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CNRS

Institut Polytechnique de Bordeaux

Université de Bordeaux

Activity Report 2017

Project-Team MNEMOSYNE

Mnemonic Synergy

RESEARCH CENTER
Bordeaux - Sud-Ouest

THEME
Computational Neuroscience and Medicine

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Project-Team MNEMOSYNE

Creation of the Team: 2012 February 01, updated into Project-Team: 2014 July 01

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1. Personnel

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2. Overall Objectives

2.1. Summary

At the frontier between integrative and computational neuroscience, we propose to model the brain as a system of active memories in synergy and in interaction with the internal and external world and to simulate it *as a whole and in situation*.

In integrative and cognitive neuroscience (*cf.* § 3.1), on the basis of current knowledge and experimental data, we develop models of the main cerebral structures, taking a specific care of the kind of mnemonic function they implement and of their interface with other cerebral and external structures. Then, in a systemic approach, we build the main behavioral loops involving these cerebral structures, connecting a wide spectrum of actions to various kinds of sensations. We observe at the behavioral level the properties emerging from the interaction between these loops.

We claim that this approach is particularly fruitful for investigating cerebral structures like the basal ganglia and the prefrontal cortex, difficult to comprehend today because of the rich and multimodal information flows they integrate. We expect to cope with the high complexity of such systems, inspired by behavioral and developmental sciences, explaining how behavioral loops gradually incorporate in the system various kinds of information and associated mnesic representations. As a consequence, the underlying cognitive architecture, emerging from the interplay between these sensations-actions loops, results from a *mnemonic synergy*.

In computational neuroscience (*cf.* § 3.2), we concentrate on the efficiency of local mechanisms and on the effectiveness of the distributed computations at the level of the system. We also take care of the analysis of their dynamic properties, at different time scales. These fundamental properties are of high importance to allow the deployment of very large systems and their simulation in a framework of high performance computing Running simulations at a large scale is particularly interesting to evaluate over a long period a consistent and relatively complete network of cerebral structures in realistic interaction with the external and internal world. We face this problem in the domain of autonomous robotics (*cf.* § 3.4) and ensure a real autonomy by the design of an artificial physiology and convenient learning protocoles.

We are convinced that this original approach also permits to revisit and enrich algorithms and methodologies in machine learning (*cf.* § 3.3) and in autonomous robotics (*cf.* § 3.4), in addition to elaborate hypotheses to be tested in neuroscience and medicine, while offering to these latter domains a new ground of experimentation similar to their daily experimental studies.

3. Research Program

3.1. Integrative and Cognitive Neuroscience

The human brain is often considered as the most complex system dedicated to information processing. This multi-scale complexity, described from the metabolic to the network level, is particularly studied in integrative neuroscience, the goal of which is to explain how cognitive functions (ranging from sensorimotor coordination to executive functions) emerge from (are the result of the interaction of) distributed and adaptive computations of processing units, displayed along neural structures and information flows. Indeed, beyond the astounding complexity reported in physiological studies, integrative neuroscience aims at extracting, in simplifying models, regularities at various levels of description. From a mesoscopic point of view, most neuronal structures (and particularly some of primary importance like the cortex, cerebellum, striatum, hippocampus) can be described through a regular organization of information flows and homogenous learning rules, whatever the nature of the processed information. From a macroscopic point of view, the arrangement in space of neuronal structures within the cerebral architecture also obeys a functional logic, the sketch of which is captured in models describing the main information flows in the brain, the corresponding loops built in interaction with the external and internal (bodily and hormonal) world and the developmental steps leading to the acquisition of elementary sensorimotor skills up to the most complex executive functions.

In summary, integrative neuroscience builds, on an overwhelming quantity of data, a simplifying and interpretative grid suggesting homogenous local computations and a structured and logical plan for the development of cognitive functions. They arise from interactions and information exchange between neuronal structures and the external and internal world and also within the network of structures.

This domain is today very active and stimulating because it proposes, of course at the price of simplifications, global views of cerebral functioning and more local hypotheses on the role of subsets of neuronal structures in cognition. In the global approaches, the integration of data from experimental psychology and clinical studies leads to an overview of the brain as a set of interacting memories, each devoted to a specific kind of information processing [46]. It results also in longstanding and very ambitious studies for the design of cognitive architectures aiming at embracing the whole cognition. With the notable exception of works initiated by [43], most of these frameworks (e.g. Soar, ACT-R), though sometimes justified on biological grounds, do not go up to a *connectionist* neuronal implementation. Furthermore, because of the complexity of the resulting frameworks, they are restricted to simple symbolic interfaces with the internal and external world and to (relatively) small-sized internal structures. Our main research objective is undoubtly to build such a general purpose cognitive architecture (to model the brain *as a whole* in a systemic way), using a connectionist implementation and able to cope with a realistic environment.

3.2. Computational Neuroscience

From a general point of view, computational neuroscience can be defined as the development of methods from computer science and applied mathematics, to explore more technically and theoretically the relations between structures and functions in the brain [48], [36]. During the recent years this domain has gained an increasing interest in neuroscience and has become an essential tool for scientific developments in most fields in neuroscience, from the molecule to the system. In this view, all the objectives of our team can be described as possible progresses in computational neuroscience. Accordingly, it can be underlined that the systemic view that we promote can offer original contributions in the sense that, whereas most classical models in computational neuroscience focus on the better understanding of the structure/function relationship for isolated specific structures, we aim at exploring synergies between structures. Consequently, we target interfaces and interplay between heterogenous modes of computing, which is rarely addressed in classical computational neuroscience.

We also insist on another aspect of computational neuroscience which is, in our opinion, at the core of the involvement of computer scientists and mathematicians in the domain and on which we think we could particularly contribute. Indeed, we think that our primary abilities in numerical sciences imply that our developments are characterized above all by the effectiveness of the corresponding computations: We provide biologically inspired architectures with effective computational properties, such as robustness to noise, self-organization, on-line learning. We more generally underline the requirement that our models must also mimick biology through its most general law of homeostasis and self-adaptability in an unknown and changing environment. This means that we propose to numerically experiment such models and thus provide effective methods to falsify them.

Here, computational neuroscience means mimicking original computations made by the neuronal substratum and mastering their corresponding properties: computations are distributed and adaptive; they are performed without an homonculus or any central clock. Numerical schemes developed for distributed dynamical systems and algorithms elaborated for distributed computations are of central interest here [33], [42] and were the basis for several contributions in our group [47], [44], [49]. Ensuring such a rigor in the computations associated to our systemic and large scale approach is of central importance.

Equally important is the choice for the formalism of computation, extensively discussed in the connectionist domain. Spiking neurons are today widely recognized of central interest to study synchronization mechanisms and neuronal coupling at the microscopic level [34]; the associated formalism [39] can be possibly considered for local studies or for relating our results with this important domain in connectionism. Nevertheless, we remain mainly at the mesoscopic level of modeling, the level of the neuronal population, and consequently interested in the formalism developed for dynamic neural fields [31], that demonstrated a richness of behavior [35] adapted to the kind of phenomena we wish to manipulate at this level of description. Our group has a long experience in the study and adaptation of the properties of neural fields [44], [45] and their use for observing the emergence of typical cortical properties [38]. In the envisioned development of more complex architectures and interplay between structures, the exploration of mathematical properties such as stability and boundedness and the observation of emerging phenomena is one important objective. This objective is also associated with that of capitalizing our experience and promoting good practices in our software production. In summary, we think that this systemic approach also brings to computational neuroscience new case studies where heterogenous and adaptive models with various time scales and parameters have to be considered jointly to obtain a mastered substratum of computation. This is particularly critical for large scale deployments.

3.3. Machine Learning

The adaptive properties of the nervous system are certainly among its most fascinating characteristics, with a high impact on our cognitive functions. Accordingly, machine learning is a domain [41] that aims at giving such characteristics to artificial systems, using a mathematical framework (probabilities, statistics, data analysis, etc.). Some of its most famous algorithms are directly inspired from neuroscience, at different levels. Connectionist learning algorithms implement, in various neuronal architectures, weight update rules, generally derived from the hebbian rule, performing non supervised (e.g. Kohonen self-organizing maps), supervised (e.g. layered perceptrons) or associative (e.g. Hopfield recurrent network) learning. Other algorithms, not necessarily connectionist, perform other kinds of learning, like reinforcement learning. Machine learning is a very mature domain today and all these algorithms have been extensively studied, at both the theoretical and practical levels, with much success. They have also been related to many functions (in the living and artificial domains) like discrimination, categorisation, sensorimotor coordination, planning, etc. and several neuronal structures have been proposed as the substratum for these kinds of learning [37], [30]. Nevertheless, we believe that, as for previous models, machine learning algorithms remain isolated tools, whereas our systemic approach can bring original views on these problems.

At the cognitive level, most of the problems we face do not rely on only one kind of learning and require instead skills that have to be learned in preliminary steps. That is the reason why cognitive architectures are often referred to as systems of memory, communicating and sharing information for problem solving. Instead of the classical view in machine learning of a flat architecture, a more complex network of modules must be considered here, as it is the case in the domain of deep learning. In addition, our systemic approach brings the question of incrementally building such a system, with a clear inspiration from developmental sciences. In this perspective, modules can generate internal signals corresponding to internal goals, predictions, error signals, able to supervise the learning of other modules (possibly endowed with a different learning rule), supposed to become autonomous after an instructing period. A typical example is that of episodic learning (in the hippocampus), storing declarative memory about a collection of past episods and supervising the training of a procedural memory in the cortex.

At the behavioral level, as mentionned above, our systemic approach underlines the fundamental links between the adaptive system and the internal and external world. The internal world includes proprioception and interoception, giving information about the body and its needs for integrity and other fundamental programs. The external world includes physical laws that have to be learned and possibly intelligent agents for more complex interactions. Both involve sensors and actuators that are the interfaces with these worlds and close the loops. Within this rich picture, machine learning generally selects one situation that defines useful sensors and actuators and a corpus with properly segmented data and time, and builds a specific architecture and its corresponding criteria to be satisfied. In our approach however, the first question to be raised is to discover what is the goal, where attention must be focused on and which previous skills must be exploited, with the help of a dynamic architecture and possibly other partners. In this domain, the behavioral and the developmental sciences, observing how and along which stages an agent learns, are of great help to bring some structure to this high dimensional problem.

At the implementation level, this analysis opens many fundamental challenges, hardly considered in machine learning : stability must be preserved despite on-line continuous learning; criteria to be satisfied often refer to behavioral and global measurements but they must be translated to control the local circuit level; in an incremental or developmental approach, how will the development of new functions preserve the integrity and stability of others? In addition, this continous re-arrangement is supposed to involve several kinds of learning, at different time scales (from msec to years in humans) and to interfer with other phenomena like variability and meta-plasticity.

In summary, our main objective in machine learning is to propose on-line learning systems, where several modes of learning have to collaborate and where the protocoles of training are realistic. We promote here a *really autonomous* learning, where the agent must select by itself internal resources (and build them if not available) to evolve at the best in an unknown world, without the help of any *deus-ex-machina* to define parameters, build corpus and define training sessions, as it is generally the case in machine learning. To that end, autonomous robotics (*cf.* § 3.4) is a perfect testbed.

3.4. Autonomous Robotics

Autonomous robots are not only convenient platforms to implement our algorithms; the choice of such platforms is also motivated by theories in cognitive science and neuroscience indicating that cognition emerges from interactions of the body in direct loops with the world (*embodiment of cognition* [32]). In addition to real robotic platforms, software implementations of autonomous robotic systems including components dedicated to their body and their environment will be also possibly exploited, considering that they are also a tool for studying conditions for a real autonomous learning.

A real autonomy can be obtained only if the robot is able to define its goal by itself, without the specification of any high level and abstract cost function or rewarding state. To ensure such a capability, we propose to endow the robot with an artificial physiology, corresponding to perceive some kind of pain and pleasure. It may consequently discriminate internal and external goals (or situations to be avoided). This will mimick circuits related to fundamental needs (e.g. hunger and thirst) and to the preservation of bodily integrity. An important objective is to show that more abstract planning capabilities can arise from these basic goals.

A real autonomy with an on-line continuous learning as described in § 3.3 will be made possible by the elaboration of protocols of learning, as it is the case, in animal conditioning, for experimental studies where performance on a task can be obtained only after a shaping in increasingly complex tasks. Similarly, developmental sciences can teach us about the ordered elaboration of skills and their association in more complex schemes. An important challenge here is to translate these hints at the level of the cerebral architecture.

As a whole, autonomous robotics permits to assess the consistency of our models in realistic condition of use and offers to our colleagues in behavioral sciences an object of study and comparison, regarding behavioral dynamics emerging from interactions with the environment, also observable at the neuronal level.

In summary, our main contribution in autonomous robotics is to make autonomy possible, by various means corresponding to endow robots with an artificial physiology, to give instructions in a natural and incremental way and to prioritize the synergy between reactive and robust schemes over complex planning structures.

4. Application Domains

4.1. Overview

One of the most original specificity of our team is that it is part of a laboratory in Neuroscience (with a large spectrum of activity from the molecule to the behavior), focused on neurodegenerative diseases and consequently working in tight collaboration with the medical domain. As a consequence, neuroscientists and the medical world are considered as the primary end-users of our researches. Beyond data and signal analysis where our expertise in machine learning may be possibly useful, our interactions are mainly centered on the exploitation of our models. They will be classically regarded as a way to validate biological assumptions and to generate new hypotheses to be investigated in the living. Our macroscopic models and their implementation in autonomous robots will allow an analysis at the behavioral level and will propose a systemic framework, the interpretation of which will meet aetiological analysis in the medical domain and interpretation of intelligent behavior in cognitive neuroscience.

The study of neurodegenerative diseases is targeted because they match the phenomena we model. Particularly, the Parkinson disease results from the death of dopaminergic cells in the basal ganglia, one of the main systems that we are modeling. The Alzheimer disease also results from the loss of neurons, in several cortical and extracortical regions. The variety of these regions, together with large mnesic and cognitive deficits, require a systemic view of the cerebral architecture and associated functions, very consistent with our approach.

Of course, numerical sciences are also impacted by our researches, at several levels. At a global level, we will propose new control architectures aimed at providing a higher degree of autonomy to robots, as well as machine learning algorithms working in more realistic environment. More specifically, our focus on some cognitive functions in closed loop with a real environment will address currently open problems. This is obviously the case for planning and decision making; this is particularly the case for the domain of affective computing, since motivational characteristics arising from the design of an artificial physiology allow to consider not only cold rational cognition but also hot emotional cognition. The association of both kinds of cognition is undoublty an innovative way to create more realistic intelligent systems but also to elaborate more natural interfaces between these systems and human users.

At last, we think that our activities in well-founded distributed computations and high performance computing are not just intended to help us design large scale systems. We also think that we are working here at the core of informatics and, accordingly, that we could transfer some fundamental results in this domain.

5. Highlights of the Year

5.1. Highlights of the Year

We published this year an important article [4] gathering 45 co-authors about the ReScience initiative which makes an important contribution that traditional scientific journals cannot offer. It provides a venue for publishing replication work, which traditional journals exclude for lack of novelty. Considering the ever increasing importance of computational methods in all scientific disciplines, we believe that our approach to replication is of interest to a broad audience of researchers.

6. New Software and Platforms

6.1. DANA

Distributed Asynchronous Numerical and Adaptive computing framework
KEYWORD: Neural networks
FUNCTIONAL DESCRIPTION: DANA is a python framework whose computational paradigm is grounded on the notion of a unit that is essentially a set of time dependent values varying under the influence of other units via adaptive weighted connections. The evolutions of a unit's value are defined by a set of differential equations expressed in standard mathematical notation which greatly ease their definition. The units are organized into groups that form a model. Each unit can be connected to any other unit (including itself) using a weighted connection. The DANA framework offers a set of core objects needed to design and run such models. The modeler only has to define the equations of a unit as well as the equations governing the training of the connections. The simulation is completely transparent to the modeler and is handled by DANA. This allows DANA to be used for a wide range of numerical and distributed models as long as they fit the proposed framework (e.g. cellular automata, reaction-diffusion system, decentralized neural networks, recurrent neural networks, kernel-based image processing, etc.).

- Participant: Nicolas Rougier
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- URL: http://dana.loria.fr/

6.2. ENAS

Event Neural Assembly Simulation

KEYWORDS: Neurosciences - Health - Physiology

SCIENTIFIC DESCRIPTION: As one gains more intuitions and results on the importance of concerted activity in spike trains, models are developed to extract potential canonical principles underlying spike coding. These methods shed a new light on spike train dynamics. However, they require time and expertise to be implemented efficiently, making them hard to use in a daily basis by neuroscientists or modelers. To bridge this gap, we developed the license free multiplatform software ENAS (https://enas.inria.fr) integrating tools for individual and collective spike analysis and simulation, with some specificities devoted to the retina. The core of ENAS is the statistical analysis of population codes. One of its main strength is to provide statistical analysis of spike trains using Maximum Entropy-Gibbs distributions taking into account both spatial and temporal correlations as constraints, allowing to introduce causality and memory in statistics. ENAS also generates simulated spike trains. On one hand, one can draw a population raster from an user-specified Gibbs distribution. On the other hand, we have integrated in ENAS our retina simulator VIRTUAL RETINA, extended here to include lateral connections in the IPL. We hope that ENAS will become a useful tool for neuroscientists to analyse spike trains and we hope to improve it thanks to user feedback. Our goal is to progressively enrich it with the latest research results, in order to facilitate transfer of new methods to the community.

FUNCTIONAL DESCRIPTION: As one gains more intuitions and results on the importance of concerted activity in spike trains, models are developed to extract potential canonical principles underlying spike coding. These methods shed a new light on spike train dynamics. However, they require time and expertise to be implemented efficiently, making them hard to use in a daily basis by neuroscientists or modelers. To bridge this gap, we developed the license free multiplatform software ENAS integrating tools for spike trains analysis and simulation. These tools are accessible through a friendly Graphical User Interface that avoids any scripting or writing code from the user. Most of them have been implemented to run in parallel to reduce the time and memory consumption. ENAS offers basic visualizations and classical analysis for statistics of spike trains analysis. It also proposes statistical analysis with Maximum Entropy-Gibbs distributions taking into account both spatial and temporal correlations as constraints, allowing to introduce causality and memory in statistics. ENAS also includes specific tools dedicated to the retina: Receptive Field computation and a virtual retina simulator. Finally, ENAS generates synthetic rasters, either from know statistics or from the VIRTUAL RETINA simulator. We expect ENAS to become a useful tool for neuroscientists to analyse spike trains and we hope to improve it thanks to users feedback. From our perspective, our goal is to progressively enrich ENAS with the latest research results, in order to facilitate transfer of new methods to the community.

- Participants: Bruno Cessac, Daniela Pamplona, Geoffrey Portelli, Hassan Nasser, Pierre Kornprobst, Rodrigo Cofre Torres, Sélim Kraria, Theodora Karvouniari and Thierry Viéville
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- URL: https://enas.inria.fr

6.3. Virtual Enaction

KEYWORDS: Neurosciences - Simulation - Health

FUNCTIONAL DESCRIPTION: VirtualEnaction: A Platform for Systemic Neuroscience Simulation. The computational models studied in this project have applications that extend far beyond what is possible to experiment yet in human or non-human primate subjects. Real robotics experimentations are also impaired by rather heavy technological constraints, for instance, it is not easy to dismantle a given embedded system in the course of emerging ideas. The only versatile environment in which such complex behaviors can be studied both globally and at the level of details of the available modeling is a virtual environment, as in video games, Such a system can be implemented as “brainy-bot” (a programmed player based on our knowledge of the brain architecture) which goal is to survive in a complete manipulable environment.

In order to attain this rather ambitious objective we both (i) deploy an existing open-source video game middleware in order to be able to shape the survival situation to be studied and (ii) revisit the existing models in order to be able to integrate them as an effective brainy-bot. It consists of a platform associated to a scenario that is the closest possible to a survival situation (foraging, predator-prey relationship, partner approach to reproduction) and in which it is easy to integrate an artificial agent with sensory inputs (visual, touch and smell), emotional and somatosensory cues (hunger, thirst, fear, ..) and motor outputs (movement, gesture, ..) connected to a "brain" whose architecture will correspond to the major anatomical regions involved in the issues of learning and action selection (cortex areas detailed here, basal ganglia, hippocampus, and areas dedicated to sensorimotor processes). The internal game clock can be slowed down enough to be able to run non trivial brainy-bot implementations. This platform has already being used by two students of the team and is now a new deliverable of the KEOpS project.

- Participants: André Garenne, Frédéric Alexandre, Nicolas Rougier and Thierry Viéville
- Contact: Frédéric Alexandre

7. New Results

7.1. Overview

This year we have explored two main cortico-basal loops of cerebral architecture, the limbic and motor loops, and their associated memory mechanisms. The limbic loop (*cf.* § 7.2) concerns the taking into account of the emotional and motivational aspects by the respondant and operant conditioning and their relations with the semantic and episodic memories. The motor loop (*cf.* § 7.3) considers the evolution of sensorimotor learning, from goal-directed behaviors to habitual behaviors.

We have also worked on the systemic integration of our models (*cf.* § 7.4), raising the question of the conditions of autonomous learning and certain global characteristics such as neuromodulation.

Finally, we study the links between our bio-inspired modeling work and Machine Learning (*cf.* § 7.5), revisiting this latter domain in the light of the principles highlighted by our models.

7.2. The limbic loop

We explore the limbic loop by studying a series of neural mechanisms that propose how respondant conditioning results from interactions between the amygdala, the nucleus accumbens and the limbic pole of the frontal cortex. In our models, this learning is also fed by exchanges with the hippocampus (episodic memory) [6] and the sensory cortex (semantic memory). We have also addressed the difficult question of the articulation between the respondant and operant conditioning in particular in the nucleus accumbens.

Also in connection with this loop, we studied the dynamics of dopamine release in the midbrain, considered to play an essential role in the coding of the prediction error. This model [12] developed in the framework of our collaboration with India (*cf.* § 9.3) proposes to introduce into the classical circuit, new actors (such as the pedunculopontine tegmental nucleus in the brainstem) and new functions (dissociation of amplitude and timing of the reward), that we will seek to corroborate in the future.

7.3. The motor loop

The nervous system structures involved in decision making constitute a circuit formed by the basal ganglia, the cortex, the thalamus and their numerous interconnections. This circuit can be described as a set of loops operating in parallel and interacting at different points. The decisions and therefore the actions of an individual emerge from the interactions between these loops and the plasticity of their connections. These emerging behaviors and arising learning processes are addressed through a closed-loop approach in which the theoretical model is in constant interaction with the environment of the task. To this end, neural modeling and dedicated analysis software tools were developed in the laboratory, at the level of the neuronal circuit.

7.4. Systemic integration

Systemic integration promotes the idea of developing large models that associate several cortico-basal loops and even other cerebral structures and more generally takes into account the influence of the body on this network [19]. This requires to propose a global picture for the organization and functional association between all these elements [18] and to analyze its consequences from a representational point of view [1] and also concerning autonomous learning [7].

It also requires to evaluate the properties of such systems from their interactions with the body and the environment, as we have done this year using the VirtualEnaction platform.

7.5. Machine Learning

In this section, we report on some neuronal adaptive mechanisms, that we develop at the frontier between Machine Learning and Computational Neuroscience. Our goal is to consider and adapt models in Machine Learning for their integration in a bio-inspired framework. We were interested this year in three paradigms of computation.

The first paradigm concerns the manipulation of temporal sequences. In a perspective of better understanding how the brain learns structured sequences we work on a model on syntax acquisition and Human-Robot Interaction using the Reservoir Computing framework (using random recurrent networks) [24], [15], [17] with our collaborators at the University of Hamburg (*cf.* § 9.3). A syntactic re-analysis system [15], which corrects syntax errors in speech recognition hypotheses, was built in order to enhance vocal Human-Robot Interaction and to enhance the previously developped model [40]. Additionally, the ability to deal with several languages (from different language families) of this later model of sentence parsing [40] was evaluated. We showed that it can successfully learn to parse sentences related to home scenarios in fifteen languages originating from Europe and Asia [24]. In a different perspective, in order to try to overcome word misrecognition at a more basic level, we tested whether the same architecture was able to process directly phonemes instead of grammatical constructions [17]. Applied on a small corpus, we see that the model has similar performance.

In an industrial application for the representation of electrical diagrams (*cf.* § 8.1), we also study how recurrent layered models can be trained to run through these schemes for prediction and sequence representation tasks [10].

The second paradigm concerns the extraction of characteristics and the use of hierarchical networks, as in the case of deep networks. An industrial application (*cf.* § 9.2) allows us to revisit these models to make them more easily usable in constrained frameworks, for example with limited size corpuses, and more interpretable introducing a new notion of prototypes and exploring the capability to learn the network architecture itself (using shortcuts) [11]. In order to push the sate of the art, the next step is going to consider not only feed-forward but also recurrent architecture, and to this end neural network recurrent weight estimation through backward tuning has been revisited [21].

The third paradigm is about spatial computation. We have designed a graphical method originating from the computer graphics domain that is used for the arbitrary and intuitive placement of cells over a two-dimensional manifold. Using a bitmap image as input, where the color indicates the identity of the different structures and the alpha channel indicates the local cell density, this method guarantees a discrete distribution of cell position respecting the local density function. This method scales to any number of cells, allows to specify several different structures at once with arbitrary shapes and provides a scalable and versatile alternative to the more classical assumption of a uniform non-spatial distribution. This preliminary work will be used in the design of a new class of model where explicit topography allows to connect structure according to known pathways.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. Contract with Algotech

Participants: Frédéric Alexandre, Ikram Chraibi Kaadoud, Nicolas Rougier, Thierry Viéville.

Algotech is a SME working in the domain of CADD software edition for electrical circuit diagram interpretation and design. Its activity is interesting for our team because they are also interested in the design, by learning, of perception (for diagram identification) and action aspects of loops (for diagram genesis) with the specificity of working at a small scale, considering the variety of items to be manipulated. This is consequently a very interesting benchmark for transfering our bio-inspired models to the domain of classical machine learning.

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. PsyPhINe

Participant: Nicolas Rougier.

Project gathering researchers from: MSH Lorraine (USR3261), InterPsy (EA 4432), APEMAC, EPSaM (EA4360), Archives Henri-Poincaré (UMR7117), Loria (UMR7503) & Mnemosyne.

PsyPhiNe is a pluridisciplinary and exploratory project between philosophers, psychologists, neuroscientists and computer scientists. The goal of the project is to explore cognition and behavior from different perspectives. The project aims at exploring the idea of assignments of intelligence or intentionality, assuming that our intersubjectivity and our natural tendency to anthropomorphize play a central role: we project onto others parts of our own cognition. To test these hypotheses, we ran a series of experiments with human subject confronted to a motorized lamp that can or cannot interact with them while they're doing a specific task. We've organized our third national conference in Nancy gathering speakers from philosophy, robotics, art and psychology and closed a three years cycle. The group now aims at publishing a book gathering text from all the invited speakers.

9.2. National Initiatives

9.2.1. FUI Sumatra

Participants: Frédéric Alexandre, Thalita Firmo Drumond, Xavier Hinaut, Randa Kassab, Nicolas Rougier, Thierry Viéville.

This FUI project, supported by the Aerospace Valley Innovation Pole, gathers two industrial groups (Safran Helicopter and SPIE), three research labs and four SME. Its goal is to provide contextualized information to maintenance operators by the online analysis of the operating scene. We are concerned in this project with the analysis of visual scenes, in industrial contexts, and the extraction of visual primitives, categories and pertinent features, best decribing the scenes, with biologically inspired neuronal models.

Firstly, this is an opportunity for us to revisit the principles of deep network architectures by adapting principles that we will elaborate from the context of the hierarchical architecture of the temporal visual cortex. Secondly, we intend to exploit and adapt our model of hippocampus to extract more heterogenous features. This project is an excellent opportunity to associate and combine our models and also to evaluate the robustness of our models in real-world applications.

9.2.2. ANR SOMA (PRCI)

Participant: Nicolas Rougier.

This new project is a convergence point between past research approaches toward new computational paradigms: adaptive reconfigurable architecture, cellular computing, computational neuroscience, and neuromorphic hardware:

1. SOMA is an adaptive reconfigurable architecture to the extent that it will dynamically re-organize both its computation and its communication by adapting itself to the data to process.
2. SOMA is based on cellular computing since it targets a massively parallel, distributed and decentralized neuromorphic architecture.
3. SOMA is based on computational neuroscience since its self-organization capabilities are inspired from neural mechanisms.
4. SOMA is a neuromorphic hardware system since its organization emerges from the interactions between neural maps transposed into hardware from brain observation.

This project represents a significant step toward the definition of a true fine-grained distributed, adaptive and decentralized neural computation framework. Using self-organized neural populations onto a cellular machine where local routing resources are not separated from computational resources, it will ensure natural scalability and adaptability as well as a better performance/power consumption tradeoff compared to other conventional embedded solutions.

9.2.3. ANR MACAQUE40

Participant: Nicolas Rougier.

Most of the theoretical models in economics proposed so far to describe money emergence are based on three intangible assumptions: the omniscience of economic agents, an infinite time and an extremely large number of agents (not bounded). The goal of this interdisciplinary study is to investigate the condition of apparition of a monetary economy in a more ecological framework provided with the assumption that the market is made up of a finite number of agents having a bounded rationality and facing a time constraint.

In this study, we propose a generic model and environment of monetary prospecting. Our first objective is to artificially identify structural (trading organisation, agents specialisation) and cognitive conditions (learning skills, memory and strategic anticipation abilities, tradeoff exploration/exploitation) that allowed money emergence. This will provide relevant environmental constraints that we will use during our manipulations in the laboratory. The agents that will be involved in these manipulations will be of two types: non-human primates (rhesus macaques) and humans.

9.2.4. Project Motus of the ANSES

Participant: André Garenne.

The MOTUS project (MOdulaTion dU Signal RF et effets sur le cerveau : approche in vivo et in vitro) is financed by the ANSES (the french national agency for health security). This 3 years project is studying the effects of GSM-RF on living matter and especially neuronal activity and development. Our main involvement concerns electrophysiological data and spike trains analysis as well as the development of pharmacological protocols to test GSM-RF effects hypotheses.

This year, we have designed and realised new experiments in order to better caracterize the effect of 1800 Mz RF field of GSM on the spontaneous activity of in-vitro cortical cell cultures. In the current study, our aim was to highlight a dose-response relationship for this effect. To do this, we have recorded the spontaneous bursting activity of cortical neurons cultures on multi-electrodes arrays. We have thus shown that at SAR (Specific Absorption Rate) ranging from 0.01 to 9.2 W/kg the signal elicited a clear decrease in bursting rate during the RF exposure phase that lasted even after the end of the exposure. Moreover, the effect grew larger with increasing SAR, and the amplitude of the change was greater with a GSM signal than with a continuous wave RF field of the same energy level. These experimental findings provide evidence for clear effects of RF signals on the bursting rate of neuronal cultures.

9.3. International Initiatives

9.3.1. Inria Associate Teams Not Involved in an Inria International Labs

9.3.1.1. Braincraft

Title: Braincraft

International Partner (Institution - Laboratory - Researcher):

University of Colorado, Boulder (United States) - Computational Cognitive Neuroscience - Randall O'Reilly

What are the processes by which animals and humans select their actions based on their motivations and on the consequences of past actions? This is a fundamental question in neurosciences, with implications to ethology, psychology, economics, sociology and computer science. Through a unique combination of expertise in cognitive psychology, neurosciences and computer science, this associate team will foster a collaboration for developing a computationally-based understanding of the neural circuits involved in decision making, namely basal ganglia and prefrontal cortex. One of the key question is to know the overall contribution of these structures and their function in the decision process.

9.3.2. Participation in Other International Programs

9.3.2.1. Project LingoRob with Germany

LingoRob - Learning Language in Developmental Robots - is a project of the Programme Hubert Curien PHC Procope with Germany (University of Hamburg). The scientific objective of the collaboration is to better understand the mechanisms underlying language acquisition and enable more natural interaction between humans and robots in different languages, while modelling how the brain processes sentences and integrates semantic information of scenes. Models developed in both labs involve artificial neural networks, and in particular Echo State Networks (ESN), also known as pertaining to the Reservoir Computing framework. These neural models allow insights on high-level processes of the human brain, and at the same time are well suited as robot control platform, because they can be trained and executed online with low computational resources. The collaborators will also combine Deep Learning networks to the reservoir models already used in order to benefit from their very good feature extraction abilities.

9.3.2.2. Project BGaL with India

In the 3-years project "Basal Ganglia at Large (BGaL)", funded by the CNRS and the CEFIPRA, we collaborate with the computer science department of IIIT Hyderabad and the biomedical department of IIT Madras, for the design of models of basal ganglia and for their implementation at large scale as well as for their relation with other brain structures. This year we have worked on a model of a dopaminergic region, VTA, central for reinforcement learning in the basal ganglia.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

Prof. Chakravarthy Srinivasa

Date: Nov-Dec 2017

Institution: IIT Madras, Chennai (India)

Johannes Twiefel

Date: 10 days, Sep 2017; 1 week, Nov 2017.

Institution: University of Hamburg, Germany.

Luiza Mici

Date: 10 days, Sep 2017.

Institution: University of Hamburg, Germany.

9.4.1.1. Internships

Remya Sankar

Date: June 2017 - Dec 2017

Institution: IIIT Hyderabad (India)

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. General Chair, Scientific Chair

Nicolas Rougier: co-chair for the organization of the 7th Symposium on the Biology of Decision Making, Bordeaux, France (http://sbdm2017.isir.upmc.fr/).

10.1.1.2. Member of the Organizing Committees

F. Alexandre: organization of the Latin-American Summer School on Computational Neuroscience (Laconeu, 9-27 january 2017, Valparaiso, Chile).

X. Hinaut: organisation of the 2nd Workshop on Machine Learning Methods for High-Level Cognitive Capabilities in Robotics (ML-HLCR), IROS, 28 September 2017, Vancouver, Canada.

10.1.2. Scientific Events Selection

10.1.2.1. Member of the Conference Program Committees

Nicolas Rougier: Scipy 2017, EuroScipy 2017, WSOM 2017

10.1.2.2. Reviewer

- F. Alexandre: NER'17; ICDL-EPIROB 2017;
- Nicolas Rougier: Frontiers in Computational Neuroscience, Complexity, JOSS, ReScience;
- X. Hinaut: CogSci'17, ICDL-EPIROB 2017, ESANN 2018;

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- Frédéric Alexandre: Review Editor for Frontiers in Neurorobotics;
- Nicolas Rougier: Editor in chief for ReScience, Academic editor for PeerJ, review editor for Frontiers in Neurorobotics.

10.1.3.2. Reviewer - Reviewing Activities

- F. Alexandre: Frontiers in Neuroscience; PLoS ONE; Cognitive Computation; Nature Scientific Reports; eLife;
- André Garenne: Journal of Integrative Neuroscience
- Xavier Hinaut: Neural Networks, Frontiers in Neurorobotics, IEEE Transactions on Cognitive and Developmental Systems (TCDS), Applied Sciences;

10.1.4. Invited Talks

F. Alexandre:

- Workshop on Comptational Neuroscience: New trends and challenges for 2030; January 18, Valparaiso, Chile.
- 2017 meeting of the GDR Neurociences of memory NeuroMem, May, 16.
- Seminar “Modeling Cognitive Processes” of the laboratory LEAD, Dijon (Nov. 24).
- Annual meeting of the AMAF medical association (“Modeling Cognitive Functions and Artificial Intelligence”, Nov. 25, Creteil).

Nicolas Rougier:

- Lex Robotica, Paris, France
- 7th Symposium on the Biology of Decision Making, Bordeaux, France.
- Open Science, Bordeaux, France
- Scientific Python, La Rochelle, France
- Reproduction is not replication, Reading, UK

X. Hinaut:

- Workshop "The role of the basal ganglia in the interaction between language and other cognitive functions", DEC, ENS Ulm, October 12-13, Paris, France.

10.1.5. Leadership within the Scientific Community

X. Hinaut:

- President of the association MindLaBDX: “open citizen lab” in Cognitive Sciences and Artificial Intelligence in Bordeaux.
- Organization of “Hack’1 Cerveau !”: the first CogSci and AI hackathon in Bordeaux, at 127° (the fablab of Cap Sciences), 8-10 December 2017. Cf https://mindlabdx.github.io/hack1cerveau and also https://lascienceenpassant.wordpress.com/2017/12/11/hackaton-hack1-cerveau and http://penseeartificielle.fr/hack1-cerveau-2017-cerveau-cap-science.
- member of the Administration Committee of Fresco association (French Federation of students in Cognitive Science)

Nicolas Rougier: Editor in chief for ReScience

10.1.6. Scientific Expertise

F. Alexandre is the french expert for Mathematics and Computer Science of the PHC (Hubert Curien Program) Utique for scientific cooperation between France and Tunisia. In 2017, he participated to the CHIST ERA Evaluation Panel, May 18-19 and acted as an expert for the ANR.

10.1.7. Research Administration

- F. Alexandre is member of the Inria Evaluation Committee; Deputy Scientific Delegate and Vice-head of the Project Committee of Inria Bordeaux Sud-Ouest; Corresponding scientist for Bordeaux Sud-Ouest of the Inria COERLE ethical committee; Member of the national Inria committee for international chairs; Member of the local Inria committee for young researchers hiring; Member of the steering committee of the regional Cluster on Information Technology and Health; of the regional Cluster on Robotics; Expert of the ITMO ’Neurosciences, Sciences Cognitive, Neurologie, Psychiatrie’
- N. Rougier is vice-head of the Mnemosyne team-project; elected member of the Inria Evaluation Committee; Responsible of the local Inria committee for invited professors; Member of the steering committee for the BioComp CNRS consortium; Editor in chief and co-founder of ReScience.
- Thierry Viéville is in charge of the http://classcode.fr project and in charge, for Inria, of the creation of a Master SmartEdTech at UCA within the scope of his mission for the Inria Sophia Antipolis - Méditérannée direction.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

F. Alexandre: teaching at the Laconeu summer school 9-27 january 2017, Valparaiso, Chile. Teaching Ethics for Inria PhD students (Sept. 25 and Oct. 6).

André Garenne (in collaboration with Xavier Nogues) created a new teaching unit for bachelor students in biology at the final stage of their graduation. This unit will be half dedicated to the learning of programming basics using Python and its scientific libraries and half dedicated to the learning of statistical data analysis methods relying mainly on machine learning approaches and the R language.

Nicolas Rougier organized a python scientific course (24h) for the doctoral students in mathematics and computer science.

Thierry Viéville is since 2009 in charge of formations of high-school teachers in popular computer science and teached computational neuroscience in the Master of Cognitive Science and Ergonomics.

In addition, many courses are given in french universities and schools of engineers at different levels (LMD) by most team members, in computer science, in applied mathematics, in neuroscience and in cognitive science.

10.2.2. Juries

We participate to many juries each year.

10.3. Popularization

For a multi-disciplinary team as Mnemosyne, science popularization is not only a nice and useful contribution to the dissemination of scientific knowledge but also a necessity since we work with colleagues from bio-sciences with whom sharing profound ideas in computer science is mandatory for a real collaboration.

- Thierry Viéville is for 50% of his time involved in popularization actions, mainly computer science large audience education, and has been promoted Officer of the Order of Academic Palms for the collective contribution of the Inria Science Outreach mission.
- F. Alexandre organized a conference about artificial intelligence with high-school children (Sept. 28, Lormont)
- I. Chraibi Kaadoud participated to the regional challenge: “My PhD in 180 seconds”
- X. Hinaut organized the 1st hackathon of Bordeaux in Cognitive Sciences and Artificial Intelligence, 8-10 December, Cap Sciences, Bordeaux. (https://mindlabdx.github.io/hack1cerveau/); Organization of a workshop on cellular automaton at Le Node, Bordeaux; Meeting groups of high-school students for their projects on Artificial Intelligence topics.
- The team participated to “La semaine du cerveau” on the Bordeaux Neurocampus (March 13-17) (http://www.bordeaux-neurocampus.fr/fr/manifestations-scientifiques/seminaires-2017/semaine-cerveau-2017.html); to the “fête de la science” on the Bordeaux Neurocampus (http://circuit-scientifique-bordelais.cnrs.fr/modules/show/261, Oct. 7-9); to the Declics program for high-schools (http://www.cerclefser.org/fr/declics/, Dec. 12)

11. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

[1] F. ALEXANDRE. *How to Understand Brain-Body-Environment Interactions? Toward a systemic Representationalism*, in "Constructivist Foundations", November 2017, vol. 13, n^{o} 1, pp. 130-131, https://hal.inria.fr/hal-01651768

[2] F. C. Y. BENUREAU, N. P. ROUGIER. *Re-run, Repeat, Reproduce, Reuse, Replicate: Transforming Code into Scientific Contributions*, in "Frontiers in Neuroinformatics", 2017, https://arxiv.org/abs/1708.08205 , forthcoming [*DOI :* 10.3389/FNINF.2017.00069], https://hal.inria.fr/hal-01577578

[3] B. CESSAC, P. KORNPROBST, S. KRARIA, H. NASSER, D. PAMPLONA, G. PORTELLI, T. VIEVILLE. *PRANAS: A New Platform for Retinal Analysis and Simulation*, in "Frontiers in Neuroinformatics", September 2017, vol. 11, 49 p. , https://hal.inria.fr/hal-01588737

[4] N. P. ROUGIER, K. HINSEN, F. ALEXANDRE, T. ARILDSEN, L. BARBA, F. C. Y. BENUREAU, C. T. BROWN, P. DE BUYL, O. CAGLAYAN, A. P. DAVISON, M. A. DELSUC, G. DETORAKIS, A. K. DIEM, D. DRIX, P. ENEL, B. GIRARD, O. GUEST, M. G. HALL, R. N. HENRIQUES, X. HINAUT, K. S. JARON, M. KHAMASSI, A. KLEIN, T. MANNINEN, P. MARCHESI, D. MCGLINN, C. METZNER, O. L. PETCHEY, H. E. PLESSER, T. POISOT, K. RAM, Y. RAM, E. ROESCH, C. ROSSANT, V. ROSTAMI, A. SHIFMAN, J. STACHELEK, M. STIMBERG, F. STOLLMEIER, F. VAGGI, G. VIEJO, J. VITAY, A. VOSTINAR, R. YURCHAK, T. ZITO. *Sustainable computational science: the ReScience initiative*, in "PeerJ Computer Science", 2017, https://arxiv.org/abs/1707.04393 - 8 pages, 1 figure, forthcoming, https://hal.inria.fr/hal-01592078

[5] N. P. ROUGIER. *[Re] Weighted Voronoi Stippling*, in "The ReScience journal", June 2017, vol. 3, n° 1 [*DOI :* 10.5281/ZENODO.802285], https://hal.inria.fr/hal-01532740

Invited Conferences

[6] F. ALEXANDRE. *Modeling the ventral hippocampus and its role in the limbic system*, in "Journée Scientifique du GDR Neurosciences de la Mémoire", Bordeaux, France, May 2017, https://hal.inria.fr/hal-01523746

[7] F. ALEXANDRE. *What Computational Neuroscience can offer Machine Learning : Autonomous Learning* , in "Workshop on Computational Neuroscience: challenges for the 2030", Valparaiso, Chile, January 2017, https://hal.inria.fr/hal-01528663

[8] K. HINSEN, N. P. ROUGIER. *ReScience*, in "Open science, transparence et évaluation. Perspectives et enjeux pour les chercheurs", Bordeaux, France, URFIST Bordeaux, April 2017, https://hal.archives-ouvertes.fr/hal-01573262

[9] N. P. ROUGIER. *Noise as a symmetry breaker*, in "SBDM 2017 - Seventh International Symposium on Biology of Decision Making", Bordeaux, France, May 2017, 26 p. , https://hal.archives-ouvertes.fr/hal-01573258

International Conferences with Proceedings

[10] I. CHRAIBI KAADOUD, N. P. ROUGIER, F. ALEXANDRE. *Implicit knowledge extraction and structuration from electrical diagrams*, in "The 30th International Conference on Industrial, Engineering, Other Applications of Applied Intelligent Systems", Arras, France, June 2017, https://hal.inria.fr/hal-01525028

[11] T. F. DRUMOND, T. VIÉVILLE, F. ALEXANDRE. *Using prototypes to improve convolutional networks interpretability*, in "31st Annual Conference on Neural Information Processing Systems: Transparent and interpretable machine learning in safety critical environments Workshop", Long Beach, United States, December 2017, https://hal.inria.fr/hal-01651964

[12] P. S. KAUSHIK, M. S. CARRERE, F. ALEXANDRE, S. B. RAJU. *A biologically inspired neuronal model of reward prediction error computation*, in "IJCNN 2017 - International Joint Conference on Neural Networks", Anchorage, United States, May 2017, 8 p. , https://hal.inria.fr/hal-01528658

[13] B. T. NALLAPU, B. R. SURAMPUDI, N. P. ROUGIER. *The art of scaling up : a computational account on action selection in basal ganglia: [FULL Version]*, in "IJCNN 2017 - International Joint Conference on Neural Networks", Anchorage, Alaska, United States, May 2017, https://hal.inria.fr/hal-01534459

[14] N. P. ROUGIER, Y. BONIFACE. *Motivated Self-Organization*, in "12th International Workshop on Self-Organizing Maps and Learning Vector Quantization,", Nancy, France, June 2017, https://hal.inria.fr/hal-01513519

[15] J. TWIEFEL, X. HINAUT, S. WERMTER. *Syntactic Reanalysis in Language Models for Speech Recognition*, in "2017 Joint IEEE International Conference on Development and Learning and Epigenetic Robotics (ICDL-EpiRob)", Lisbon, Portugal, September 2017, https://hal.inria.fr/hal-01558462

Conferences without Proceedings

[16] F. C. Y. BENUREAU, T. BORAUD, N. P. ROUGIER. *Habits That Contradict Rewards*, in "7th Joint IEEE International Conference on Development and Learning and on Epigenetic Robotics", Lisbon, Portugal, September 2017, https://hal.inria.fr/hal-01535484

[17] X. HINAUT. *From Phonemes to Robot Commands with a Neural Parser*, in "IEEE ICDL-EPIROB Workshop on Language Learning", Lisbon, Portugal, September 2017, pp. 1-2, https://hal.inria.fr/hal-01665823

Scientific Books (or Scientific Book chapters)

[18] F. ALEXANDRE. *A behavioral framework for information representation in the brain*, in "Computational Models of Brain and Behavior", A. A. MOUSTAFA (editor), Wiley, November 2017, pp. 403-412, https://hal.inria.fr/hal-01651751

[19] M.-J. U. ESCOBAR, F. ALEXANDRE, T. VIÉVILLE, A. PALACIOS. *Rapid Prototyping for Bio–Inspired Robots*, in "Rapid Roboting: Recent Advances on 3D Printers and Robotics", Intelligent Systems, Control and Automation: Science and Engineering, Springer, February 2017, 300 p. , https://hal.inria.fr/hal-01427958

Research Reports

[20] B. CESSAC, P. KORNPROBST, S. KRARIA, H. NASSER, D. PAMPLONA, G. PORTELLI, T. VIÉVILLE. *PRANAS: A new platform for retinal analysis and simulation*, Inria Sophia Antipolis ; Inria Bordeaux Sud-Ouest, August 2017, n^{o} RR-8958, 27 p. , https://hal.inria.fr/hal-01377307

[21] T. VIÉVILLE, X. HINAUT, T. F. DRUMOND, F. ALEXANDRE. *Recurrent neural network weight estimation through backward tuning*, Inria Bordeaux Sud-Ouest, October 2017, n^{o} RR-9100, pp. 1-54, https://hal.inria.fr/hal-01610735

Scientific Popularization

[22] T. F. DRUMOND, L. VIENNOT, T. VIÉVILLE, V. FRANÇOIS. *Jouez avec les neurones de la machine*, in "Blog Binaire LeMonde.fr", October 2017, pp. 1-3, https://hal.inria.fr/hal-01620451

Other Publications

[23] X. HINAUT, A. CAZALA, C. DEL NEGRO. *Neural coding of variable song structure in the songbird*, May 2017, 1 p. , EBM 2017 - European Birdsong Meeting, Poster, https://hal.inria.fr/hal-01665824

[24] X. HINAUT, J. TWIEFEL. *Teach Your Robot Your Language! Trainable Neural Parser for Modelling Human Sentence Processing: Examples for 15 Languages*, December 2017, working paper or preprint, https://hal.inria.fr/hal-01665807

[25] N. P. ROUGIER. *A graphical, scalable and intuitive method for the placement and the connection of biological cells*, October 2017, https://arxiv.org/abs/1710.05189 - Corresponding code at https://github.com/rougier/spatial-computation [*DOI :* 10.05189], https://hal.inria.fr/hal-01617732

[26] N. P. ROUGIER. *Decision Making: who's in charge?*, September 2017, pp. 1-19, Lex Robotica, https://hal.inria.fr/hal-01656676

[27] N. P. ROUGIER, J. TIMMER. *Ten Simple Rules for Scientific Fraud & Misconduct*, July 2017, working paper or preprint, https://hal.inria.fr/hal-01562601

[28] S. SHIVKUMAR, V. S. CHAKRAVARTHY, N. P. ROUGIER. *Modeling the Role of Striatum in Stochastic Multi Context Tasks*, December 2017, working paper or preprint [*DOI :* 10.1101/196543], https://hal.inria.fr/hal-01654436

[29] M. TOPALIDOU, D. KASE, T. BORAUD, N. P. ROUGIER. *One critic, two actors: evidence for covert learning in the basal ganglia*, April 2017, working paper or preprint, https://hal.archives-ouvertes.fr/hal-01337332

References in notes

[30] F. ALEXANDRE. *Biological Inspiration for Multiple Memories Implementation and Cooperation*, in "International Conference on Computational Intelligence", V. KVASNICKA, P. SINCAK, J. VASCAK, R. MESIAR (editors), 2000

[31] S. AMARI. *Dynamic of pattern formation in lateral-inhibition type neural fields*, in "Biological Cybernetics", 1977, vol. 27, pp. 77–88

[32] D. H. BALLARD, M. M. HAYHOE, P. K. POOK, R. P. N. RAO. *Deictic codes for the embodiment of cognition*, in "Behavioral and Brain Sciences", 1997, vol. 20, n° 04, pp. 723–742, http://dx.doi.org/10.1017/S0140525X97001611

[33] D. BERTSEKAS, J. TSITSIKLIS. *Parallel and Distributed Computation: Numerical Methods*, Athena Scientific, 1997

[34] R. BRETTE, M. RUDOLPH, T. CARNEVALE, M. HINES, D. BEEMAN, J. BOWER, M. DIESMANN, A. MORRISON, P. H. GOODMAN, F. C. JR. HARRIS, M. ZIRPE, T. NATSCHLÄGER, D. PECEVSKI, B. ERMENTROUT, M. DJURFELDT, A. LANSNER, O. ROCHEL, T. VIÉVILLE, E. MULLER, A. DAVISON, S. E. BOUSTANI, A. DESTEXHE. *Simulation of networks of spiking neurons: a review of tools and strategies*, in "Journal of Computational Neuroscience", 2007, vol. 23, n° 3, pp. 349–398

[35] S. COOMBES. *Waves, bumps and patterns in neural field theories*, in "Biol. Cybern.", 2005, vol. 93, pp. 91-108

[36] P. DAYAN, L. ABBOTT. *Theoretical Neuroscience : Computational and Mathematical Modeling of Neural Systems*, MIT Press, 2001

[37] K. DOYA. *What are the computations of the cerebellum, the basal ganglia and the cerebral cortex?*, in "Neural Networks", 1999, vol. 12, pp. 961–974

[38] J. FIX, N. P. ROUGIER, F. ALEXANDRE. *A dynamic neural field approach to the covert and overt deployment of spatial attention*, in "Cognitive Computation", 2011, vol. 3, n° 1, pp. 279-293 [*DOI :* 10.1007/S12559-010-9083-Y], http://hal.inria.fr/inria-00536374/en

[39] W. GERSTNER, W. KISTLER. *Spiking Neuron Models: Single Neurons, Populations, Plasticity*, Cambridge University Press, Cambridge University Press, 2002

[40] X. HINAUT, P. F. DOMINEY. *Real-time parallel processing of grammatical structure in the fronto-striatal system: A recurrent network simulation study using reservoir computing*, in "PloS one", 2013, vol. 8, n° 2, e52946 p.

[41] T. MITCHELL. *Machine Learning*, Mac Graw-Hill Press, 1997

[42] D. MITRA. *Asynchronous relaxations for the numerical solution of differential equations by parallel processors*, in "SIAM J. Sci. Stat. Comput.", 1987, vol. 8, n° 1, pp. 43–58

[43] R. O'REILLY, Y. MUNAKATA. *Computational Explorations in Cognitive Neuroscience: Understanding the Mind by Simulating the Brain*, MIT Press, Cambridge, MA, USA, 2000

[44] N. P. ROUGIER, A. HUTT. *Synchronous and Asynchronous Evaluation of Dynamic Neural Fields*, in "J. Diff. Eq. Appl.", 2009

[45] N. P. ROUGIER. *Dynamic Neural Field with Local Inhibition*, in "Biological Cybernetics", 2006, vol. 94, n° 3, pp. 169-179

[46] L. SQUIRE. *Memory systems of the brain: a brief history and current perspective*, in "Neurobiol. Learn. Mem.", 2004, vol. 82, pp. 171-177

[47] W. TAOUALI, T. VIÉVILLE, N. P. ROUGIER, F. ALEXANDRE. *No clock to rule them all*, in "Journal of Physiology", 2011, vol. 105, n° 1-3, pp. 83-90

[48] T. TRAPPENBERG. *Fundamentals of Computational Neuroscience*, Oxford University Press, 2002

[49] T. VIÉVILLE. *An unbiased implementation of regularization mechanisms*, in "Image and Vision Computing", 2005, vol. 23, n° 11, pp. 981–998, http://authors.elsevier.com/sd/article/S0262885605000909