide variety of tasks such as path-finding, estimation of time to collision, perception of gestures, movement control, etc.

We have developed a bio-inspired neural architecture to detect, extract and segment the direction and speed components of the optical flow within sequences of images. The structure of this model derives directly from the course of the optical flow in the human brain. It begins in the retina and receives various treatments at every stage of its magnocellular pathway through the thalamus and the cortex.

We have mainly focused on two fundamental problems in the treatment of a sequence of images. Firstly, the computation of their optical flow (a three-stage process: pre-processing based on filters, extraction of elementary characteristics and integration into a 2D optical flow), and secondly, the extraction of several moving objects in a scene with some possible egomotion. This work faces many concrete difficulties, such as specular effects, shadowing, texturing, occlusion and aperture problems. Moreover, the complexity of this task must be dealt with within the implementation constraint of real-time processing.

Our model mostly handles the properties of three cortical areas called V1, MT (middle temporal), and MST (middle superior temporal): the MT area detects patterns of movement, while spatio-temporal integration is made at the local level by V1 and at the global level by both MT and MST, so that a multi-level detection and integration may discriminate egomotion from movements of objects in a scene and from the scene itself.

Recent works have focused on the hardware implementation of the spatio-temporal estimations of local movements and of the bio-inspired inhibitory/excitatory mechanism that induces local competitions between antagonistic movements so as to make coherent moving areas appear.

Current works aim at introducing strong feedback interactions between the different layers of this architecture, as they exist between the different involved cortical areas. Such interactions may improve the coherence of the local motions that interact in the model, and they may lead to the detection of specific motions.

6.1.2. Attention and active vision

In the domain of robotic, modeling perceptive and executive attention is a critical feature given the limited computational power available on mobile devices. More specifically, it allows to recruit the vast majority of available resources for processing of a given location of the considered space (either perceptive or motor) in order to process it finely while the remaining resources are allocated for a broader processing of the remaining space. We have been exploring the perceptive attentional paradigm in for the visual space.

Based on the Continuum Neural Field Theory (CNFT), we have first designed a simple model in order to study properties of that theory (*cf.* § 5.2). We have been able to show that such a simple model implement a very rudimentary form of attention that is an emergent property of the model. More specifically, we numerically demonstrated that such a model is very resistant to both noise and distractors and is able to bypass the saliency hierarchy by attending any stimulus of the visual scene, independently of its intrinsic saliency.

We then further refined this model to be able to switch "at will" using a more complex and biologically inspired architecture that allows to memorize visited stimulus. Visited stimuli are possibly moving within the visual field and the model has to keep track of them. This has been done using a dynamic working memory based on a reverbatory loop. Finally, the model has been implemented on a real robot (PeopleBot) to track three identical targets. The challenge was to be able to look at them successively without looking twice at the same target. From experiments we conducted, the model is very reliable and also very resistant to both noise and distractors. This model [5] has been developed as a first step toward active vision where saccadic eye movements are considered to be a part of the recognition process.

We further developed these ideas and designed a model able to build a motor representation of its environment by actively memorizing what saccades would be necessary to reach any object that has been focused in the past. This allows for example to efficiently scan a given scene in order to find a given object. This has been implemented both as a simulation and on the real robot.

6.1.3. Anticipation

Anticipation is known to be largely based on unconscious mechanisms that provide us with a feeling of stability while the whole retina is submerged by different information at each saccade : producing a saccade results in a complete change in the visual perception of the outer world. If a system is unable to anticipate its own saccadic movements, it cannot pretend to obtain a coherent view of the world: each image would be totally uncorrelated from the others. One stimulus being at one location before a saccade could not be identified easily as being the same stimulus at another location after the saccade. Anticipation is then critical in establishing a coherent view of the environment. Using the same theoritical framework as in the previous section, we have investigated some visual anticipation mechanisms and designed a computational model that rely on those mechanisms to efficiently scan a visual scene with saccadic movements. The model [24] is based on three distinct mechanisms. The first one is a competition mechanism that involves potential targets represented in a saliency map and previously computed according to visual input. Second, to be able to focus only once on each stimulus, the locations of the scanned targets are stored in a memory map using retinotopic coordinates. Finally, since we are considering overt attention, the model is required to produce a camera movement, centering the target onto the fovea, in order to update the working memory. This third mechanism works in conjunction with two inputs: current memory and parameters of the next saccade. This allows the model to compute quite accurately a prediction of the future state of the visual space, restricted to the targets that have been already memorized.

6.1.4. From spikes to frequency

The Continuum Neural Field Theory as it has been introduced in the above sections is mainly concerned with the functional modeling of neural structures at the level of the population. At the level of a single neuron, the model that is used is a mean frequency model where the electrical activity of a neuron is approximated by a single potential. However, there also exist several spiking neuron models that represent both a finer and more accurate model of a real biological neuron. In the framework of the CNFT, they allow to bypass the inherent time discretization implicitely brought by mean frequency models. This section presents the work that has been engaged in this direction and tries to bridge the gap between these two different levels of description.

Based on previous works, we developed a model of visual attention using spiking neurons with several objectives:

- A 'fine grain' validation, closer to our biological inspiration, from numerical models, with spiking communication between neurons.
- A study of the dynamics and properties of the CNFT at continuous time.
- A study and a validation of the functional properties of a temporal coding of the CNFT.
- The study and the design of the emergence of functional properties from populations of networks of spiking neurons.
- The study, definition and representation of the concept of a network activity within a population of spiking neurons.

Those studies allowed in a first time to design a model that is able to reproduce functional properties and dynamic of the numerical and 'discrete time' equivalent network. But, beyond the scope of the Continuum Neural Field Theory, these works underline the necessity to thoroughly study the temporal coding of the information flow and to study the dynamic of such functional spiking neurons networks. The next step in this work is then to study the learning of the emergence of functional properties with a temporally coding neural network, using for example learning methods such as the STDP (Spike-Timing Dependent Plasticity).

6.1.5. Propagation in neural networks

The dynamics of pattern formation in lateral-inhibition type neural fields with global inhibition has been extensively studied in a number of works where it has been demonstrated that these kinds of fields are able to maintain a localized packet of neuronal activity that can for example represent the current state of an agent in a continuous space or reflect some sensory input feeding the field. Such networks most generally use excitatory recurrent collateral connections between the neurons as a function of the distance between them and global inhibition is used to ensure the uniqueness of the bubble of activity within the field. We designed a model [11] that performs global competition (leading to the creation of a unique bubble of activity) by only using local excitation and inhibition without the use of any supervisor or central executive. This is made possible by using a diffusion of the inhibition throughout the network. This locality yields several advantages. First, in terms of pure computational power, it is far more quicker to have a few local interactions when computing activity within the network. Second, having real local and distributed computing makes the model a real candidate for parallelization.

6.2. Spiking neurons

Participants: Yann Boniface, Dominique Martinez, Noelia Montejo-Cervera, Arnaud Tonnelier, Thomas Voegtlin.

Our research in fine grain computational neuroscience (*cf.* § 3.4) is performed at different structural scales: the cellular, the circuit and the systems levels. We investigate how information is processed at these different levels and we aim at elucidating the link from cellular functions to cognitive functions.

6.2.1. Time Coding using Neuronal Response Properties

The temporal coding hypothesis states that information is encoded in the precise timing of action potentials sent by neurons. In realistic neuron models, the timing of a spike depends on the timing of synaptic currents, in a way that is classically described by the Phase Response Curve. This has implications for temporal coding: an action potential that arrives on a synapse has an implicit meaning, that depends on the position of the postsynaptic neuron on the firing cycle.

We have developed a new theory of time coding, that uses this implicit neural code, in order to perform computations. This theory takes advantage of the fact that the effect of synaptic currents depends on the internal state of the post-synaptic neuron. We have shown that it is possible to train artificial neural networks using this principle.

For that, we proposed several biologically plausible learning rules, that are variants of Spike Timing Dependent Plasticity (STDP). More precisely, we investigated how STDP can be used to achieve minimization of an error criterion, using three possible mechanisms :

- spike prediction : Neurons learn to predict spike times, ie to spike at desired times.
- spike cancellation : Synaptic efficacies are optimized so that an input stimulus (excitation) and its prediction (inhibition) arrive at the same time, so that the neuron does not spike at all if its input is correctly predicted.
- phase cancellation : Neurons receive an external input (excitation) and a prediction of the input (inhibition). Synaptic efficacies are optimized so that neurons of a population learn to spike in synchrony, even though their external input taken alone would have the effect of desynchronizing them. Resynchronization is performed through inhibition; in this sense, the inhibitory cells learn to cancel the phase of excitatory cells.

This work is being pursued in collaboration with Samuel McKennoch, a graduate student at the Washington University in Seattle.

6.2.2. Neural synchronization, Network oscillation and Traveling waves

Neural synchronization, network oscillation and traveling waves are very often observed in recorded brain activity. They seem to play an important role in the coding of sensory information by providing a *clock* or temporal frame of reference for the encoding neurons. In the hippocampus of rats for example, place cells exhibit phase-dependent firing activity relative to the EEG theta oscillation. In the olfactory system, projection neurons are phase-locked to the network oscillation.

Role of inhibition in shaping oscillatory synchronization

Several experimental and modeling studies have shown that inhibitory feedback shapes oscillatory synchronization. These studies however have focused on macroscopic network properties, such as the emergence of oscillations and global synchronization, and did not consider the fact that some neurons exhibit phase-locked activity while others do not. How does the received inhibition affect the probability of individual neurons to be phase-locked to the simultaneously recorded field potential? We have developed several models to understand the role of inhibition in early olfactory systems.

Local field potentials recorded in the rat olfactory bulb exhibit oscillations with a frequency that changes from one band to another. Network models of inhibitory coupled neurons fail to explain how oscillations may be generated in different frequency bands. In [13], we studied the effect of synchronous versus asynchronous inhibition in a simplified model of the olfactory bulb. We observed that frequency and synchronization are reduced when release is asynchronous; the standard deviation of activity bursts increases linearly, while their period increases in a sublinear way. A mathematical analysis supports these observations. Therefore, not only the time constant of the inhibition, but also its mode of release could play an important role in setting up the oscillatory frequency. The switch from gamma to beta frequencies might result from a change from asynchronous to synchronous release caused by feedback from the olfactory cortex.

GABAergic inhibition via local interneurons plays a role in enhancing spike timing precision in principal cells, since it tends to eliminate the influence of initial conditions. However, both the number and the timing of inhibitory synaptic events may be variable across repeated trials. How does this variability affect the spike timing precision in principal neurons? In [18], we have derived an analytical expression for the spike output jitter as a function of the variability of the received inhibition. This study predicts that variable inhibition is especially tolerated as the number of inhibitory cells is large and the decay time constant of the GABAergic synapse is small. Unlike fast inhibition, slow inhibition is not robust to a variability in the number of received inhibitory events. This suggests that complementary pieces of information may be conveyed, in the precise timing of neurons receiving fast inhibition and in the firing rate of neurons receiving slow inhibition.

We have developed, simulated and analyzed simplified models of early olfactory structures. This work allows us a better understanding of the role of inhibition in shaping oscillatory synchronization. It also provides insights for designing bio-inspired algorithms applicable for data analysis in electronic noses and on-board implementation on olfactory robots [10].

Traveling waves in spiking neural network

We have studied an homogeneous network of spiking neurons that supports two types of discharge propagation : continuous and complex waves. Complex waves have a spatio-temporal periodicity and are similar to the lurching pulses observed in the continuum approximation of neural network. Our approach opens up the way for further studies of lurching propagation from a mathematical perspective.

6.2.3. Numerical simulation of spiking neurons

Two strategies have been used for the simulation of integrate-and-fire neural networks: time-stepping methods that approximate the membrane voltage of neurons on a discretized time and event-driven schemes where the timings of spikes are calculated exactly (*cf.* § 5.1). By definition time-stepping approximations are imprecise and it has been shown that time steps have to be chosen correctly to reproduce the synchronization properties of networks of spiking neurons. Event-driven strategies have been used to simulate exactly spiking neural networks. Previous works are limited to linear integrate-and-fire neurons. We have extended event driven schemes to a class of nonlinear integrate-and-fire models [12]. Results are obtained for the quadratic integrate-and-fire model with instantaneous or exponential synaptic currents. Extensions to conductance-based currents and exponential integrate-and-fire neurons are presented.

6.3. Data exploitation and interpretation

Participants: Frédéric Alexandre, Shadi Al Shehabi, Mohammed Attik, Laurent Bougrain, Randa Kassab, Nizar Kerkeni, Jean-Charles Lamirel, Georges Schutz, Marie Tonnelier.

This research aims at adapting classical models of connectionism (*cf.* § 3.1) to extend their use to data interpretation and knowledge extraction (*cf.* § 3.2). As we exposed, to improve the performance of neural information processing systems, several approaches can be followed depending of the prior knowledge available. They can be gathered into supervised and unsupervised learning. Another way to improve the performance is to set up collaborative approaches such as neuro-symbolic systems or committee machines.

6.3.1. Supervised models

Novelty detection The main objective of novelty detection is to emphasize the novelty in yet unseen data with respect to previously learned ones. We have achieved successful development of this approach in filtering context. In this context, we have applied the novelty detection principle in a reverse way, i.e. the data that are similar to a model learned from positive examples will be selected. The specific novelty detector filter (NDF) we have developed for such task has been recently tested in large text multi-labelled collection, like reuters-10 collection [29], [30]. Our experiments have proven that this new model can outperform other recent approaches, like SVM, for text filtering tasks. Moreover, they have proven that one of the main advantages of the NDF model is its ability to accurately build up an overall data profile and to evaluate, in a parallel way, the coherency of this profile. Thanks to an online learning algorithm, the NDF model is also able to track overall changes in the data profile over time. We have recently illustrated these useful capabilities through an original experiment of dynamic filtering threshold adaptation performed on reuters-10 and reuters-90 collection. In a near future, we plan to more specifically focus on the novelty detection capability of the NDF and on its capabilities of combination with other filtering techniques, like collaborative filtering. We will also extend the scope of our technique to a larger panel of data type, like biological data, as well as to the management of different kind of temporal data.

6.3.2. Unsupervised models

Knowledge extraction The unsupervised neural models which are used in the MVDA (Multi Viewpoint Data Analysis) paradigm can be used both for efficient mining rules and for extracting more specific kinds of knowledge. In the rule extraction task, the generalization mechanism can be specifically used for controlling the number of extracted association rules. The intercommunication mechanism will be useful for highlighting association rules figuring out relationships between topics belonging to different viewpoints. The closed property sets and the generators represent specific subsets of the global set of data properties. The closed property sets are the properties sets that maximize the information carried on the dataset and the generators are the properties sets that minimize it. It has been formerly shown that these two kinds of itemsets can be used for extracting the class of informative association rules, i.e. the rules with minimal premises (generators) and maximal consequences (closed itemsets). We have recently proposed a new approach for extracting this class of rules. This cluster-based approach that partly relies on the PASCAL algorithm does not make any use of additional core dataset information. It has been proven in [22] that it significantly outperforms reference methods, like the Zart method, especially in the case of very sparse multidimensional data.

Visualization techniques for data analysis Any task of interpretation of the results of a data analysis method, as well as those of a data mining method, requires powerful and interactive methods of visualization. We developed this year a specific method of hyperbolic visualization. This method combines an original algorithm of hierarchical classification, based on the density, with a mechanism of visualization by hyperbolic trees [14]. In our case, it is specifically exploited for the visualization of the results of the NG/GNG (Neural Gas/Growing Neural Gas) methods. Its main advantage is to suppress the cognitive overload of the classical graph-based or mapping methods while preserving the information about the original data density and its topology in the description space. Moreover, it allows an easy visual characterization of outliers. This method is also directly applicable on rough data.

Temporal self-organization First, we have pursued our work of combination of classical SOM (Self Organization Map) with Dynamic Time Warping adapted algorithms for industrial as well as medical temporal signal (*cf.* § 7.3) and we have obtained interesting ways to extract knowledge and forecast temporal series [4], [31]. Second, we have worked on spatiotemporal biologically inspired models for the preprocessing and learning of temporal signals. These algorithms and encoding approaches are based on SOM (Self Organization Map) trained using two algorithms: ST-Kohonen and TOM [41] using respectively the complex and temporal approaches for processing and coding the spatio-temporal structure inherent to signals. The first takes its root on the work of the neurobiologist Rall; it codes the input using the complex domain and offers static and dynamic ways to represent temporal and spatial information together. The second, based on neurobiological experimental results, uses an Inter Stimulus Interval coding, involved in many behavioral tasks.

These algorithms were used for speaker-independent speech recognition of isolated digit [35], [34]. The obtained results show that ST-Kohonen with dynamic encoding of inputs performs better than ST-Kohonen with static encoding at the level of model architecture, number of inputs, speech recognition rate and number of epochs. However, better recognition rate is obtained with TOM algorithm which means that the dynamic map offers better spatiotemporal classification than a dynamic input encoding.

6.3.3. Neuro-Symbolic systems

[1] is an important step to generalize our former neuro-symbolic approaches in a global paradigm of neuro-symbolic information processing. The Multi Viewpoint Data Analysis (MVDA) paradigm covers two complementary fields, namely the data analysis itself and the data mining. Its main advantage is to be usable to analyze the information issued from different kinds of data as well as from different kinds of descriptions of the same data and to be especially efficient on high dimensional and sparse data. Moreover, even if it has

been specifically experienced with topographic neural methods using documentary data, the MDVA paradigm is theoretically applicable to all kinds of clustering methods using all kinds of data. As we have demonstrated the superiority of the NG method for the analysis of high dimensional and sparse data, we give priority to this method in the paradigm. The MVDA paradigm makes extensive use of specific symbolic criteria of Recall and Precision for clustering evaluation. We have formerly demonstrated that if both values of Recall and Precision criteria reach the unity value for a clustering model, the set of clusters represents a Galois lattice. Basic mechanisms associated to the MVDA paradigm could be used to perform dynamic and/or interactive data analysis. The mechanism of cascading online generalization can be applied to the optimal model associated to each point of view. This mechanism makes it possible to operate the choices of the focus of the analysis at the time of the exploitation of the results. These choices can take place dynamically because the generalization mechanism is compatible with the inter-topographies communication mechanism. The generalization mechanism can also be used for the selection of the rules extracted during the data mining phase [32]. The mechanism of comparison of views is a powerful mechanism that makes it possible to dynamically perform overall comparison between different data analyses, and this on a large scale. The comparison level can be tuned with the generalization mechanism. Comparison of views has proven to be efficient for solving yet unsolved data analysis problems involving posterior hybridization between multiple results.

6.3.4. Committee machines and techniques

Personal File Consolidation (PFC) The PFC approach is related to the automatic and dynamic construction of consolidated thematic text folders. The construction of such folders uses several stages: seek the most significant documents starting from a keywords-based query, dynamic classification of the result of the query by using several classifiers with differentiated behaviours, like neural and symbolic classifiers, combination of the results of these classifiers, and finally, personalization of the organization by introducing users' choices. In the PFC model a statistical evaluation of the parameters used by the classifiers made it possible to measure their interest and especially their incidences on the final constitution of the thematic clusters. In addition of the users, other operators of the broader type: groups or communities can interact with the system to enrich it. A pilot application of the PFC model has been developed this year [17].

The cluster label analysis problem is a specific kind of committee problem. It consists in defining labels that could optimally represent the cluster contents and/or to highlight specific knowledge related to this cluster contents. It is known as a very difficult and very open problem. The CADML methodology represents a new cluster labeling and contents mining strategy [19], [20]. One of its main originalities is to enable managing different kinds of labels that represent either data properties that have been used during the clustering phase (endogenous properties), or additional data properties that are external to this phase (exogenous properties). The CAMDL methodology uses specific criteria of Entropy on cluster members' properties. It represents an extension of the Recall and Precision criteria towards the probability theory. The entropy criteria have also been proven to be operational for the control of model learning.

Feature selection in ensembles of neural networks We have also worked in the area of variable selection in ensembles of classifiers within the framework of supervised learning for classification problems. Variable selection techniques aim at removing irrelevant or redundant variables that deteriorate the potential good performance of classifiers. An ensemble consists of a set of learners trained on the same task that joined together provide a sole solution for the classification (or regression) problem. In the last years there has been evidence that ensembles may achieve higher accuracy than single models. Building an ensemble involves two tasks, namely constructing the members of the ensemble (base classifiers) and integrating them together. Several techniques for each of these tasks already exist. Feature selection has been used in the context of ensembles of learners to produce diverse members.

Some works merging together feature selection and ensembles of classifiers already exist that involve various kind of learners like decision trees, simple Bayes classifiers, k-nearest neighbors and neural networks. A new algorithm for feature selection in ensembles of neural networks was defined and implemented within the Weka world wide used environment. More precisely, we adapt a method for ensemble feature selection proposed by Tsymbal et al. for Naive Bayes Classifiers. The method focuses mainly on: the creation of the members of the ensemble of neural networks on different variable subsets and it follows the idea of firstly selecting an initial random subset of variables for each base neural network; and, performing a further refinement of the members by exploring adjacent points of the initial subsets of variables and ideally finding better subsets.

We considered classification problems with low number of variables (less than thirty). A measure of diversity is selected based on previous results obtained from Tsymbal et al. and Kuncheva and Whitaker. We applied it on binary classification problems in medicine already used as benchmarks by others approches and which present a great disproportion of classes. First experimentations show an improvement of the performance. Doing the refinement cycle using diversity is better than not.

Moreover, two novel approaches for feature selection in order to select a subset with relevant features were proposed. These approaches can be considered as a direct extension of the ensemble feature selection approach. The first one deals with identifying relevant features by using a single feature selection method. While, the second one uses different feature selection methods in order to identify more correctly the relevant features. We have illustrated the effectiveness of the proposed methods on artificial databases where we have a priori the informations about the relevant features [2].

6.4. Hardware implementations

Participants: Khaled Ben Khalifa, Bernard Girau.

Three main axes appear in our study of connectionist parallelism in conjunction with reconfigurable digital hardware : new hardware-adapted frameworks of neural computation, dedicated embeddable implementations, and automatic neural synthesis on FPGAs.

Many neural implementations on FPGAs handle simplified neural computations. Furthermore, many efficient implementation methods (on ASICs, neuro-computers, etc) have to limit themselves to few well-fitted neural architectures. An upstream work is preferable: neural computation paradigms may be defined to counterbalance the main implementation problems, and the use of such paradigms naturally leads to neural models that are more tolerant of hardware constraints. In this domain, our main contribution is the definition and application of the FPNA paradigm (Field Programmable Neural Array) : this hardware-adapted framework of neural computation leads to powerful neural architectures that are easy to map onto FPGAs, by means of a simplified topology and an original data exchange scheme. This work is now mature and current studies intend to include it both in the technological solutions that will be handled by our automatic neural synthesis tool (*cf.* § 5.5), and in embedded low-power implementations. Two works illustrate this evolution. We have used FPNAs to extend our works about embeddable vigilance detection to on-chip detection using mutlilayer networks in [26]. Moreover, several studies are carried out within our collaboration with the TIM project (Monastir), to more automatically generate FPNA from specified constraints (*cf.* § 7.3).

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. We both handle neural models that are still in a research process and neural networks that are applied to concrete problems. Recent works in this axis have mainly focused on implementations of spiking neural networks for image segmentation [27].

The third axis is the development of a generic synthesis tool to fully automatically specify, parameterize and implement neural networks on FPGAs. This work has been detailed in § 5.5. This tool mainly handles neural networks, but its design may cover other massively distributed models. As an example, a study of the embedded implementation of harmonic and optimal control for dynamic trajectory planning on FPGA has been started with researchers of the MAIA project-team.

7. Other Grants and Activities

7.1. Regional initiatives

7.1.1. Collaboration with INIST

Participants: Randa Kassab, Jean-Charles Lamirel, Shadi Al Shehabi.

The goal of this collaboration is to propose neural models for the creation of easily interpretable representations issued from very big documentary databases. The main characteristic of this problem is the sparseness of the description space (large set of descriptors, but only a small number of descriptors associated to each document. We are more specifically studying pre-processing, neural clustering, visualization and novelty detection techniques that can be applied on this specific kind of data [9].

7.1.2. *Action Teleoperation and Intelligent Assistants of the CPER*

Participants: Frédéric Alexandre, Hervé Frezza-Buet, Dominique Martinez, Nicolas Rougier, Julien Vitay.

In the framework of the Contrat de Plan État Région, we are contributing to the project Teleoperation and Intelligent Assistants, whose goal is to study systems for the monitoring of industrial processes. More specifically, our role is to develop a biologically inspired connectionist system for visual perception and to integrate it on an autonomous robot.

7.2. National initiatives

7.2.1. *Exploitation of Geographical Information Systems*

Participants: Frédéric Alexandre, Mohammed Attik, Laurent Bougrain.

Our collaboration with the BRGM (the french geological survey) intends to study how neural networks can be used efficiently in a practical problem of mineral exploration, where general domain knowledge alone is insufficient to satisfactorily model the potential controls on deposit formation using the available information in continent-scale information systems. The BRGM is interested by the understanding of the formation of ore deposits (precious and base metals) and the contribution to the exploration and discovery of new occurrences using artificial neural networks and specially artificial neural networks which are able to construct a revised model for knowledge extraction. We have applied our new algorithms (*cf.* § 6.3) on this problem.

7.2.2. *Ministry Grant "New analytic methodologies and sensors" SAWCapt*

Participant: Dominique Martinez.

Because of the simplicity and compactness of hardware implementation, spiking neurons are very appealing for addressing embedded systems for robotics or portable low-power smart sensors in vision or olfaction. The objective of the SAWCapt project is to develop a spiking neural network capable of solving the non-selectivity problem encountered in gas sensors and to consider its use for designing an electronic nose featuring small size and low cost of fabrication. This research project, in collaboration with the Laboratoire de Physique des Milieux Ionisés et Applications in Nancy, will develop and broaden knowledge in both software implementation of olfactory neuromorphic systems and pattern recognition algorithms as well as hardware implementation of smart sensing applied to an electronic nose.

7.2.3. *Ministry Grant Systèmes Complexes pour les Sciences Humaines et Sociales*

Participant: Arnaud Tonnelier.

Our studies in theoretical neuroscience address the dynamics at the cellular and network level. In order to investigate the related cognitive functions, we are interested in modeling the psychological processes and revealing the underlying neural substrate. The fundamental question of space and time dependencies is studied using a mathematical model. In this multidisciplinary project, in collaboration with M.D. Giraudo (MCF, UMR Mouvement et Perception) and V. Kostrubiec (MCF, Adaptation percepto-motrice et Apprentissage, Toulouse), we study in the model (i) the accuracy of the reponse and (ii) the dynamical properties of the variability observed over trials.

7.2.4. *Action de Recherche Coopérative RDNR*

Participants: Dominique Martinez, Arnaud Tonnelier.

This project focuses on network dynamics and non-smooth systems. We investigate the dynamical properties of networks coming from the modeling of spiking neural networks. We are mainly interested in the numerical simulations from non-smooth systems viewpoint (event driven, time stepping and hybrid computation methods). The theoretical part of this project is devoted to the understanding of emergent properties of these networks (synchronization, oscillations, traveling waves). (More information on the Web Page : http://www.inrialpes.fr/bipop/people/tonnelier/ArcRDNR.html)

7.2.5. Convention with the Museum of La Villette

Participant: Jean-Charles Lamirel.

This project deals with intelligent access to the collections of the museum, with the interest to multiply user's views on these collections and also to lead historians and administrators to discover unexpected links between the objects exposed in the collections. The central idea we apply for that goal is the coupling of two different classification methods for visualizing the collection of objects, for constructing viewpoints on these objects, for constructing object subsets with variable level of granularity, and lastly for highlighting correlation between some of the properties of the objects. This approach represents a collaboration between the Cortex team and the Orpailleur team who deals with the Galois lattice classification technique.

7.3. European initiatives

7.3.1. NoE GOSPEL

Participants: Maxime Ambard, Dominique Martinez.

GOSPEL (General Olfaction and Sensing Projects on a European Level) is a Network of Excellence (NoE) under funding of the European Commission in the 6th framework programme.

The aim of GOSPEL is to structure the European research in the field of Artificial Olfaction with the declared goal of establishing Europe as a world leader in this field. The leadership shouldn't be limited just to the scientific understanding, as it happened many times in the past, but expand into the technological development and commercial exploitation.

More information is available at http://www.gospel-network.org.

7.4. International cooperation

7.4.1. INRIA Associate Team BIOSENS

Participant: Dominique Martinez.

BIOSENS is a collaboration between the Cortex team at INRIA and the Smart Sensory Integrated Systems lab from the Hong Kong University of Science and Technology. The objective of BIOSENS is to develop biologically inspired sensory processing for artificial vision and olfaction.

7.4.2. PAI Procore with Hong Kong

Participant: Dominique Martinez.

The PAI Procore will last from January 2004 until december 2006 with EE Dept. Hong Kong University of Science and Technology (HKUST) on the topic "Electronic Nose Microsystem based on an array of gas sensors and advanced pattern recognition algorithms".

The overall aim of this joint research project is to investigate advanced and robust pattern recognition algorithms applied to electronic nose applications.

7.4.3. Common project with Tunisia

Participants: Frédéric Alexandre, Khaled Ben Khalifa, Laurent Bougrain, Bernard Girau, Nizar Kerkeni.

We are working with the faculty of medicine in Monastir on physiological signal interpretation (EEG, EMG, EOG). On the one hand, we have developed a connectionist system able to discriminate vigilance states with a good accuracy. We have laid emphasis this year on artefact detection. This system has been implemented on an FPGA, to get a light and easy-to-wear system. On the other hand, we are working with physiologist physicians to better understand sleep and associated pathologies. Accordingly, we have studied the human expertise on the topic [15] and we have tried this year to discriminate the different stages of sleep with self-organizing maps [31].

7.4.4. Joint venture INRIA-NSC Taiwan and NIEHS USA

Participant: Jean-Charles Lamirel.

The domain of application of this project is the analysis of gene-sickness interactions through the use of textual information issued from biological databases combined with DNA-Microarray experimental information. The role of the Cortex team is to provide flexible methods of data analysis and knowledge extraction in order to solve the gene-sickness interactions problem relatively to such kind of data.

7.4.5. Joint venture with Dalian university

Participant: Jean-Charles Lamirel.

The domains of application of this project are the scientometrics and the webometrics domains. It consists in setting up and supervising a new research team at the University of Technology of Dalian (DUT), China in these domains. The collaboration includes high level teaching, research exchange and PhD student research project management. On the Cortex side, the focus is put on the use of the recent research results of the team in the domains of unsupervised clustering, knowledge extraction and hyperbolic visualization. Teaching sessions and workshops have been achieved during the year 2006 in parallel with the initiation of student research projects. This joint venture also includes a complementary collaboration with the department of Social Sciences of the Humboldt University of Berlin.

8. Dissemination

8.1. Leadership within the scientific community

- In october 2006, the permanent staff of the Cortex team has organised in Lorraine the first french conference on Computational Neuroscience (NeuroComp06), aiming at gathering the french community on the topic: 70 papers submitted, 120 registration (cf http://neurocomp.loria.fr/).
- In november 2006, organisation of a one-day special session about “Embedded systems”, at the AMINA’06 conference (Applications Médicales de l’Informatique: Nouvelles Applications) (B. Girau);
- Organisation of the COLLNET Conference 2006 (J.C. Lamirel).
- Responsible for the axis “Teleoperation and intelligent assistants”, of the CPER with the Lorraine Region (F. Alexandre).
- Head of the Network Grand-Est for Cognitive Science (F. Alexandre)
- Reviewing for journals: Biological Psychology (F. Alexandre); Nature, Neural Computation (D. Martinez); JIMS, WISER Journal (J.C. Lamirel); IEEE TNN and NCA (Neural Computing and Applications) (B. Girau);
- Member of program committee: CAP’06, IEA/AIE2006, NeuroComp06 (F. Alexandre), Amina06 (B. Girau and F. Alexandre)
- Organisation with University Louis Pasteur (Strasbourg) of a scientific meeting about “Emotion and Spatial Memory” (F. Alexandre).
- Expertise for several program of the ANR and for the European Science Foundation (F. Alexandre)

- invited talks: Monell Chemical Senses Center, Philapdephia (USA), Workshop on Biological and Artificial Olfaction : "Oscillatory synchronization in a model of the insect antennal lobe"; Bio-Techno Workshop, Rome Spet. 27-28 : "Biomimetic Pattern Analysis (BioPatAna)" (D. Martinez); 2 talks at Scientometrics, February, Berlin, Germany (J.C Lamirel); September, Dalian, China (J.C Lamirel) [33]; One talk to the CogniEst network days devoted to anticipation in Haguenau (L. Bougrain).

8.2. Teaching

- Courses given at different levels (DEA, DESS, IUT, Licence-Maîtrise) in computer science in Nancy and Strasbourg by most team members;
- Member of PhD defense committees (F. Alexandre, B. Girau, D. Martinez, J.C. Lamirel, N. Rougier, A. Tonnelier);
- Co-supervision of PhD in Tunisia and Algeria (J.-C. Lamirel, F. Alexandre).

8.3. Miscellaneous

- Participation to the seminar of the ENS-Paris (F. Alexandre), of the laboratory Mouvement et Perception in Marseille (A. Tonnelier)
- Participation to the Eurobio06 forum (L. Bougrain).

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