INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

# *Project-Team CORTEX*

# *Neuromimetic Intelligence*

*Lorraine*

THEME COG

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# Table of contents

# 1. Team

*CORTEX is a project-team of the LORIA (UMR 7503) common to CNRS, INRIA, University Henri* POINCARÉ *Nancy 1 (UHP), University Nancy 2 and National Polytechnic Institute of Lorraine.*

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# 2. 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 perception to reasoning (*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 for more cognitive tasks like interpretation and knowledge extraction, which 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 to obtain data analysis close to the one performed by statistical methods but with other interesting properties. To improve the performance of such information processing system, statistical or neuronal pre-processing can deal with missing data, redundancy information and outliers.

Networks with a minimal achitecture can be obtained by 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 (selection of variables, rule extraction).

Knowledge extraction may also use an unsupervised neural network as a front-end for extracting rules. The symbolic methods, when they are used for the same task, are unable to perform selection among the huge set of rules which are usually produced in a realistic data analysis application. An unsupervised neural network copes with this problem because its synthesis capabilities can be used both for reducing the number of rules and for extracting the most significant ones. Moreover, the rule extraction is facilitated as soon as multi-viewpoint unsupervised neural network model is used.

## 3.3. Computational neuroscience: behavioral approach

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

In the behavioral approach of computational neuroscience, inspiration from neuroscience corresponds to defining and modeling the main information flows in the brain, together with the functional role of the main neuronal structures and their relation to some cognitive tasks.

The main cognitive tasks we are 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 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*.

**Participants:** Etienne Hugues, Dominique Martinez, Olivier Rochel.

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 [1]. 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 developed this year 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.

We have designed a computational model based on the Continuum Neural Field Theory (CNFT). This theory implicitely requires heavy calculation and memory since any unit in a map can potentially be linked to all other units from the same map. In order to be able to handle such heavy calculation on regular desktop machine, we had to design efficient management of both CPU and memory. The model is embedded within a simulator, implemented in C++, and is "type-aware". It means that the user can virtually edit any variables or objects using a graphical interface. It allows, for examples, to edit the activation of a single unit, to resize a map, to redesign the generic pattern of connectivity between two maps, etc. 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:** Mohammed Attik, Laurent Bougrain, Guillaume Ferrier, Nizar Kerkeni.

DynNet is a decision-making platform written in Java. It has been developed to simplify the development and use of neural networks in general and of dynamical architecture in particular. This platform is composed of three parts : a data importation and manipulation library, a neural networks library and a graphical user interface that integrates these tools into an application that handles every aspect of the decision-making process. As system requirements, any operating system that includes a Java Virtual Machine such as Microsoft Windows 98 and later, GNU/Linux, Solaris, MacOS are compatible operating systems. The software requires a configuration with Pentium III or equivalent and at least 256 MB of memory.

## 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 synthesis 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 [30] (*cf.* § 7.3 and § 7.4). The versions 1 and 2 of this software have been patented by INRIA. The MicroNOMAD-MultiSOM software has been chosen as one of the two softwares of reference for analyzing Web data in the framework of the European EICSTES project (*cf.* § 7.3). The version 3 of this software that offers numerous extensions for analyzing unstructured data as well as numerous functions for the automation of analysis is currently finalized in the project. Many different analyses have been conducted with the MicroNOMAD-MultiSOM software in the framework of this project. Comparison of the results with the ones that have been obtained with the other software selected in the project have also been performed [9]. A new extension of the MicroNOMAD-MultiSOM is currently under construction. It consists in adding an automatic rule extraction module.

## 5.5. Neural network synthesis on FPGA

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

**Participants:** Bernard Girau, Cesar Torres-Huitzil.

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 intend to develop a generic methodology to fully automatically specify, parameterize and implement neural networks according to various application and technological constraints (e.g. area of targetted FPGAs, required precision, etc).

This project implies that we handle very different aspects: it starts from a state of the art and a critical analysis of existing solutions for the implementation of connectionist computations on reconfigurable circuits, it needs to determine and maximize the genericity of all already developped neural blocks, and it requires a precise analysis of the relations between application data, device specifications, and performances, for each valid technological solution.

# 6. New Results

## 6.1. Behavioral computational neuroscience

**Participants:** Frédéric Alexandre, Yann Boniface, Claudio Castellanos Sanchez, Rémi Coulom, Hervé Frezza-Buet, Olivier Ménard, Nicolas Rougier, Julien Vitay, Thomas Voegtlin.

This section summarizes our recent results in the domain of modeling the cortex (motion detection, attention and active vision, visiomotor coordination, multimodal integration).

### *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 are developing 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.

Our first attempts have dealt mainly with manipulation of the optical flow by testing various spatio-temporal filters followed by neural processing based on inhibitory/excitatory connections. Current efforts are looking at the definition of a model of the magnocellular pathway for the detection of the movement of one or several objects in various dynamic scenes.

This model currently consists of three layers. The first one extracts spatio-temporal estimations of local movements. The second one performs a bio-inspired inhibitory/excitatory mechanism where strong local inhibitions exist between neurons that represent antagonistic movements and makes coherent moving areas appear [5][23]. The third layer is based on CNFT principles (*cf.* § 5.2). Using different data such as motion intensities in the second layer, this third layer is able to identify one or several moving objects. Current work studies the properties of this architecture in various contexts.

### 6.1.2. Attention and active vision

In the domain of robotic, modeling perceptive and executive attention is quite a critical feature given the limited computational power available on such 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 executive) in order to process it finely while rest of resources are allocated for a broader processing of the remaining space. In the framework of the Europen MirroBot project MirrorBot project (*cf.* § 7.3), the Robea CNRS project (*cf.* § 7.2) and the CPER (*cf.* § 7.1), 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 were 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 moving within the visual field and the model have 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 has been developed as a first step toward active vision where saccadic eye movements are considered to be a part of the recognition process. The first step is then naturally to be able to shift attention from one location of interest to another and to finally use the executed motor sequence to help object recognition. Furthemore, we foresee to apply this same attentional generic mechanism to executive attention where the motor space is considered.

### 6.1.3. Visiomotor coordination

In the domain of robotic, modeling the visiomotor axis is an important issue that we explore for various aims described in the European MirrorBot project (*cf.* § 7.3), the Robea CNRS project (*cf.* § 7.2) and the CPER (*cf.* § 7.1).

Visiomotor transformations are among the basic elements of the cognitive and motor behaviour of a robot. This step was studied extensively and permitted the use of redundant and distributed representations (such as our models of visual perception) which can be reused by other modules. They were applied to our Peoplebot robot which is now able to perform gaze centering and grasping tasks in a reactive way with a satisfying precision, and they were also applied to a robotic arm performing pointing tasks. These transformations are furthermore reversible, which means they can be used to predict the sensorial consequences of an action, either executed or imagined. This is capital for cognitive tasks requiring evaluation of an eventual reward depending on the action.

The underlying associative models have been developed to highlight several aspects like the design of an original and cheap connectivity between the visual and motor information [36] and the unsupervised self-organized learning of these two representations together with the associative visiomotor distributed representation. Using a simple reward signal, given only at the motor level, was possible because of the joint multimodal learning. This prevents us from using an inverse model [32]. This model was also successfully used to learn a motor-dependent phonetic representation in an application including language instructions for a moving robot [31].

### 6.1.4. Multi-modal integration

Beyond visiomotor association, we are more generally working on the difficult problem of multi-modal integration in the context of the Ministry Grant “Integrative and computational neuroscience” (*cf.* § 7.2). This phenomenon provides us with an integrated representation of the world and the different stimuli we perceive (sound, view, odor, etc.).

In this work, we began on the basis of a model developed at the Institut des Sciences Cognitives in Lyon. With a DEA student, we have built some new algorithms to code the integration layer (an associative layer) and to learn this integration [34]. The first aim of this work was to focus on the on-line aspects of the learning.

This year, we have developed a new version of this model, based on spiking neurons (*cf.* § 3.4). Our purpose is to study the relations between the different modules (perceptive and associative modules) and the learning of theses relations.

Properties of these classes of neurons allow us to study models of attention. We expect to build models which discriminate stimuli as a function of their role in attention. We will study attention properties in the modal pre-processing and in the integration processing in associative areas. We claim that these properties contribute to the integrated representation of the world.

## 6.2. Spiking neurons

**Participants:** Frédéric Alexandre, Yann Boniface, Bernard Girau, Etienne Hugues, Dominique Martinez, Olivier Rochel, Arnaud Tonnelier.

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. The new results obtained at these three different scales are developed in three parts (1) neural excitability (2) propagation in neural networks and (3) neural synchronization and network oscillations.

Modeling is based on mathematical tools : we used the nonlinear dynamical systems theory and the associated limit cycles. Since they largely appear in physical and biological systems, limit cycles have attracted a wide attention. Limit cycles model self sustained oscillations that are involved in numerous applications and observed in several experiments. The existence of a periodic regime for a system is related to the existence of a limit cycle for the associated dynamical system. The question of the number and the position of limit cycles for a dynamical system is a difficult question that is related to the unsolved Hilbert's 16th problem. Given the difficulty of the general problem, we restrict our attention to the so-called Liénard system

$$\begin{array}{rcl} \dot{x} & = & p(x) - y, \\ \dot{y} & = & x, \end{array} \tag{1}$$

where $(x, y) \in R^2$ and $p(x)$ is a piecewise linear function. One expects that results from piecewise linear systems can lead to insights into the general problem. The phase plane of (1) is divided into zones so that the restriction of the system into each zone is a linear system. We have conjectured : "The piecewise linear Liénard system (1) with $n + 1$ zones has up to $2n$ limit cycles". In [11], we give a general class of Lienard systems satisfying the conjecture. Moreover, we give a simple recursive algorithm to generate this class of functions.

### *6.2.1. Neural Excitability*

Action potential or spike is the elementary unit of signal processing and signal transmission in biological neural networks. Despite the large number of ionic mechanisms underlying the initiation of action potentials, a broad class of neurons presents two types of excitability. The properties of membrane excitability are determined according to the emerging frequency of repetitive firing. The frequency response of a single cell is crucial since it models the input-output relation, i.e. the gain function, commonly used in firing rate description of neural networks. The caracterization of the frequency curve as a function of the intrinsic properties of the neuron provides a link between the *spike code* paradigm and the *rate code* paradigm. Previous studies for classifying excitability used the bifurcation resulting in transition from quiescent to an oscillatory state. However, this classification is not perfect and suffers from a lack of quantitative predictions. In [3] we present an easy and intuitive way to charactetize the neural excitability of spiking neurons: the existence of a delayed afterdepolarization monitors the type of excitability. Our criterion suggests that the excitability of a neuron is mainly determined by the voltage-dependent potassium currents. Our analysis used the analytical framework of the spike-response-model that allows us to derive the value of the emerging frequency. We check the validity of our classification on more complex models.

### 6.2.2. Propagation in neural networks

Homogeneous networks of neurons can be in a state of synchronous or asynchronous activity. In spatially structured networks additional states are possible that are characterized by the propagation of wave-like activity patterns. Recently, a number of experiments have indicated the existence of propagating activity waves in neuronal tissue, notably the cortex, thalamus and hippocampus. The mechanisms underlying the wave propagation is believed to be synaptic in origin and has recently been the subject of several theoretical studies. There are basically two complementary frameworks where the propagation has been investigated: models of spiking neurons and firing rate models. We have investigated the propagation of an excitatory activity in both networks:

- We have studied the propagation of solitary waves in a discrete one-dimensional excitatory network of integrate-and-fire neurons. We have shown the existence and the stability of a fast wave and a family of slow waves. Stable slow waves have not been previously reported in purely excitatory networks. The number of these waves is parametrized by the number of presynaptic neurons and their existence depends crucially on the form of the EPSP (excitatory post-synaptic potential). The presence of weak noise does not alter our results but we have shown that a moderate amount of noise can induce both propagation failure or switching between different stable propagating modes. The complete description of our results has been published in [4].
- Neural tissues are commonly seen as neural fields which form and propagate patterns of excitation. We have considered a firing rate model of a neural network consisting of an excitatory and inhibitory layer with an excitatory feedforward connectivity. We have demonstrated the role of inhibition in stable pulse propagation. In a purely excitatory network, pulse waves are unstable because of the existence of stable front wave and back wave with different velocities leading to an enlarging pulse. When excitation is balanced appropriately by inhibition the growing pulse observed in the excitatory network is suppressed and an initial perturbation converges towards the traveling pulse solution. The regime where a traveling pulse propagates depends strongly on the kinetic of the inhibitory population.

### 6.2.3. Neural synchronization and network oscillations

We study the role of spike synchronization and field potential oscillations in sensory coding by means of computational modeling. More specifically, during the past few years, our work focused on the insect olfactory system for the following two reasons :

- The insect olfactory system is one of the simplest perceptive system and thus one of the best understood. For example, in the antennal lobe, the first structure of the insect olfactory system, recent experimental data have shown that, in the presence of an olfactory stimulus, transient synchronization of a subset of neurons occurs during a particular oscillation of the network and that this subset changes in time in an odor-specific manner (spatio-temporal coding).
- Understanding how sensory information is encoded and processed by the insect olfactory system could be highly beneficial for designing efficient electronic noses for which gas sensors are highly nonselective and respond to a wide variety of odors, as do the broadly tuned olfactory receptors in insects.

In order to understand the underlying mechanisms that generate such a spatio-temporal coding and to explore their computational capabilities, we have used both mathematical analysis and numerical simulations of simplified models of spiking networks. Starting from a biologically detailed model of the antennal lobe, we derived a simplified model. In contrast to the original model that consists of conductance-based type neurons and biologically detailed synapses, our model simply consists of one-variable neurons coupled via simple exponential synapses. Theoretical investigations, confirmed by simulations with the time-driven simulator engine SIRENE (*cf.* § 5.1), have allowed to understand why the network activity is oscillatory and, on the individual neuron level, to discover that during a particular oscillation some neurons robustly emit a spike at quite precise times. This individual behaviour has been found to be stimulus-specific, thus defining a real code of the stimulus. Furthermore, time has been found to increase the distance between the codes of two close stimuli.

These findings thus provide a direct input for designing data analysis methods for artificial electronic noses. However, it becomes necessary to adapt the model so as to interface it with real gas sensors. We then derived a more abstract spiking neural network, that has a lower complexity compatible with our applications in artificial olfaction, but can still capture the spatio-temporal coding of our former model. In addition, a very efficient event-driven simulation engine (*cf.* § 5.1) was developed by O. Rochel during his PhD thesis [1] for simulating this more abstract model using sequential or parallel machines.

## 6.3. Data exploitation and interpretation

**Participants:** Frédéric Alexandre, Shadi Al Shehabi, Mohammed Attik, Yann Boniface, Laurent Bougrain, Hervé Frezza-Buet, Randa Kassab, Jean-Charles Lamirel, Georges Schutz.

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).

Our knowledge extraction approches are focused on two main techniques : unsupervised networks and pruning algorithms for supervised networks. Concerning pruning methods, we are interested by a subpart of these methods where a connection is removed according to a relevance criterion often named the weight saliency (also termed sensitivity). More precisely, the weight with the smallest saliency will generate the smallest error variation if it is removed. We proposed several variants based on Optimal Brain Surgeon (OBS) and Unit-Optimal Brain Surgeon (Unit-OBS) [15][16]. The first variant called F-OBS performs a backward selection by successively removing single weights from the input variables to the hidden units in a fully connected multilayer perceptron (MLP) for variable selection. The second one removes a subset of non-significant weights in one step. The last one combines the two properties presented above. The first motivation of this work is that the weight saliency distributions in the different layers of a MLP are not the same. It can be observed experimentally that the first layer is more stable, which explains that the saliency in the first layer is small as compared to the other ones. Accordingly, it can be interesting to selectively remove weights in the first layer. The second motivation is to propose a novel way to select the weights in the Generalized Optimal Brain Surgeon method. We used statistic methods to compare empirical performances of these different variants. Unit-OBS presents some better results with high frequencies for a large number of pruned variables compared to F-OBS, but our algorithm is faster and keep better the variables which are associated to rules to extract. We proposed an implementation of G-OBS with a criterion to eliminate a subset of weights by selecting the weights with the smallest saliencies, which allows to make G-OBS faster. The results obtained are comparable to OBS, which allows to use G-OBS as a fast method for MLP topology optimization. In the aim of making F-OBS faster, we proposed GF-OBS which eliminates several weights at the same time. Moreover, we presented a comparison between OBS and Unit-OBS more detailed that the previous studies. We have also presented new algorithms for variable selection in MLPs. We have shown [15][16] the advantages of applying OBS on the architecture obtained by a variable selection method. We have also presented new hybrid methods for variable selection based on the previous idea that only weights between the first and the second layer should be removed at first.

These techniques were applied to geographical information systems (*cf.* § 7.2) and medical databases (*cf.* § 7.4). In this latter domain, we have studied how self-organizing algorithms can indicate interesting hints to differentiate EEG signals for epileptic seizure prediction and vigilance state identification [18]. This has also led to the implementation on FPGA of a portable system (*cf.* § 6.4) [19][20]. All these applications have been made possible by our DynNet software library (*cf.* § 5.3).

We have also studied the interpretation of databases including an important temporal aspect, namely databases of sensor signals of a very complicated industrial machine in the domain of steelmaking. We have more particularly proposed an hybridization between self-organizing maps and dynamic time warping [35].

We are also working on unsupervised approaches for the design of an information retrieval/data mining system. This approach implies the design of specific models for developing strong interaction capabilities with the user, as well as extended capabilities of adaptation to the context. An important example of such a model is the map conjunction model (i.e. the multicriteria classification model) that we have developed. This model, whose name is MicroNOMAD-MultiSOM, represents an important extension of the Kohonen SOM model (*cf.* § 5.4). The automatic deduction capabilities of the model represent a major advantage as compared to usual classification methods in the domain of data analysis. Hence, these latter methods do not permit the dynamical management of several viewpoints that can be considered as several different dimensions on the same information.

We focused this year on the overall validation of our approach by comparing it with classical models, like probabilistic models. We have proven that the intercommunication mechanism between viewpoints can be assimilated to a bayesian inference whenever the propagation mechanism is suitably adapted [12]. This proof represents an important advance for our approach because the indirect effect of the related adaptation is to increase the accurary of the deduction that have been obtained with the model. Thus, it opens new ways for accurately comparing different classifications that have been obtained on the same data [8]. In the framework of webometrics and science evaluation, it also permits us to suitably compare the behaviour of our model with the one of more classical network analysis model. This led us to proof its added value as compared to these latter models [9].

Documentary data have such a characteristic that each datum is individually defined in low size description spaces, with low overlapping of one datum with another. This situation led to global description space of important size but of low density for documentary data. Dimension reduction and outliers elimination becomes thus mandatory for the optimisation of the analysis of such data. We explore this year different techniques. One of our significant advancement in this area concerns our proposal of adaptation of singular value decomposition techniques for data selection and cleaning. This proposal has been set up thanks to the quasi-symbolic evaluation criteria for measuring the quality of numerical classification that we have proposed last year. More specifically, these criteria allow us to highlight the defects of classical methods, like latent semantic indexing, and, to set up this new proposal. In a complementary way, we are furthermore investigating in non linear data projection techniques.

The result of our comparison between topographic methods also highlights the superiority of Neural Gas as compared to other topographic methods, like SOM or Growing Neural Gas, for documentary information analysis [8]. Hence, the Neural Gas method appeared to be the most stable one for information analysis which are conducted on a small number of classes when data are sparse, like documentary ones. Taking this result into account we are currently extending the Neural Gas model in order to adapt it to our multicriteria classification approach. Our new multi Gas approach also led us to focus on information visualisation techniques for representing relationships between classes initially defined in highly multidimensional spaces. Hence, one of our recent alleys of research consists in developing an hyperbolic visualisation model based on the definition of hierarchies of Gas classes. A model proposal has been set up this year.

The limitations of the numerical classification methods, like MicroNOMAD-MultiSOM, are related to the errors of interpretation that they may generate as soon as they are used without preliminary care by non-specialists for the precise analysis of a given domain. On their own side, symbolic methods when they are used for the same goal present the limitation to deliver results of unmanageable size. After having set up a matching mechanism between Galois lattice and SOM Maps and defined a quasi-symbolic evaluation criterion for measuring the quality of numerical classification, we are pursuing our studies about the complementarities that can exist between the two types of methods. This year we have developed a new principle of knowledge extraction that consists in using an unsupervised neural network as a front-end for extracting rules. An unsupervised neural network copes with the problem of rules inflation that is inherent to symbolic methods because of its synthesis capabilities that can be used both for reducing the number of rules and for extracting the most significant ones. Moreover, the rule extraction is facilitated as soon as multi-viewpoint unsupervised neural network model with low topologic constraints and including generalization, like the Multigas model we have already proposed, is used.

Another technique issued from our systemic approach is under development. It concerns a specific novelty detection model based on the Moore-Penrose projectors. This technique is in its preliminary phase. Nevertheless, our first experiment led us to expect promising results both for user's profile modelling and analysis of flow of permanently changing information. This technique is currently used in the framework of an international project (*cf.* § 7.4).

## 6.4. Hardware implementations

**Participants:** Khaled Ben Khalifa, Bernard Girau, Cesar Torres-Huitzil.

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 ([7][6]) and current studies intend to include it both in embedded low-power implementations and in the technological solutions that will be handled by our automatic neural synthesis tool.

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. For example, we have proposed an FPGA implementation for a neural network that discriminates vigilance states in humans from electroencephalographic (EEG) signals : it is based on a full-parallel architecture that uses serial operators, and its performances in terms of area, speed and especially power consumption are highly satisfactory (its target is a light, easy to wear system) [19][20]. Another recent example is the implementation work of the first two layers of our bio-inspired model for motion perception.

The third axis is the development of a generic synthesis tool to fully automatically specify, parameterize and implement neural networks on FPGAs. To date, we have defined, implemented and tested various neural blocks (from multilayer perceptrons to spiking neurons) on a FPGA-equipped reconfigurable board. Moreover, we have developped and validated a software tool that handles the automatic generation of VHDL code from a simple generic description of standard multilayer neural networks. This project still requires a huge amount of work. Current studies focus on generic communication schemes between the FPGA and its host.

# 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 large documentary databases. We firstly worked on the detection of the best data projection subspaces and we then pursued the extraction and the representation of concepts that provide a reliable interpretation of the database content. Other neural solutions we are working on are the ones that can be applied for detecting marginal documents or marginal tendencies in a very large documentary database. The approach we have proposed is based on the experimentation of different kinds of neural projectors implementing novelty detection functions. Another domain of application of these approaches is the analysis of the relations between the different laboratories of the academic domain through the content of their Web pages.

### *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 Etat 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 [17].

### *7.2.2. Interdisciplinary Program Cognition and Information Processing of the CNRS - Project Olfactive Aversion*

**Participant:** Frédéric Alexandre.

In the framework of the project "Networks and mechanisms of learning: neurobiological and computational approaches of olfactive aversion in rats" of the Interdisciplinary Program "Cognition and Information Processing" of the CNRS, we were collaborating with the Cognitive Neuroscience Laboratory in Bordeaux and the Cognitive Sciences Institute in Lyon. This project, that finished this year, was studying the modifications in olfactive signal processing in amygdala, cortex and hippocampus in aversive conditioning tasks. We proposed the modeling part, with emphasis on the underlying circuitry (network of structures) and the associated learning rules, based on pavlovian learning.

### *7.2.3. Interdisciplinary Program Cognition and Information Processing of the CNRS - Project electronic nose*

**Participants:** Etienne Hugues, Dominique Martinez, Olivier Rochel.

The objective of this project, that finished this year, was to develop a biologically detailed model of the olfactory bulb, the analog for mammals of the insect antennal lobe. This work was in collaboration with the Institut des Sciences Cognitives and the Laboratoire de Neurosciences et Olfaction in Lyon.

### *7.2.4. Project Robea of the CNRS - Learning of visiomotor transformations*

**Participants:** Frédéric Alexandre, Hervé Frezza-Buet, Olivier Ménard, Nicolas Rougier, Julien Vitay.

This project, in collaboration with Supélec-Metz, INSERM-Paris and EDF-Chatou, was proposing a generic neuronal methodology inspired from the modular cortical architecture to learn complex visiomotor loops, with application to manipulation, reaching and grasping tasks for complex robots. Despite a positive scientific review in Toulouse last january, the CNRS withdrew the funding for administrative internal reasons and the project had to stop.

### 7.2.5. *Ministry Grant "Integrative and computational neuroscience"*

**Participants:** Frédéric Alexandre, Yann Boniface, Dominique Martinez.

This interdisciplinary project entitled "Distributed models of spiking neural networks for multisensory integration" gathers different teams interested in mathematics, robotic, psychology, biology and computer science around a model designed for multi-modal integration. This model has been first developed by the team Connexionnisme et Modélisation Cognitive in the Institut des Sciences Cognitives in Lyon and was adapted by our team (*cf.* § 6.1).

### 7.2.6. *Ministry Grant "New analytic methodologies and sensors" SAWCapt*

**Participants:** Etienne Hugues, Dominique Martinez, Olivier Rochel.

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.

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

**Participant:** Arnaud Tonnelier.

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 investigate the dynamic phenomena in the memory representation. We plan to study emergent states using both modeling and experiments.

### 7.2.8. *CNRS Specific Action: Perceptive supply and interface*

**Participants:** Didier Fass, Hervé Frezza-Buet, Nicolas Rougier.

The aim of the "Perceptive supply and interface" project that finished in january was to contribute to set up a theorical ergonomy of assisting devices for people with perceptive disabilities with the multi-disciplinary views of cognitive sciences, ergonomy, interface engineering, robotic, philosophy of the technics and anthropology.

### 7.2.9. *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. This approach represents a collaboration with the Orpailleur team which deals with the Galois lattice classification technique (*cf.* § 6.3).

The work of this year consisted in finalizing the multicriteria classification approach on 3-dimensional representations of the object of the collections. The goal of this new approach, that has been initiated last year, is to dynamically highlight relation between the objects depending on the current view a user has of an object at a given time.

## 7.3. European initiatives

### 7.3.1. *Project IST MirrorBot*

**Participants:** Frédéric Alexandre, Hervé Frezza-Buet, Olivier Ménard, Nicolas Rougier, Julien Vitay.

This project from the European initiative FET (Future Emergent Technology) gathers INRIA-Lorraine, Sunderland University, Parma University, Ulm University and the Cognition and Brain Sciences Unit in

Cambridge. Its main topic is biologically inspired multimodal neuronal learning for an autonomous robot acting on, perceiving, and representing the world, as described in (*cf.* § 6.1).

More information is available at http://www.his.sunderland.ac.uk/mirrorbot/.

### *7.3.2. NoE GOSPEL*

**Participant:** 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.

### *7.3.3. Drivesafe*

**Participant:** Didier Fass.

In a CRAFT project of the Sixth framework program, for horizontal research activities involving SMES, we are working on the development of 3-D Eye tracking device for safer driving and more efficient Web Page production.

### *7.3.4. IST Project EICSTES*

**Participants:** Jean-Charles Lamirel, Shadi Al Shehabi.

The goal of this project is to set up both indicators and methods for the analysis of the Web data. The data that are managed in the framework of the project concern the Web pages of the institutional Web sites as well as the log files associated to the different servers and services provided by the institutions. The project covers a large scope of competence because it enhances collaborations between statisticians, social scientists and computer scientists. The MicroNOMAD-MultiSOM method (*cf.* § 5.4) is one of the two reference methods of the project [9].

## 7.4. International cooperation

### *7.4.1. European Project SAT-At-ONCE*

**Participants:** Jean-Charles Lamirel, Randa Kassab.

The goal of the SAT-At-ONCE project, starting in september 2004, is to propose a unified user-oriented environment for accessing to multiple satellite services. Our role in this project is to set-up a personalised user-filtering system for a specific service of Web contents delivery. The LORIA part of this project is achieved in cooperation with the Orpailleur and the Maia teams.

### *7.4.2. PAI Procore with Hong Kong*

**Participant:** Dominique Martinez.

The PAI Procore will last from january 2004 until december 2004 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. Project STIC 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 [18]. 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 and we have tried this year to discriminate the different stages of sleep with self organizing maps.

#### *7.4.4. Joint venture INRIA-NSC Taiwan*

**Participant:** Jean-Charles Lamirel.

The domain of application of this project is a multimedia digital library including both text and images that can be accessed on-line on the Internet. The goal of the final project is to offer extended querying functionalities including query by keywords as well as query by example. Our approach is both based on the MicroNOMAD-MultiSOM model and on the methods of similarity computation in the highly multidimensional spaces developed in our team. We are currently working on the operational implementation of the model.

# 8. Dissemination

## 8.1. Leadership within the scientific community

- Head of the Network Grand-Est for Cognitive Science; member of the piloting committee of the CNRS UMS RISC (F. Alexandre)
- Reviewing for journals: International Journal of Neural Systems (F. Alexandre), Physical Review and Mathematical Review (A. Tonnelier).
- Reviewing for conferences: IJCAI (L. Bougrain, J.-C. Lamirel), AISTA (J.-C. Lamirel)
- Organization of the workshop AMINA'04, Monastir, Tunisia, April 5-8 (F. Alexandre, L. Bougrain, B. Girau)
- Organization of the special session "artificial neural networks" in the IFAC MMM'04 (L. Bougrain)
- Invited seminars (Paris, Viabilité, Jeux et Contrôle and Marseilles, Perception et Mouvement) A. Tonnelier
- Invited talk at 4th International Conference on University Evaluation and Research Evaluation, sep. 27-29, Wuhan, China (J.-C. Lamirel).

## 8.2. Teaching

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

## 8.3. Miscellaneous

- Popularization activities to heighten school-boy awareness of scientific and technological studies (F. Alexandre);

# 9. Bibliography

## Doctoral dissertations and Habilitation theses


[1] O. ROCHEL. *Une approche événementielle pour la modélisation et la simulation de réseaux de neurones impulsionnels*, Thèse d'université, Université H. Poincaré, March 2004, http://www.loria.fr/publications/2004/A04-T-047/A04-T-047.ps.


## Articles in referred journals and book chapters


[2] F. ALEXANDRE. *Quels modèles neuronaux comme base de l'anticipation ?*, in "L'Anticipation à l'horizon du Présent", R. SOCK, B. VAXELAIRE (editors)., Psychologie et Sciences Humaines, Mardaga, November 2004.

[3] F. ALEXANDRE, H. FREZZA-BUET. *From Natural to Artificial Intelligence: Numerical processing for cognitive tasks*, in "Cognitive Economics", P. BOURGINE, J.-P. NADAL (editors)., Springer, November 2004, p. 113–130.

[4] L. BADEL, A. TONNELIER. *Pulse propagation in discrete excitatory networks of integrate-and-fire neurons*, in "Physical Review E", vol. 70, n° 1, July 2004, p. 011906-1–011906-7.

[5] C. CASTELLANOS SÁNCHEZ, B. GIRAU, F. ALEXANDRE. *Approche connexionniste de la perception du mouvement*, in "International Journal for Information Sciences for Decision Making - ISDM, Special Issue Colloque MajecSTIC'03", n° 13, January 2004, p. 72–81.

[6] B. GIRAU. *FPNA: applications and implementations*, in "FPGA Implementations of Neural Networks", J. R. AMOS OMONDI (editor)., Kluwer Academic Publishers, December 2004, p. 43–79.

[7] B. GIRAU. *FPNA: concepts and properties*, in "FPGA Implementations of Neural Networks", J. R. AMOS OMONDI (editor)., Kluwer Academic Publishers, December 2004, p. 1–42.

[8] J.-C. LAMIREL, S. AL SHEHABI, C. FRANCOIS, M. HOFFMANN. *New classification quality estimators for analysis of documentary information: application to patent analysis and web mapping*, in "Scientometrics", vol. 60, n° 3, February 2004, p. 445–462.

[9] J.-C. LAMIREL, S. AL SHEHABI, C. FRANCOIS, X. POLANCO. *Using a compound approach based on elaborated neural network for Webometrics: An example issued from the EICSTES project*, in "Scientometrics", vol. 61, n° 3, January 2004, p. 427–441.

[10] D. MARTINEZ, E. HUGUES. *A spiking neural network model of the locust antennal lobe: Towards neuromorphic electronic noses inspired from insect olfaction*, in "Electronic noses & sensors for the detection of explosives", J. GARDNER, J. YINON (editors)., NATO Science Series, vol. 159, chap. 14, n° 14, Kluwer Academic Publishers, May 2004, p. 209–234.

[11] A. TONNELIER. *On the number of limit cycles in piecewise linear Liénard systems*, in "International Journal of Bifurcation and Chaos", October 2004.

## Publications in Conferences and Workshops

[12] S. AL SHEHABI, J.-C. LAMIREL. *Inference Bayesian Network for Multi-topographic neural network communication: a case study in documentary data*, in "International Conference on Information and Communication Technologies: from Theory to Applications - ICTTA 2004, Damascus, Syria", April 2004, http://www.loria.fr/publications/2004/A04-R-482/A04-R-482.ps.

[13] S. AL SHEHABI, J.-C. LAMIREL. *Unsupervised neural networks of topographic and gas families documentary data classification*, in "The 8th World Multi-Conference on Systemics, Cybernetics and Informatics - SCI'04, Orlando, Florida, USA", July 2004.

[14] F. ALEXANDRE. *A computational neuronal model for hemispheric specialization*, in "International Conference on Mathematical Biology and Ecology - MABE'04, Corfu, Greece", August 2004, http://www.loria.fr/publications/2004/A04-R-157/A04-R-157.ps.

[15] M. ATTIK, L. BOUGRAIN, F. ALEXANDRE. *Optimal Brain Surgeon Variants for Feature Selection*, in "International Joint Conference on Neural Networks - IJCNN'04, Budapest, Hungary", July 2004, http://www.loria.fr/publications/2004/A04-R-457/A04-R-457.ps.

[16] M. ATTIK, L. BOUGRAIN, F. ALEXANDRE. *Optimal Brain Surgeon Variants for Optimization*, in "16h European Conference on Artificial Intelligence - ECAI'04, Valencia, Spain", August 2004, http://www.loria.fr/publications/2004/A04-R-459/A04-R-459.ps.

[17] M. ATTIK, L. BOUGRAIN, D. CASSARD, V. BOUCHOT, F. ALEXANDRE, A. LIPS. *Classification and Predictive maps on Ore Deposits: A Case Study in GIS Andes*, in "32nd International Geological Congress, Florence, Italy", August 2004.

[18] K. BEN KHALIFA, M. H. BÉDOUI, M. DOGUI, F. ALEXANDRE. *Alertness States Classification By SOM and LVQ Neural Networks*, in "International Conference on Information Technology - ICIT'04, Istanbul, Turkey", December 2004.

[19] K. BEN KHALIFA, B. GIRAU, F. ALEXANDRE, M. H. BEDOUI. *Parallel FPGA implementation of self-organizing maps*, in "International Conference on Microelectronics - ICM'04, Tunis, Tunisia", December 2004.

[20] K. BEN KHALIFA, B. GIRAU, M. H. BEDOUI, F. ALEXANDRE, R. RAYTCHEV. *Implantation basse-consommation de cartes auto-organisatrices pour la détection de l'hypovigilance*, in "14e congrès Francophone AFRIF-AFIA de Reconnaissance des Formes et Intelligence Artificielle - RFIA'04, Toulouse, France", January 2004.

[21] A. BERMAK, D. MARTINEZ. *A reconfigurable hardware implementation of tree classifiers based on a custom chip and a CPLD for gas sensor applications*, in "IEEE Tencon 2004, Chiang Mai, Thailand", November 2004.

[22] L. BOUGRAIN. *Practical introduction to artificial neural networks*, in "IFAC symposium on automation in Mining, Mineral and Metal Processing - MMM'04, Nancy, France", September 2004, http://www.loria.fr/publications/2004/A04-R-463/A04-R-463.ps.

[23] C. CASTELLANOS SÁNCHEZ, B. GIRAU, F. ALEXANDRE. *A connectionist approach for visual perception of motion*, in "Brain Inspired Cognitive Systems - BICS 2004, Stirling, United Kingdom", L. SMITH, A. HUSSAIN, I. ALEKSANDER (editors)., University of Stirling, International Computing Sciences Conferences (ICSC) Canada, and University of Stirling, Scotland and Imperial College, London, England, September 2004, p. BIS3-1 1–7.

[24] R. COULOM. *High-Accuracy Value-Function Approximation with Neural Networks Applied to the Acrobot*, in "12th European Symposium on Artificial Neural Networks - ESANN'2004, Bruges, Belgium", M. VERLEYSEN (editor)., d-side, Michel Verleysen, April 2004, p. 7–12, http://www.loria.fr/publications/2004/A04-R-082/A04-R-082.ps.

[25] F. DAVID, E. HUGUES, N. BUONVISO, D. MARTINEZ. *Evoked gammma oscillations in the olfactory bulb: a modeling study*, in "AMSE International Conference on Modelling and Simulation - MS'2004, Lyon, France", July 2004.

[26] C. FRANCOIS, M. HOERLESBERGER, X. POLANCO, J.-C. LAMIREL, S. AL SHEHABI. *Visualization of Web data: Complementarities between a graph and a multi-maps approach*, in "8th International Conference on Science and Technology Indicators - ST 2004, Leiden, Nederlands", September 2004, p. 94–95.

[27] E. HUGUES, D. MARTINEZ. *Encoding in a network of sparsely connected spiking neurons: application to locust olfaction*, in "Thirteenth Annual Computational Neuroscience Meeting - CNS'2004, Baltimore, Maryland", July 2004.

[28] J.-C. LAMIREL, S. AL SHEHABI, C. FRANCOIS, X. POLANCO, M. HOFFMANN. *Using a compound approach based on elaborated neural network for Webometrics: an example issued from the EICSTES project*, in "5th COLNET Meeting - COLLNET 2004, Roorkee, India", March 2004.

[29] J.-C. LAMIREL. *New neural methods for Webometrics*, in "4th International Conference on University Evaluation and Research Evaluation, Wuhan, China", September 2004.

[30] J.-C. LAMIREL. *Optimized Data Analysis Based on Neural Networks: Experiments on the MultiSOM Model in the Framework of Patent and Web Data Analysis*, in "The 4th Sino Franco Workshop on Web Technologies, Tamkang, Taiwan", March 2004.

[31] O. MÉNARD, F. ALEXANDRE, H. FREZZA-BUET. *Multi-criteria self-organization: Example of motor-dependent phonetic representation for a multi-modal robot*, in "Neurobotics Workshop of the 27th German Conference on Artificial Intelligence, Ulm, Germany", September 2004, http://www.loria.fr/publications/2004/A04-R-318/A04-R-318.ps.

[32] O. MÉNARD, H. FREZZA-BUET. *Rewarded multi-modal neuronal self-organization: Example of the arm reaching movement*, in "International Conference on Advances in Intelligent Systems - Theory and Applications - AISTA'04, Luxembourg-Kirchberg, Luxembourg", November 2004, http://www.loria.fr/publications/2004/A04-R-319/A04-R-319.ps.

[33] O. MÉNARD, S. VIALLE, H. FREZZA-BUET. *Making Cortically-Inspired Sensorimotor Control Realistic for Robotics: Design of an Extended Parallel Cellular Programming Model*, in "International Conference on Advances in Intelligent Systems - Theory and Applications - AISTA 2004, Luxembourg", November 2004,

http://www.loria.fr/publications/2004/A04-R-317/A04-R-317.ps.

[34] A. REGHIS, F. ALEXANDRE, Y. BONIFACE. *Un réseau de neurones pour des associations multimodales*, in "14ème Congrès Francophone AFRIF-AFIA de Reconnaissance des Formes et Intelligence Artificielle - RFIA'2004, Toulouse, France", January 2004, http://www.loria.fr/publications/2004/A04-R-001/A04-R-001.ps.

[35] G. SCHUTZ, S. GILLÉ, F. ALEXANDRE. *Unsupervised extraction of temporal evolution patterns on an electric arc furnace process*, in "11th IFAC Symposium on Automation in Mining, Mineral and Metal processing - IFAC-MMM 2004, Nancy, France", Elsevier IFAC Publications, Société de l'Electricité, de l'Electronique, et des Technologies de l'Information et de la Communication - France, September 2004.

[36] J. VITAY, N. ROUGIER, F. ALEXANDRE. *Reducing connectivity by using cortical modular bands*, in "European Symposium on Artificial Neural Networks - ESANN'2004, Bruges, Belgium", D-SIDE, Michel Verleysen, April 2004, p. 373–378, http://www.loria.fr/publications/2004/A04-R-148/A04-R-148.ps.