



RESEARCH CENTER  
Bordeaux - Sud-Ouest

FIELD

Activity Report 2018

# Section Partnerships and Cooperations

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## **LFANT Project-Team**

# **7. Partnerships and Cooperations**

## **7.1. National Initiatives**

### **7.1.1. ANR *Alambic – AppLicAtions of MalleaBility in Cryptography***

**Participant:** Guilhem Castagnos.

<https://crypto.di.ens.fr/projects:alambic:main>

The ALAMBIC project is a research project formed by members of the Inria Project-Team CASCADE of ENS Paris, members of the AriC Inria project-team of ENS Lyon, and members of the CRYPTIS of the university of Limoges. G. Castagnos is an external member of the team of Lyon for this project.

Non-malleability is a security notion for public key cryptographic encryption schemes that ensures that it is infeasible for an adversary to modify ciphertexts into other ciphertexts of messages which are related to the decryption of the first ones. On the other hand, it has been realized that, in specific settings, malleability in cryptographic protocols can actually be a very useful feature. For example, the notion of homomorphic encryption allows specific types of computations to be carried out on ciphertexts and generate an encrypted result which, when decrypted, matches the result of operations performed on the plaintexts. The homomorphic property can be used to create secure voting systems, collision-resistant hash functions, private information retrieval schemes, and for fully homomorphic encryption enables widespread use of cloud computing by ensuring the confidentiality of processed data.

The aim of the ALAMBIC project to investigate further theoretical and practical applications of malleability in cryptography. More precisely, this project focuses on three different aspects: secure computation outsourcing and server-aided cryptography, homomorphic encryption and applications and << paradoxical >> applications of malleability.

### **7.1.2. ANR *CLap–CLap – The $p$ -adic Langlands correspondence: a constructive and algorithmical approach***

**Participant:** Xavier Caruso.

The  $p$ -adic Langlands correspondence has become nowadays one of the deepest and the most stimulating research programs in number theory. It was initiated in France in the early 2000's by Breuil and aims at understanding the relationships between the  $p$ -adic representations of  $p$ -adic absolute Galois groups on the one hand and the  $p$ -adic representations of  $p$ -adic reductive groups on the other hand. Beyond the case of  $GL_2(\mathbb{Q}_p)$  which is now well established, the  $p$ -adic Langlands correspondence remains quite obscure and mysterious new phenomena enter the scene; for instance, on the  $GL_n(F)$ -side one encounters a vast zoology of representations which seems extremely difficult to organize.

The CLap–CLap ANR project aims at accelerating the expansion of the  $p$ -adic Langlands program beyond the well-established case of  $GL_2(\mathbb{Q}_p)$ . Its main originality consists in its very constructive approach mostly based on algorithmics and calculations with computers at all stages of the research process. We shall pursue three different objectives closely related to our general aim:

1. draw a conjectural picture of the (still hypothetical)  $p$ -adic Langlands correspondence in the case of  $GL_n$ ,
2. compute many deformation spaces of Galois representations and make the bridge with deformation spaces of representations of reductive groups,
3. design new algorithms for computations with Hilbert and Siegel modular forms and their associated Galois representations.

This project will also be the opportunity to contribute to the development of the mathematical software SAGEMATH and to the expansion of computational methodologies.

## 7.2. European Initiatives

### 7.2.1. H2020 Projects

Title: OpenDreamKit

Program: H2020

Duration: January 2016 - December 2020

Coordinator: Nicolas Thiéry

Inria contact: Karim Belabas

Description [http://cordis.europa.eu/project/rcn/198334\\_en.html](http://cordis.europa.eu/project/rcn/198334_en.html), <http://opendreamkit.org>

OpenDreamKit is a Horizon 2020 European Research Infrastructure project (#676541) that will run for four years, starting from September 2015. It provides substantial funding to the open source computational mathematics ecosystem, and in particular popular tools such as LinBox, MPIR, SageMath, GAP, Pari/GP, LMFDB, Singular, MathHub, and the IPython/Jupyter interactive computing environment.

## 7.3. International Initiatives

### 7.3.1. Inria International Labs

#### **International Laboratory for Research in Computer Science and Applied Mathematics**

Associate Team involved in the International Lab:

#### 7.3.1.1. FAST

Title: (Harder Better) FAster STronger cryptography

International Partner

Université des Sciences et Techniques de Masuku (Gabon) - Tony Ezome and the PRMAIS project

Start year: 2017

See also: <https://www.inria.fr/en/associate-team/fast>

The project aims to develop better algorithms for elliptic curve cryptography with prospect of the two challenges ahead: - securing the internet of things - preparing towards quantum computers.

Elliptic curves are currently the fastest public-key cryptosystem (with a key size that can fit on embeded devices) while still through a different mode of operation beeing (possibly) able to resist quantum based computers.

Activities for this year involved:

- Tony Ezome organised a Cimpa school on Courbes algébriques pour une arithmétique efficace des corps finis from 17/11/2018 - 30/11/2018 in Ziguinchor (Sénégal), Institution Université Assane Seck de Ziguinchor.
- Abdoul Asiz Ciss and Damien Robert represented the team at the Journées du Lirima. One of the suggestion was to find industrial collaborations in Africa, especially in Senegal. Ongoing work is done by the team to find such a collaboration, especially on the new challenges of post-quantum cryptography.
- Abdoulaye Maiga visited in Bordeaux to work with Damien Robert from 22/10/2018 to 18/01/2019. Tony Ezome and Mohamadou Sall visited from 08/12/2018 to 22/12/2018.

Activities for this year involved the funding of Luca De Feo to speak at the EMA “Mathématiques pour la Cryptographie Post-quantique et Mathématiques pour le Traitement du Signal”, organised by Djiby Sow and Abdoul Asiz Ciss organised an EMA at the École Polytechnique de Thiès (Sénégal) from May 10 to May 23, about “Cryptographie à base d’isogénies”; the visit of Abdoulaye Maïga to the LFANT team where he worked with Damien Robert to find absolute invariants of good reduction modulo 2 for abelian surfaces; and the organisation by Damien Robert of a workshop in Bordeaux with most of the team members from September 04 to September 08. The slides or proceedings are available at <https://lfant.math.u-bordeaux.fr/index.php?category=seminar&page=2017>.

### **7.3.2. Inria International Partners**

#### *7.3.2.1. Informal International Partners*

The team is used to collaborate with Leiden University through the ALGANT program for PhD joint supervision.

Eduardo Friedman (U. of Chile), long term collaborator of K. Belabas and H. Cohen is a regular visitor in Bordeaux (about 1 month every year).

## **7.4. International Research Visitors**

### *7.4.1. Visits of International Scientists*

- Nicolas Mascot (American University of Beirut, Lebanon) visited the team for a week (8-12/01/2018).
- Alex Bartel (University of Glasgow, UK) visited the team for two weeks (27/03/2018 to 07/04/2018).
- Takashi Fukuda (Nihon University, Japan) visited the team for two months (20/01/2018 to 25/03/2018)
- Tony Ezome (Université des Sciences et Techniques de Masuku) and Mohamadou Sall (Dakar) visited the team for two weeks in December. Abdoul Aziz (Dakar) visited the team for one week in September.
- Abdoulaye Maïga visited the team for three months, from October to January 2019.

Researchers visiting the team to give a talk to the team seminar include Elie Eid (Université de Rennes), Jean-François Biasse (University of South Florida), Francesco Battistoni (University of Milan), Alex Bartel (Glasgow University), Tristan Vaccon (Université de Limoges), and Takashi Fukuda (Nihon University).

### *7.4.2. Visits to International Teams*

A. Page visited Alex Bartel (University of Glasgow, UK) for two weeks (16-27/07/2018) and Michael Lipnowski (McGill University, Montreal, Canada) for two weeks (10-23/11/2018).

A. Page and Alex Bartel did a research stay in Oberwolfach (Allemagne) with the Research In Pairs programme for three weeks (14/10/2018-3/11/2018).

## **CAGIRE Project-Team**

# **9. Partnerships and Cooperations**

## **9.1. Regional Initiatives**

### **9.1.1. SEIGLE**

**Participants:** Enrique Gutierrez Alvarez, Jonathan Jung, Vincent Perrier.

SEIGLE means "Simulation Expérimentation pour l'Interaction de Gouttes Liquides avec un Ecoulement fortement compressible". It is a 3-year program which has started since October 2017 and was funded by Régional Nouvelle-Aquitaine, ISAE-ENSMA, CESTA and Inria. The interest of understanding aerodynamic mechanisms and liquid drops atomization is explained by the field of applications where they play a key role, specially in the new propulsion technologies through detonation in the aerospace as well as in the securities field. The SEIGLE project was articulated around a triptych experimentation, modeling and simulation. An experimental database will be constituted. It will rely on a newly installed facility (Pprime), similar to a supersonic gust wind tunnel/ hypersonic from a gaseous detonation tube at high pressure. This will allow to test modeling approaches (Pprime / CEA) and numerical simulation (Inria / CEA) with high order schemes for multiphasic compressible flows, suitable for processing shock waves in two-phase media. Enrique Gutierrez Alvarez (post-doctoral) joined the team in October 2018 to work on this project.

### **9.1.2. HPC scalable ecosystem**

**Participants:** Jonathan Jung, Vincent Perrier, [A two-year Post-doc starting in 2019 or 2020].

HPC scalable ecosystem is a 3-year program funded by Région Nouvelle-Aquitaine (call 2018), Airbus, CEA-CESTA, University of Bordeaux, INRA, ISAE-ENSMA and Inria. A two-year post-doc will be hired in 2019 or 2020. The objective is to extend the prototype developed in [47] to high order (discontinuous Galerkin) and non-reactive diffusive flows in 3d. The same basis will be developed in collaboration with Pprime for WENO based methods for reactive flows.

## **9.2. National Initiatives**

### **9.2.1. GIS Success**

**Participant:** Pascal Bruel.

We are members of the CNRS GIS Success (Groupement d'Intérêt Scientifique) organised around two of the major CFD codes employed by the Safran group, namely AVBP and Yales2. No scientific activity has been devoted around those codes during 2018, but a 2-day Yales2 training session held in Rouen was attended by Pascal Bruel. Some technical activity was also devoted to install Yales2 at Evora University (Portugal) in the framework of the on-going informal scientific cooperation with Dr. P. Correia.

### **9.2.2. ANR MONACO\_2025**

**Participant:** Rémi Manceau.

The ambition of the MONACO\_2025 project, coordinated by Rémi Manceau, is to join the efforts made in *two different industrial sectors* in order to tackle the industrial simulation of transient, turbulent flows affected by buoyancy effects. It brings together two academic partners, the project-team Cagire hosted by the university of Pau, and the institute Pprime of the CNRS/ENSMA/university of Poitiers (PPRIME), and R&D departments of two industrial partners, the PSA group and the EDF group, who are major players of the automobile and energy production sectors, respectively.

- The main **scientific objective** of the project is to make a breakthrough in *the unresolved issue* of the modelling of turbulence/buoyancy interactions in transient situations, within the continuous hybrid RANS/LES paradigm, which consists in preserving a computational cost compatible with industrial needs by relying on statistical approaches where a fine-grained description of the turbulent dynamics is not necessary. The transient cavity flow experiments acquired during MONACO\_2025 will provide the partners and the scientific community with *an unrivalled source of knowledge* of the physical mechanisms that must be accounted for in turbulence models.
- The main **industrial objective** is *to make available computational methodologies* to address dimensioning, reliability and security issues in buoyancy-affected transient flows. It is to be emphasized that such problems are *not tackled using CFD at present in the industry*. At the end of MONACO\_2025, a panel of methodologies, ranging from simple URANS to sophisticated hybrid model based on improved RANS models, will be evaluated in transient situations, against the dedicated cavity flow experiments and a real car underhood configuration. This final benchmark exercise will form *a decision-making tool* for the industrial partners, and will thus pave the way towards high-performance design of low-emission vehicles and highly secure power plants. In particular, the project is in line with the *Full Digital 2025 ambition*, e.g., the declared ambition of the PSA group to migrate, within the next decade, to a design cycle of new vehicles nearly entirely based on CAE (computer aided engineering), without recourse to expensive full-scale experiments.

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### 9.3.1.1. SOPRANO

**Participants:** Rémi Manceau, Pascal Bruel, [A one-year Post-doc starting in January 2019].

Topic: MG-1.2-2015 - Enhancing resource efficiency of aviation

Project acronym: SOPRANO

Project title: Soot Processes and Radiation in Aeronautical inNOvative combustors

Duration: 01/09/2016 - 31/08/2020

Coordinator: SAFRAN

Other partners:

- France: CNRS, CERFACS, INSA Rouen, SAFRAN SA, Snecma SAS, Turbomeca SA.
- Germany: DLR, GE-DE GmbH, KIT, MTU, RRD,
- Italy: GE AVIO SRL, University of Florence
- United Kingdom: Rolls Royce PLC, Imperial College of Science, Technology and Medicine, Loughborough University.

Abstract: For decades, most of the aviation research activities have been focused on the reduction of noise and NO<sub>x</sub> and CO<sub>2</sub> emissions. However, emissions from aircraft gas turbine engines of non-volatile PM, consisting primarily of soot particles, are of international concern today. Despite the lack of knowledge toward soot formation processes and characterization in terms of mass and size, engine manufacturers have now to deal with both gas and particles emissions. Furthermore, heat transfer understanding, that is also influenced by soot radiation, is an important matter for the



improvement of the combustor's durability, as the key point when dealing with low-emissions combustor architectures is to adjust the air flow split between the injection system and the combustor's walls. The SOPRANO initiative consequently aims at providing new elements of knowledge, analysis and improved design tools, opening the way to: • Alternative designs of combustion systems for future aircrafts that will enter into service after 2025 capable of simultaneously reducing gaseous pollutants and particles, • Improved liner lifetime assessment methods. Therefore, the SOPRANO project will deliver more accurate experimental and numerical methodologies for predicting the soot emissions in academic or semi-technical combustion systems. This will contribute to enhance the comprehension of soot particles formation and their impact on heat transfer through radiation. In parallel, the durability of cooling liner materials, related to the walls air flow rate, will be addressed by heat transfer measurements and predictions. Finally, the expected contribution of SOPRANO is to apply these developments in order to determine the main promising concepts, in the framework of current low-NOx technologies, able to control the emitted soot particles in terms of mass and size over a large range of operating conditions without compromising combustor's liner durability and performance toward NOx emissions.

In the SOPRANO project, our objective is to complement the experimental (ONERA) and LES (CERFACS) work by RANS computations of the flow around a multiperforated plate, in order to build a database making possible a parametric study of mass, momentum and heat transfer through the plate and the development of multi-parameter-dependent equivalent boundary conditions. This year, we attended the two ITR meetings in Stuttgart (Germany) and Bordes (France) and recruited a post-doc bound to start by mid-january 2019.

## 9.4. International Initiatives

### 9.4.1. Inria International Partners

#### 9.4.1.1. Informal International Partners

- Institute of Mathematics, Almaty, Kazakhstan:  
Collaboration with Drs A. Beketaeva and A. Naïmanova for the RANS simulations of a supersonic jet in crossflow configuration for a wide range of pressure ratio (1 journal paper submitted in 2018). The low-Mach preconditioning of an in-house ENO based compressible flow solver was also further investigated. [PB] (one 13-day stay in Almaty).
- Collaboration with P. Correia (University of Evora, Portugal) related to the development of enhanced boundary conditions for the simulations of Mach zero flows with the artificial compressibility method and low Mach flows with a pressure-based approach. [PB] ( two 5-day stays in Evora).
- Collaboration with S. Lardeau (Siemens Industry Software Computational Dynamics, Nuremberg, Germany) on the EB-RSM model and hybrid RANS/LES model for industrial applications. [RM]

### 9.4.2. Participation in International Programs

**Participants:** Pascal Bruel, Jonathan Jung, Rémi Manceau, Vincent Perrier.

- ECOS-Sud A17A07 project with UNC (Cordoba, Argentina): this is the first year of this project devoted to the simulations of the wind around aerial fuel tank. Jonathan Jung and Pascal Bruel spent several weeks at UNC in the framework of this project.

## 9.5. International Research Visitors

- Dr. Juan Pablo Saldia (University of Cordoba, Argentina) spent one month in the team in the framework of the A17A07 Ecos-Sud project.

## **CARDAMOM Project-Team**

# **9. Partnerships and Cooperations**

## **9.1. Regional Initiatives**

### **9.1.1. CRA - Region Nouvelle Aquitaine EVE**

Title : Virtual prototyping of EVE engines

Type : Co-funded from Region Aquitaine and Inria

Duration : 36 months

Starting : January 2017

Coordinator : P.M. Congedo

Abstract : The main objective of this thesis is the construction of a numerical platform, for permitting an efficient virtual prototyping of the EVE expander. This will provide EXOES with a numerical tool, that is much more predictive with respect to the tools currently available and used in EXOES, by respecting an optimal trade-off in terms of complexity/cost needed during an industrial design process. Two research axes will be mainly developed. First, the objective is to perform some high-predictive numerical simulation for reducing the amount of experiments, thanks to a specific development of RANS tools (Reynolds Averaged Navier-Stokes equations) for the fluids of interest for EXOES. These tools would rely on complex thermodynamic models and a turbulence model that should be modified. The second axis is focused on the integration of the solvers of different fidelity in a multi-fidelity platform for performing optimization under uncertainties. The idea is to evaluate the system performances by using massively the low-fidelity models, and by correcting these estimations via only few calculations with the high-fidelity code.

### **9.1.2. CRA - Region Nouvelle Aquitaine SANSON**

Title : CRA/15-CARDAMOM THESE SANSON-10199

Type : Co-funded from Region Aquitaine and Inria

Duration :

Starting :

Coordinator :

Abstract :

### **9.1.3. CRA - Region Aquitaine ETRURIA**

Title : Evaluation des Risques de submersion côtière et Urbaine par Remaillage et déformation Adaptative de maillage (ETRURIA)

Type : Co-funded from Region Aquitaine and Inria

Duration : 36 months

Starting : November 2018

Coordinator : M. Ricchiuto

Abstract : the objective of this project is to develop improved tools for the simulation of coastal floods by combining mesh adaptation techniques based on remeshing and deformation, representations of the coastal structures allowing to mix exact meshing and embedded representations, and high order schemes. The tools developed will be used to study inundation of French coasts, and in particular coasts of the Nouvelle Aquitaine Region, in collaboration with BRGM, and the Rivages ProTech Center of SUEZ.

## **9.2. National Initiatives**

### **9.2.1. ANR VISCAP**

Title:

Type: ANR

Duration: 48 months

Starting date : 1st Jan 2018

Coordinator: Vignoles Gerard (Université de Bordeaux and LCTS - UMR 5801)

Abstract: Self-healing Ceramic-Matrix Composites (SH-CMCs) have extremely long lifetimes even under severe thermal, mechanical and chemical solicitations. They are made of ceramic fibres embedded in a brittle ceramic matrix subject to multi-cracking, yielding a 'damageable-elastic' mechanical behaviour. The crack network resulting from local damage opens a path to fibre degradation by corrosion and ultimately to failure of the composite, e.g. under static fatigue in high-temperature oxidative conditions. But these materials have the particularity of protecting themselves against corrosion by the formation of a sealing oxide that fills the matrix cracks, delaying considerably the fibres degradation. Applications encompass civil aeronautic propulsion engine hot parts and they represent a considerable market; however this is only possible if the lifetime duration of the materials is fully certified. Numerical modelling is an essential tool for such an aim, and very few mathematical models exist for these materials; fulfilling the needs requires a strong academic-level effort before considering industrial valorisation. Therefore, the ambition of this innovative project is to provide reliable, experimentally validated numerical models able to reproduce the behaviour of SH-CMCs. The starting point is an existing image-based coupled model of progressive oxidative degradation under tensile stress of a mini-composite (i.e. a unidirectional bundle of fibres embedded in multi-layered matrix). Important improvements will be brought to this model in order to better describe several physic-chemical phenomena leading to a non-linear behaviour: this will require an important effort in mathematical analysis and numerical model building. A systematic benchmarking will allow creating a large database suited for the statistical analysis of the impact of material and environmental parameter variations on lifetime. Experimental verifications of this model with respect to tests carried out on model materials using in-situ X-ray tomography in a specially adapted high-temperature environmental & mechanical testing cell and other characterizations are proposed. The extension of the modelling procedure to Discrete Crack Networks for the large-scale description of the material life will be the next action; it will require important developments on mesh manipulations and on mathematical model analysis. Finally, experimental validation will be carried out by comparing the results of the newly created software to tests run on 3D composite material samples provided by the industrial partner of the project. The project originality lies in a multidisciplinary character, mixing competences in physico-chemistry, mechanics, numerical and mathematical modelling, software engineering and high-performance computing. It aims creating a true computational platform describing the multi-scale, multidimensional and multi-physics character of the phenomena that determine the material lifetime. Important outcomes in the domain of civil aircraft jet propulsion are expected, that could relate to other materials than those considered in this study.

### **9.2.2. FUI ICARUS**

Title: Intensive Calculation for AeRo and automotive engines Unsteady Simulations.

Type: FUI

Duration: January 2017 - December 2019

Coordinator: Turbomeca, Safran group

Abstract: Large Eddy Simulation is an accurate simulation tool for turbulent flows which is becoming more and more attractive as the parallel computing techniques and platforms become more and more efficient. This project aims at improving the performances of some existing simulation tools (such as AVBP, Yales and ARGO), at developing meshing/re-meshing tools tailored to LES simulations, at improving the ergonomics of these tools to the industrial world (improved interfaces, data handling, code coupling, etc), and validate the progress made on case studies representative of typical design simulations in the automotive and aeronautic industry

subsectionFUI ICARUS

Title: Intensive Calculation for AeRo and automotive engines Unsteady Simulations.

Type: FUI

Duration: January 2017 - December 2019

Coordinator: Turbomeca, Safran group

### **9.2.3. APP University of Bordeaux**

Title : Modélisation d'un système de dégivrage thermique

Type : Project University of Bordeaux

Duration : 36 months

Starting : October 2016

Coordinator : H. Beaugendre and M. Colin

Abstract : From the beginning of aeronautics, icing has been classified as a serious issue : ice accretion on airplanes is due to the presence of supercooled droplets inside clouds and can lead to major risks such as aircrash for example. As a consequence, each airplane has its own protection system : the most important one is an anti-icing system which runs permanently. In order to reduce gas consumption, de-icing systems are developed by manufacturers. One alternative to real experiment consists in developing robust and reliable numerical models : this is the aim of this project. These new models have to take into account multi-physics and multi-scale environment : phase change, thermal transfer, aerodynamics flows, etc. We aim to use thin films equations coupled to level-set methods in order to describe the phase change of water. The overall objective is to provide a simulation platform, able to provide a complete design of these systems.

## **9.3. European Initiatives**

### **9.3.1. FP7 & H2020 Projects**

Program: FET-Future & emerging technologies

Project acronym: ExaQUte

Project title: EXAscale Quantification of Uncertainties for Technology and Science Simulation

Duration: 2018-2021

Coordinator: Riccardo Rossi (CIMNE, Barcelona)

Other partners: EPFL (Switzerland), UPC (Spain), TUM (Germany), VSB (Czech Republic), structure GmbH (Germany)

The ExaQUte project aims at constructing a framework to enable Uncertainty Quantification (UQ) and Optimization Under Uncertainties (OUU) in complex engineering problems using computational simulations on Exascale systems. The stochastic problem of quantifying uncertainties will be tackled by using a Multi Level MonteCarlo (MLMC) approach that allows a high number of stochastic variables. New theoretical developments will be carried out to enable its combination with adaptive mesh refinement, considering both, octree-based and anisotropic mesh adaptation. Gradient-based optimization techniques will be extended to consider uncertainties by developing methods to compute stochastic sensitivities, This requires new theoretical and computational developments.

With a proper definition of risk measures and constraints, these methods allow high-performance robust designs, also maximizing the solution reliability. The description of complex geometries will be possible by employing embedded methods, which guarantee a high robustness in the mesh generation and adaptation steps, while allowing preserving the exact geometry representation. The efficient exploitation of Exascale system will be addressed by combining State-of-the-Art dynamic task-scheduling technologies with space-time accelerated solution methods, where parallelism is harvested both in space and time. The methods and tools developed in ExaQUte will be applicable to many fields of science and technology. The chosen application focuses on wind engineering, a field of notable industrial interest for which currently no reliable solution exists. This will include the quantification of uncertainties in the response of civil engineering structures to the wind action, and the shape optimization taking into account uncertainties related to wind loading, structural shape and material behavior. All developments in ExaQUte will be open-source and will follow a modular approach, thus maximizing future impact.

### **9.3.2. Collaborations in European Programs, Except FP7 & H2020**

Program: Ocean ERANET

Project acronym: MIDWEST

Project title: Multi-fidelity decision making tools for wave energy systems

Duration: October 2015- October 2018

Coordinator: Mario Ricchiuto

Other partners: Chalmers University (Sweden), IST Lisbon (Portugal), DTU Compute (Denmark)

MIDWEST is a project starting in 2016 (kick-off in December 2015) and funded by the EU-OceaneraNET program by the French ADEME, by the Swedish SWEA, and by the Portuguese FCT, aiming at proposing new tools for the wave energy industry. Wave energy converters (WECs) design currently relies on low-fidelity linear hydrodynamic models. While these models disregard fundamental nonlinear and viscous effects which might lead provide sub-optimal designs high-fidelity fully nonlinear Navier-Stokes models are prohibitively computational expensive for optimization. The MIDWEST project will provide an efficient asymptotic nonlinear finite element model of intermediate fidelity, investigate the required fidelity level to resolve a given engineering output, construct a multi-fidelity optimization platform using surrogate models blending different fidelity models. Combining know how in wave energy technology, finite element modelling, high performance computing, and robust optimization, the MIDWEST project will provide a new efficient decision making framework for the design of the next generation WECs which will benefit all industrial actors of the European wave energy sector.

## **9.4. International Initiatives**

### **9.4.1. Inria Associate Teams Not Involved in an Inria International Labs**

#### **9.4.1.1. HAMster**

Title: High order Adaptive moving MeSh finiTE elements in immeRsed computational mechanics

International Partner (Institution - Laboratory - Researcher):

Duke (United States) - Civil & Environmental Engineering and Mechanical Engineering & Material Science - Guglielmo Scovazzi

Inria Bordeaux Sud-Ouest (France) - CARDAMOM team - Mario Ricchiuto

Start year: 2017

See also: <https://team.inria.fr/athamster/>

This project focuses on adaptive unstructured mesh finite element-type methods for fluid flows with moving fronts. These fronts may be interfaces between different fluids, or fluid/solid, and modelling or physical  $\hat{\Lambda}$  fronts (e.g. shock waves) present in the flow. The two teams involved in the project have developed over the years complementary strategies,  $\hat{\Lambda}$  one focusing more on an Eulerian description aiming at capturing fronts on adaptive unstructured grids,  $\hat{\Lambda}$  the other  $\hat{\Lambda}$  working more on Lagrangian approaches aiming at following exactly some of these features. Unfortunately, classical Lagrangian methods are at a disadvantage in the presence of complex deformation patterns, especially for fronts undergoing large deformations, since the onset of vorticity quickly leads to mesh rotation and eventually tangling. On the other end, capturing approaches, as well as Immersed Boundary/Embedded (IB/EB) methods, while providing  $\hat{\Lambda}$  enormous flexibility when considering complex cases,  $\hat{\Lambda}$  require a careful use of mesh adaptivity to guarantee an accurate capturing of interface physics. The objective of this team is to study advanced hybrid methods combining high order, adaptive, monotone capturing techniques developed in an Eulerian or ALE setting, with fitting techniques and fully Lagrangian approaches.

### **9.4.2. Inria International Partners**

#### *9.4.2.1. Informal International Partners*

- We entertain since many years a collaboration with Ecole de Technologie Supérieure de Montréal (Quebec), and in particular with Prof. Francois Morency, on the modelling of wing icing
- Collaboration with Università La Sapienza i (Prof. Renato Paciorri) and Università della Basilicata (Prof. Aldo Bonfiglioli) on the development of shock fitting techniques. We have regular exchanges of mutual visits and of students (this year Mirco Ciallella)
- We collaborate with Politecnico di Milano (Prof. Alberto Guardone) on the development of adaptive mesh techniques for time dependent problems. Within this collaboration Luca Cirrottola has spend part of his PhD in CARDAMOM
- We work with DTU Compute in Denmark (Prof. Allan-Peter Engsig Karup) and with and RISE in Sweden (Dr. Claes Eskilsson) on the simulation of free surface flows with floating structures. The PhD of U. Bosi is partially (and informally) co-supervised by Prof. Engsig-Karup and Dr. Eskilsson
- We work with Alireza Mazaheri (NASA LaRC, Virginia) on high order adaptive discretizations for compressible flows. Marco Lorini visited the NASA center in March/April

## **9.5. International Research Visitors**

### *9.5.1. Visits of International Scientists*

- L. Nouveau
- G. Scovazzi, Professor at Duke University (Durham, NC), has visited Mario Ricchiuto in January and in June 2018 to work on high order embedded methods
- Aron Roland, CEO of BGS IT&E (Information Technology & Engineering) has visited Mario Ricchiuto in February 2018 to work on the simulation of flash floods
- Nicolas Perinet, Postdoctoral fellow at University of Chile has visited Mario Ricchiuto to work on the benchmarking of the SLOWS CODE. From Jul 2018 until Sep 2018
- Tatsuya Watanabe, Professor at Kyoto Sangyo University has visited Mathieu Collin to work on Born-Infeld theory in March 2018.
- Francois Morency, Professeur at Ecole de Technologie Supérieure de Montréal has visited Héloïse Beaugendre to work on aircraft icing, roughness modeling and performance degradation, on Jul 2018 and from Sep to Dec 2018

#### *9.5.1.1. Internships*

- Agnes Chan (Inria, M. Sc. Student). From Jun 2018 until Sep 2018.
- Beatrice Battisti (Inria, M. Sc. Student). From Apr 2018 until Sep 2018.
- Elie Solai (Inria, M. Sc. Student). From Mar 2018 until Aug 2018.
- Mirco Ciallella (Inria, M. Sc. Student). From Nov 2018.

## **CQFD Project-Team**

# **8. Partnerships and Cooperations**

## **8.1. National Initiatives**

### ***8.1.1. ANR StocMC (2014-2018) of the program Project Blanc of the ANR***

The involved research groups are Inria Rennes/IRISA Team SUMO; Inria Rocquencourt Team Lifeware; LIAFA University Paris 7; Bordeaux University.

The aim of this research project is to develop scalable model checking techniques that can handle large stochastic systems. Large stochastic systems arise naturally in many different contexts, from network systems to system biology. A key stochastic model we will consider is from the biological pathway of apoptosis, the programmed cell death.

### ***8.1.2. ANR BNPSI: Bayesian Non Parametric methods for Signal and Image Processing***

Statistical methods have become more and more popular in signal and image processing over the past decades. These methods have been able to tackle various applications such as speech recognition, object tracking, image segmentation or restoration, classification, clustering, etc. We propose here to investigate the use of Bayesian nonparametric methods in statistical signal and image processing. Similarly to Bayesian parametric methods, this set of methods is concerned with the elicitation of prior and computation of posterior distributions, but now on infinite-dimensional parameter spaces. Although these methods have become very popular in statistics and machine learning over the last 15 years, their potential is largely underexploited in signal and image processing. The aim of the overall project, which gathers researchers in applied probabilities, statistics, machine learning and signal and image processing, is to develop a new framework for the statistical signal and image processing communities. Based on results from statistics and machine learning we aim at defining new models, methods and algorithms for statistical signal and image processing. Applications to hyperspectral image analysis, image segmentation, GPS localization, image restoration or space-time tomographic reconstruction will allow various concrete illustrations of the theoretical advances and validation on real data coming from realistic contexts.

### ***8.1.3. Gaspard Monge Program for Optimisation and Operational Research (2017-2019)***

The involved research groups are Inria Bordeaux Sud-Ouest Team CQFD and Thales Optronique. This new collaboration with Thales Optronique that started in October 2017 is funded by the Fondation Mathématique Jacques Hadamard. This is the continuation of the PhD Thesis of A. Geeraert. The objective of this project is to optimize the maintenance of a multi-component equipment that can break down randomly. The underlying problem is to choose the best dates to repair or replace components in order to minimize a cost criterion that takes into account costs of maintenance but also the cost associated to the unavailability of the system for the customer. In the PhD thesis of A. Geeraert, the model under consideration was rather simple and only a numerical approximation of the value function was provided. Here, our objective is more ambitious. A more realistic model will be considered and our aim is to provide a tractable quasi-optimal control strategy that can be applied in practice to optimize the maintenance of such equipments.

## **8.2. European Initiatives**

### ***8.2.1. Collaborations in European Programs, Except FP7 & H2020***

- Program: Direccion General de Investigacion Cientifica y Tecnica, Gobierno de Espana
- Project acronym: GAMECONAPX
- Project title: Numerical approximations for Markov decision processes and Markov games
- Duration: 01/2017 - 12/2019

- Coordinator: Tomas Prieto-Rumeau, Department of Statistics and Operations Research, UNED (Spain)
- Abstract:

This project is funded by the Gobierno de Espana, Direccion General de Investigacion Cientifica y Tecnica (reference number: MTM2016-75497-P) for three years to support the scientific collaboration between Tomas Prieto-Rumeau, Jonatha Anselmi and Francois Dufour. This research project is concerned with numerical approximations for Markov decision processes and Markov games. Our goal is to propose techniques allowing to approximate numerically the optimal value function and the optimal strategies of such problems. Although such decision models have been widely studied theoretically and, in general, it is well known how to characterize their optimal value function and their optimal strategies, the explicit calculation of these optimal solutions is not possible except for a few particular cases. This shows the need for numerical procedures to estimate or to approximate the optimal solutions of Markov decision processes and Markov games, so that the decision maker can really have at hand some approximation of his optimal strategies and his optimal value function. This project will explore areas of research that have been, so far, very little investigated. In this sense, we expect our techniques to be a breakthrough in the field of numerical methods for continuous-time Markov decision processes, but particularly in the area of numerical methods for Markov game models. Our techniques herein will cover a wide range of models, including discrete- and continuous-time models, problems with unbounded cost and transition rates, even allowing for discontinuities of these rate functions. Our research results will combine, on one hand, mathematical rigor (with the application of advanced tools from probability and measure theory) and, on the other hand, computational efficiency (providing accurate and ?applicable? numerical methods). In this sense, particular attention will be paid to models of practical interest, including population dynamics, queueing systems, or birth-and-death processes, among others. So, we expect to develop a generic and robust methodology in which, by suitably specifying the data of the decision problem, an algorithm will provide the approximations of the value function and the optimal strategies. Therefore, the results that we intend to obtain in this research project will be of interest for researchers in the fields of Markov decision processes and Markov games, both for the theoretical and the applied or practitioners communities

## 8.3. International Initiatives

### 8.3.1. Inria International Partners

#### 8.3.1.1. Declared Inria International Partners

**Tree-Lab, ITT.** TREE-LAB is part of the Cybernetics research line within the Engineering Science graduate program offered by the Department of Electric and Electronic Engineering at Tijuana's Institute of Technology (ITT), in Tijuana Mexico. TREE-LAB is mainly focused on scientific and engineering research within the intersection of broad scientific fields, particularly Computer Science, Heuristic Optimization and Pattern Analysis. In particular, specific domains studied at TREE-LAB include Genetic Programming, Classification, Feature Based Recognition, Bio-Medical signal analysis and Behavior-Based Robotics. Currently, TREE-LAB incorporates the collaboration of several top researchers, as well as the participation of graduate (doctoral and masters) and undergraduate students, from ITT. Moreover, TREE-LAB is actively collaborating with top researchers from around the world, including Mexico, France, Spain, Portugal and USA.

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

Oswaldo Costa (Escola Polit cnica da Universidade de S o Paulo, Brazil) collaborate with the team on the theoretical aspects of continuous control of piecewise-deterministic Markov processes. He visited the team during two weeks in december 2018.



Tomas Prieto-Rumeau (Department of Statistics and Operations Research, UNED, Madrid, Spain) visited the team during 2 weeks in 2018. The main subject of the collaboration is the approximation of Markov Decision Processes.

## **GEOSTAT Project-Team**

# **9. Partnerships and Cooperations**

## **9.1. National Initiatives**

- ANR project *Voice4PD-MSA*, led by K. Daoudi, which targets the differential diagnosis between Parkinson's disease and Multiple System Atrophy. The total amount of the grant is 468555 euros, from which GeoStat has 203078 euros. The duration of the project is 42 months. Partners: CHU Bordeaux (Bordeaux), CHU Toulouse, IRIT, IMT (Toulouse).
- PhD grant for G. Singh from IIT Roorkee, under co-supervision with D. Singh (IIT Roorkee).
- The PHC-Toubkal project "Caractérisation multi-capteurs et suivi spatio-temporel de l'Upwelling sur la côte atlantique marocaine par imagerie satellitaire", led by K. Daoudi, is in its second year. The partners in this project are: Faculté des sciences de Rabat, Centre Royal de Télédétection Spatiale, Mercator-Ocean and GEOSTAT.
- GEOSTAT is a member of ISIS (Information, Image & Vision) and AMF (Multifractal Analysis) GDRs.
- GEOSTAT is participating in the CNRS IMECO project *Intermittence multi-échelles de champs océaniques : analyse comparative d'images satellitaires et de sorties de modèles numériques*. CNRS call AO INSU 2018. PI: F. Schmitt, DR CNRS, UMR LOG 8187. Duration: 2 years.

## **9.2. European Initiatives**

### **9.2.1. Collaborations in European Programs, Except FP7 & H2020**

GENESIS Program: supported by Deutsche Forschungsgemeinde (DFG) and the Agence national de recherche (ANR). *GENeration and Evolution of Structures in the ISm*. Duration: start 1.5. 2017, 3 years. Coordinator: N. Schneider (I. Physik, Cologne). Other partners: Cologne (R. Simon, N. Schneider, V. Ossenkopf, M. Roellig), LAB (S. Bontemps, A. Roy, L. Bonne, F. Herpin, J. Braine, N. Brouillet, T. Jacq), ATN Canberra (Australia), LERMA Paris (France), MPIfR Bonn (Germany), CEA Saclay (France), ITA/ZAH Heidelberg (Germany), Institute of Astronomy, Cardiff (UK), ESO (Germany, Chile), CfA Harvard (USA), IPAG Grenoble (France), Argelander Institut Bonn (Germany), CASS San Diego (USA), University of Sofia (Bulgaria). Web site: [link](#).

## **9.3. International Initiatives**

### **9.3.1. Inria International Partners**

#### **9.3.1.1. IFCAM: Generalization for land cover identification. Geostat and the Indo-French Centre For Applied Mathematics**

Land cover classification from satellite imagery is an important application for agriculture, environmental monitoring, tracking changes foremergency, etc. The typical methodology is to train a machine learning algorithm to recognize specified classes (urban, forest, fields, etc...) over regions of interest and classify new images when they become available. Yet, the generalization ability of such systems often not accounts for spatial consistency. High scores are obtained on the reference points, but nearby points of the same class are incorrectly classified. Local context, pixels around the selected one, may help in recovering that spatial consistency and increase the recognition rate. This may also induce spurious patterns and overfit the learning algorithm, which is especially the case for with Convolutional Networks trained on limited number of data. This proposal investigates how to use local context and how to best sample the data in order to provide the best generalization ability. Data will be sampled on reference locations and used for training and validation.

PIs: N. Brodu (Geostat) and D. Singh (IIT Roorkee).

Duration: 3 years. Starting 2018.

## **9.4. International Research Visitors**

### ***9.4.1. Visits of International Scientists***

- S. Bogning Dongue [CNRS, from Dec 2018]
- K. Minaoui [Rabat University, Jul 2018]

## **MEMPHIS Project-Team**

# **8. Partnerships and Cooperations**

## **8.1. Regional Initiatives**

Leading team of the regional project "Investigation and Modeling of Suspensions with the LOMA and LOF labs in Bordeaux.

## **8.2. National Initiatives**

We are part of the GDR AMORE on ROMs.

## REALOPT Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

- **HPC scalable ecosystem:** This project is funded by Region Nouvelle Aquitaine for 4 years, starting in 2018. It is coordinated by Emmanuel Agullo (Hiepac Inria project-team) and it gathers researchers from Inria, Inra, LaBRI but also from UPPA (University of Pau), Pprime Institute (Poitiers), CEA and Airbus. It aims at building a convergent approach between numerical simulation and HPC on the one hand, and Data Science and Big Data on the other hand. The goal is to study the feasibility of approaches based on runtime schedulers to achieve a high level of scalability.
- **SysNum Cluster** SysNum is a Cluster of Excellence of Bordeaux Idex that aims at bringing Bordeaux academic players in the digital sciences closer to each other around large-scale distributed digital systems. The cluster is organized around 4 methodological axes (Interconnected object systems; Reliability and safety; Modeling and numerical systems; Massive and heterogeneous data) and 3 application platforms around major societal issues (ecology, mobile systems, interconnected objects and data analysis).
  - François Clautiaux is leading the methodological WP on Interconnected object systems. Understanding and controlling the complexity of systems of interconnected objects is a major challenge for both industrial and everyday life applications. We think, in particular, to fields like robotics, car industry, energy distribution or smart buildings, where it is essential to tackle autonomous heterogeneous objects and to develop robust control tools to optimize their interconnections. Our research in this direction will be developed within three interconnected tasks.
  - Olivier Beaumont is leading the methodological WP on Modeling and numerical systems. Mathematical modeling and numerical simulation are by now highly important tools currently used in physics, chemistry, biology, medicine and humanities. The forthcoming development of exaflop computers should allow to simulate with High Performance Computing new multi-scale and multi-physics phenomena, generating massive data (High Performance Data Analytics). One of the major challenges of the years to come is thus both to build new robust numerical modeling tools, working on several millions processors computers and to be able to accommodate on a single platform both HPC and BigData applications.

## 9.2. European Initiatives

### 9.2.1. FP7 & H2020 Projects

- **EXDCI-2:** EXDCI-2 is a H2020 project (type: CSA – Coordination & support action), coordinated by PRACE for a duration of 30 months, starting on March 2018.

Through the joint action of PRACE and ETP4HPC, EXDCI-2 mobilises the European HPC stakeholders. The project participates in the support of the European HPC Ecosystem with two main goals:

- Development and advocacy of a competitive European HPC Exascale Strategy by supporting the implementation of a common European HPC strategy, open to synergistic areas including High Performance Data Analytics (HPDA) and Artificial Intelligence (AI). The expertise of the partners and stakeholders will permit to elaborate a transversal prospective vision.

- Coordination of the stakeholder community for European HPC at the Exascale through joint community structuring and synchronisation. This entails ensuring EXDCI-2 stakeholder representation in the main development of the European HPC eco-system towards Exascale, such as: The development of relationships with other ecosystems including upstream technologies as photonics and electronics, High Performance Embedded Computing (HiPEAC) and Big Data (BDVA) In the context of the upcoming European Data Infrastructure (EDI) a road mapping activity toward future converged HPC, HPDA and AI needs and new services from PRACE users communities and CoE The continuation of BDEC activities, for international participation of European stakeholders on the integration from edge computing to HPC, including Data Analytics and AI The mapping and analysis of related national and international R&I research agendas EXDCI-2 gives particular attention to creating synergies with the CoEs – for example with the CSA FocusCoE – and to building on the outcomes of FET HPC projects.

Olivier Beaumont is involved the task that will work on building a consensus based transversal vision and aims at proposing Ecosystem level concepts. Recommendations implementing the vision will be proposed. The work will benefit from the CoE connection established in the first EXDCI CSA. It is on purpose implemented on the first year of the CSA in order to allow it to be taken into account in the other WP.

## **9.3. International Initiatives**

### ***9.3.1. Inria International Partners***

#### *9.3.1.1. Informal International Partners*

We continue close collaboration with the LOGIS laboratory (Universidade Federal Fluminense, Niteroi, Brazil) after the end of the Inria Associate Team SAMBA. In 2018, we had two two-weeks visits of Prof. Eduardo Uchoa. Prof. Artur Pessoa spent his sabbatical of 11 months with us.

Orlando Rivera Letelier is pursuing a co-tutelle thesis (with Universidad Adolfo Ibáñez, Peñalolén, Santiago, Chile)

## **9.4. International Research Visitors**

Prof. Artur Pessoa (Universidade Federal Fluminense, Niteroi, Brazil) spent his sabbatical of 11 months with us (February–December 2018).

## CARMEN Project-Team

# 7. Partnerships and Cooperations

## 7.1. Regional Initiatives

### 7.1.1. PhD thesis O. Bouhamama

L. Weynans and L. Bear (Liryc) obtained funding for a PhD thesis from the Université de Bordeaux, for a project titled “Méthodes numériques pour la résolution du problème inverse en électrocardiographie dans le cas d’anomalies structurelles du tissu cardiaque.” Candidate O. Bouhamama started in October 2018.

### 7.1.2. CALM

The project “Cardiac Arrhythmia Localization Methods,” granted by the Région Nouvelle-Aquitaine, with matching from funds held by our clinical collaborators H. Cochet and P. Jaïs, has started. The purpose of this project is to develop a tool that can predict the exit site of an arrhythmia with moderate accuracy (1 cm) in an absolute sense, with respect to the anatomy of the heart in situ, and with a resolution of about 2 mm in a relative sense, with respect to a nearby pacing site. This tool must fulfill the following criteria:

- it uses only data that are already recorded in the cathlab by other systems: ECG data and electroanatomical mapping data;
- it must work in nearly real-time; catheter displacement advice must be available within 5 seconds after a paced beat;
- it must work automatically, requiring the operator only to indicate which ECG data correspond to the target arrhythmia; and
- it must be safe and easy to operate.

We will in the first place test a number of proposed methods using synthetic data, produced with our realistic models of cardiac electrophysiology and accurate geometric models of different patients. This in-silico testing phase will answer a number of important practical questions. Subsequently we will use offline clinical data, and within 2 years we aim to build a clinical prototype that can be tested (without interfering in the procedure) in the cathlab. In order to work real-time we will initially use very simple methods. However, the clinical prototype and the collection of synthetic data that we created will later serve also as a platform to test also more sophisticated inverse methods.

## 7.2. National Initiatives

### 7.2.1. ANR EXACARD

We started a collaboration with the STORM team at Inria Bordeaux Sud-Ouest to work on further scaling of the Propag code, to push the limit from about  $10^4$  to  $10^6$  parallel processors. A proposal for this project was funded this year by ANR. It allows a postdoc to be employed for 2 years.

### 7.2.2. ANR MITOCARD

The MITOCARD project (Electrophysiology of Cardiac Mitochondria), coordinated by S. Arbault (Université de Bordeaux, ISM), was granted by the ANR in July 2017. The objective of MITOCARD is to improve understanding of cardiac physiology by integrating the mitochondrial properties of cell signaling in the comprehensive view of cardiac energetics and rhythm pathologies. It was recently demonstrated that in the heart, in striking contrast with skeletal muscle, a parallel activation by calcium of mitochondria and myofibrils occurs during contraction, which indicates that mitochondria actively participate in  $Ca^{2+}$  signaling in the cardiomyocyte. We hypothesize that the mitochondrial permeability transition pore (mPTP), by rhythmically depolarizing inner mitochondrial membrane, plays a crucial role in mitochondrial  $Ca^{2+}$  regulation and, as

a result, of cardiomyocyte  $\text{Ca}^{2+}$  homeostasis. Moreover, mitochondrial reactive oxygen species (ROS) may play a key role in the regulation of the mPTP by sensing mitochondrial energetics balance. Consequently, a deeper understanding of mitochondrial electrophysiology is mandatory to decipher their exact role in the heart's excitation-contraction coupling processes. However, this is currently prevented by the absence of adequate methodological tools (lack of sensitivity or selectivity, time resolution, averaged responses of numerous biological entities). The MITOCARD project will solve that issue by developing analytical tools and biophysical approaches to monitor kinetically and quantitatively the  $\text{Ca}^{2+}$  handling by isolated mitochondria in the cardiomyocyte.

MITOCARD is a multi-disciplinary project involving 4 partners of different scientific fields: the CARMEN team as well as

- **ISM**, the largest chemistry laboratory of the Université de Bordeaux, where the necessary measurement methods will be developed;
- **Liry**, where mitochondria are studied at all levels of integration from the isolated mitochondrion to the intact heart; and
- **LAAS**, the MiCrosystèmes d'Analyse (MICA) group at the Laboratory of Analysis and Architecture of Systems, which develops the biological microsensors for this project.

The project will

- develop chips integrating 4 different electrochemical microsensors to monitor in real-time key mitochondrial signaling parameters:  $\text{Ca}^{2+}$ , membrane potential, quinone reduction status,  $\text{O}_2$  consumption, and ROS production;
- develop microwell arrays integrating ring nanoelectrodes to trap single mitochondria within micrometric chambers and measure locally by combined fluorescence microscopy and electrochemical techniques intra- (by fluorescence) and extra-mitochondrial (electrochemistry) metabolites; and
- develop a mathematical model of mitochondrial  $\text{Ca}^{2+}$  and ROS handling built on existing knowledge, new hypotheses, and the measured data.

The model may serve both to assess biological assumptions on the role of mitochondria in  $\text{Ca}^{2+}$  signaling and to integrate pathological data and provide clues for their global understanding.

### 7.2.3. GENCI

GENCI (*grand équipement national de calcul intensif*) is the agency that grants access to all national high-performance resources for scientific purposes in France. GENCI projects have to be renewed yearly. Our project renewal *Interaction between tissue structure and ion-channel function in cardiac arrhythmia*, submitted in September 2018, has been granted 8 million core-hours on the three major systems Irene, Occigen, and Turing. This compute time is primarily destined for our research into the interaction between ionic and structural heart disease in atrial fibrillation, Brugada syndrome, and early repolarisation syndrome [7] [65], and for new HPC developments [27].

## 7.3. European Initiatives

### 7.3.1. Collaborations with Major European Organizations

BCAM (Basque Center for Applied Mathematics), Bilbao, Spain: L. Gerardo-Giorda.

We develop surrogate models of Radiofrequency Catheter Ablation for machine learning purposes, with the ambition to provide real-time estimations of lesion depths to clinicians (M. Leguèbe, Y. Coudière).

## 7.4. International Initiatives

### 7.4.1. Inria International Labs

International Laboratory for Research in Computer Science and Applied Mathematics



Associate Team involved in the International Lab:

#### 7.4.1.1. EPICARD

Title: inversE Problems In CARDiac electrophysiology

International Partner (Institution - Laboratory - Researcher):

ENIT (Tunisia) - Department of Intelligence Science and Technology - Nabil Gmati

Start year: 2018

See also: <https://team.inria.fr/carmen/epicard/>

Model personalization is a very challenging question in the numerical modeling community, especially for medical applications like cardiac electrophysiology. Our main idea is to adapt the input data like model parameters and boundary conditions of the electrophysiological measurements. There are two mathematical problems raising from this challenge. The first issue is the identifiability of the parameters and the sensitivity of the identification problem to the measured data. The question is: For given measurements, could we prove that there exist a set of parameters that allows to fit these measurements? The second issue is, how can we estimate parameters, when they are identifiable? Our idea is to provide a theoretical analysis for the identification of each of the parameters and to construct suitable numerical methods to estimate them.

### 7.4.2. Inria International Partners

#### 7.4.2.1. Informal International Partners

Y. Coudière works with the group of Prof. Y. Bourgault from the Department of Mathematics and Statistics of the University of Ottawa (Canada). Some results on the numerical analysis of time-stepping methods from C. Douanla's PhD were carried out together, as well as some theoretical results on parameter identification in the PhD of A. Gérard.

M. Potse works with the group of Prof. U. Schotten at Maastricht University (The Netherlands) and the Center for Computational Medicine in Cardiology at the *Università della Svizzera italiana* (Lugano, Switzerland) on simulation studies of atrial fibrillation [56]. The Maastricht group was partially funded by the FP7 project EUTRAF and our simulations were supported by GENCI (section 7.2.3).

N. Zemzemi works with Cesare Corrado at King's College London on the development of new eikonal models allowing conduction velocity adaptation [16].

## **MAGIQUE-3D Project-Team**

# **8. Partnerships and Cooperations**

## **8.1. Regional Initiatives**

### **8.1.1. Partnership with I2M in Bordeaux supported by Conseil Régional d'Aquitaine**

title: Imaging complex materials.

Coordinator: H el ene Barucq

Other partners: I2M CNRS Universit e Bordeaux I

The detection, localization and monitoring of the defect evolution in composite materials, concrete and more generally heterogeneous materials is a challenging problem for Aeronautics and energy production. It is already possible to localize defects in homogeneous materials by using methods based on ultrasonic inspection and sometimes, they are usable in particular heterogeneous materials, most of the time in 2D. Classical methods rely on the correspondence between the distance and the propagation time of the wave traveling between the defect and the receivers. In complex media, such a correspondence may be lapsed, for instance when the velocity depends on the frequency (dispersion) or of the propagation direction (anisotropy). The defect signature can also be embedded in the acoustic field sent by the structure (multiple reflections). The complexity of the propagation in heterogeneous materials makes then difficult the accurate localization of the defect, in particular in 3D.

Topological imaging techniques can be applied to heterogeneous media. They can find the positions of defects from two simulations performed in a safe experimental medium. They have been developed at I2M laboratory to carry on 2D single/multi mode inspection in isotropic and anisotropic waveguides. They have also been applied to a highly reflecting medium observed with a single sensor. The objective of this work is to extend the technique to 3D problems. In particular, we are going to handle detection in composite plates and in highly heterogeneous media including a collection of small scatterers.

This project is supported by the Conseil R egional d'Aquitaine, for a duration of 2 years.

## **8.2. National Initiatives**

### **8.2.1. Depth Imaging Partnership**

Magique-3D maintains active collaborations with Total. In the context of Depth Imaging, Magique-3D coordinates research activities dealing with the development of high-performance numerical methods for solving wave equations in complex media. This project has involved 2 other Inria Team-Projects (Hiepac and Nachos) which have complementary skills in mathematics, computing and in geophysics. DIP is fully funded by Total by the way of an outline agreement with Inria.

In 2014, the second phase of DIP has begun. Lionel Boillot has been hired as engineer to work on the DIP platform. Six PhD students have defended their PhD since 2014 and they are now post-doctoral researchers or engineers in Europe. DIP is currently employing 2 PhD students and one post-doctoral researcher.

### **8.2.2. PRE Concert**

Magique 3D is hosting an Inria "exploratory research project" (PRE) about modeling and designing wind musical instruments. This project is funding the post-doctoral position of Robin Tournemene since July 2017.

### **8.2.3. ANR Num4Sun**

The ANR has launched a specific program for supporting and promoting applications to European or more generally International projects. Magique-3D has been selected in 2016 after proposing a project to be applied as a FET project on the occasion of a call that will open in 2017 April. This project will gather researchers of the MPS (<https://www.mps.mpg.de/en>), of the BSC (<https://www.bsc.es/>), of the BCAM (<http://www.bcamath.org/en/>), of Heriot-Watt University (<https://www.hw.ac.uk/>) and Inria teams.

A kick-off meeting has been held in November 2016 in Strasbourg and a second one in Paris in July 2017. Thanks to this support, we have submitted a ETPHPC proposal in September 2017. The project is funded for 18 months starting from August 2016. The funding amounts 30000€.

#### **8.2.4. ANR NonLocalDD**

Magique 3-D is a partner of the ANR project entitled "Non Local Domain Decomposition Methods in Electromagnetics" that begins in October 2015. The aim of this project is to develop domain decomposition methods for the efficient solution of acoustics and Maxwell's equation either with boundary integral equations or finite element volume method. To obtain an exponential convergence of the iterative solution, non-local operators are studied and optimized to achieve a faster convergence. A post-doctoral student Marcella Bonazzoli has been hired by Magique 3-D in 2017 to study multi-domain integral equations for wave propagation. This student is supervised by Xavier Claeys, a partner of the NonLocalDD ANR project.

#### **8.2.5. Grant from Fondation Blaise Pascal**

The project Louis 14.0 has been selected by the Fondation Blaise Pascal as one of their supported projects for 2019. See more about the project at <https://project.inria.fr/louis14point0/>, in french.

### **8.3. European Initiatives**

#### **8.3.1. H2020 Projects**

##### *8.3.1.1. Mathrocks*

Title: Multiscale Inversion of Porous Rock Physics using High-Performance Simulators: Bridging the Gap between Mathematics and Geophysics

Program: H2020

Duration: April 2018 - March 2022

Coordinator: Universidad Del Pais Vasco (EHU UPV)

Partners:

Bcam - Basque Center for Applied Mathematics Asociacion (Spain)

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Universidad Del Pais Vasco Ehu Upv (Spain)

Universitat Politecnica de Catalunya (Spain)

REPSOL SA (Spain)

Pontificia Universidad Catolica de Valparaiso (Chile)

Curtin University of Technology (Australia)

The University of Texas System (USA)

University Nacional de Columbia (Colombia)

Pontificia Universidad Catolica de Chile (Chile)

Universidad Central de Venezuela (Venezuela)

University de Buenos Aires (Argentina)

Macquarie University (Australia)

Inria contact: Hélène BARUCQ

We will develop and exchange knowledge on applied mathematics, high-performance computing (HPC), and geophysics to better characterize the Earth's subsurface. We aim to better understand porous rocks physics in the context of elasto-acoustic wave propagation phenomena. We will develop parallel high-continuity isogeometric analysis (IGA) simulators for geophysics. We will design and implement fast and robust parallel solvers for linear equations to model multi-physics electromagnetic and elasto-acoustic phenomena. We seek to develop a parallel joint inversion workflow for electromagnetic and seismic geophysical measurements. To verify and validate these tools and methods, we will apply the results to: characterise hydrocarbon reservoirs, determine optimal locations for geothermal energy production, analyze earthquake propagation, and jointly invert deep-azimuthal resistivity and elasto-acoustic borehole measurements. Our target computer architectures for the simulation and inversion software infrastructure consists of distributed-memory parallel machines that incorporate the latest Intel Xeon Phi processors. Thus, we will build a hybrid OpenMP and MPI software framework. We will widely disseminate our collaborative research results through publications, workshops, postgraduate courses to train new researchers, a dedicated webpage with regular updates, and visits to companies working in the area. Therefore, we will perform a significant role in technology transfer between the most advanced numerical methods and mathematics, the latest super-computer architectures, and the area of applied geophysics.

## **8.4. International Initiatives**

### **8.4.1. Inria International Partners**

#### *8.4.1.1. Declared Inria International Partners*

##### 8.4.1.1.1. MAGIC2

Title: Advance Modeling in Geophysics

International Partner (Institution - Laboratory - Researcher):

California State University at Northridge (United States) - Department of Mathematics -  
Djellouli Rabia

The Associated Team MAGIC was created in January 2006 and renewed in January 2009. At the end of the program in December 2011, the two partners, MAGIQUE-3D and the California State University at Northridge (CSUN) decided to continue their collaboration and obtained the "Inria International Partner" label in 2013.

See also: <https://project.inria.fr/magic/>

The ultimate objective of this research collaboration is to develop efficient solution methodologies for solving inverse problems arising in various applications such as geophysical exploration, underwater acoustics, and electromagnetics. To this end, the research program will be based upon the following three pillars that are the key ingredients for successfully solving inverse obstacle problems. 1) The design of efficient methods for solving high-frequency wave problems. 2) The sensitivity analysis of the scattered field to the shape and parameters of heterogeneities/scatterers. 3) The construction of higher-order Absorbing Boundary Conditions.

In the framework of Magic2, Rabia Djellouli (CSUN) visited Magique 3D in February 2018

## **8.5. International Research Visitors**

### **8.5.1. Visits of International Scientists**

- José M. Carcione (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, OGS) visited Magique 3D in December 2018.
- Guy Chavent (Inria Rocquencourt, Emeritus professor) visited Magique 3D in December 2018.
- Barbara Romanowicz (Berkeley Seismological Laboratory, Collège de France) visited Magique 3D in November 2018

- Mounir Tlemcani (Université d'Oran, Algeria) visited Magique 3D in March 2018.
- Rabia Djellouli (CSUN) visited Magique 3D in February 2018.

### **8.5.2. Visits to International Teams**

#### *8.5.2.1. Research Stays Abroad*

- Justine Labat visited Benjamin Stamm, RTWH Aachen University, Germany, in December 2018.
- In the framework of DIP, Pierre Jacquet visited Total Research Center at Houston, USA, in December 2018.

## MNEMOSYNE Project-Team

# 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 describing 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)*

**Participants:** Nicolas Rougier, Remya Sankar.

This 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. Altogether, our experimental findings provide evidence for dose-dependent effects of RF signals on the bursting rate of neuronal cultures and suggest that part of the mechanism is nonthermal (publication in Journal of Neurophysiology). In an attempt to elucidate the depressing effect of GSM on in-vitro neuronal activity, pharmacological studies have also been realized on cortical cells.

## **9.3. International Initiatives**

### **9.3.1. Participation in International Programs**

#### *9.3.1.1. 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.

## MONC Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. Plan Cancer

#### 9.1.1.1. NUMEP

Plan Cancer NUMEP: 2016–2019. Numerics for Clinical Electroporation Funding: 460 k€ Partners: Inria Team MONC, Institut de Pharmacologie de Toulouse, CHU J. Verdier de Bondy Duration: Octobre 2016—Septembre 2019 Project leader: C. Poignard Co-PI: M-P. Rols (IPBS), O. Séror (CHU J. Verdier)

#### 9.1.1.2. Dynamo

Plan Cancer DYNAMO: 2015–2018. Dynamical Models for Tissue Electroporation Funding: 370 k€ Partners: Laboratoire Ampère, Lab. Vectorology and Anticancerous Therapies (IGR), Inria Team MONC Duration: Octobre 2015—Septembre 2018 Project leader: R. Scorretti (Laboratoire Ampère) Co-PI: L.M. Mir (IGR), C. Poignard (Inria Team MONC)

#### 9.1.1.3. Moglimaging

- Project acronym - Moglimaging: Modeling of Glioblastoma treatment-induced resistance and heterogeneity by multi-modal imaging.
- Partners -
- Duration - from Nov. 2016 to Nov 2019.
- Coordinator - E. Cohen-Jonathan Moyal, Institut Universitaire du Cancer Toulouse / Local coordinator - O. Saut.
- Team participants - S. Benzekry, A. Collin, C. Poignard, O. Saut.

#### 9.1.1.4. Systems Biology of Renal Carcinoma

- Title: Plan Cancer Systems Biology of Renal Carcinoma using a Mouse RCC model
- Partners : LAMC, INSERM-Univ. Bordeaux.
- Duration - June 2018 to June 2021
- Team participants: O. Saut, S. Benzekry (co-PI)
- 116.64k€

### 9.1.2. Transnation call: INCA/ARC

- Title: Minimally and non-invasive methods for early detection and/or progression of cancer
- Acronym: TRANSCAN
- Team participants: A. Collin, C. Poignard, O. Saut (local PI)
- Total funds: 1M150, Monc's share 275k€.

### 9.1.3. Competitivity Clusters

- Labex TRAIL (<http://trail.labex.u-bordeaux.fr>): MOD Project Consolidation. 1 2-years post-doc position (100k€), led by A. Collin, 1 PhD funding (100k€) led by O. Saut.

## 9.2. European Initiatives

MONC is partner of the European Lab EBAM devoted to electroporation. C.Poignard is member of the steering committee.



## 9.3. International Initiatives

### 9.3.1. Inria International Labs

#### **Inria@SiliconValley**

Associate Team involved in the International Lab:

#### 9.3.1.1. Num4SEP

Title: Numerics for Spherical Electroporation

International Partner (Institution - Laboratory - Researcher):

University of California, Santa Barbara (United States) - Department of Mechanical Engineering - Frederic Gibou

Start year: 2017

See also: <http://num4sep.bordeaux.inria.fr/>

Electroporation-based therapies (EPTs) consist in applying high voltage short pulses to cells in order to create defects in the plasma membrane. They provide interesting alternatives to standard ablative techniques, for instance for deep seated badly located tumors. However their use is still limited due to a lack of knowledge of tissue electroporation. The goal of the associate team is to focus on the multiscale numerical modeling of spheroid electroporation, in order to provide new insights in electroporation at the mesoscopic scales (spheroids provide interesting tumor-like biological models). Benefiting from the expertise of F. Gibou's team in HPC for multiphysics, and the expertise of the team MONC in tumor growth and cell electroporation modeling, the goal of the associate team Num4SEP is to obtain accurate and efficient numerical tools for the quantitative evaluation of the EPTs at the mesoscopic scale.

### 9.3.2. Inria Associate Teams Not Involved in an Inria International Labs

#### 9.3.2.1. METAMATS

Title: Modeling ExperimentAI MetAsTasiS

International Partner (Institution - Laboratory - Researcher):

Roswell Park Cancer Institute (United States) - Department of Cancer Genetics Department of Medicine Department of Pharmacology and Therapeutics (Graduate Program) - John Ebos

Start year: 2017

See also: <http://metamats.bordeaux.inria.fr/>

The aim of the METAMATS associate team is to bring together a cancer biology experimental laboratory led by John ML Ebos (Roswell Park Cancer Institute) and the inria MONC team composed of applied mathematicians. The Ebos laboratory is specialized in the study of anti-cancer therapeutics (in particular, novel biologically targeted therapeutics such as anti-angiogenics and immunotherapies) on the development of metastases and produces unique, hard-to-obtain data sets on this process' dynamics. The MONC team is specialized in mathematical models in oncology, with a dedicated axis about modeling support and methodological development for analysis of data from preclinical studies. In particular, the work of S. Benzekry puts emphasis on proposing, studying and validating mathematical models of metastatic development under the action of various therapeutic modalities. Indeed, metastatic expansion remains the main challenge in the treatment of cancer and integrative studies combining experiments, mathematical models and clinical data have the potential to yield predictive computational tools of help to assist both the design of clinical trials and clinical oncologists in therapeutic decisions such as the control of the toxicity/efficacy balance or the optimal combination of treatment modalities.

### 9.3.3. Other international initiatives

MONC is partner of the European Lab EBAM devoted to electroporation. C.Poignard is member of the steering committee.

#### ***9.3.4. Informal International Partners***

- Collaboration with Jonathan Mochel at the Department of Biomedical Sciences of Iowa State University (Ames, Iowa, USA). Development of mechanistic pharmacokinetics/pharmacodynamics models for comparative oncology (i.e. translational oncology across species integrating veterinary medicine). Sebastien Benzekry is Affiliate Assistant Professor at Iowa State University.
- Collaboration between Sebastien Benzekry and the laboratory of Yuval Shaked at the Rappaport Faculty of Medicine of the Technion (Israel Institute of Technology, Haifa, Israel). Our joint work deals with validating mathematical models of host-mediated resistance mechanisms to anti-cancer therapies.

### **9.4. International Research Visitors**

#### ***9.4.1. Visits of International Scientists***

June 2018: Visit of John Ebos (Roswell Park Cancer Institute, Buffalo, USA) in the context of the METAMATS Inria Associate team.

## PLEIADE Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. High-performance computing and metabarcoding

PLEIADE is member of two projects, one funded by the Région Nouvelle Aquitaine and one funded as Inria ADT Gordon, connecting Chameleon, StartPU and NewMadeleine, where the use case of metabarcoding (questions, data sets) have been selected to link these layers together. This will permit us to address unsupervised clustering of one million reads next year. These projects are in collaboration with the HiePACS, TADAAM, and STORM project-teams.

### 8.1.2. COTE – Continental to Coastal Ecosystems

The Labex cluster of excellence COTE (Continental To coastal Ecosystems: evolution, adaptability and governance) develops tools to understand and predict ecosystem responses to human-induced changes as well as methods of adaptive management and governance to ensure their sustainability. The LabEx includes nine laboratories of the University of Bordeaux and major national research institutes involved in research on terrestrial and aquatic ecosystems (INRA, CNRS, IFREMER and IRSTEA). PLEIADE is a partner in two projects funded by COTE:

- *Malabar: Métabarcoding appliqué à la biodiversité des communautés algales du Bassin d'Arcachon*
- *Aerobarcoding: détection de pollens allergénisants. 2017-18.*

## 8.2. National Initiatives

### 8.2.1. Biocontamination in aircraft reservoirs

ANTICOR is an industrial-academic research and development working group coordinated by Dassault Aviation, investigating the causes of microbial contamination in aircraft reservoirs and aimed at developing mitigating procedures and equipment. Previous results have shown that this contamination forms biofilms at the fuel-water interface and is comprised of complex communities of hundreds of bacterial and fungal species. PLEIADE is particularly interested in measuring and modeling these communities, especially as concerns understanding how they change based on environmental conditions and on reservoir geometry.

This working group continues work started in CAER – Alternative Fuels for Aeronautics, a 6 M-Euro contract with the Civil Aviation Directorate (Direction Générale de l'Aviation Civile, DGAC), coordinated by the French Petroleum Institute (Institut français de pétrole-énergies nouvelles, IFPEN) on behalf of a large consortium of industrial (EADS, Dassault, Snecma, Turbomeca, Airbus, Air France, Total) and academic (CNRS, INRA, Inria) partners to explore different technologies for alternative fuels for aviation.

### 8.2.2. Agence Française pour la Biodiversité

The AFB is a public law agency of the French Ministry of Ecology that supports public policy in the domains of knowledge, preservation, management, and restoration of biodiversity in terrestrial, aquatic, and marine environments. PLEIADE is a partner in two AFB projects developed with the former ONEMA:

- *Methods for metabarcoding. 2017-18.*
- *Molecular diagnosis of freshwater quality. 2014-present.*

### 8.2.3. Inria Projet Lab in silico Algae

In 2017 PLEIADE joined the IPL “In silico Algae” coordinated by Olivier Bernard. The IPL addresses challenges in modeling and optimizing microalgae growth for industrial applications. PLEIADE worked this year on comparative genomic analysis of genes implicated in lipid production by the picoalgae *Ostreococcus tauri*, in collaboration with Florence Corellou of the CNRS UMR 5200 (Laboratoire de Biogénèse Membranaire). The goal of this work is the production of long-chain polyunsaturated fatty acids, developed as nutritional additives. Mercia Ngoma Komb’s two-month internship in PLEIADE contributed to this work.

## 8.3. European Initiatives

### 8.3.1. Collaborations in European Programs, Except FP7 & H2020

Alain Franc is co-chair of Working Group 4 (Data Analysis and Storage) of COST DNAqua.net<sup>0</sup>, with the main task of developing contact with HPC and metabarcoding for serving the whole community. He chaired the meeting of this groups in Pécs in 2018. The goal of DNAqua-Net is to nucleate a group of researchers across disciplines with the task to identify gold-standard genomic tools and novel eco-genomic indices and metrics for routine application for biodiversity assessments and biomonitoring of European water bodies.

## 8.4. International Initiatives

### 8.4.1. Vitapalm – Food and nutrition security and sustainable agriculture in Africa

PLEIADE has joined the Vitapalm program financed by LEAP-Agri<sup>0</sup>, the joint Europe Africa Research and Innovation (R&I) initiative related to Food and Nutrition Security and Sustainable Agriculture. Vitapalm will use genomics and selection to improve the nutritional quality and the stability of palm oil produced by Africa smallholdings for local consumption. Project partners are from Cameroon, France, Germany, and Ghana.

### 8.4.2. Simulation of metacommunities

In collaboration with the Pasteur Institute in Cayenne and the INRA MIA Research Team in Toulouse, PLEIADE is developing a stochastic model for simulation of metacommunities, in the framework of patch occupancy models. The objective is a better understanding of zoonose propagation, namely rabies through bat hosts in connection with disturbances of pristine forests in French Guiana, which have an impact on the exposure of human populations to wildlife that act as reservoirs of zoonoses.

### 8.4.3. CEBA – Center for the study of biodiversity in Amazonia

The Laboratoire of excellence CEBA promotes innovation in research on tropical biodiversity. It brings together a network of internationally-recognized French research teams, contributes to university education, and encourages scientific collaboration with South American countries. PLEIADE participates in three current international projects funded by CEBA:

- *MicroBIOMES: Microbial Biodiversities*. 2017-19.
- *Neutrophyl: Inferring the drivers of Neotropical diversification*. 2017-19.
- *Phyloguianas: Biogeography and pace of diversification in the Guiana Shield*. 2015-present

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<sup>0</sup><http://dnaqua.net/>

<sup>0</sup><http://www.leap-agri.com/>

## SISTM Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

The team have strong links with :

- Research teams of the research center INSERM U1219 : "Injury Epidemiology, Transport, Occupation" (IETO), "Biostatistics", "Pharmacoepidemiology and population impact of drugs", "Multi-morbidity and public health in patients with HIV or Hepatitis" (MORPH3Eus), "Computer research applied to health" (ERIAS) emerging research team.
- Bordeaux and Limoges CHU ("Centre Hospitalier Universitaire").
- Institut Bergonié, Univ Bordeaux through the Euclid platform
- Inria Project-team MONC, M3DISIM and CQFD

The project team members are involved in:

- EUCLID/F-CRIN clinical trials platform (Laura Richert)
- The research project "Self-management of injury risk and decision support systems based on predictive computer modelling. Development, implementation and evaluation in the MAVIE cohort study" funded by the Nouvelle-Aquitaine regional council (Marta Avalos).
- Phenotyping from Electronic Health Records pilot project in cooperation with with the ERIAS Inserm emerging team in Bordeaux and the Rheumatology service from the Bordeaux Hospital (Boris Hejblum)
- A cancer research project in collaboration with Inria MONC team on glioblastoma

## 9.2. National Initiatives

- Labex Vaccine Research Institute (VRI) There are strong collaborations with immunologists involved in the Labex Vaccine Research Institute (VRI) as Rodolphe Thiébaud is leading the Data science division (previously Biostatistics/Bioinformatics) <http://vaccine-research-institute.fr>.
- Collaboration with Inserm PRC (pôle Recherche clinique).
- Collaboration with Inserm Reacting (REsearch and ACTION targeting emerging infectious diseases) network

### 9.2.1. Expert Appraisals

- Rodolphe Thiébaud is a member of the CNU 46.04 (Biostatistiques, informatique médicale et technologies de communication).
- Rodolphe Thiébaud is a member of the Scientific Council of INSERM.
- Mélanie Prague is an expert for ANRS (France Recherche Nord&Sud Sida-HIV Hépatites) in the CSS 3 (Recherches cliniques et physiopathologiques dans l'infection à VIH) and AC 47 (Dynamique et contrôle des épidémies VIH et hépatites).
- Laura Richert is an expert for the PHRC (Programme hospitalier de recherche Clinique).
- Marta Avalos is an expert for the ANSM (Agence nationale de sécurité du médicament et des produits de santé)

### 9.2.2. Various Partnership

The project team members are involved in:

- DRUGS-SAFE platform funded by ANSM (Marta Avalos). Initiated in 2015-2018. Renewed for 2019.
- F-CRIN (French clinical research infrastructure network) was initiated in 2012 by ANR under two sources of founding "INBS/Infrastructures nationales en biologie et en santé" and "Programme des Investissements d'avenir". (Laura Richert)
- I-REIVAC is the French vaccine research network. This network is part of the "Consortium de Recherche en Vaccinologie (CoReVac)" created by the "Institut de Microbiologie et des Maladies Infectieuses (IMMI)". (Laura Richert)
- INCA (Institut National du Cancer) funded the project « Evaluation de l'efficacité d'un traitement sur l'évolution de la taille tumorale et autres critères de survie : développement de modèles conjoints. » (Principal PI Virginie Rondeau Inserm U1219, Mélanie Prague is responsible of Work package 4 mechanistic modeling of cancer: 5800 euros).
- Contrat Initiation ANRS MoDeL-CI: Modeling the HIV epidemic in Ivory Coast (Principal PI Eric Ouattara Inserm U1219 in collaboration with University College London, Mélanie Prague is listed as a collaborator).

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

The member of SISTM Team are involved in EHVA (European HIV Vaccine Alliance):

Program: Most information about this program can be found at <http://www.ehv-a.eu>.

Coordinator: Rodolphe Thiébaud is Work Package leader of the WP10 "Data Integration".

Other partners: The EHVA encompasses 39 partners, each with the expertise to promote a comprehensive approach to the development of an effective HIV vaccine. The international alliance, which includes academic and industrial research partners from all over Europe, as well as sub-Saharan Africa and North America, will work to discover and progress novel vaccine candidates through the clinic.

Abstract: With 37 million people living with HIV worldwide, and over 2 million new infections diagnosed each year, an effective vaccine is regarded as the most potent public health strategy for addressing the pandemic. Despite the many advances in the understanding, treatment and prevention of HIV made over the past 30 years, the development of broadly-effective HIV vaccine has remained unachievable. EHVA plans to develop and implement:

Discovery Platform with the goal of generating novel vaccine candidates inducing potent neutralizing and non-neutralizing antibody responses and T-cell responses

Immune Profiling Platform with the goal of ranking novel and existing (benchmark) vaccine candidates on the basis of the immune profile

Data Management/Integration/Down-Selection Platform, with the goal of providing statistical tools for the analysis and interpretation of complex data and algorithms for the efficient selection of vaccines

Clinical Trials Platform with the goal of accelerating the clinical development of novel vaccines and the early prediction of vaccine failure.

### 9.3.2. Collaborations in European Programs, Except FP7 & H2020

Program: The EBOVAC2 project is one of 8 projects funded under IMI Ebola+ programme that was launched in response to the Ebola virus disease outbreak. The project aims to assess the safety and efficacy of a novel prime boost preventive vaccine regimen against Ebola Virus Disease (EVD). Project acronym: EBOVAC2 Project title: EBOVAC2 Coordinator: Rodolphe Thiébaud Other partners: Inserm (France), Labex VRI (France), Janssen Pharmaceutical Companies of Johnson

& Johnson, London School of Hygiene & Tropical Medicine (United Kingdom), The Chancellor, Masters and Scholars of the University of Oxford (United Kingdom), Le Centre Muraz (Burkina Faso), Inserm Transfert (France) Given the urgent need for an preventive Ebola vaccine strategy in the context of the current epidemic, the clinical development plan follows an expedited scheme, aiming at starting a Phase 2B large scale safety and immunogenicity study as soon as possible while assuring the safety of the trial participants.

Phase 1 trials to assess the safety and immunogenicity data of the candidate prime-boost regimen in healthy volunteers are ongoing in the UK, the US and Kenya and Uganda. A further study site has been approved to start in Tanzania. Both prime-boost combinations (Ad26.ZEBOV prime + MVA-BN-Filo boost; and MVA-BN-Filo prime + Ad26.ZEBOV boost) administered at different intervals are being tested in these trials.

Phase 2 trials (this project) are planned to start as soon as the post-prime safety and immunogenicity data from the UK Phase I are available. Phase 2 trials will be conducted in healthy volunteers in Europe (France and UK) and non-epidemic African countries (to be determined). HIV positive adults will also be vaccinated in African countries. The rationale for inclusion of European volunteers in Phase 2, in addition to the trials in Africa, is to allow for higher sensitivity in safety signal detection in populations with low incidence of febrile illnesses, to generate negative control specimens for assay development, to allow for inclusion of health care workers or military personnel that may be deployed to Ebola-endemic regions.

EBOVAC3 As a follow-up project, the IMI-2 funded EBOVAC3 project, has started in 2018. In this project, the vaccine strategy will be further evaluated in specific populations in Africa (infants in Guinea and Sierra Leone; and front line workers in RDC). The project includes a work package on modelling, which is led by Rodolphe Thiebaut.

### **9.3.3. Collaborations with Major European Organizations**

University of Oxford;  
 London School of Hygiene and Tropical Medicine;  
 University Hospital Hamburg;  
 Heinrich Pette Institute for Experimental Virology, Hamburg;  
 MRC, University College London;  
 MRC Biostatistics Unit, University of Cambridge.

## **9.4. International Initiatives**

- Prevac-Up: this EDCTP-funded research program will collect and analyze important information on the effectiveness and maintainability of Ebola vaccination in sub-Saharan Africa.
- NIPAH program: a Franco-Chinese collaboration of 1 million euros per country over 5 years to develop a program to better understand Nipah Virus infection, its physiopathology and to develop new tools for diagnosis, treatment and prevention.

### **9.4.1. Inria International Labs**

#### **Inria@SiliconValley**

Associate Team involved in the International Lab:

#### 9.4.1.1. SWAGR

Title: Statistical Workforce for Advanced Genomics using RNAseq

International Partner (Institution - Laboratory - Researcher):

RAND Corporation (United States) - Statistics group - Denis Agniel

Start year: 2018

See also: <https://team.inria.fr/swagr/>

The SWAGR Associate Team aims at bringing together a statistical workforce for advanced genomics using RNAseq. SWAGR combines the biostatistics experience of the SISTM team from Inria BSO with the mathematical expertise of the statistics group at the RAND Corporation in an effort to improve RNAseq data analysis methods by developing a flexible, robust, and mathematically principled framework for detecting differential gene expression. Gene expression, measured through the RNAseq technology, has the potential of revealing deep and complex biological mechanisms underlying human health. However, there is currently a critical limitation in widely adopted approaches for the analysis of such data, as edgeR, DESeq2 and limma-voom can all be shown to fail to control the type-I error, leading to an inflation of false positives in analysis results. False positives are an important issue in all of science. In particular in biomedical research when costly studies are failing to reproduce earlier results, this is a pressing issue. SWAGR propose to develop a rigorous statistical framework modeling complex transcriptomic studies using RNAseq by leveraging the synergies between the works of B. Hejblum and D. Agniel. The new method will be implemented in open-source software as a Bioconductor R package, and a user friendly web-application will be made available to help dissemination. The new method will be applied to clinical studies to yield significant biological results, in particular in vaccine trials through existing SISTM partnerships. The developed method is anticipated to become a new standard for the analysis of RNAseq data, which are rapidly becoming common in biomedical studies, and has therefore the potential for a large impact.

#### 9.4.2. Inria International Partners

Fred Hutchinson Cancer center, Seattle;

Baylor Institute for Immunology (Dallas);

Duke University -Duke Global Health Institute, Elizabeth Turner.

Harvard University - Department of Population Medicine - Rui Wang. M. Prague is a co-PI in an amfAR project for co-supervision of a PhD student.

university of San Diego UCSD / Harvard School of public health - NIH program project grant "Revealing Reservoirs During Rebound", Harvard School of Public Health (HSPH) and the University of California, San Diego (P01AI131385, total budget \$1.5M/yr for 5 years starting Oct 2017, both university manage the funding. Mélanie Prague is part of modelling unit of the "Quantitative Methods" research project (budget \$220,000/yr). The principal investigator for this core is Victor de Grutolla (HSPH) The overall goal of this grant is to characterize viral rebound following antiretroviral therapy cessation in cohorts of patients who have started therapy early in infection, as well as in a cohort of terminally-ill patients who will interrupt therapy before death and subsequently donate their bodies to research.

Harvard University - program for evolutionary dynamics - Alison hill and Martin Nowak. Project submitted by M Prague for the Inria associated team with this laboratory.

Collaborations through clinical trials: NIH and University of Minnesota for the Prevac trial, NGO Alima for the Prevac trial, Several African clinical sites for Ebovac2 and Prevac trials;

Tianxi Cai from Harvard University on developing methods for the linkage and analysis of Electronic Health Records data (Boris Hejblum).

Katherine Liao from Harvard University on the analysis of Electronic Health Records data in the context of Rheumatoid Arthritis (Boris Hejblum).



Sylvia Richardson from MRC Biostatistics Unit Cambridge University on the scaling up of nonparametric Bayesian approaches to Big data (Boris Hejblum).

Machine learning team Data61 at CSIRO, Australia (Marta Avalos)

## **9.5. International Research Visitors**

### **9.5.1. Visits to International Teams**

Marta Avalos visited Marcela Henríquez Henríquez 1 week in December 2018, Medical School, Pontifical Catholic University of Chile (Chile). Travel grant from the French Embassy in Chile and the French Institute of Chile

Boris Hejblum visited the RAND Corporation for a week in July 2018 for a research collaboration with Denis Agniel (Santa-Monica, USA).

Boris Hejblum visited the MRC BSU for 10 days in October 2018 for a research collaboration with Sylvia Richardson & Paul Kirk.

Chloé Pasin visited Harvard School of Public Health on May 9-11 2018 and Columbia University, Department of Pathology and Cell Biology on May 14-17 2018.

Mélanie Prague got invited in University of Montreal (Canada) for a 3-days research trip in the pharmacy department on December 19-22 2018 to be member of the jury committee of the PhD defense of Steven Sanche (Effet des antiretroviraux sur la pathogénèse du VIH), as well as giving an invited talk.

Mélanie Prague spent 3 weeks in Boston as an invited researcher in Harvard School of Public Health & Department of evolutionary dynamics, Biostatistics department in January and february 2018.

#### *9.5.1.1. Research Stays Abroad*

- Laura Richert spent 6 months (March-August 2018) as a visiting researcher at the Heinrich Pette Institut for Experimental Virology, Research Department Virus Immunology, Hamburg, Germany (head: Marcus Altfeld).

## HIEPACS Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

### 8.1.1. HPC Scalable Ecosystem

**Participants:** Emmanuel Agullo, Olivier Coulaud, Aurélien Esnard, Mathieu Faverge, Luc Giraud, Abdou Guermouche, Pierre Ramet.

**Grant:** Regional council

**Dates:** 2018 – 2020

**Partners:** EPIs **REALOPT**, **STORM** from Inria Bordeaux Sud-Ouest, CEA-CESTA and l’Institut pluridisciplinaire de recherche sur l’environnement et les matériaux (IPREM) .

**Overview:**

Numerical simulation is today integrated in all cycles of scientific design and studies, whether academic or industrial, to predict or understand the behavior of complex phenomena often coupled or multi-physical. The quality of the prediction requires having precise and adapted models, but also to have computation algorithms efficiently implemented on computers with architectures in permanent evolution. Given the ever increasing size and sophistication of simulations implemented, the use of parallel computing on computers with up to several hundred thousand computing cores and consuming / generating massive volumes of data becomes unavoidable; this domain corresponds to what is now called High Performance Computing (HPC). On the other hand, the digitization of many processes and the proliferation of connected objects of all kinds generate ever-increasing volumes of data that contain multiple valuable information; these can only be highlighted through sophisticated treatments; we are talking about Big Data. The intrinsic complexity of these digital treatments requires a holistic approach with collaborations of multidisciplinary teams capable of mastering all the scientific skills required for each component of this chain of expertise.

To have a real impact on scientific progress and advances, these skills must include the efficient management of the massive number of compute nodes using programming paradigms with a high level of expressiveness, exploiting high-performance communications layers, effective management for intensive I / O, efficient scheduling mechanisms on platforms with a large number of computing units and massive I / O volumes, innovative and powerful numerical methods for analyzing volumes of data produced and efficient algorithms that can be integrated into applications representing recognized scientific challenges with high societal and economic impacts. The project we propose aims to consider each of these links in a consistent, coherent and consolidated way.

For this purpose, we propose to develop a unified Execution Support (SE) for large-scale numerical simulation and the processing of large volumes of data. We identified four Application Challenges (DA) identified by the Nouvelle-Aquitaine region that we propose to carry over this unified support. We will finally develop four Methodological Challenges (CM) to evaluate the impact of the project. This project will make a significant contribution to the emerging synergy on the convergence between two yet relatively distinct domains, namely High Performance Computing (HPC) and the processing, management of large masses of data (Big Data); this project is therefore clearly part of the emerging field of High Performance Data Analytics (HPDA).

## 8.2. National Initiatives

### 8.2.1. ANR

#### 8.2.1.1. SASHIMI: Sparse Direct Solver using Hierarchical Matrices

**Participants:** Mathieu Faverge, Pierre Ramet, Aurelien Esnard.

**Grant:** ANR-18-CE46-0006

**Dates:** 2018 – 2022

**Overview:** Nowadays, the number of computational cores in supercomputers has grown largely to a few millions. However, the amount of memory available has not followed this trend, and the memory per core ratio is decreasing quickly with the advent of accelerators. To face this problem, the SaSHiMi project wants to tackle the memory consumption of linear solver libraries used by many major simulation applications by using low-rank compression techniques. In particular, the direct solvers which offer the most robust solution to strategy but suffer from their memory cost. The project will especially investigate the super-nodal approaches for which low-rank compression techniques have been less studied despite the attraction of their large parallelism and their lower memory cost than for the multi-frontal approaches. The results will be integrated in the PaStiX solver that supports distributed and heterogeneous architectures.

#### 8.2.1.2. *DEDALES: Algebraic and geometric domain decomposition for subsurface/groundwater flows*

**Participants:** Emmanuel Agullo, Mathieu Faverge, Luc Giraud, Louis Poirel.

**Grant:** ANR-14-CE23-0005

**Dates:** 2014 – 2018

**Partners:** Inria EPI POMDAPI (leader); Université Paris 13 - Laboratoire Analyse, Géométrie et Applications; Maison de la Simulation; Andra.

**Overview:** Project **DEDALES** aims at developing high performance software for the simulation of two phase flow in porous media. The project will specifically target parallel computers where each node is itself composed of a large number of processing cores, such as are found in new generation many-core architectures. The project will be driven by an application to radioactive waste deep geological disposal. Its main feature is phenomenological complexity: water-gas flow in highly heterogeneous medium, with widely varying space and time scales. The assessment of large scale model is of major importance and issue for this application, and realistic geological models have several million grid cells. Few, if at all, software codes provide the necessary physical features with massively parallel simulation capabilities. The aim of the **DEDALES** project is to study, and experiment with, new approaches to develop effective simulation tools with the capability to take advantage of modern computer architectures and their hierarchical structure. To achieve this goal, we will explore two complementary software approaches that both match the hierarchical hardware architecture: on the one hand, we will integrate a hybrid parallel linear solver into an existing flow and transport code, and on the other hand, we will explore a two level approach with the outer level using (space time) domain decomposition, parallelized with a distributed memory approach, and the inner level as a subdomain solver that will exploit thread level parallelism. Linear solvers have always been, and will continue to be, at the center of simulation codes. However, parallelizing implicit methods on unstructured meshes, such as are required to accurately represent the fine geological details of the heterogeneous media considered, is notoriously difficult. It has also been suggested that time level parallelism could be a useful avenue to provide an extra degree of parallelism, so as to exploit the very large number of computing elements that will be part of these next generation computers. Project **DEDALES** will show that space-time DD methods can provide this extra level, and can usefully be combined with parallel linear solvers at the subdomain level. For all tasks, realistic test cases will be used to show the validity and the parallel scalability of the chosen approach. The most demanding models will be at the frontier of what is currently feasible for the size of models.

### 8.2.2. *FUI*

#### 8.2.2.1. *ICARUS: Intensive Calculation for AeRo and automotive engines Unsteady Simulations*

**Participants:** Cyril Bordage, Aurelien Esnard.

**Grant:** FUI-22

**Dates:** 2016-2019

**Partners:** SAFRAN, SIEMENS, IFPEN, ONERA, DISTENE, CENAERO, GDTECH, Inria, CORIA, CER-FACS.

**Overview:** Large Eddy Simulation (LES) is an increasingly attractive unsteady modelling approach for modelling reactive turbulent flows due to the constant development of massively parallel supercomputers. It can provide open and robust design tools that allow access to new concepts (technological breakthroughs) or a global consideration of a structure (currently processed locally). The mastery of this method is therefore a major competitive lever for industry. However, it is currently constrained by its access and implementation costs in an industrial context. The ICARUS project aims to significantly reduce them (costs and deadlines) by bringing together major industrial and research players to work on the entire high-fidelity LES computing process by:

- increasing the performance of existing reference tools (for 3D codes: AVBP, Yales2, ARGO) both in the field of code coupling and code/machine matching;
- developing methodologies and networking tools for the LES;
- adapting the ergonomics of these tools to the industrial world: interfaces, data management, code interoperability and integrated chains;
- validating this work on existing demonstrators, representative of the aeronautics and automotive industries.

## **8.3. European Initiatives**

### **8.3.1. FP7 & H2020 Projects**

#### *8.3.1.1. EoCoE*

Title: Energy oriented Centre of Excellence for computer applications

Programm: H2020

Duration: October 2015 - October 2018

Coordinator: CEA

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Commissariat A L Energie Atomique et Aux Energies Alternatives (France)

Centre Europeen de Recherche et de Formation Avancee en Calcul Scientifique (France)

Consiglio Nazionale Delle Ricerche (Italy)

The Cyprus Institute (Cyprus)

Agenzia Nazionale Per le Nuove Tecnologie, l'energia E Lo Sviluppo Economico Sostenibile (Italy)

Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)

Instytut Chemii Bioorganicznej Polskiej Akademii Nauk (Poland)

Forschungszentrum Julich (Germany)

Max Planck Gesellschaft Zur Foerderung Der Wissenschaften E.V. (Germany)

University of Bath (United Kingdom)

Universite Libre de Bruxelles (Belgium)

Universita Degli Studi di Trento (Italy)

Inria contact: Michel Kern

The aim of the present proposal is to establish an Energy Oriented Centre of Excellence for computing applications, (EoCoE). EoCoE (pronounce “Echo”) will use the prodigious potential offered by the ever-growing computing infrastructure to foster and accelerate the European transition to a reliable and low carbon energy supply. To achieve this goal, we believe that the present revolution in hardware technology calls for a similar paradigm change in the way application codes are designed. EoCoE will assist the energy transition via targeted support to four renewable energy pillars: Meteo, Materials, Water and Fusion, each with a heavy reliance on numerical modelling. These four pillars will be anchored within a strong transversal multidisciplinary basis providing high-end expertise in applied mathematics and HPC. EoCoE is structured around a central Franco-German hub coordinating a pan-European network, gathering a total of 8 countries and 23 teams. Its partners are strongly engaged in both the HPC and energy fields; a prerequisite for the long-term sustainability of EoCoE and also ensuring that it is deeply integrated in the overall European strategy for HPC. The primary goal of EoCoE is to create a new, long lasting and sustainable community around computational energy science. At the same time, EoCoE is committed to deliver high-impact results within the first three years. It will resolve current bottlenecks in application codes, leading to new modelling capabilities and scientific advances among the four user communities; it will develop cutting-edge mathematical and numerical methods, and tools to foster the usage of Exascale computing. Dedicated services for laboratories and industries will be established to leverage this expertise and to foster an ecosystem around HPC for energy. EoCoE will give birth to new collaborations and working methods and will encourage widely spread best practices.

#### 8.3.1.2. PRACE 5IP

Title: PRACE Fifth Implementation Phase (PRACE-5IP) project

Duration: January 2017 - April 2019

Partners: see the following [url](#)

Inria contact: Stéphane Lanteri

The mission of PRACE (Partnership for Advanced Computing in Europe) is to enable high-impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society. PRACE seeks to realise this mission by offering world class computing and data management resources and services through a peer review process. PRACE also seeks to strengthen the European users of HPC in industry through various initiatives. PRACE has a strong interest in improving energy efficiency of computing systems and reducing their environmental impact.

The objectives of **PRACE-5IP** are to build on and seamlessly continue the successes of PRACE and start new innovative and collaborative activities proposed by the consortium. These include:

- assisting the transition to PRACE2 including an analysis of TransNational Access;
- strengthening the internationally recognised PRACE brand;
- continuing and extend advanced training which so far provided more than 18 800 person-training days;
- preparing strategies and best practices towards Exascale computing;
- coordinating and enhancing the operation of the multi-tier HPC systems and services;
- supporting users to exploit massively parallel systems and novel architectures.

## 8.4. International Initiatives

### 8.4.1. Inria International Labs

In the framework of the Joint Laboratory for Extreme Scale Computing (JLESC) within a collaboration between Inria and Argonne national laboratory an new joint project studies how lossy compression can be monitored by Krylov solvers to significantly reduce the memory footprint when solving very-large sparse

linear systems. The resulting solvers will alleviate the I/O penalty paid when running large calculations using either check-point mechanisms to address resiliency or out-of-core techniques to solve huge problems. For the solution of large linear systems of the form  $Ax = b$  where  $A \in \mathbb{R}^{n \times n}$ ,  $x$  and  $b \in \mathbb{R}^n$ , Krylov subspace methods are among the most commonly used iterative solvers; they are further extended to cope with extreme scale computing as one can integrate features such as communication hidden in their variants referred to as pipelined Krylov solvers [7]. On the one hand, the Krylov subspace methods such as GMRES allow some inexactness when computing the orthonormal search basis; more precisely theoretical results [24], [25] show that the matrix-vector product involved in the construction of the new search directions can be more and more inexact when the convergence towards the solution takes place. An inexact scheme of that form writes into a generalized Arnoldi equality

$$[(A + E_1)v_1, \dots, (A + E_k)v_k] = [v_1, \dots, v_k, v_{k+1}]\overline{H}_k, \quad (1)$$

where the theory gives a bound on  $\|E_k\|$  that depends on the residual norm  $\|b - Ax_k\|$  at step  $k$ , where  $x_k$  is the  $k^{\text{th}}$  iterate. Such a result has a major interest in applications where the matrix is not formed explicitly, e.g., in the fast multipole (FMM) or domain decomposition (DDM) methods context, where this allows one to drastically reduce the computational effort.

On the other hand, novel agnostic lossy data compression techniques are studied to reduce the I/O footprint of large applications that have to store snapshots of the calculation, for a posteriori analysis, because they implement out-of-core calculation or for checkpointing data for resilience. Those lossy compression techniques allow for precise control on the error introduced by the compressor to ensure that the stored data are still meaningful for the considered application. In the context of the Krylov method, the basis  $V_{k+1} = [v_1, \dots, v_k, v_{k+1}]$  represents the most demanding data in terms of memory footprint, so that, in a fault-tolerant or out-of-core context, storing it in a lossy form would allow for a tremendous saving.

The objective of this work, developed within the post-doc of N. Schenkels, is to dynamically control the compression error of  $V_{k+1}$  to comply with the inexact Krylov theory. The main difficulty is to translate the known theoretical inexactness on  $E_k$  into a suited lossy compression mechanism for  $v_k$  with loss  $\|\delta v_k\|$ .

## **PHOENIX-POST Team**

# **7. Partnerships and Cooperations**

## **7.1. International Initiatives**

- Idex cooperation programme UB-UUW-Canada — Category B - Emerging Cooperation (2017-2018), managed by M. Fernandes and H. Sauzéon.
- Idex cooperation programme UB-UUW-Canada — Category A - Research projects - Priority topics (Aging) – (2017-2018), managed by M. Fernandes and H. Sauzéon.

## STORM Project-Team

# 8. Partnerships and Cooperations

## 8.1. Regional Initiatives

HPC Cloud Computing

**Participants:** Olivier Aumage, Nathalie Furmento, Samuel Thibault.

Other participants : David Auber, Olivier Beaumont, Lionel Eyraud-Dubois, Gérald Point

Abstract: The goal of this project is to gather teams from the HPC and Big Data communities to work at the intersection between these domains. We will focus on how StarPU can be adapted to achieve good performances on Big Data platforms.

## 8.2. National Initiatives

ELCI The ELCI PIA project (Software Environment for HPC) aims to develop a new generation of software stack for supercomputers, numerical solvers, runtime and programming development environments for HPC simulation. The ELCI project also aims to validate this software stack by showing its capacity to offer improved scalability, resilience, security, modularity and abstraction on real applications. The coordinator is Bull, and the different partners are CEA, Inria, SAFRAN, CERFACS, CNRS CORIA, CENAERO, ONERA, UVSQ, Kitware and AlgoTech.

### 8.2.1. ANR

ANR SOLHAR (<http://solhar.gforge.inria.fr/doku.php?id=start>).

ANR MONU 2013 Program, 2013 - 2018 (36 months extended )

Identification: ANR-13-MONU-0007

Coordinator: Inria Bordeaux/LaBRI

Other partners: CNRS-IRIT, Inria-LIP Lyon, CEA/CESTA, EADS-IW

Abstract: This project aims at studying and designing algorithms and parallel programming models for implementing direct methods for the solution of sparse linear systems on emerging computers equipped with accelerators. The ultimate aim of this project is to achieve the implementation of a software package providing a solver based on direct methods for sparse linear systems of equations. Several attempts have been made to accomplish the porting of these methods on such architectures; the proposed approaches are mostly based on a simple offloading of some computational tasks (the coarsest grained ones) to the accelerators and rely on fine hand-tuning of the code and accurate performance modeling to achieve efficiency. This project proposes an innovative approach which relies on the efficiency and portability of runtime systems, such as the StarPU tool developed in the runtime team (Bordeaux). Although the SOLHAR project will focus on heterogeneous computers equipped with GPUs due to their wide availability and affordable cost, the research accomplished on algorithms, methods and programming models will be readily applicable to other accelerator devices such as ClearSpeed boards or Cell processors.

ANR EXACARD

AAPG ANR 2018 (42 months)

Coordinator: Yves Coudière (Carmen) Inria Bordeaux



Abstract: Cardiac arrhythmia affect millions of patients and cause 300,000 deaths each year in Europe. Most of these arrhythmia are due to interaction between structural and electrophysiological changes in the heart muscle. A true understanding of these phenomena requires numerical simulations at a much finer resolution, and larger scale, than currently possible. Next-generation, heterogeneous, high-performance computing (HPC) systems provide the power for this. But the large scale of the computations pushes the limits of current runtime optimization systems, and together with task-based parallelism, prompts for the development of dedicated numerical methods and HPC runtime optimizations. With a consortium including specialists of these domains and cardiac modeling, we will investigate new task-based optimization techniques and numerical methods to utilize these systems for cardiac simulations at an unprecedented scale, and pave the way for future use cases.

### 8.2.2. ADT - Inria Technological Development Actions

ADT SwLoc (<http://swloc.gforge.inria.fr/>)

**Participants:** Raymond Namyst, Pierre-André Wacrenier, Andra Hugo, Brice Goglin, Corentin Salingue.

Inria ADT Campaign 2017, 10/2017 - 9/2019 (24 months)

Coordinator: Raymond Namyst

Abstract: The Inria action ADT SwLoc is aiming at developing a library allowing dynamic flexible partitioning of computing resources in order to execute parallel regions concurrently inside the same processes.

ADT Gordon

**Participants:** Denis Barthou, Nathalie Furmento, Samuel Thibault, Pierre-André Wacrenier.

Inria ADT Campaign 2018, 11/2018 - 11/2020 (24 months)

Coordinator: Emmanuel Jeannot (Tadaam)

Other partners: HiePACS, PLEIADE, Tadaam (Inria Bordeaux)

Abstract: Teams HiePACS, Storm and Tadaam develop each a brick of an HPC software stack, namely solver, runtime, and communication library. The goal of the Gordon project is to consolidate the HPC stack, to improve interfaces between each brick, and to target a better scalability. The bioinformatics application involved in the project has been selected so as to stress the underlying systems.

ADT AFF3CT Matlab

**Participants:** Denis Barthou, Olivier Aumage, Adrien Cassagne.

Inria ADT Campaign 2018, 12/2018 - 12/2019 (12 months)

Coordinator: Denis Barthou

Other partners: C.Jego and C.Leroux (IMS lab, U.Bordeaux)

Abstract: AFF3CT is a toolchain for designing, validation and experimentation of new Error Correcting codes. This toolchain is written in C++, and this constitutes a difficulty for many industrial users, who are mostly electronicians. The goal of this ADT is to widen the number of possible users by designing a Matlab and Python interface for AFF3CT, in collaboration with existing users, and proposing a parallel framework in OpenMP.

### 8.2.3. IPL - Inria Project Lab

HAC-SPECIS (High-performance Application and Computers, Studying PErformance and Correctness In Simulation)

**Participants:** Samuel Thibault, Luka Stanisic, Emmanuelle Saillard, Olivier Aumage, Idriss Daoudi.

Inria IPL 2016 - 2020 (48 months)

Coordinator: Arnaud Legrand (team Polaris, Inria Rhône Alpes)

Since June 2016, the team is participating to the HAC-SPECIS <http://hacspecis.gforge.inria.fr/> Inria Project Lab (IPL). This national initiative aims at answering methodological needs of HPC application and runtime developers and allowing to study real HPC systems both from the correctness and performance point of view. To this end, it gathers experts from the HPC, formal verification and performance evaluation community.

HPC-BigData (High Performance Computing and Big Data)

**Participant:** Samuel Thibault.

Inria IPL 2018 - 2022 (48 months)

Coordinator: Bruno Raffin (team DataMove, Inria Rhône Alpes)

Since June 2018, the team is participating to the HPC-BigData <https://project.inria.fr/hpcbigdata/> Inria Project Lab (IPL). The goal of this HPC-BigData IPL is to gather teams from the HPC, Big Data and Machine Learning (ML) areas to work at the intersection between these domains. Research is organized along three main axes: high performance analytics for scientific computing applications, high performance analytics for big data applications, infrastructure and resource management.

## 8.3. European Initiatives

### 8.3.1. H2020 Projects

INTERTWinE

- Title: Programming Model INTERoperability ToWards Exascale
- Program: H2020
- Duration: October 2015 - October 2018
- Coordinator: EPCC
- Inria contact: Olivier Aumage
- Partners:
  - \* Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)
  - \* Deutsches Zentrum für Luft - und Raumfahrt Ev (Germany)
  - \* Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev (Germany)
  - \* Institut National de Recherche en Informatique et en Automatique (France)
  - \* Kungliga Tekniska Hoegskolan (Sweden)
  - \* T-Systems Solutions for Research (Germany)
  - \* The University of Edinburgh (United Kingdom)
  - \* Universitat Jaume I de Castellon (Spain)
  - \* The University of Manchester (United Kingdom)

This project addresses the problem of programming model design and implementation for the Exascale. The first Exascale computers will be very highly parallel systems, consisting of a hierarchy of architectural levels. To program such systems effectively and portably, programming APIs with efficient and robust implementations must be ready in the appropriate timescale. A single, “silver bullet” API which addresses all the architectural levels does not exist and seems very unlikely to emerge soon enough. We must therefore expect that using combinations of different APIs at different system levels will be the only practical solution in the short to medium term. Although there remains room for improvement in individual programming models and their implementations, the main challenges lie in interoperability between APIs. It is this interoperability,

both at the specification level and at the implementation level, which this project seeks to address and to further the state of the art. INTERTWinE brings together the principal European organisations driving the evolution of programming models and their implementations. The project will focus on seven key programming APIs: MPI, GASPI, OpenMP, OmpSs, StarPU, QUARK and PaRSEC, each of which has a project partner with extensive experience in API design and implementation. Interoperability requirements, and evaluation of implementations will be driven by a set of kernels and applications, each of which has a project partner with a major role in their development. The project will implement a co-design cycle, by feeding back advances in API design and implementation into the applications and kernels, thereby driving new requirements and hence further advances.

#### Exa2PRO

- Title: Enhancing Programmability and boosting Performance Portability for Exascale Computing systems
- Program: H2020-FETHPC
- Duration: May 2018 - April 2021
- Coordinator: ICCS
- Inria contact: Samuel Thibault
- Partners:
  - \* Institute of Communications and Computer Systems (ICCS) (Greece)
  - \* Linköping University (LIU) (Sweden)
  - \* Centre for Research and Technology Hellas (CERTH) (Greece)
  - \* Institut National de Recherche en Informatique et en Automatique (Inria) (France)
  - \* Maxeler Technologies Limited (MAX) (UK)
  - \* Forschungszentrum Jülich (JUELICH) (Germany)
  - \* Centre National de la Recherche Scientifique (CNRS) (France)

The vision of EXA2PRO is to develop a programming environment that will enable the productive deployment of highly parallel applications in exascale computing systems. EXA2PRO programming environment will integrate tools that will address significant exascale challenges. It will support a wide range of scientific applications, provide tools for improving source code quality, enable efficient exploitation of exascale systems' heterogeneity and integrate tools for data and memory management optimization. Additionally, it will provide various fault-tolerance mechanisms, both user-exposed and at runtime system level and performance monitoring features. EXA2PRO will be evaluated using 4 use cases from 4 different domains, which will be deployed in JUELICH supercomputing center. The use cases will leverage the EXA2PRO tool-chain and we expect:

- Increased applications performance based on EXA2PRO optimization tools (data and memory management)
- Efficient exploitation of heterogeneity by the applications that will allow the evaluation of more complex problems.
- Identification of trade-offs between design qualities (source code maintainability/reusability) and run-time constraints (performance/energy consumption).
- Evaluation of various fault-tolerance mechanisms for applications with different characteristics.

EXA2PRO outcome is expected to have major impact in a) the scientific and industrial community that focuses on application deployment in supercomputing centers: EXA2PRO environment will allow efficient application deployment with reduced effort. b) on application developers of exascale application: EXA2PRO will provide tools for improving source code maintainability/ reusability, which will allow application evaluation with reduced developers' effort. c) on the scientific community and the industry relevant to the EXA2PRO use cases. At least two of the EXA2PRO use cases will have significant impact to the CO2 capture and to the Supercapacitors industry.

### **8.3.2. Collaborations in European Programs, Except FP7 & H2020**

#### PRACE-5IP

- Title: PRACE 5th Implementation Phase
- Program: PRACE
- Duration: 2017 - 2019
- Coordinator: PRACE
- Inria contact for team STORM: Olivier Aumage
- Abstract: The objectives of PRACE-5IP are to build on and seamlessly continue the successes of PRACE and start new innovative and collaborative activities proposed by the consortium. These include:
  - \* assisting the transition to PRACE2 including analysis of TransNational Access;
  - \* strengthening the internationally recognised PRACE brand;
  - \* continuing and extend advanced training which so far provided more than 18 800 persontraining days;
  - \* preparing strategies and best practices towards Exascale computing;
  - \* coordinating and enhancing the operation of the multi-tier HPC systems and services;
  - \* supporting users to exploit massively parallel systems and novel architectures.

A high level Service Catalogue is provided. The proven project structure will be used to achieve each of the objectives in 6 dedicated work packages. The activities are designed to increase Europe's research and innovation potential especially through:

- \* seamless and efficient Tier-0 services and a pan-European HPC ecosystem including national capabilities;
- \* promoting take-up by industry and new communities and special offers to SMEs;
- \* implementing a new flexible business model for PRACE 2;
- \* proposing strategies for deployment of leadership systems;
- \* collaborating with the ETP4HPC, CoEs and other European and international organisations on future architectures, training, application support and policies.

## **8.4. International Research Visitors**

- Costin Iancu, LBNL (USA), from Oct. 8 to Oct. 12, 2018

### **8.4.1. Internships**

- Dana Akhmetova, KTH (Sweden), PhD Internship, from Feb. 18, 2018 to Mar. 24, 2018, within the context of H2020 INTERTWinE.

## TADAAM Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. CRA HPC Scalable Ecosystem, 2018-2021

2018 - 2021 (36 months)

Coordinator: Emmanuel AGULLO

Other partners: INRA, Institut Pprime, UPPA, Airbus, CEA, CATIE

Abstract: The goal is to design a unified runtime-system for numerical simulation at large-scale and with a large amount of data. We aim at contributing significantly to the convergence between HPC and BigData. TADAAM is involved in scheduling data access and managing communication efficiently on large-scale system.

## 9.2. National Initiatives

### 9.2.1. PIA ELCI, Environnement Logiciel pour le Calcul Intensif, 2014-2018

The ELCI PIA project is coordinated by BULL with several partners: CEA, Inria, SAFRAN, UVSQ.

This project aims to improve the support for numerical simulations and High Performance Computing (HPC) by providing a new generation software stack to control supercomputers, to improve numerical solvers, and pre- and post computing software, as well as programming and execution environment. It also aims at validating the relevance of these developments by demonstrating their capacity to deliver better scalability, resilience, modularity, abstraction, and interaction on some application use-cases. TADAAM is involved in WP1 and WP2 ELCI Work Packages. Emmanuel JEANNOT is the Inria representative in the ELCI steering committee.

### 9.2.2. ANR

ANR SATAS SAT as a Service (<http://www.agence-nationale-recherche.fr/Project-ANR-15-CE40-0017>).

AP générique 2015, 01/2016 - 12/2019 (48 months)

Coordinator: Laurent Simon (LaBRI)

Other partners: CRIL (Univ. Artois), Inria Lille (Spirals)

Abstract: The SATAS project aims to advance the state of the art in massively parallel SAT solving. The final goal of the project is to provide a “pay as you go” interface to SAT solving services and will extend the reach of SAT solving technologies, daily used in many critical and industrial applications, to new application areas, which were previously considered too hard, and lower the cost of deploying massively parallel SAT solvers on the cloud.

ANR DASH Data-Aware Scheduling at Higher scale (<https://project.inria.fr/dash/>).

AP générique JCJC 2017, 03/2018 - 02/2022 (48 months)

Coordinator: Guillaume AUPY (Tadaam)

Abstract: This project focuses on the efficient execution of I/O for High-Performance applications. The idea is to take into account some knowledge on the behavior of the different I/O steps to compute efficient schedules, and to update them dynamically with the online information.

### 9.2.3. ADT - Inria Technological Development Actions

ADT Gordon

10/2018 - 09/2020 (24 months)

Coordinator: Emmanuel JEANNOT

Other partners: Storm, HiePACS, PLEIADE (Inria Bordeaux)

Abstract: Teams HiePACS, Storm and Tadaam develop each a brick of an HPC software stack, namely solver, runtime, and communication library. The goal of the Gordon project is to consolidate the HPC stack, to improve interfaces between each brick, and to target a better scalability. The bioinformatics application involved in the project has been selected so as to stress the underlying systems.

### 9.2.4. IPL - Inria Project Lab

High-Performance computing and BigData

**Participants:** Guillaume Aupy, Emmanuel Jeannot, Julien Herrmann and Nicolas Vidal.

HPC and Big Data evolved with their own infrastructures (supercomputers versus clouds), applications (scientific simulations versus data analytics) and software tools (MPI and OpenMP versus Map/Reduce or Deep Learning frameworks). But Big Data analytics is becoming more compute-intensive (thanks to deep learning), while data handling is becoming a major concern for scientific computing. The goal of this HPC-BigData IPL is to gather teams from the HPC, Big Data and Machine Learning (ML) areas to work at the intersection between these domains. Research is organized along three main axes: high performance analytics for scientific computing applications, high performance analytics for big data applications, infrastructure and resource management

## 9.3. European Initiatives

### 9.3.1. Collaborations in European Programs, Except FP7 & H2020

NESUS: Network for Ultrascale Computing (<http://www.nesus.eu>)

Program: COST

Project acronym: NESUS

Project title: Network for Ultrascale Computing

Duration: April 2014 - April 2018

Coordinator: University Carlos III de Madrid

Other partners: more than 35 countries

Abstract: Ultrascale systems are envisioned as large-scale complex systems joining parallel and distributed computing systems that will be two to three orders of magnitude larger than today's systems. The EU is already funding large scale computing systems research, but it is not coordinated across researchers, leading to duplications and inefficiencies. The goal of the NESUS Action is to establish an open European research network targeting sustainable solutions for ultrascale computing aiming at cross fertilization among HPC, large scale distributed systems, and big data management. The network will contribute to glue disparate researchers working across different areas and provide a meeting ground for researchers in these separate areas to exchange ideas, to identify synergies, and to pursue common activities in research topics such as sustainable software solutions (applications and system software stack), data management, energy efficiency, and resilience. Some of the most active research groups of the world in this area are members of this proposal. This Action will increase the value of these groups at the European-level by reducing duplication of efforts and providing a more holistic view to all researchers, it will promote the leadership of Europe, and it will increase their impact on science, economy, and society. Emmanuel JEANNOT is the vice-chair of this Action.

### **9.3.2. Collaborations with Major European Organizations**

Partner 1: INESC-ID, Lisbon, (Portugal)

Subject 1: Application modeling for hierarchical memory system

Partner 2: University Carlos III de Madrid, (Spain)

Subject 2: I/O Scheduling

## **9.4. International Initiatives**

### **9.4.1. Inria International Labs**

Joint-Lab on Extreme Scale Computing (JLESC):

Coordinators: Franck Cappello (general) and Yves Robert (Inria coordinator).

Other partners: Argonne National Lab, University of Urbana Champaign (NCSA), Tokyo Riken, Jülich Supercomputing Center, Barcelona Supercomputing Center (BSC).

Abstract: The purpose of the Joint Laboratory for Extreme Scale Computing (JLESC) is to be an international, virtual organization whose goal is to enhance the ability of member organizations and investigators to make the bridge between Petascale and Extreme computing. The founding partners of the JLESC are Inria and UIUC. Further members are ANL, BSC, JSC and RIKEN-AICS.

### **9.4.2. Inria International Partners**

#### *9.4.2.1. Informal International Partners*

Partner 1: Argonne National Lab

Subject 1: Binomial Checkpointing Strategies for Machine Learning (recipient of a FACCTS grant, 2018-2020)

Partner 2: Vanderbilt University

Subject 2: Scheduling for Neurosciences

Partner 3: ICL at University of Tennessee

Subject 3: on instrumenting MPI applications and modeling platforms (works on HWLOC take place in the context of the OPEN MPI consortium) and MPI and process placement

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

- Sri Hari Krishna Narayanan (Argonne National Lab), April 2018
- Sri Hari Krishna Narayanan (Argonne National Lab), Jan Hückelheim and Navjot Kukreja (Imperial College), June 2018
- Jesus Carretero, David E. Singh (Univ. Carlos III, Madrid), Dean Chester (Univ. of Warwick), Raymond Nou (BSC), October 2018
- Paul Hovland (Argonne National Lab) and Navjot Kukreja (Imperial College), December 2018

### **9.5.2. Visits to International Teams**

#### *9.5.2.1. Research Stays Abroad*

Valentin HONORÉ visited Ana Gainaru, Padma Raghavan, and Hongyang Sun at Vanderbilt University (USA) for three months in the context of the project “Scheduling for Neurosciences”.

## **AUCTUS Team**

# **9. Partnerships and Cooperations**

## **9.1. Regional Initiatives**

### ***9.1.1. Woobot***

The main objective of Woobot is to propose a methodology for designing and controlling a collaborative robotic system to assist and secure an operator's actions. The system must preserve the health and sensory expertise of the operator while guaranteeing his or her mobility. Motivated by a pilot case from carpentry, the determination of the behavior of the collaborative robot will be based on a human-centered approach and based on a precise ergonomic analysis of the task and the biomechanical performances and needs of the operator. Two scientific issues are important: the choice of the system architecture (type of collaborative robot, number of degrees of freedom, level of redundancy with respect to the task, type of interaction of the collaborative robot with the task and/or the human...), and the behavior of the collaborative robot that must be implemented in the control. To answer these questions, it is then necessary to consider in the same formalism the human and task constraints from the point of view of:

- of the performance necessary for the task (cutting forces, trajectories);
- of the operator's biomechanical performance (kinematics -i.e. dexterity; static -i.e. manipulability and human dynamics).
- ergonomic (task, work environment, human posture).

## **9.2. International Research Visitors**

### ***9.2.1. Visits of International Scientists***

- Gionata Salvietti, Affiliated Researcher at IIT Central Research Lab Genova, Italy, visited the team on February 7-8, 2018 and gave a talk.
- Milan Hladík, Associate Professor at Charles University in Prague, Czech Republic, visited the team on August 21-24, 2018.
- Chee Yap, Professor at the Courant Institute of Mathematical Sciences at New York University, visited the team on December 6-7, 2018. He gave a talk entitled "New Approach to FIND-PATH: a Paradigmatic Problem in Robotics, AI and SC".



## FLOWERS Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### 9.1.1. Perseverons

Perseverons

Program: eFran

Duration: January 2016 - December 2019

Coordinator: PY Oudeyer, Inria Flowers

Partners: Inria Flowers

Funding: 140 keuros

The Perseverons project (Perseverance with / by digital objects), coordinated by the university via the ESPE (Higher School of Teaching and Education) of Aquitaine, and by the Rectorat of Bordeaux via the DANE (Academic Delegation digital education), aims to measure the real effectiveness of digital techniques in education to improve school motivation and perseverance, and, in the long term, reduce dropout. The project proposes to analyze the real effects of the use of two types of objects, robots, tablets, by comparing the school and non-school contexts of the *fablabs*. It is one of the 22 winners <http://www.gouvernement.fr/efran-les-22-laureats> of the "E-Fran" call for projects (training, research and digital animation spaces), following the Monteil mission on digital education, as part of the Investissement d'Avenir 2 program <http://ecolenumerique.education.gouv.fr/2016/09/23/1244/>. Formed of 12 sub-projects, "perseverons" has many partnerships, especially with the Poppy Education project of Inria Flowers. It is funding the PhD of Thibault Desprez.

#### 9.1.1.1. Partner schools

In 2018, we have 36 partner schools (show Fig 41 ). 15 directly from the Poppy Education project. 19 new establishments were equipped in September 2017 by the Perseverons project. 21 of these establishments are located in Gironde. We have 27 high schools, 5 middle school.

### 9.1.2. KidLearn and Region Aquitaine

KidLearn

Program: Région Aquitaine research grant

Duration: 2016 - 2018

Coordinator: PY Oudeyer and M Lopes, Inria Flowers

Partners: Inria Flowers

Funding: 140 keuros (PhD grant of Benjamin Clément)

We propose here a research project that aims at elaborating algorithms and software systems to help humans learn efficiently, at school, at home or at work, by adapting and personalizing sequences of learning activities to the particularities of each individual student. This project leverages recent innovative algorithmic models of human learning (curiosity in particular, developed as a result of ERC European project of the Flowers team), and combines it with state-of-the-art optimization algorithms and an original integration with existing expert knowledge (human teachers). Given a knowledge domain and a set of possible learning activities, it will be able to propose the right activity at the right time to maximize learning progress. It can be applied to many learning situations and potential users: children learning basic knowledge in schools and with the support of their teachers, older kids using educational software at home, of adults needing to acquire new skills through professional training ("formation professionnelle"). Because it combines innovations in computational sciences (machine learning and optimization) with theories of human cognition (theories of human learning and of education), this project is also implementing a strong cross-fertilization between technology and human sciences (SHS).

Attachement	Type	Name	Adresse	Tel	Web
Poppy Education	High School	Alfred Kastler	14 Avenue de l'Université,33402 Talence, France	+33 5 57 35 40 70	<a href="http://www.lyceekastler.fr/">http://www.lyceekastler.fr/</a>
Poppy Education	Middle School	Anatole France	28 Rue des Micocouliers,33410 Cadillac, France	+33 5 56 62 98 42	<a href="http://www.afcadillac.net/">http://www.afcadillac.net/</a>
PERSEVERONS	High School	André Malraux	3 Rue du 8 Mai 1945,64200 Biarritz, France	+33 5 59 01 20 40	<a href="http://lycee-malraux-biarritz.fr/">http://lycee-malraux-biarritz.fr/</a>
Poppy Education	High School	Camille Jullian	29 Rue de la Croix Blanche,33000 Bordeaux, France	+33 5 56 01 47 47	<a href="http://www.camillejullian.com/">http://www.camillejullian.com/</a>
Poppy Education	Middle School	de France	Rue du Cimetière Saint-Benoist,75005 Paris, France	+33 1 44 27 12 11	<a href="http://www.college-de-france.fr/">http://www.college-de-france.fr/</a>
Poppy Education	High School	des Graves	238 Cours du Général de Gaulle,33170 Gradignan, France	+33 5 56 75 77 56	<a href="http://www.grandlebrun.com/">http://www.grandlebrun.com/</a>
PERSEVERONS	High School	Élie Faure	63 Avenue de la Libération,33310 Lormont, France	+33 5 56 38 23 23	<a href="http://www.lyc-eliefaure.fr/">http://www.lyc-eliefaure.fr/</a>
PERSEVERONS	High School	Elisée Reclus	7 Avenue de Verdun,33220 Pineuilh, France	+33 5 57 41 92 50	<a href="http://lycee-foyen.fr/">http://lycee-foyen.fr/</a>
Poppy Education	High School	François Mauriac	1 Rue Henri Dunant,33000 Bordeaux, France	+33 5 56 38 52 82	<a href="http://lyceemaauriac.fr/">http://lyceemaauriac.fr/</a>
PERSEVERONS	High School	Gaston Febus	20 Avenue Georges Moutet,64300 Orthez, France	+33 5 59 67 07 26	<a href="http://webetab.ac-bordeaux.fr/cite-gaston-febus-orthez/">http://webetab.ac-bordeaux.fr/cite-gaston-febus-orthez/</a>
PERSEVERONS	Middle School	Giraud de Borneil	10 Boulevard André Dupuy,24160 Excideuil, France	+33 5 53 62 21 16	<a href="http://www.gdeborneil.fr/">http://www.gdeborneil.fr/</a>
PERSEVERONS	High School	Grand Air	Avenue du Docteur Lorentz Monod,33120 Arcachon, France	+33 5 56 22 38 00	<a href="http://webetab.ac-bordeaux.fr/lycee-grand-air/">http://webetab.ac-bordeaux.fr/lycee-grand-air/</a>
PERSEVERONS	High School	Gustave Eiffel	143 Rue Ferbos,33000 Bordeaux, France	+33 5 56 33 83 00	<a href="http://www.eiffel-bordeaux.org/">http://www.eiffel-bordeaux.org/</a>
PERSEVERONS	High School	Jacques Monod	10 Rue du Parvis,64230 Lescar, France	+33 5 59 77 92 00	<a href="http://lyceejacquesmonod.fr/">http://lyceejacquesmonod.fr/</a>
Poppy Education	High School	Jean Moulin	Avenue de la République,33210 Langon, France	+33 5 56 63 62 30	<a href="http://webetab.ac-bordeaux.fr/lycee-jean-moulin-langon/">http://webetab.ac-bordeaux.fr/lycee-jean-moulin-langon/</a>
Poppy Education	Middle School	Jean Zay	41 Rue Henri Cochet,33380 Biganos, France	+33 5 57 17 01 70	<a href="http://collegibiganos.fr/">http://collegibiganos.fr/</a>
Poppy Education	High School	La Morlette	62 Rue du Docteur Roux,33150 Cenon, France	+33 5 57 80 37 00	<a href="http://lycee-lamorlette.fr/">http://lycee-lamorlette.fr/</a>
PERSEVERONS	High School	Les Iris	13 Rue Sourbès,33310 Lormont, France	+33 5 57 80 10 60	<a href="http://www.lyceesiris.fr/">http://www.lyceesiris.fr/</a>
PERSEVERONS	High School	Louis Barthou	2 Boulevard Barbanègre,64000 Pau, France	+33 5 59 98 98 00	<a href="http://www.cyberlycee.fr/">http://www.cyberlycee.fr/</a>
PERSEVERONS	High School	Louis de Foix	4 Avenue Jean Rostand,64100 Bayonne/Bayona/Baiona, France	+33 5 59 63 31 10	<a href="http://www.louisdefoix.com/">http://www.louisdefoix.com/</a>
PERSEVERONS	High School	Maine de Biran	108 Rue Valette,24100 Bergerac, France	+33 5 53 74 50 00	<a href="http://webetab.ac-bordeaux.fr/lycee-maine-de-biran/">http://webetab.ac-bordeaux.fr/lycee-maine-de-biran/</a>
Poppy Education	Middle School	Mios	Route du Pujeau,33380 Mios, France	+33 5 56 03 00 77	<a href="http://www.villemios.fr/enfance-jeunesse/college/">http://www.villemios.fr/enfance-jeunesse/college/</a>
PERSEVERONS	High School	Nord Bassin	128 Avenue de Bordeaux,33510 Andemos-les-Bains, France	+33 5 56 82 20 77	<a href="http://www.lyceenordbassin.com/">http://www.lyceenordbassin.com/</a>
Forum Poppy	Primary School	Notre-Dame du Mur	19 Rue de Kermadiou,29600 Morlaix, France	+33 2 98 88 18 69	<a href="http://lycee.ecmorlaix.fr/">http://lycee.ecmorlaix.fr/</a>
PERSEVERONS	High School	Pape Clément	1 Rue Léo Lagrange,33600 Pessac, France	+33 5 57 26 63 00	<a href="http://lyceepapeclément.fr/">http://lyceepapeclément.fr/</a>
PERSEVERONS	High School	Pays de Soule	Avenue Jean Monnet,64130 Chéraute, France	+33 5 59 28 22 28	<a href="http://www.lyceedupaysdesoule.fr/index.php">http://www.lyceedupaysdesoule.fr/index.php</a>
PERSEVERONS	High School	Pré De Cordy	5 Avenue Joséphine Baker,24200 Sarlat-la-Canéda, France	+33 5 53 31 70 70	<a href="http://lycee-predecordy-sarlat.com/">http://lycee-predecordy-sarlat.com/</a>
Poppy Education	High School	Raoul Follereau	9 Boulevard Saint-Exupéry,58000 Nevers, France	+33 3 86 60 36 00	<a href="http://lyc58-renardfollereau.ac-dijon.fr/">http://lyc58-renardfollereau.ac-dijon.fr/</a>
PERSEVERONS	High School	René Cassin	2 Rue de Lassegnette,64100 Bayonne/Bayona/Baiona, France	+33 5 59 58 42 00	<a href="http://webetab.ac-bordeaux.fr/lycee-rene-cassin/">http://webetab.ac-bordeaux.fr/lycee-rene-cassin/</a>
PERSEVERONS	High School	Saint-Cricq	4 Piste Cyclable,64000 Pau, France	+33 5 59 30 50 55	<a href="http://www.lycee-saint-cricq.org/">http://www.lycee-saint-cricq.org/</a>
Poppy Education	High School	Saint-Genès	160 Rue de Saint-Genès,33000 Bordeaux, France	+33 5 56 33 84 84	<a href="http://www.saint-genes.com/">http://www.saint-genes.com/</a>
PERSEVERONS	High School	Saint-John Perse	2 Chemin de Bairncou,64000 Pau, France	+33 5 59 62 73 11	<a href="http://www.lycee-saint-john-perse.fr/">http://www.lycee-saint-john-perse.fr/</a>
Poppy Education	High School	Sainte-Marie Grand Lebrun	164 Rue François Mauriac,33200 Bordeaux, France	+33 5 56 08 32 13	<a href="http://www.grandlebrun.com/">http://www.grandlebrun.com/</a>
inria	High School	Sainte-Saintonge	12 Rue de Saintonge,33000 Bordeaux, France	+33 5 56 99 39 29	<a href="http://www.lyceesaintefamille.com/">http://www.lyceesaintefamille.com/</a>
Poppy Education	High School	Sud-Médoc	Piste du Médoc Bleu,33320 Le Taillan-Médoc, France	+33 5 56 70 10 10	<a href="http://www.lyceesudmedoc.fr/">http://www.lyceesudmedoc.fr/</a>
Poppy Education	High School	Victor Louis	2 Rue de Mégret,33400 Talence, France	+33 5 56 80 76 40	<a href="http://lyceevictorlouis.fr/">http://lyceevictorlouis.fr/</a>

Figure 41. List of partner schools

## 9.2. National Initiatives

### 9.2.1. Myoelectric prosthesis - PEPS CNRS

PY Oudeyer collaborated with Aymar de Rugy, Daniel Cattaert, Mathilde Couraud, Sébastien Mick and Florent Pacllet (INCI, CNRS/Univ. Bordeaux) about the design of myoelectric robotic prostheses based on the Poppy platform, and on the design of algorithms for co-adaptation learning between the human user and the prosthesis. This was funded by a PEPS CNRS grant.

### 9.2.2. Poppy Station structure

- Since 1 september 2017 until february 2019, PerPoppy and Poppy Station Projects : D. Roy, P.-Y. Oudeyer. These projects aim to perpetuate the Poppy robot ecosystem by creating an external structure from outside Inria, with various partners. After the Poppy Robot Project, the Poppy Education Project has ended and Poppy Station structure is born. PerPoppy is the project which is building the new structure, and Poppy Station is the name of the new structure. Poppy Station, which includes Poppy robot ecosystem (hardware, software, community) from the beginning, is a place of excellence to build future educational robots and to design pedagogical activities to teach computer science, robotics and Artificial Intelligence. <https://www.poppystation.org>
- Partners of Poppy Station : Inria, La Ligue de l'Enseignement, HESAM Université, SNCF Développement, IFÉ-ENS Lyon, MOBOTS – EPFL, Génération Robots, Pollen Robotics, KONEX-Inc.

## 9.3. European Initiatives

### 9.3.1. DREAM

Title: Deferred Restructuring of Experience in Autonomous Machines

Programm: H2020

Duration: January 2015 - December 2018

Coordinator: UPMC

Partners:

Armines (ENSTA ParisTech)

Edinburgh (Scotland)

University of A Coruna (Spain)

Vrije University Amsterdam (Holland)

Contact: David Filliat

Abstract: A holy grail in robotics and artificial intelligence is to design a machine that can accumulate adaptations on developmental time scales of months and years. From infancy through adulthood, such a system must continually consolidate and bootstrap its knowledge, to ensure that the learned knowledge and skills are compositional, and organized into meaningful hierarchies. Consolidation of previous experience and knowledge appears to be one of the main purposes of sleep and dreams for humans, that serve to tidy the brain by removing excess information, to recombine concepts to improve information processing, and to consolidate memory. Our approach – Deferred Restructuring of Experience in Autonomous Machines (DREAM) – incorporates sleep and dream-like processes within a cognitive architecture. This enables an individual robot or groups of robots to consolidate their experience into more useful and generic formats, thus improving their future ability to learn and adapt. DREAM relies on Evolutionary Neurodynamic ensemble methods (Fernando et al, 2012 *Frontiers in Comp Neuro*; Bellas et al., *IEEE-TAMD*, 2010 ) as a unifying principle for discovery, optimization, re-structuring and consolidation of knowledge. This new paradigm will make the robot more autonomous in its acquisition, organization and use of knowledge and skills just as long as they comply with the satisfaction of pre-established basic motivations. DREAM will enable robots to cope with the complexity of being an information-processing entity in domains that are open-ended both in terms of space and time. It paves the way for a new generation of robots whose existence and purpose goes far beyond the mere execution of dull tasks. <http://www.robotsthatdream.eu>

### **9.3.2. Collaborations in European Programs, except FP7 & H2020**

#### **9.3.2.1. IGLU**

Title: Interactive Grounded Language Understanding (IGLU)

Programm: CHIST-ERA

Duration: October 2015 - September 2018

Coordinator: University of Sherbrooke, Canada

Partners:

University of Sherbrooke, Canada

Inria Bordeaux, France

University of Mons, Belgium

KTH Royal Institute of Technology, Sweden

University of Zaragoza, Spain

University of Lille 1 , France

University of Montreal, Canada

Inria contact: Pierre-Yves Oudeyer

Language is an ability that develops in young children through joint interaction with their caretakers and their physical environment. At this level, human language understanding could be referred as interpreting and expressing semantic concepts (e.g. objects, actions and relations) through what can be perceived (or inferred) from current context in the environment. Previous work in the field of artificial intelligence has failed to address the acquisition of such perceptually-grounded knowledge in virtual agents (avatars), mainly because of the lack of physical embodiment (ability to interact physically) and dialogue, communication skills (ability to interact verbally). We believe that robotic agents are more appropriate for this task, and that interaction is a so important aspect of human language learning and understanding that pragmatic knowledge (identifying or conveying intention) must be present to complement semantic knowledge. Through a developmental approach where knowledge grows in complexity while driven by multimodal experience and language interaction with a human, we propose an agent that will incorporate models of dialogues, human emotions and intentions as part of its decision-making process. This will lead anticipation and reaction not only based on its internal state (own goal and intention, perception of the environment), but also on the perceived state and intention of the human interactant. This will be possible through the development of advanced machine learning methods (combining developmental, deep and reinforcement learning) to handle large-scale multimodal inputs, besides leveraging state-of-the-art technological components involved in a language-based dialog system available within the consortium. Evaluations of learned skills and knowledge will be performed using an integrated architecture in a culinary use-case, and novel databases enabling research in grounded human language understanding will be released. IGLU will gather an interdisciplinary consortium composed of committed and experienced researchers in machine learning, neurosciences and cognitive sciences, developmental robotics, speech and language technologies, and multimodal/multimedia signal processing. We expect to have key impacts in the development of more interactive and adaptable systems sharing our environment in everyday life. <http://iglu-chistera.github.io/>

## **9.4. International Initiatives**

### **9.4.1. Inria Associate Teams Not Involved in an Inria International Labs**

#### **9.4.1.1. NEUROCURIOSITY**

Title: NeuroCuriosity

International Partner (Institution - Laboratory - Researcher):

Columbia Neuroscience (United States) - Cognitive Neuroscience - JACQUELINE GOTTLIEB

Start year: 2016

See also: <https://flowers.inria.fr/neurocuriosity>

Curiosity can be understood as a family of mechanisms that evolved to allow agents to maximize their knowledge of the useful properties of the world. In this project we will study how different internal drives of an animal, e.g. for novelty, for action, for liking, are combined to generate the rich variety of behaviors found in nature. We will approach such challenge by studying monkeys, children and by developing new computational tools.

#### 9.4.1.2. *Idex Bordeaux-Univ. Waterloo collaborative project on curiosity in HCI*

Title: Curiosity

International Partner (Institution - Laboratory - Researcher):

University of Waterloo (Canada), Edith Law's HCI Lab and Dana Kulic's Robotics lab.

Start year: 2018

Pierre-Yves Oudeyer collaborated with Edith Law's HCI research group at University of Waterloo on the topic of "Curiosity in HCI system". They obtained a grant from Univ. Bordeaux to set up a project with Inria Potioc team and with Dana Kulic, Robotics lab, Univ. Waterloo. They organized several cross visits and collaborated on the design and experimentation of an educational interactive robotic system to foster curiosity-driven learning. This led to an article accepted at CHI 2019.

#### 9.4.1.3. *Informal International Partners*

Pierre-Yves Oudeyer and Didier Roy have create a collaboration with LSRO EPFL and Pr Francesco Mondada, about Robotics and education. The two teams co-organize the annual conference "Robotics and Education" in Bordeaux. Didier Roy teaches "Robotics and Education" in EPFL several times a year.

Didier Roy has created a collaboration with HEP VAud (Teachers High School) and Bernard Baumberger and Morgane Chevalier, about Robotics and education. Scientific discussions and shared professional training.

Florian Golemo and PY Oudeyer have had an active collaboration with Aaron Courville from MILA Montreal to work on the IGLU project together.

William Schueller and PY Oudeyer continued to collaborate with Vittorio Loreto (CNR Rome and Sony CSL Paris).

A collaboration with Johan Lilius and Sebastien Lafond from Abo Akademi University, Turku (Finland) is ongoing to sign an Erasmus contract for researchers and students visits on the topic of autonomous boats.

Funding applications have been submitted jointly with Davide Maltoni and Vincenzo Lomonaco from University of Bologna (Italy) on the topic of continual learning. Also the project <https://www.continualai.org/> is being further developed jointly and on the way to become a non-profit organization.

#### 9.4.2. *Participation in Other International Programs*

David Filliat participates in the ITEA3 DANGUN project with Renault S.A.S. in France and partners in Korea. The purpose of the DANGUN project is to develop a Traffic Jam Pilot function with autonomous capabilities using low-cost automotive components operating in France and Korea. By incorporating low-cost advanced sensors and simplifying the vehicle designs as well as testing in different scenarios (France & Korea), a solution that is the result of technical cooperation between both countries should lead to more affordable propositions to respond to client needs in the fast moving market of intelligent mobility.

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

- Bart de Boer, VUB Brussels (Dec 2018)
- Dan Dediu, Univ. Lyon (Dec 2018)
- Kenny Smith, Univ. Edinburgh (Dec 2018)
- Jochen Triesch, Univ. Frankfurt (Nov 2018)
- Vincenzo Lomonaco, University of Bologna, Italy (Aug. 2018)

### **9.5.2. Internships**

- Ashley Hill, Univ. Paris-Sud, Paris Saclay.
- René Traoré, UPMC, Sorbonne Universite, Paris.
- Josias Lévi Alvarès, ENSC, Bordeaux.
- Sandy Manolios, Univ. de Lyon, Lyon.
- Rémy Portelas, UPMC, Paris.
- Chuan Qin, ENSTA, Paris Saclay.

## MANAO Project-Team

# 9. Partnerships and Cooperations

## 9.1. National Initiatives

### 9.1.1. ANR

#### 9.1.1.1. “Young Researcher” VIDA (2017-2021)

LP2N-CNRS-IOGS Inria

**Leader** R. Pacanowski (LP2N-CNRS-IOGS)

**Participant** P. Barla (Inria)

This project aims at establishing a framework for direct and inverse design of material appearance for objects of complex shape. Since the manufacturing processes are always evolving, our goal is to establish a framework that is not tied to a fabrication stage.

#### 9.1.1.2. “Young Researcher” RichShape (2014-2018)

MANAO

**Leader** G. Guennebaud

This project aims at the development of novel representations for the efficient rendering and manipulation of highly detailed shapes in a multi-resolution context.

#### 9.1.1.3. ISAR (2014-2018)

POTIOC, MANAO, LIG-CNRS-UJF, Diotasoft

**Leader** M. Hachet (POTIOC)

The ISAR project focuses on the design, implementation and evaluation of new interaction paradigms for spatial augmented reality, and to systematically explore the design space.

#### 9.1.1.4. MATERIALS (2015-2019)

MAVERICK, LP2N-CNRS (MANAO), Musée d’Ethnographie de Bordeaux, OCÉ-Print

**Leader** N. Holzschuch (MAVERICK)

**Local Leader** R. Pacanowski (LP2N-CNRS)

Museums are operating under conflicting constraints: they have to preserve the artifacts they are storing, while making them available to the public and to researchers. Cultural artifacts are so fragile that simply exposing them to light degrades them. 3D scanning, combined with virtual reality and 3D printing has been used for the preservation and study of sculptures. The approach is limited: it acquires the geometry and the color, but not complex material properties. Current 3D printers are also limited in the range of colors they can reproduce. Our goal in this project is to address the entire chain of material acquisition and restitution. Our idea is to scan complex cultural artifacts, such as silk cloths, capturing all the geometry of their materials at the microscopic level, then reproduce them for study by public and researchers. Reproduction can be either done through 2.5D printing or virtual reality displays.

#### 9.1.1.5. FOLD-Dyn (2017-2021)

IRIT, IMAGINE, MANAO, TeamTo, Mercenaries

**Leader** L. Barthe (IRIT)

**Local Leader** G. Guennebaud (Inria)

The FOLD-Dyn project proposes the study of new theoretical approaches for the effective generation of virtual characters deformations, when they are animated. These deformations are two-folds: character skin deformations (skinning) and garment simulations. We propose to explore the possibilities offered by a novel theoretical way of addressing character deformations: the implicit skinning. This method jointly uses meshes and volumetric scalar functions. By improving the theoretical properties of scalar functions, the study of their joint use with meshes, and the introduction of a new approach and its formalism - called multi-layer 3D scalar functions - we aim at finding effective solutions allowing production studios to easily integrate in their pipeline plausible character deformations together with garment simulations.

#### *9.1.1.6. CaLiTrOp (2017-2021)*

IRIT, LIRIS, MANAO, MAVERICK

**Leader:** M. Paulin (IRIT)

**Local Leader** X. Granier (Inria)

What is the inherent dimensionality, topology and geometry of light-paths space? How can we leverage this information to improve lighting simulation algorithms? These are the questions that this project wants to answer from a comprehensive functional analysis of light transport operators, with respect to the 3D scene's geometry and the reflectance properties of the objects, but also, to link operators with screen-space visual effects, with respect to the resulting picture.

## **9.2. International Research Visitors**

### ***9.2.1. Visits of International Scientists***

Masatake Sawayama, Research Scientist, NTT Communication Science Laboratories, Japan



## POTIOC Project-Team

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### HOBIT:

Funding: Aquitaine Science Transfer

Duration: 2018

Local coordinator: Martin Hachet

Partners: Université de Bordeaux

We are currently moving our platform HOBIT from his lab state to a commercial product.

### Erlen:

Funding: Université de Bordeaux - Hacketafac program

Duration: 2018-2019

Local coordinator: Pierre-Antoine Cinquin

We won a grant from Université de Bordeaux to explore awareness of power consumption by way of tangible and ambient interfaces.

### Neuroperf:

Funding: Idex Université Bordeaux

Duration: 2017-2019

Coordinator: Jean-Arthur Micoulaud Franci

Local coordinator: Fabien Lotte

Partners: SANPSY - Potioc

This project aims at studying EEG-based Neurofeedback to reduce fatigue symptoms in sleep-deprived individuals. See <http://brain.labex.u-bordeaux.fr/Actualites/Selection-projets-recherche-Clinique-2017-i5064.html>

## 9.2. National Initiatives

### eTAC: Tangible and Augmented Interfaces for Collaborative Learning:

Funding: EFRAN

Duration: 2017-2021

Coordinator: Université de Lorraine

Local coordinator: Martin Hachet

Partners: Université de Lorraine, Inria, ESPE, Canopé, OpenEdge,

the e-TAC project proposes to investigate the potential of technologies "beyond the mouse" in order to promote collaborative learning in a school context. In particular, we will explore augmented reality and tangible interfaces, which supports active learning and favors social interaction.

**ANR Rebel:**

Duration: 2016-2019

Coordinator: Fabien Lotte

Funding: ANR Jeune Chercheur Jeune Chercheuse Project

Partners: Disabilities and Nervous Systems Laboratory Bordeaux

Brain-Computer Interfaces (BCI) are communication systems that enable their users to send commands to computers through brain activity only. While BCI are very promising for assistive technologies or human-computer interaction (HCI), they are barely used outside laboratories, due to a poor reliability. Designing a BCI requires 1) its user to learn to produce distinct brain activity patterns and 2) the machine to recognize these patterns using signal processing. Most research efforts focused on signal processing. However, BCI user training is as essential but is only scarcely studied and based on heuristics that do not satisfy human learning principles. Thus, currently poor BCI reliability is probably due to suboptimal user training. Thus, we propose to create a new generation of BCI that apply human learning principles in their design to ensure the users can learn high quality control skills, hence making BCI reliable. This could change HCI as BCI have promised but failed to do so far.

**Inria Project Lab BCI-LIFT:**

Duration: 2015-2018

Partners: Inria team Athena (Inria Sophia-Antipolis), Inria team Hybrid (Inria Rennes), Inria team Neurosys (Inria Nancy), LITIS (Université de Rouen), Inria team DEMAR (Inria Sophia-Antipolis), Inria team MINT (Inria Lille), DyCOG (INSERM Lyon)

Coordinator: Maureen Clerc (Inria Sophia Antipolis)

Local coordinator: Fabien Lotte

The aim is to reach a next generation of non-invasive Brain-Computer Interfaces (BCI), more specifically BCI that are easier to appropriate, more efficient, and suit a larger number of people. With this concern of usability as our driving objective, we will build non-invasive systems that benefit from advanced signal processing and machine learning methods, from smart interface design, and where the user immediately receives supportive feedback. What drives this project is the concern that a substantial proportion of human participants is currently categorized “BCI-illiterate” because of their apparent inability to communicate through BCI. Through this project we aim at making it easier for people to learn to use the BCI, by implementing appropriate machine learning methods and developing user training scenarios.

website: <http://bci-lift.inria.fr/>

**Inria Project Lab AVATAR:**

Duration: 2018-2022

Partners: Inria project-teams: GraphDeco, Hybrid, Loki, MimeTIC, Morpheo

Coordinator: Ludovic Hoyet (Inria Rennes)

Local coordinator: Martin Hachet

This project aims at designing avatars (i.e., the user’s representation in virtual environments) that are better embodied, more interactive and more social, through improving all the pipeline related to avatars, from acquisition and simulation, to designing novel interaction paradigms and multi-sensory feedback.

website: <https://avatar.inria.fr>

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

#### **BrainConquest:**

Program: ERC Starting Grant

Project title: BrainConquest - Boosting Brain-Computer Communication with High Quality User Training

Duration: 2017-2022

Coordinator: Fabien Lotte

Abstract: Brain-Computer Interfaces (BCIs) are communication systems that enable users to send commands to computers through brain signals only, by measuring and processing these signals. Making computer control possible without any physical activity, BCIs have promised to revolutionize many application areas, notably assistive technologies, e.g., for wheelchair control, and man-machine interaction. Despite this promising potential, BCIs are still barely used outside laboratories, due to their current poor reliability. For instance, BCIs only using two imagined hand movements as mental commands decode, on average, less than 80% of these commands correctly, while 10 to 30% of users cannot control a BCI at all. A BCI should be considered a co-adaptive communication system: its users learn to encode commands in their brain signals (with mental imagery) that the machine learns to decode using signal processing. Most research efforts so far have been dedicated to decoding the commands. However, BCI control is a skill that users have to learn too. Unfortunately how BCI users learn to encode the commands is essential but is barely studied, i.e., fundamental knowledge about how users learn BCI control is lacking. Moreover standard training approaches are only based on heuristics, without satisfying human learning principles. Thus, poor BCI reliability is probably largely due to highly suboptimal user training. In order to obtain a truly reliable BCI we need to completely redefine user training approaches. To do so, I propose to study and statistically model how users learn to encode BCI commands. Then, based on human learning principles and this model, I propose to create a new generation of BCIs which ensure that users learn how to successfully encode commands with high signal-to-noise ratio in their brain signals, hence making BCIs dramatically more reliable. Such a reliable BCI could positively change man-machine interaction as BCIs have promised but failed to do so far.

### 9.3.2. Collaborations in European Programs, Except FP7 & H2020

#### **VISTE:**

Program: Erasmus + Key Action 2: Cooperation for Innovation and Exchange of Good Practices

Project title: VISTE: Empowering spatial thinking of students with visual impairment

Duration: 01/09/2016 - 31/08/2019

Coordinator: Professor Marinos Kavouras (Vice-Rector, National Technical University of Athens and VISTE Project Leader)

Partners: National Technical University of Athens, Inria, Intrasoft International S.A., Casa Corpului Didactic Cluj, Eidiko Dimotiko Sxolio Tiflon Kallitheas, Liceul Special pentru Deficienti de Vedere Cluj-Napoca. External collaborators : IRSA, RealityTech

Abstract: Six partners from four European countries are working together to develop strategies, educational components and an ICT toolkit towards effective spatial thinking of students with VI, facilitating inclusion. The competence of spatial thinking, usage and interpretation of maps or other spatial tools is not self-evident for all; it is a dexterity which must be cultivated. For students experiencing disabilities, such as visual impairment (VI), spatial thinking proves to be an imperative skill for perceiving the world far beyond their immediate experience. Learning functional ways to utilize spatial experiences as an entirety and realize the relationships between objects in space and themselves is vital. Maps and other spatial representations are a splendid source of information for

portraying space and environment. By using tactile maps and innovative ICT technologies, children may deploy their spatial notion more effectively compared to proximate orientation experiences in accordance with verbal directions. Providing thus a concrete set of such tools would empower specific spatial thinking skills not only of those with VI but of all students. VISTE aims at empowering the spatial thinking skills of students with VI. This will be accomplished by providing an innovative methodological framework and a semantic and technical infrastructure for developing appropriate inclusive educational modules to foster spatial thinking. The project's main target groups are primary/secondary education students, as well as teachers, teachers' trainers, and staff involved in their education.

#### **RSVP-BCI:**

Program: DGA-DSTL Project

Project title: Assessing and Optimising Human-Machine Symbiosis through Neural signals for Big Data Analytics

Duration: 2014-2018

Coordinator: Damien Coyle and Fabien Lotte

Partners: Ulster University, UK, Potioc, France

Abstract: This project objective is to design new tools for Big Data analysis, and in particular visual analytics tools that tap onto human cognitive skills as well as on Brain-Computer Interfaces. The goal is to enable the user to identify and select relevant information much faster than what can be achieved by using automatic tools or traditional human-computer interfaces. More specifically, this project will aim at identifying in a passive way various mental states (e.g., different kinds of attention, mental workload, relevant stimulus perception, etc.) in order to optimize the display, the arrangement of the selection of relevant information.

#### **9.3.3. Collaborations with Major European Organizations**

Partner 1: Univ. Freiburg (Germany)

EEG signal processing and decoding using robust methods

Partner 2: TU Berlin (Germany)

EEG data generation and simulation

### **9.4. International Initiatives**

#### **9.4.1. Inria International Partners**

##### *9.4.1.1. Informal International Partners*

Partner: RIKEN Brain Science Institute, Japan

Topic: BCI, Neurofeedback and EEG signal decoding

#### **9.4.2. Participation in Other International Programs**

Partner: University of Waterloo, Canada

Program: Idex Bordeaux collaboration grant

Duration: 2018

Coordinators: Edith Law (Canada), Pierre-Yves Oudeyer (France)

Topic: Curiosity

### **9.5. International Research Visitors**

#### **9.5.1. Visits of International Scientists**

##### *9.5.1.1. Internships*

- Marie Gonzales, Universidad Chile
- Mehdi Bugallo, University of Minho, Portugal
- Satyam Kumar, IIT Kanpur, India

#### **9.5.2. Visits to International Teams**

##### *9.5.2.1. Research Stays Abroad*

- RIKEN Brain Science Institute, Japan (Fabien Lotte)